Why California Needs a Quality Specification for Linear LED Lamps

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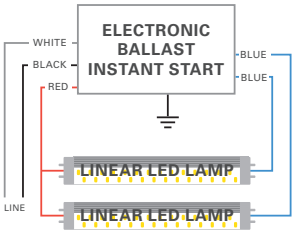
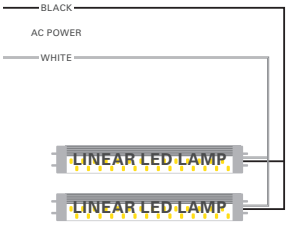
Today, California's buildings are undertaking aggressive energy efficiency and carbon reduction upgrades to address statewide and system-specific sustainability goals.[1] This, coupled with utility programs, has led to initial purchases and installation of low-cost linear LED lamps to replace linear fluorescent lamps.

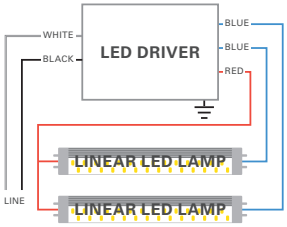
Linear LED lamps are designed to replace linear fluorescent lamps. This relatively new product category consists of three primary types of linear LED products.



UL Type A
Linear LED lamp with an internal driver that is designed to operate with a linear fluorescent lamp ballast



UL Type B
Linear LED lamp with an internal driver that must be connected directly to line voltage for power



UL Type C
Linear LED lamp with an external driver that is designed to replace the linear fluorescent lamp and ballast

In addition, some linear LED lamp products can operate as multiple product types. These hybrid products, also called dual-mode products, are currently available in UL Types AB and AC.

Performance expectations for linear LED lamps are defined by industry organizations, including ENERGY STAR® and the DesignLights Consortium (DLC®); however, most of the focus is on energy efficiency instead of quality.

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1 **The Global Warming Solutions Act of 2006** (AB 32), **California's Statewide Energy Efficiency Strategic Plan, Clean Energy and Pollution Reduction Act of 2015** (SB-350), **University of California's Carbon Neutrality Initiative**.

The Problem

California currently has no quality specification for linear LED lamps. In the absence of a well-defined specification, the market has experienced a proliferation of lower quality products that may derail the sustainability goals that, in part, motivated the upgrades. Anecdotally, when a building owner upgrades the lighting with an efficient product but it has dissatisfactory quality performance, the new product is often removed and replaced with a less efficient product that has higher quality. This negates the energy savings and carbon reduction benefits of the project. Additionally, this repeated experience sets the stage for push back of future sustainability programs.

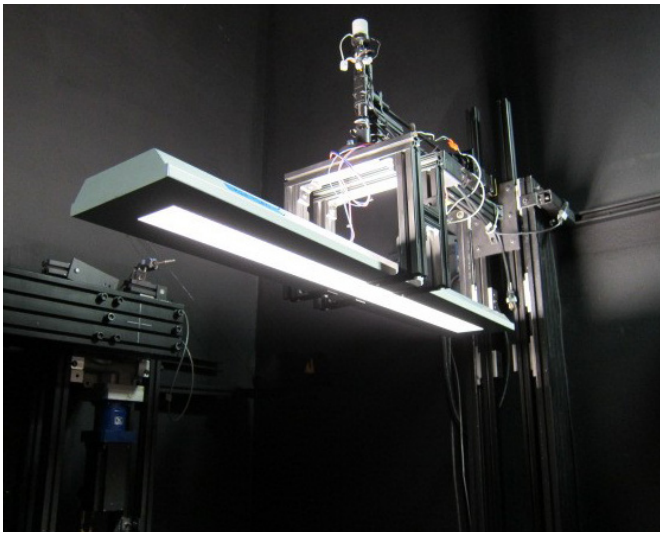
To understand the quality issues related to linear LED lamps, the California Lighting Technology Center (CLTC) at UC Davis conducted a comprehensive photometric and electrical assessment of products that are readily-available to purchase in California.

System Efficacy

A large portion of the linear LED lamp market focuses on the UL Type A electrical configuration due to its low cost, ease of retrofit, and wide-availability. Given the universal design of UL Type A products, system efficacy is often sacrificed. A recent CLTC market assessment shows system efficacy of UL Type A products can be 12 to 24 percent less efficacious than UL Type B and UL Type C products.[2]

Optical Efficiency

Some linear LED lamps reduce the optical performance by restricting beam angle. While this may reduce cost and increase performance of the lamp in isolation, it can significantly compromise the performance inside select luminaire types, such as direct/indirect.[3]



Interoperability

Interoperability issues between existing ballasts and UL Type A linear LED lamps can lead to poor performance or premature product failure. Results from CLTC testing of UL Type A linear LED lamps paired with commonly installed ballasts indicate that more than 50 percent of the configurations operated with significantly different light output and power compared to the manufacturer reported values for the lamp when paired with a manufacturer-specified ballast.[4]

When installed correctly, UL Type C linear LED lamps are better at preventing customers from changing the LED retrofit back to the original technology. Since UL Type C requires ballast removal and replacement with a LED driver, reversal back to fluorescent from LED would require significant work compared to UL Type A LED lamps, which only requires a lamp replacement.

