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LIGHTING UPGRADE TECHNOLOGIES

This document provides brief descriptions of currently available lighting upgrade technologies, and it lists common applications and limitations. Many product variations exist within each technology described; for application assistance for specific product types, contact a lighting professional or the ENERGY STAR Hotline.

At the end of this document are extensive reference tables for lighting system performance and product manufacturer information.

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FLUORESCENT UPGRADES

Recent advances in lighting technology have created new opportunities for reducing energy consumption while enhancing the quality of fluorescent lighting systems. Select the combination of the following lighting upgrade approaches that will yield the maximum energy savings, while maintaining or improving lighting quality and earning an after-tax internal rate of return of at least 20%.

Full-Output Electronic Ballasts

Definition

Full-output electronic ballasts are high-frequency versions of conventional magnetic “core-and-coil” ballasts. Electronic ballasts operate fluorescent lamps more efficiently at frequencies greater than 20,000 Hz. The resulting increase in lamp efficacy, combined with reduced ballast losses boosts fluorescent system efficacy by up to 30 percent.

Full-output ballasts are rated with a ballast factor of at least 0.85 (see definition of ballast factor in the partial-output electronic ballast section below).

Applications

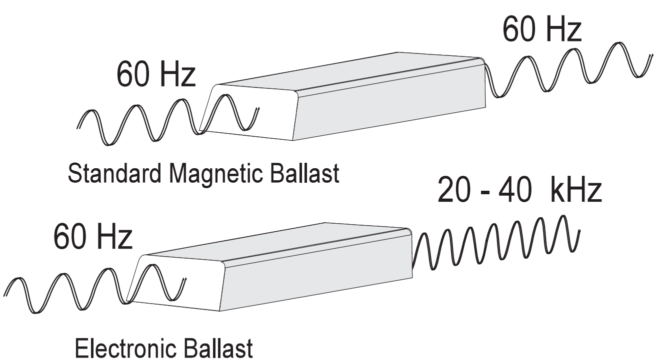
In nearly every fluorescent lighting system, full-output electronic ballasts can replace conventional ballasts, providing similar light output with significant reductions in energy consumption.

Other advantages are reduced weight, less humming noise, virtually no flicker, and the capability to operate up to four lamps at a time.

Although most magnetic ballasts are designed to operate only two lamps at a time, some electronic ballasts can simultaneously operate as many as four lamps. The use of 3- and 4-lamp ballasts instead of 2-lamp ballasts (where feasible) can yield savings in material, labor and energy costs, because fewer ballasts will be required, and because these ballast systems may be more efficient. In applications with 2-lamp luminaires, consider “tandem wiring” pairs of two-lamp systems to share single 4-lamp ballasts. Check with your ballast supplier to determine the maximum wire length between lamps and ballast for reliable operation.

MAGNETIC AND ELECTRONIC BALLASTS

Source: CEC/DOE/EPRI



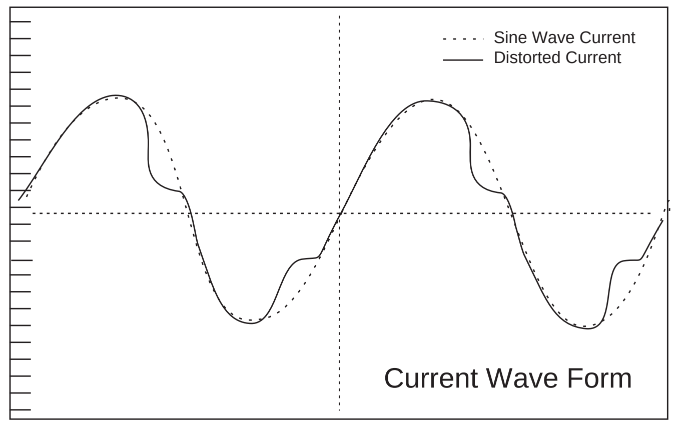
Qualifications

All types of fluorescent ballasts produce some degree of total harmonic distortion (THD) which, if severe, has the potential to interfere with the operation of sensitive electronic equipment. Harmonic distortion is also caused my many other types of electronic devices such as fax machines, printers, computers, and copy machines. Here are the typical ranges of THD for each ballast type:

