RESEARCH | Exploring Linear LED Lamp Performance in a Variety of Commercial Fixtures

By Cori Jackson

Even with all the detailed information available on the performance of linear LED replacement lamps by reputable research institutions, a significant gap remains: performance testing for linear LED lamps operating in common commercial fixtures that *are not* recessed or surface-mounted troffers. Troffers are ubiquitous in commercial buildings. Much like the copier and the break-room, every commercial building has one (or 20 or 200). But what about all those other fixtures? Pendants, wraps, cove lighting, wall washers? While certainly not the mainstay like the common troffer, these fixtures are abundant across the commercial sector. How do linear LED lamps perform in these fixtures?

A "linear LED lamp" follows the same geometry and sizing conventions as linear fluorescent lamps—T5, T8, T12 and 2-ft, 4-ft, 8-ft, etc. Most linear LED lamp designs use an array of LED sources distributed along the length of the tube to mimic the distribution and performance of its fluorescent counterpart. There are three primary types of linear LED products currently available:

- Type A: Linear LED lamp with internal driver that is designed to operate on a linear fluorescent lamp ballast
- Type B: Linear LED lamp with internal driver that must be connected directly to line voltage for power
- Type C: Linear LED lamp with external driver that is designed to replace both the linear fluorescent lamp and fluorescent lamp ballast

In addition, some products can operate under multiple scenarios such as with a fluorescent ballast and also with a compatible LED driver. These hybrid products, also called dual-mode products, are currently available in Types AB and AC.

Recent surveys show that linear LED lamps currently constitute less than 1 percent of the total installed base, yet the breadth of commercially available linear LED alternatives continues to grow. More than 15,000 linear LED lamp products have been added to the DesignLights Consortium's Qualified Products List in the past three years.

EVALUATING THE PRODUCT CATEGORY

To help quantify linear LED performance in common non-troffer fixtures, CLTC partnered with Pacific Gas & Electric Company on a series of linear LED product assessments. CLTC completed photometric and electrical evaluations of 11 commercially available linear LED lamps (denoted LED B through LED N) and one standard, 700-series linear fluorescent system, which served as the baseline (**Figure 1**). Selected LED products included Type A, Type B, Type C, Type AB and Type AC. Selected products were all 4-ft lamps operating in a two-lamp fixture with a two-lamp ballast or driver. Additionally, CLTC selected products with the following attributes:

- Range of wattages marketed as replacements for standard light output, 4-ft, 32-W T8 linear fluorescent lamps
- CCT target: 4000K
- Frosted lamp tube
- Dimmable, if available

Two common fixtures were utilized for application testing along with characterization of bare-lamp performance, which is used as the baseline for comparison (**Figure 2**). Characterization was conducted for each selected product operating in a bare-lamp strip fixture, a suspended pendant and a surface-mounted wrap. Market analysis showed these three fixtures were the next most common fixture types present in commercial buildings after the troffer.

LED Type A Configuration. Test results for Type A products show a wide range of performance in terms of light output and system efficacy when comparing data for lamps operating in the same fixture and on the same fluorescent ballast. As compared to the fluorescent baseline, Type A LED replacements delivered significantly less light in all three fixtures tested. Only one product tested delivered more light than the fluorescent system. This occurred in the wrap fixture where fluorescent performance was significantly degraded as compared to its performance in the bare-strip or pendant fixtures. Because the fluo-

