Fluorescent Dimming Ballasts

Response to California Energy Commission
2013 Pre-Rulemaking Appliance Efficiency
Invitation to Participate

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Summary

The information below provides direct responses to the California Energy Commission's (CEC) Invitation to Participate (ITP) for the 2013 Appliance Efficiency Pre-Rulemaking, regarding Fluorescent Dimming Ballasts, including reference to several primary sources, some of which are attached separately (see References for more details). This document includes all of the questions asked in the ITP, even for those with no response.

In summary, CEC has an excellent opportunity to explore energy efficiency standards for fluorescent dimming ballasts. No state or federal efficiency standards currently exist for these products, and with updates to Title 24 building codes set to become effective on January 1, 2014, installations of fluorescent dimming ballasts are expected to increase dramatically. Cost-effective opportunities exist for these products that will ensure that energy savings from the new Title 24 standards are optimized.

Primary sources of data for fluorescent dimming ballasts include the analysis and rulemaking documents compiled by the US Department of Energy (DOE) in support of federal standards for fluorescent ballasts (which apply primarily to fixed output fluorescent ballasts). These documents include general scope and definitional language, estimates for national stock and annual shipments, annual operating hours, expected lifetime, and other key data for fluorescent ballasts. The Database for Energy Efficient Resources (DEER), sponsored by CEC and the California Public Utilities Commission (CPUC), also provides useful estimates for annual operating hours and expected lifetime.

Another useful data source is the Consortium for Energy Efficiency (CEE) list of high performing fluorescent dimming ballasts. This list compiles the highest efficiency fluorescent dimming ballasts on the market, based on their full output performance.

Finally, SCE is in conducting efficiency testing on 35 unique fluorescent dimming ballasts, including multiple samples of each model, to evaluate their performance at full output and when dimmed. SCE is currently able to share complete test results for six unique fluorescent dimming ballasts and will share additional test results in mid-2013.

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1 Basic Information

1.1 Category definition and scope

Fluorescent lamp and ballast systems are commonly used to light commercial office space, but can also be found in residential, industrial manufacturing, warehouse, and sign lighting applications. In order to operate, all fluorescent lamps require a ballast. Figure 1 below illustrates the key components of a fluorescent lamp. To start the lamp, the ballast provides a high initial voltage to the lamp electrodes (sometimes referred to as cathodes) at each end of the lamp. These electrodes are used to initiate the electrical arc through the tube. The electrical arc excites mercury atoms which produce short-wave ultraviolet light that then causes wall phosphors to fluoresce, producing visible light. The ballast then rapidly limits the lamp current to safely sustain the discharge and keep the lamp lit. Figure 2 provides an image of typical fluorescent ballasts.

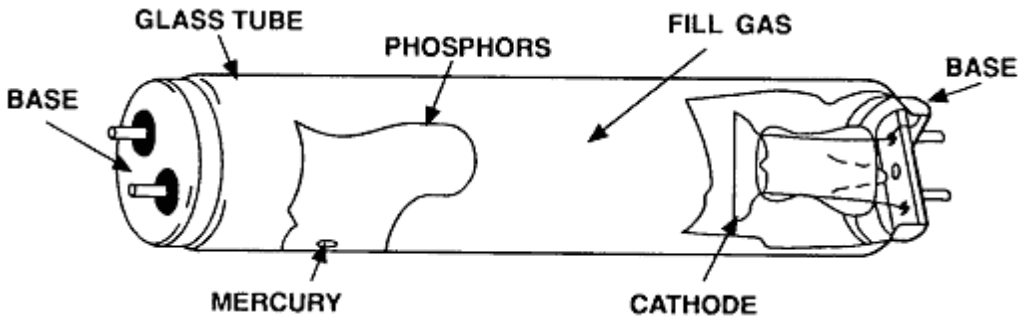

Figure 1. Diagram of a Fluorescent Lamp
Source: http://www.geappliances.com/email/lighting/specifier/2008_07/downloads/DimmingLFL.pdf