- ☞ Magnetic: 12 - 30% THD
- ☞ Hybrid: 12 - 25% THD
- ☞ Electronic: 5 - 20% THD

Because many utilities have not offered rebates on electronic ballasts unless the THD is below 20 percent, nearly all electronic ballasts now meet this criterion. Some electronic ballasts with integrated circuits produce less than 5 percent THD. Because electronic ballasts require reduced current, maintaining the same *percent* THD will yield a *reduction* in the harmonic current. **Therefore, installing low-harmonic electronic ballasts can significantly reduce the total harmonic current that exists in a building’s power distribution system.**

HARMONIC DISTORTION



Another factor to evaluate regarding electronic ballasts is *inrush current.* Inrush current is the current flow occurring at the instant the lighting circuit is switched on. Electronic ballasts that are designed to produce less than 10 percent THD may cause excessive inrush current – as high as 35 amps. High inrush current can damage light switches, occupancy sensors and lighting control contactors (relays). In some cases, high inrush current can trip circuit breakers. However, ballasts with THD between 10 and 20 percent cause inrush currents in the range of 10-15 amps and do not appear to be causing problems with switching equipment.

Not all lamps work with all ballasts. For example, T8 lamps (265mA) are designed to work with T8 (265mA) ballasts, and high-output T12 lamps (800mA) lamps are designed to work with high-output (800mA) ballasts. Some electronic ballasts with integrated circuits can adapt to operate both T8 (265mA) and T12 (430mA) lamp types. Also, lamps with only one electrical contact at each end require operation with an instant-start ballast. Check with your lighting consultant or supplier about compatibility.

There are some rare occasions in which certain high-frequency ballasts may be incompatible with existing technologies. For example, some older-technology occupancy sensor relays may fail when installed on the same circuit with some electronic ballasts. Check with your occupancy sensor supplier for compatibility with specific electronic ballast products. Another system compatibility problem may occur when electronic ballasts are installed in a circuit controlled by a high-frequency power line carrier (PLC) control system.

Finally, electronic ballasts may impair the operation of a library's magnetic detector system when installed within 10-15 feet of the detector. Note that the above potential incompatibility problems can be resolved or avoided, and they should not be used to disqualify the use of electronic ballasts in other applications.

Verify input wattage values for your proposed lamp-ballast combination because manufacturers' products will vary in this regard. Lower input wattages will increase energy savings and profitability, but will typically decrease light output. Refer to the tables at the end of this booklet for listings of system wattages, ballast factors, light output and efficacies of various lamp-ballast combinations.

Nearly all ballasts are designed to reliably start the lamps at a minimum ambient temperature of 50°F. Refer to manufacturer literature regarding minimum starting temperatures for your specific lamp-ballast combination. Typical minimum starting temperatures are:

Note that some ballasts can start high-output (800mA) lamps at temperatures as low as -20°F.

Lamps	Minimum Starting Temperature
34WT12	+60°F minimum
60WT12	+60°F minimum
59WT8	+50°F minimum
other fluorescents	+50°F or 0°F

*Performance data for specific name-brand electronic ballasts can be found in **Specifier Reports: Electronic Ballasts**, Volume 2 Number 3, National Lighting Product Information Program, May 1994. The data tables include listings of system performance for approximately 200 ballasts in 4-foot and 8-foot fluorescent applications. Also, refer to Specific Reports Supplements published in 1995 and 1996.*