UL Type B linear LED lamps also prevent customers from changing back to their original technology because of wiring differences; however, UL Type B introduces other potential hazards as the main electrical voltage would now be present at the fixture lamp holders. This poses a higher risk to the consumer than the low voltage connections found at the output of traditional fluorescent ballasts and UL Type C drivers.

2 California Lighting Technology Center. 2017. **Linear LED Lamps: Application and Interoperability Evaluation**. Page 28.
3 California Lighting Technology Center. 2017. **Linear LED Lamps: Application and Interoperability Evaluation**. Page 14.
4 California Lighting Technology Center. 2019. **From the Laboratory to the California Marketplace: A New Generation of LED Lighting Systems**. Page 34.

Product Life Characteristics

The drive for low-cost can lead to compromise in the quality of components and assembly of products. CLTC's most recent linear LED lamp life testing over 12,000 hours showed that 26 percent of linear LED lamp samples failed due to poor quality components or assembly.[5]

Dimming

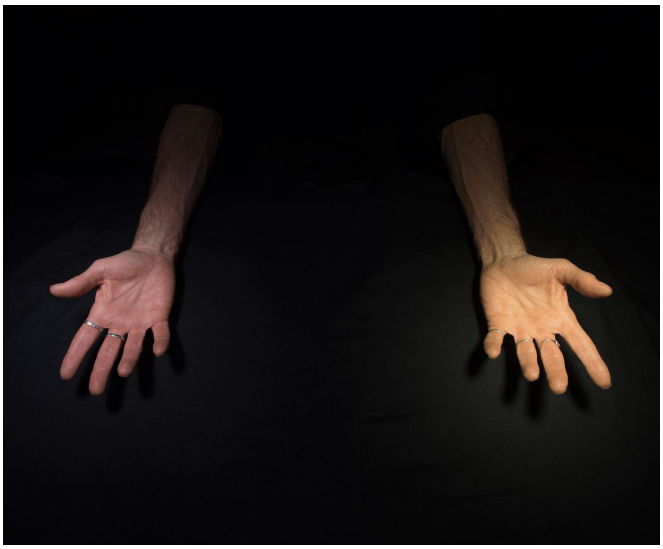
Many linear LED lamps do not dim well and may not be able to comply with California's Energy Standards requirements for commercial building renovations. Furthermore, by not being able to dim, future savings opportunities associated with lighting controls and demand response are lost.

Recent CLTC testing shows that when a cross-section of UL Type A products were dimmed to their minimum light output, the system efficacy ranged from 49 to 84 percent less than a dimmed commercially available UL Type C product.[6]

Color Quality

A recent CLTC study identified color fidelity thresholds preferred by consumers. When individuals were faced with a color sorting task under two different color fidelity light sources, the majority of the participants indicated that the higher fidelity light source enabled them to sort colors better and that the light felt more natural.

Due to the limitations of the Color Rendering Index (CRI) color samples and color space uniformity, CLTC recommends measuring color fidelity (R_f) with IES TM-30-18. CLTC recommends linear LED lamps have an R_f value greater than or equal to 90.[7]



5 California Lighting Technology Center. 2019. **From the Laboratory to the California Marketplace: A New Generation of LED Lighting Systems**. Page 31.
6 California Lighting Technology Center. 2019. **From the Laboratory to the California Marketplace: A New Generation of LED Lighting Systems**. Page 33.
7 California Lighting Technology Center. 2019. **From the Laboratory to the California Marketplace: A New Generation of LED Lighting Systems**. Page 18.

The Solution

Based on these results, CLTC developed a quality specification to help the public building partnership (University of California, California State University, California Community Colleges, and State of California Department of General Services) purchase high-quality LED products. Additionally, CLTC collaborated with the partnership to develop a unified purchasing program called the Million LED Challenge using the same quality specification referenced below.

This program was designed by the public building partnership to encourage a high-quality lighting performance specification combined with a competitive bid process to leverage bulk purchasing buying power statewide.

Minimum performance criteria for linear LED lamps:

- **Electrical Architecture** – UL Type C
- **Light Output**
  - Bare single lamp light output of 2,250 lumens for 4′ lamps
  - Bare single lamp light output of 1,125 lumens for 2′ lamps
- **System Efficacy** – at least 120 lumens per Watt (system includes lamp and driver)
- **Dimming** – dimming level to at least 10 percent of maximum power
- **Controllability** – be able to pair with lighting control devices (control-ready)[8]
- **Flicker** – produces no greater than 30 percent flicker at 200 Hz or below when paired with control devices per Title 24 JA10
- **Color Fidelity** – R_f value greater than or equal to 90 as measured by IES TM-30-18
- **Distribution** – beam angle of at least 220 degrees with no less than 20 percent of total flux emitted in the 100–180 degree zone
- **Driver Physical Dimensions** – provide physical dimensions of driver to allow consumers to compare to space in fixture before purchasing
- **All Else** – meet DLC Standard minimum criteria

Technical research informing the Quality Specification for Linear LED Retrofit Solutions was supported by the EPIC Program at the California Energy Commission.

The **Million LED Challenge** is a collaboration between the University of California, California State University California Community Colleges, and Department of General Services with the objective of deploying high-quality, high-efficacy LED light sources. Visit **millionLEDchallenge.org** for more information.

8 All LED retrofit solutions should be able to be paired with lighting controls that will allow for control strategies, including personal tuning, occupancy sensing, daylight harvesting, and automated demand response, where appropriate.