Figure 1. Typical Fluorescent Ballasts
Source: Google Images

For a fluorescent lamp to be dimmed, it must be driven by a fluorescent dimming ballast. Fluorescent dimming ballasts are capable of reducing the lamp light output to at least one intermediate light level between 100 percent full output and off mode. Some fluorescent dimming ballasts, known as "step dimming" ballasts can achieve only one or more specific intermediate light levels, while "continuously-dimming" ballasts can dim gradually to any level from 100 percent down to a specified minimum percent light output. Most step dimming ballasts are not capable of dimming below 50% of full light output, and are therefore pre-empted by federal standards for fluorescent ballasts.

There is a broad range of efficiencies among fluorescent dimming ballasts, most of which have never been regulated by federal efficiency standards. Higher efficiency fluorescent dimming ballasts can perform the same operation as poorer performing fluorescent dimming ballasts while consuming less energy. Fluorescent dimming ballasts also exhibit different behavior when dimming, with some products far outperforming others. Given the lack of an existing performance metric useful for evaluating these products, particularly when they operate in dimmed settings, consumers are unable to easily identify high efficiency products. Furthermore, as there appears to be no observable correlation between product efficiency and other key purchase drivers, such as cost, there is unlikely to be significant natural market adoption of higher efficiency products. California therefore has a significant opportunity to generate significant energy savings through an efficiency standard for fluorescent dimming ballasts.

1.2 Standards (existing or under development)

While DOE completed a rulemaking in 2011 to update standards for fixed-output fluorescent ballasts and fluorescent dimming ballasts that do not dim below 50% full output, currently no state or federal standards cover fluorescent dimming ballasts that dim to below 50% full output. Although all ballasts (including all dimming ballasts) are technically defined in EPCA as "covered products," language in Sections 327(b) and 327(c) of EPCA, which define preemption for federally covered products, provides special exemptions for fluorescent ballasts for which standards have not been set. In subsequent updates to fluorescent ballast standards, scope definitions have explicitly excluded fluorescent ballasts that dim below 50% full output from the scope of coverage. Furthermore, no new federal rulemakings have been planned to cover these products.

With respect to state standards, beginning January 1, 2014, the 2013 revision of Title 24 is expected to drastically increase the sales and installation of fluorescent dimming ballasts in California. In these newly adopted standards, Section 130.1(b) "Multi-Level Lighting Controls" states that all fluorescent lighting systems installed in any enclosed area 100 square feet or larger,[1] with a connected lighting load that exceeds 0.5 watts per square foot be capable of the number of control steps detailed in Table 1 (CEC 2012).

[1] Exceptions to this requirement: classrooms with a connected general lighting load of 0.7 watts per square foot or less (which are required to have at least one control step between 30-70 percent of full rated power), and areas enclosed by ceiling height partitions with only one luminaire consisting of no more than two lamps.

Table 1 Control requirements for linear fluorescent lamps; modified from Title 24: TABLE 130.1-A MULTI-LEVEL LIGHTING CONTROLS AND UNIFORMITY REQUIREMENTS

Luminaire Wattage	**Minimum Required Control Steps (% full rated power)**				**Uniform level of illuminance shall be achieved by:**
<13 Watts	Minimum one step between 30-70%				Step dimming; or Continuous dimming; or Switching alternate lamps in a luminaire
>13 Watts	Minimum one step in each range:				Stepped dimming; or Continuous dimming; or switching alternate lamps in each luminaire, having a minimum of 4 lamps per luminaire, illuminating the same area and in the same manner
	20-40%	50-70%	80-85%	100%	

1.3 Test procedures (existing or under development)

Ballast efficiency has historically been measured using the BEF metric. BEF is defined as the ratio of the ballast factor (percent) to the ballast input power (W); ballasts with higher BEFs are more efficient. ANSI National Standard C82.2-1984 sets forth the test conditions required for measuring BEF. For fluorescent dimming ballasts, BEF is generally only measured and reported at full light output.