Partial-Output Electronic Ballasts

Definition

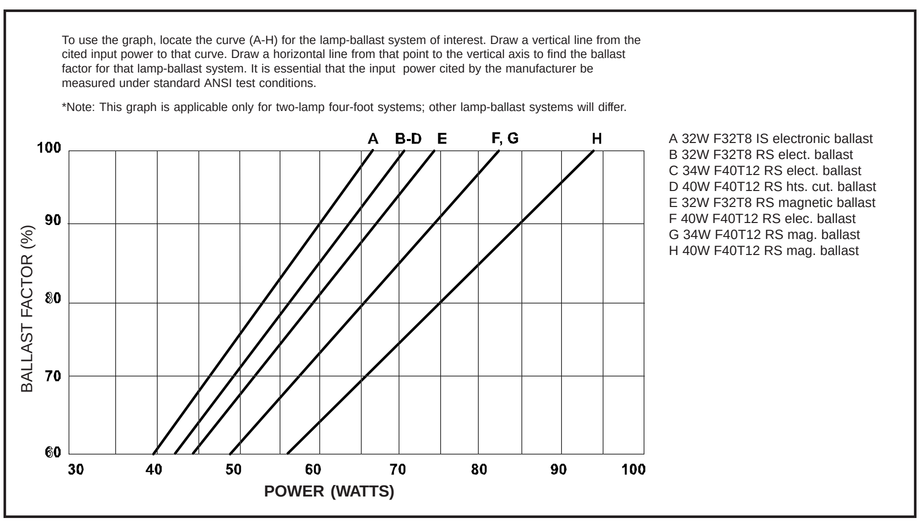
Partial-output (also known as "low-wattage") electronic ballasts operate fluorescent lamps at the same high efficacy as other electronic ballasts, but with specified reductions in both light output and energy consumption. The light output from a ballast operated on a specific lamp is expressed by the *ballast factor* (BF). The ballast factor is simply the percentage of the lamps' rated lumens that will be produced by the specified lamp-ballast combination. Most magnetic ballasts have a ballast factor in the range of 0.93 - 0.95. Electronic ballasts are available in a wide range of ballast factors. For example, they can be purchased with high ballast factor (1.00 - 1.30) to boost light output, or a low ballast factor could be specified (0.67 - 0.80) to reduce light output. Full-output electronic ballasts have ballast factors that exceed a minimum of 0.85. Most electronic ballast brochures now list the ballast factor for the various lamp-ballast combinations that are available.

Applications

Partial-output electronic ballasts should be used for minimizing electricity consumption where reduced illumination is acceptable. The availability of electronic ballasts with various output quantities enables specifiers to select ballasts with the appropriate output that will most closely meet the target light level. There

POWER VS. BALLAST FACTOR CURVES FOR TWO-LAMP FOUR-FOOT FLUORESCENT LAMP-BALLAST SYSTEMS

Source: CEC/DOE/EPRI



are several applications where the use of reduced-wattage electronic ballasts will result in maximum energy savings and improved lighting quality:

- ★ ***Task/Ambient Lighting***: By providing task lights at office work stations, the illumination required from the overhead lighting system is significantly reduced. In some cases, delamping alone will not reduce light levels to the 20-30 footcandles recommended for the ambient component of a task/ambient lighting system. Reduced-output electronic ballasts can lower the light level while improving visual comfort (through reduced luminaire brightness or glare).

- ★ ***Alternative to Delamping***: Particularly with parabolic louver luminaires, delamping can result in unfavorable luminaire appearances. The use of reduced-wattage electronic ballasts can maintain uniform brightness across the entire luminaire aperture while providing the appropriate amount of illumination on task surfaces.

- ★ ***Replacing 34-Watt Fluorescent Lamps:*** Conventional “energy-saver” 34W T12 lamps (which are reduced-output lamps) and magnetic ballasts can be replaced with 32W T8 lamps and partial-output electronic ballasts (with BF = 0.70-0.75) to achieve comparable light levels.

- ★ ***New Luminaire Layouts***: Where ceiling heights are low and where low levels of illumination are specified, wider spacing of luminaires is needed to achieve the target illumination. In some cases, the required luminaire spacing with full-output ballasts will be so great that non-uniform illuminance will result. Reduced-wattage ballasts can provide the target illuminance without exceeding the luminaire’s spacing criterion.

Because reduced-wattage electronic ballasts reduce energy consumption with little or no premium cost compared to standard-wattage electronic ballasts, BOTH energy savings and internal rate of return (IRR) will be increased. For example, the cost of a .73 BF reduced-wattage ballast is comparable to that of a full-output electronic ballast.

Qualifications

The same qualifications that apply to full-output electronic ballasts also apply to partial-output electronic ballasts.

