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Purchasing for Pollution Prevention

High-Bay Lighting: Opportunities for Mercury Reduction and Energy Efficiency

What is high-bay lighting?

High-bay lighting is used in high-ceiling areas to light surfaces more than 15 feet away. Common high-bay applications include industrial manufacturing, gymnasiums, warehouses, and warehouse-type retailers. All lamps typically used in high-bay applications contain mercury, although some varieties – most notably high-output T5s and induction fluorescents – offer opportunities for mercury reduction.

Why should I be concerned about the mercury content of lamps?

Mercury is a highly persistent and toxic chemical that is building up to dangerous concentrations in fish, wildlife, and human beings throughout the US. By choosing high-efficiency lamps that contain less mercury, you help reduce the environmental impacts and health risks of lamp breakage during use, transport, and disposal.

What types of lighting systems can be used in high-bay settings?

The light from a standard fluorescent tube or incandescent bulb is too diffuse to adequately light a surface at the distance required for high-bay applications. Therefore, high-bay lighting typically requires one of the following:

- Metal halide high-intensity discharge (HID) lamps
- High-pressure sodium HID lamps
- High-output linear fluorescent T5 (HO T5) lamps
- Electrode-less induction fluorescent lamps.

Metal halide HID lamps have historically been the most commonly used lamps in these applications. High-pressure sodium HID lamps have poor color rendering, and so are not used as frequently as other lamps and are not discussed below. When comparing HID, HO T5, and induction lighting, it is important to consider the costs and environmental impacts of the entire fixture (or "system"), not just the individual lamps, since each requires a different number of bulbs to produce equivalent levels of illumination.

Which systems contain less mercury?

When calculating the amount of mercury used in a high-bay lighting system, it is important to consider the rated lamp life and the number of lamps required to provide equivalent amounts of light. Using lamps with a higher rated life reduces the overall amount of mercury entering the waste stream, because the lamps are changed less frequently. The following table shows the amount of mercury used for every 20,000 hours of use per system. Keep in mind that rated life and mercury amounts per lamp can vary widely depending on lamp model and manufacturer.

Mercury Use in Three High-Bay Lighting Systems

Lamp Type	Mercury Use per Equivalent Lighting System[1]	Rated Lamp Life (hours)[2]	Mercury Use per 20,000 Hours of Lamp Use
HO T5 linear fluorescent (four lamps)	5.6 – 20 mg	20,000	5.6 – 20 mg
Induction (two lamps)	28 – 34 mg	100,000	5.6 – 6.8 mg
Metal halide (one 400 watt lamp)	40 – 65 mg	20,000	40 – 65 mg

HO T5 lamps use the least amount of mercury at any one time (5.6 to 20 mg per equivalent system), reducing the health risks related to lamp breakage during use. Induction lamps, however, because they are rated for 100,000 hours, are responsible for smaller amounts of mercury and lamp waste over time, reducing solid waste and the liability risks of lamp breakage during transport and disposal. For more information on mercury in lamps, see "The Lowdown on Low-Mercury Lamps" at http://www.informinc.org/fact_P3fluorescentlamps.php.

To get an idea of the amount of mercury used by different lighting systems over time in a typical high-bay application, imagine a midsize retailer with 200 open-plan facilities. Each 10,000 square foot facility uses 24 fixtures operating 16 hours per day. Over a 10-year period, this retailer could reduce its mercury use from over 500 grams to 81 grams by switching from metal halide to HO T5 lamps. (100 grams of mercury can contaminate almost 75,000 fish to the point that they are unsafe for human consumption.)

Mercury Use Over 10 Years in Three High-Bay Lighting Systems

Lamp Type	10-Year Mercury Use per Facility	10-Year Companywide Mercury Use
HO T5 (four lamps)	0.40 – 1.4 grams	81 – 290 grams
Induction (two lamps)	0.67 – 0.82 grams	130 – 160 grams
Metal halide (one lamp)	2.9 – 4.7 grams	580 – 940 grams

What are the drawbacks of metal halide HIDs?

Metal halide HID lamps have several drawbacks, three of which are related to energy efficiency:

- HIDs require several minutes to warm up. During this "re-strike" period, the lamps consume electricity but produce no usable light.
- Energy-saving occupancy sensors, which automatically turn lights on when the area is occupied and off when the area is unoccupied, cannot be used with metal halide HIDs.
- Dimming systems for HIDs are on the expensive side and are not as efficient as those for fluorescent control systems, reducing the benefits of decreasing light levels during low-use periods to save energy.
- In addition to these energy-efficiency factors, HID lamps can contain larger quantities of mercury compared with HO T5s and induction fluorescents.
- Metal halide systems use one lamp per fixture. When a lamp fails it requires immediate replacement, since a failed lamp represents a 100 percent reduction in the illumination provided by that fixture. In an HO T5 system, there are four lamps, so when a lamp fails there is only a 25 percent reduction in illumination, allowing a facility to operate safely until it is convenient to change the failed lamp.