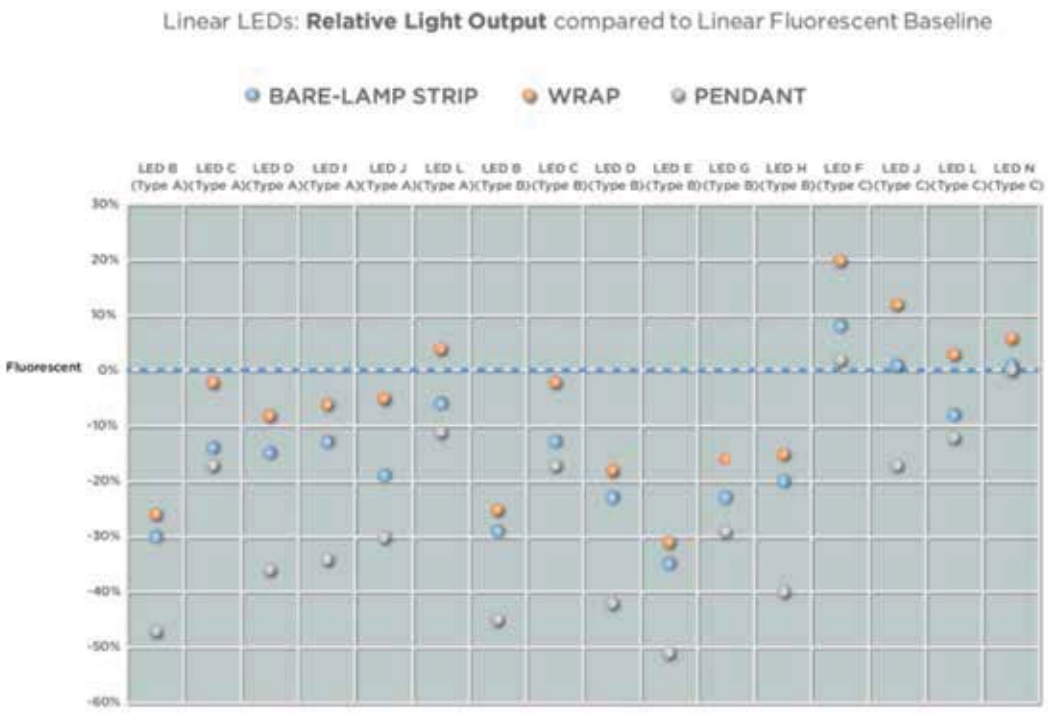

Figure 1.

rescent system was impacted by the elevated temperature conditions created by the enclosed wrap fixture, the LED solutions were able to compete better in terms of light output with five of six tested products delivering total light output within 10 percent of the fluorescent baseline. At these levels, most observers will not notice the reduced light output. Across all three fixtures, Product LED L performed best out of all tested linear LED lamps.

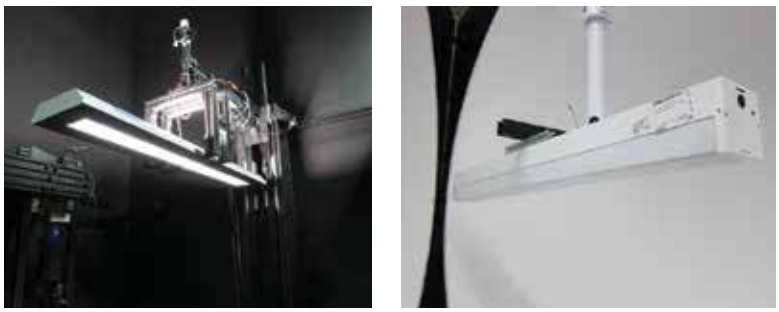

Figure 2. Linear suspended pendant (left) and linear wrap (right).

In terms of system efficacy, however, the LED solutions outperformed the fluorescent baseline in 20 of 21 cases. One LED product operating in the suspended pendant had lower system efficacy as compared to the fluorescent system. In that case, the LED lamps on the instant start ballast were approximately seven percent less efficacious than the fluorescent baseline.

For the bare-lamp fixture, system efficacy for a two-lamp LED system operating on a standard instant-start ballast ranged from approximately 100 lumens per watt to 128 lm/W (a range

of 25 percent). For the wrap and pendant fixtures, the percent difference between minimum and maximum system efficacy of tested LED products was 33 and 40 percent, respectively.

Energy savings ranged from 36 to 48 percent for operation in both the bare-strip fixture and suspended pendant. Savings were somewhat less for operation in the wrap due in part to the reduced performance of the fluorescent itself. The input power and light output of the fluorescent system operating in the wrap was roughly 13 percent lower than expected due to the elevated temperature present inside the fixture. Because of this, energy savings were also reduced between the LED systems and the fluorescent.

LED Type B Configuration. Type B linear LED lamps also provided less light than a standard, 700-series fluorescent baseline. For the bare-lamp fixture, linear LED lamps delivered 13 to 35 percent less light than the fluorescent baseline. In the pendant, light output was reduced by 17 to 51 percent. Type B LEDs performed best in the wrap fixture as compared to the fluorescent, again, because the fluorescent experienced degraded performance due to the elevated temperature present within the fixture. For the wrap, LEDs delivered 2 to 31 percent less light as compared to the fluorescent. Type B products, though, consistently outperformed the fluorescent baseline in terms of system efficacy. The only fixture where fluorescent was able to compete with LED in terms of system efficacy was in the pendant. In this fixture, 50 percent of tested LED products were on par with the fluorescent baseline.

LED Type C Configuration. Type C LED products performed best of all tested linear LED systems. Type C products utilize an external LED driver, which is often optimized for a particular linear LED lamp. This leads to improved overall performance and increased light output. On average, Type C LED products delivered about 10 percent more light in the wrap as compared to the fluorescent, 10 percent less in the pendant and about the same in the bare-lamp fixture.

In the bare-lamp fixture, Type C products delivered light output on par with fluorescents. Three of four tested products delivered more light than the fluorescent. In the wrap fixture, all tested LEDs performed better than the fluorescent. LEDs operating in the pendant fixture delivered the least amount of light. Product LED F performed best of all tested LED products. It consumed less energy and delivered more light output, resulting in a higher system efficacy as compared to the fluorescent baseline for all fixtures tested.