When specifying partial-output electronic ballasts, choose rapid-start ballasts which maintain cathode voltage during low-current operation, thereby preserving rated lamp life.

Dimmable Electronic Ballasts

Definition

Dimmable electronic ballasts are specifically designed to vary the light output of a fluorescent luminaire based on input from a light sensor, manual dimmer, time clock, or occupancy sensor. Most dimmable ballasts are equipped with two additional low-voltage control leads that receive the signal directly from the controlling device. Other ballast designs receive the dimming signal over the line-voltage circuit.

Although most controllable ballasts are available only in the 2-lamp configuration, 3-lamp controllable ballasts have been introduced, which lower the material costs needed for dimming 3-lamp luminaires.

Applications

Daylight dimming is one of the most popular and cost-effective applications of controllable electronic ballasts. Other applications include lumen maintenance control, manually-operated dimming, and occupancy-sensed dimming. When more than one control device is used to control ballast output (such as a photosensor with an occupancy sensor), an integrated load controller is needed to determine the appropriate signal to send to the ballasts. For more information about dimming controls, refer to the controls section in this booklet.

Qualifications

The controlling devices — photosensors, occupancy sensors, dimmers, etc. — must be compatible with the controllable electronic ballast. Check with the manufacturers to verify compatibility.

Harmonic distortion for most controllable electronic ballasts is very low due to the use of integrated circuit technology. Although harmonic distortion does increase as the lamps are dimmed, the total harmonic distortion typically remains under 20 percent, even in low-current conditions.

Due to higher ballast losses, dimming electronic ballasts may draw 5-10 percent more energy at full light output than non-dimming electronic ballasts. A typical 2-lamp T8 dimming ballast may draw 64-65 watts at full output, compared to 58-62 watts for non-dimming instant-start or rapid-start T8 electronic ballasts.

At 20 percent of full light output (maximum dimming for many controllable ballast designs), the system efficacy drops from about 84 lumens per watt to about 58. Yet, this 80 percent reduction in light output is produced with a 70 percent reduction in power.

Lamp life is not appreciably affected because the ballasts maintain cathode voltage when dimming.

When calculating energy cost savings expected from a dimming system, take into account the specific electric demand charge and rate structure; some rate schedules include a ratcheted demand charge that could delay or reduce cost savings resulting from reduced peak demand.

For independently measured performance data for specific dimming electronic ballasts, refer to ***Specifier Reports: Dimming Electronic Ballasts****, 1995, National Lighting Product Information Program.*

Step-Dimming Electronic Ballasts

Definition

A low-cost method for providing occupants with a choice of light levels is to install electronic ballasts with “step-dimming” capabilities. Depending on the ballast design, users may select up to five different light levels from their wall switch. Some of these light-level switching ballasts can be controlled by the user with a hand-held remote control. To limit user control over light levels, some ballast designs allow the installer to adjust the light output by changing a setting directly on the ballast. Another alternative is to install bi-level (or tri-level) switching electronic ballasts that preserve the dual-switching capability in most modern office spaces, while keeping all the lamps uniformly illuminated.

Applications

Some types of 2-lamp and 3-lamp light-level switching ballasts can be controlled from manual switches without requiring additional wiring. Other step-dimming ballasts will respond to signals delivered by low-voltage wiring. A 4-lamp ballast is also available that provides inboard/outboard switching capability.

Where dual switching systems currently control 3-lamp or 4-lamp fixtures, it may not be economical to replace both of the fixture’s ballasts with fixed-output electronic models to maintain the existing dual switching configuration. An alternative would be to tandem-wire 4-lamp ballasts to replace pairs of 2-lamp ballasts, and tandem-wire 2-lamp ballasts to replace pairs of 1-lamp ballasts (in 3-lamp fixtures). However, the added labor cost for tandem-wiring may exceed the added cost of installing only one light-level switching ballast per fixture.

Qualifications

Although step-dimming is an economical way to adjust light levels, occupants may prefer continuous dimming for establishing their preferred light level or for providing daylight-dimming control.

To protect your investment in step-dimming ballasts, provide employee education about the proper light level settings based on their visual tasks and their visual capabilities.