What are the benefits of high-output T5s and induction fluorescents?

Switching from HID lamps to HO T5 fluorescent lamps is now a common strategy for increasing energy efficiency in warehouses and other high-bay lighting situations. Both HO T5s and induction fluorescents:

- Are capable of instant-on and instant re-strike.
- Can be used with energy-saving occupancy sensors.
- Can be adjusted through dimming (with a dimmable ballast).
- Have lower average mercury content than metal halide HID lamps.

Do high-output T5 and induction fluorescents perform as well as metal halide HID lamps in high-bay applications?

Yes. Several attributes are used to compare lamp performance:

1. *Rated life* is the average amount of time a lamp will function before failing.
2. The *color rendering index* (CRI) indicates how accurately a light source renders colors. A CRI of 100 is equivalent to sunlight. Lower CRIs indicate poorer color rendering.
3. A *lumen* is a measure of light flow. The higher the lumens, the more light is produced by the lamps in the fixture.
4. The *lumen maintenance* is a function of the rated life, showing the percentage of original lumens present after a certain percentage of the rated life has

passed. Lumens decrease over the life of most lamps, so a lamp that maintains its lumen output for a longer period is more desirable.

5. The *color temperature* describes the appearance of the light in terms of the red and blue tones. Light that we perceive as redder or warmer has a lower color temperature, light that we perceive as bluer has a higher color temperature. While the color temperature of fluorescent and induction fluorescent lamps is stable over the life of the lamp, metal-halide lamps tend to shift color over their lifetime.

Performance of Three High-Bay Lamp Types

Attribute	High-Output T5 Linear Fluorescent [3]	Induction Fluorescent[4]	Metal Halide HID[5]
Rated life (hours)	20,000	100,000	20,000
CRI	82	80	65
Lumen maintenance	93% @ 40% of life	70% @ 60% of life	65% @ 40% of life

Are both high-output T5 linear fluorescent and induction fluorescent lamps appropriate for all high-bay applications?

No. Fluorescent induction systems are the best choice for very cold conditions because they retain their efficiency at extremes of temperature. Because of their exceedingly long life, they also make sense in applications where it is difficult or costly to change a spent lamp. T5s, however, are more energy-efficient at moderate temperatures (25˚C to 35˚C) than induction lamps, so for locations that do not experience temperature extremes and where labor costs to change a spent lamp are not significant, HO T5s may be preferable.

Which high-bay lighting systems are more energy-efficient?

When calculating energy efficiency, it is important to consider the number of lamps contained in equivalent systems, as well as the number of watts per lamp. For instance, in the example in the table below, four HO T5 lamps or two induction fluorescent lamps are required to produce approximately the same amount of light as one metal halide HID lamp. The higher the lumens per watt, the less electricity is needed to produce equivalent light. The fewer the kilowatt-hours per year used by a lighting system, the less electricity a facility uses and pays for.

Energy Efficiency of Three High-Bay Lighting Systems

Lamp Type	Mean Lumens per System	Mean Lumens per Watt	Kilowatt-Hours per Year*
HO T5 linear fluorescent (four lamps)	16,544 – 18,600	70 – 79	1,060
Induction (two lamps)	17,760	57	1,380
Metal halide (one lamp)	24,440	54	1,980

*Assumes the lamps run 12 hours per day, 365 days per year.

Which lamps are less expensive to purchase and run?

Comparative purchase prices can vary widely depending on volume purchased and location. Based on a small survey, metal halide systems are less expensive to purchase than either of the fluorescent systems, costing approximately 25 percent less ($150) than an equivalent four-lamp T5 system ($200). An equivalent two-lamp induction system costs about four times an equivalent T5 system ($800).[6]

"Payback time" is the period that elapses before an initial investment is recouped, in this case through savings in electricity, lamp replacement, and maintenance/disposal costs. Payback time varies based on the size of the lighting project, the electricity rate, the particular fixtures selected, and other variables. The Los Angeles Department of Water and Power has a payback calculator at http://www.ladwp.com/energyadvisor/PA_46.html where you can input your variables.

A variety of case studies have reported payback times of 1.8 to 29.9 years for HO T5 high-bay replacement projects.[7] One case study reported a five- to eight-year payback period for an induction fluorescent high-bay relighting project.[8]

Recommendations

- Facility owners, managers, and architects specifying high-bay lighting applications should choose the most energy-efficient system with the lowest mercury content appropriate for their construction and remodeling projects.
- Retrofit projects should be analyzed carefully for payback and benefits such as improved color rendering.
- Before purchasing a lighting system, buyers should consult a lighting professional who can analyze the

entire project for energy efficiency, lighting level, and appropriate color rendering. Tell your chosen professional that your organization would like to specify low-mercury alternatives wherever possible.