Consistent with Type A and Type B products, Type C products are characterized by higher system efficacy as compared to the fluorescent system. In all fixtures tested, Type C products outperformed fluorescents with respect to system efficacy by an average of 45 percent in the bare-lamp fixture, 48 percent in the wrap and 33 percent in the pendant.

Product ID	Operating Mode (Type A, B or C)	Bare-Lamp Strip			Wrap			Pendant		
		Power (W)	Light Output (lm)	System Efficacy (lm/W)	Power (W)	Light Output (lm)	System Efficacy (lm/W)	Power (W)	Light Output (lm)	System Efficacy (lm/W)
Fluorescent	-	57.1	4,675	81.9	52.4	3,092	59	56.8	4,196	73.9
LED B	A	32.6	3,251	99.7	32.2	2,295	71.3	32.4	2,235	69
LED B	B	29.3	3,302	112.7	28.9	2,325	80.4	29.2	2,299	78.7
LED C	A	34.9	4,017	115.1	34.6	3,032	87.6	34.9	3,466	99.3
LED C	B	29.5	4,087	138.5	29.2	3,045	104.3	29.4	3,476	118.2
LED D	A	33.6	3,974	118.3	33.3	2,840	85.3	33.9	2,679	79
LED D	B	28.6	3,612	126.3	28.1	2,550	90.7	28.5	2,446	85.8
LED J	A	29.6	3,792	128.1	29.5	2,926	99.2	29.6	2,955	99.8
LED J	C	34.9	4,716	135.1	34.1	3,453	101.3	34.9	3,483	99.8
LED L	A	36.3	4,404	121.3	36	3,229	89.7	36.2	3,748	103.5
LED L	C	35.7	4,315	120.9	35.4	3,178	89.8	35.6	3,693	103.7

Table 1. Linear LED Lamps - Hybrids: Input power, light output and system efficacy for two-lamp configuration.

LED Hybrid Configurations. Light output of hybrid products varied significantly across manufacturers and products (**Table 1**). For most Type AB products tested, light output did not vary significantly between operating mode A versus operating mode B. One Type AB product, Product D, demonstrated slightly reduced light output operating as in a Type B configuration as compared to Type A. Of the two Type AC products tested, one demonstrated significantly increased light output operating as a Type C, while the other showed no significant difference in light output between operating mode C and A.

However, in terms of input power and system efficacy, Type AB products varied significantly between Mode A and Mode B. Type AC products tested, in contrast, demonstrated nearly identical performance between Type A and Type C operating modes.

CONCLUSIONS

Based on project test results, linear LED lamps marketed to replace standard 4-ft linear fluorescents often cannot compete in terms of total light output. While the tested LED products are very efficacious at the system level, overall energy savings are achieved, in part, by reducing light output, not just power. In all three fixtures tested, Type A and Type B LED products, including hybrid Type AB, consistently demonstrated significantly reduced light output as compared to the fluorescent baseline.

While Type A lamps may appear to be a simple, energy saving product, based on test results, these products appear to be best only for retrofits where the space is currently overlit or reduced light levels will not negatively impact occupants or operations. In addition, Type A products require the use of a fluorescent lamp ballast and consumers will be required to stock both LED lamps and compatible ballasts in order to replace failed components.

Research shows that a smart alternative to Type A products are Type AC hybrid LED lamps. Type C lamps demonstrated the highest light output and system efficacy of all tested products. These lamps, when paired with recommended drivers, consistently delivered light levels that were generally equivalent to or better than the selected fluorescent system used as a baseline for comparison. For consumers who wish to make a quick and easy change to linear LED from linear fluorescent, Type AC products can fit those requirements. Initial installation is quick as a Type A. When fluorescent ballasts fail, they can be replaced with LED drivers that will maximize light output and long-term energy savings.

Specific to the wrap fixture testing, the elevated temperature operating environment present inside the wrap reduced the baseline linear fluorescent performance by roughly 13 percent. LED performance, in contrast, was not as significantly impacted and the tested LED products experienced only an average of five percent degradation in light output. LED light output relative to fluorescent improved by 6 to 10 percent when operating in the wrap fixture. Results indicate that some LEDs may perform better and deliver more light than fluorescents due to these elevated temperature impacts.

15,000+ LED lamp products added to the QPL in the past three years

A full report on this study is published by Pacific Gas & Electric on the Emerging Technologies Coordinating Council website. The report is available for download at *www.etcc-ca.com*. The full report contains detailed analysis of distribution performance and product interoperability, in addition to the environmental testing summarized in this article. ☐

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