There are some inherent shortcomings to the BEF metric. For instance, BEF cannot be scaled across fluorescent ballasts designed to operate different lamp wattages or lamp quantities; a 4-lamp ballast and a 2-lamp ballast with comparable efficiencies will have very different BEFs. Past efficiency standards therefore required multiple product classes to be able to provide even coverage of different fluorescent ballasts.

In the most recent rulemaking to revise federal fluorescent ballast standards (which will take effect November 14, 2014), DOE developed a new metric and test method to measure fluorescent ballast efficiency, informed by many months of research as well as input from industry representatives and energy efficiency advocate groups. This metric is known as "ballast luminous efficiency" (BLE), and is defined by the following equation:

Equation 4.1: Equation that defines ballast luminous efficiency (BLE)

$$BLE = \frac{Measured\ Lamp\ Arc\ Power}{Ballast\ Input\ Power} * 100 * \beta$$

Where β is defined as an adjustment factor used to account for the lamp efficacy advantages of high frequency operation.

BLE scales between fluorescent ballasts designed to operate lamps of different wattages and different lamp quantities, and allows for greatly simplified product class breakdowns. This in turn facilitates more complete and uniform standards coverage of different fluorescent ballast types.

DOE provides the complete test procedure in *10CFR Part 430: Test Procedures for Fluorescent Lamp Ballasts, Final Rule* (DOE 2011a). It includes a procedure for measuring standby power consumption, though this measurement is not required for compliance with the federal standard. Additionally, DOE provides guidance to account for variation in test results among fluorescent ballasts of the same model in *10CFR Parts 429, 430, and 431: Certification, Compliance, and Enforcement for Consumer Products and Commercial and Industrial Equipment; Final Rule*. This rule requires a minimum of four samples of a single fluorescent ballast model be tested, and relies on statistical analysis to determine a representative result for the model.

Though BLE was originally designed for use with fixed output fluorescent ballasts, relatively simple modifications would allow the test procedure to be applied to fluorescent dimming ballasts as well. To capture fluorescent dimming ballast performance in dimmed modes, manufacturers could be required to also measure and report BLE at dimmed settings, in addition to at 100 percent full power. These dimmed settings could be defined as tuning the fluorescent dimming ballast input power to specific percentages of manufacturers' full rated power.

10CFR Part 430, also provides a test procedure for measuring standby power consumption. As DALI and other communications enabled fluorescent dimming ballasts draw power even when lamps are fully off, setting standards for standby mode energy use may be a significant opportunity for energy savings.

1.4 Sources of test data (confidential or public)

SCE is in the process of conducting energy efficiency testing on 35 unique fluorescent dimming ballasts, with multiple samples of each, measuring BLE at full power and dimmed operating modes. SCE is also taking measurements on standby mode energy use, power factor, and total harmonic distortion. SCE is currently able to provide complete test results for six unique fluorescent dimming ballasts, with manufacturer and model number censored, and intends to share the results of the rest of testing once it has been completed (SCE 2013a).

1.5 Energy use metrics (e.g., lumens vs. beam lumens per watt)

See section 1.3.

1.6 Relevant performance indicators

No response.

1.7 Range of typical performance for each indicator

No response.

1.8 Incremental costs of energy efficiency features

No response.

1.9 Product development trends

No response.

1.10 Market barriers to energy efficiency

No response.

1.11 Number of California small businesses associated with manufacture, sale, distribution, or installation

No response.

1.12 Commercial vs. residential vs. governmental sector sales

DOE's National Impact Analysis in support of federal fluorescent ballast standards adopted in 2011 provides national shipment estimates for fluorescent ballasts. DOE provides a spreadsheet model that presents annual shipments of different types of fluorescent ballasts through 2045 (DOE 2011b). Shipments estimates are available for thirteen separate product classes, as identified on the "Formats" tab. DOE also provides estimates for two different scenarios to model the total shipments with and without the potential infiltration of emerging technologies that might be used in place of fluorescent lighting, such as LEDs.