- Facilities should recycle all mercury-containing products, including all HID lamps, T5s, and induction fluorescents.

Characteristics of Three High-Bay Lamps and Lighting Systems

Attribute	T5 HO Linear Fluorescent (25˚C/35˚C)*	Induction	Metal Halide
Rated life (hours)	20,000	100,000	20,000
CRI	82	80	65
Lumen maintenance	93% @ 40% of life	70% @ 60% of life	65% @ 40% of life
Re-strike time	Instant on	Instant on	10 Minutes
Number of lamps per equivalent system	4	2	1
System watts	234	314	452
System initial lumens	17,800/ 20,000	24,000	37,600
System mean lumens	16,544/ 18,600	17,760	24,440
Mercury in the system	5.6 – 20 mg	28 – 34 mg	40 – 65 mg
Initial system cost (fixture and ballast)	$200	$800	$150

* Lumens produced by HO T5 lamps depend on operating temperature.

For more information

- T5 Fluorescent High-Bay Lighting Systems: http://www.smud.org/education/cat/cat_pdf/T5.pdf
- Induction Lighting Systems: http://www.smud.org/education/cat/cat_pdf/Induction%20Lighting.pdf
- Induction Lamps Installations at Kowloon Bay Indoor Games Hall: http://www.emsd.gov.hk/emsd/e_download/pee/Induction%20lamps%20at%20kbigh.pdf
- Lighting: HID Versus Fluorescent for High-Bay Lighting: http://www.ladwp.com/energyadvisor/PA_46.html

Notes

1 Personal communications, Pamela Horner, OSRAM Sylvania, August 27 and September 4, 2003; Paul Walitsky, Philips Lighting, April 1 and August 27, 2003.

2 David Bisbee, Sacramento Municipal Utility District, T5 Fluorescent High-Bay Lighting Systems, Customer Advanced Technologies Program Technology Evaluation Report, May 15, 2002, http://www.smud.org/education/cat/cat_pdf/T5.pdf; Osram Sylvania, ICETRON Inductively-Coupled Electrodeless Systems, http://www.sylvania.com/business/fluorescent/ icetron.htm; Fluorescent Product Specifications, http://www. sylvania.com/ business/fluorescent/specs.htm#ice; *Lamp & Ballast Product Catalog*, February 2002, http://www.sylvania. com/catalog/pdfs/ cat_full.pdf.

3 Bisbee, T5 Fluorescent High-Bay Lighting Systems.

4 These numbers are based on the Sylvania ICETRON lamp. Osram Sylvania, ICETRON Inductively-Coupled Electrodeless Systems, Fluorescent Product Specifications, and Lamp & Ballast Product Catalog.

5 Bisbee, T5 Fluorescent High-Bay Lighting Systems.

6 Personal communications, Randy Miller, 1st Source Lighting, August 27 and September 4, 2003; Patrick Lew, Lindy Lighting, August 28, 2003.

7 Bisbee, T5 Fluorescent High-Bay Lighting Systems; Federal Energy Management Program, "Waste Isolation Pilot Plant Finds Savings in Lighting Retrofit," *FEMP Focus Newsletter*, January/February 2001, http://www.eere.energy.gov/femp/newsevents/femp_focus/feb01_waste.html; Martin WU Kwok-tin, Hong Kong Electrical and Mechanical Services Department, "Report of the Pilot High Output 'T5' Fluorescent Lighting Project at East Kai Tak Indoor Games Hall," www.emsd.gov.hk/emsd/e_download/pee/t5_ektigh.doc.

8 Martin WU Kwok-tin, Hong Kong Electrical and Mechanical Services Department, "Induction Lamps Installations at Kowloon Bay Indoor Games Hall," http://www.emsd.gov.hk/emsd/e_download/pee/Induction%20lamps%20at%20kbigh.pdf .

9 Bisbee, T5 Fluorescent High-Bay Lighting Systems.

10 These numbers are based on the Sylvania ICETRON lamp. Osram Sylvania, ICETRON Inductively-Coupled Electrodeless Systems, Fluorescent Product Specifications, and *Lamp & Ballast Product Catalog*.

11 Bisbee, T5 Fluorescent High-Bay Lighting Systems.

12 Personal communications, Pamela Horner and Paul Walitsky. .

13 Personal communication, Randy Miller.

14 *Ibid.*

15 Personal communication, Patrick Lew.

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