Since most fluorescent ballasts are assumed to be installed to light commercial spaces, national ballast shipments data can be scaled to California-level data by relying on estimates of the percentage of US commercial floor area in the Pacific West census region (EIA 2003) and the portion of the Pacific West population that resides in California (Census Bureau 2010).

1.13 How do consumers identify efficient products on the market

The Consortium for Energy Efficiency (CEE) provides a list of "High Performance Dimming Ballasts," which identified fluorescent dimming ballasts that meet the CEE specification for fixed output programmed-rapid start fluorescent ballasts when operated at 100% full output (CEE 2013). The energy efficiency performance piece of the CEE specification sets minimum BEFs as a function of lamp number and ballast factor (CEE 2009). As of April 1, 2013, the CEE list of qualifying products contains 164 unique fluorescent dimming ballast models.

Within the CEE list of qualifying products, there is a range in fluorescent dimming ballast efficiency. Even when isolating ballast factor and lamp number, there are some products with higher BEFs, and accordingly, higher ballast input watts, than others. Higher efficiency products save on the order of 3-5 watts compared to lower efficiency products on the CEE list of qualifying products.

1.14 Any other information relevant to this proceeding

Both DOE rulemaking documents in support of 2011 federal fluorescent ballast standards and the CEC and California Public Utilities Commission (CPUC) sponsored Database for Energy Efficient Resources (DEER) provide estimates for other key ballast properties that are useful for estimating savings from a fluorescent dimming ballast standard, such as expected lifetime and annual operating hours for fluorescent ballasts installed in residential, commercial, and industrial applications (DOE 2011c; DEER 2013).

1.15 Logical product categorization for analysis

1.15.1 Market share by category

No response.

1.16 Features that impact efficiency across the dimming range and in standby mode, and options to improve efficiency

No response.

1.17 Cost vs. ballast luminous efficiency (BLE)

SCE procured 35 unique fluorescent dimming ballasts to test their efficiencies and recorded the prices for each of these ballasts. This pricing data, with manufacturer and model number censored, is provided as an excel worksheet (SCE 2013b).

1.18 BLE and lamp arc power across the dimming range

See section 1.4.

1.19 Typical range of color shift/flicker at dimmed levels

No response.

1.20 Controller impact on energy consumption

See section 1.4.

2 References

(References attached separately are highlighted in grey)

[CEC] California Energy Commission. 2012. "2013 Building Energy Efficiency Standards." Title 24, Part 6, and Associated Administrative Regulations in Part 1. May.

[CEE] Consortium for Energy Efficiency. 2009. "High-Performance T8 Specification." June 30.

[CEE] Consortium for Energy Efficiency. 2013. "High-Performance 120, 277, 347, and 480V T8 Dimming Ballasts." April 1.

[DEER] California Database of Energy-Efficient Resource. 2013. http://www.energy.ca.gov/deer/.

[DOE 2011a] U.S. Department of Energy. "10CFR Part 430: Test Procedures for Fluorescent Lamp Ballasts, Final Rule." Federal Register Vol. 76, No. 86. May 4.

[DOE 2011b] U.S. Department of Energy. "National Impacts Analysis." Excel spreadsheet. November 4.

[DOE 2011c] U.S. Department of Energy. 2011. "Final Rule Technical Support Document." November 14.

[EIA] Energy Information Administration. 2003. Residential Energy Consumption Survey. Washington, D.C.: Department of Energy.

[SCE 2013a] Southern California Edison. 2013. Test results for six unique dimming ballasts. May.

[SCE 2013b] Southern California Edison. 2013. Database of pricing for 25 unique dimming ballasts. May.

U.S. Census Bureau. 2010. Population Estimates by Region of the United States. https://www.census.gov/2010census/.