A low-cost alternative to the light-level switching ballast is the parallel-wired, fixed-output electronic ballast. The parallel wiring allows maintenance staff to lower light levels by selectively removing one or more of the lamps while the remaining lamps remain illuminated. Check with the ballast manufacturer regarding possible adverse effects resulting from operating the four-lamp ballast without its full complement of lamps. In addition, determine if the appearance of partially delamped fixtures will be acceptable.

Cathode-Disconnect (Hybrid) Magnetic Ballasts

Definition

Cathode-disconnect ballasts consist of standard, energy-efficient magnetic ballasts that incorporate electronic components that disconnect power to the cathodes (filaments) after the fluorescent lamps are lit, resulting in an additional energy savings of about 8% with T12 lamps and about 13% with T8 lamps.

Applications

Suitable for all 2-lamp magnetic ballast applications for 4-foot T8, T10 or T12 rapid-start fluorescent lamps. In addition, there are hybrid magnetic ballasts now available for 8-foot high-output (800mA) T12 lamps. Hybrid magnetic ballasts are 15-25% less expensive and nearly as efficient as 2-lamp rapid-start electronic ballasts. However, greater energy and material cost savings can be realized using instant-start electronic ballasts or 3- and 4-lamp rapid-start electronic ballasts where applicable.

In applications where electromagnetic interference (EMI) from electronic ballasts is a potential problem (in the immediate vicinity of very sensitive electronic equipment), hybrid magnetic ballasts should be considered. Both electronic and hybrid ballasts pass the FCC requirements for EMI, but total EMI is lower with hybrid ballasts.

Qualifications

Hybrid T12 ballasts are manufactured as either full-output ballasts or partial-output ballasts. The partial-output hybrid ballasts consume about the same wattage as T12 electronic ballasts, but produce about 10 percent less light output. Full-output T12 and T8 hybrid magnetic ballasts are available that produce light output that is comparable to either standard magnetic ballasts or full-output electronic ballasts. Refer to the ballast charts at the end of this booklet for wattages and relative light output data.

Because hybrid ballasts do not provide cathode heating during lamp operation, they should not be used in any panel-level dimming applications.

Hybrid ballasts operate at 60 Hz and can potentially produce the same hum and flicker problems caused by conventional low-frequency ballasts.

At present, all hybrid magnetic ballasts for 40W T12 and 32W T8 lamps are only available in the 2-lamp configuration.

For maximum efficiency and energy savings, consider installing instant-start electronic ballasts or 3- and 4-lamp rapid-start electronic ballasts as alternatives. For example, the 4-lamp T8 electronic ballast produces approximately 87 lumens per watt (maintained), compared to 80 lumens per watt for the 2-lamp T8 cathode-disconnect ballast.

For independently measured performance data for specific name-brand hybrid ballasts, refer to ***Specifier Reports: Cathode-Disconnect Ballasts****, Volume 2 Issue 1, June 1993, National Lighting Product Information Program*.

"Energy-Efficient" Magnetic Ballasts

Definition

These ballasts are premium versions of the older standard magnetic "core-and-coil" ballasts. As of April 1992, the Federal Appliance Standard prohibited the issue of the older magnetic ballasts, making "energy-efficient" magnetic ballasts the new standard for magnetic ballast production. These are, by the way, the *least energy-efficient* ballasts that you can buy to operate full-size fluorescent lighting systems!

Applications

All magnetic ballast applications for full-size fluorescent lamps.

Qualifications

Energy-efficient magnetic ballasts may have the lowest first cost, but they have the highest operating cost. *Other more efficient ballast options exist, such as electronic or hybrid magnetic ballasts.*

FLUORESCENT LAMP UPGRADES

T8 Lamp-Ballast Upgrade

Definition

The T8 lamp-ballast system has the highest efficacy of any fluorescent system — up to 90 lumens per watt when used with a 4-lamp electronic ballast.

Applications

T8 lamps have the same medium bipin bases of T12 lamps, allowing them to fit into the same sockets. T8 lamps operate on a reduced current (265mA) and, therefore, must be operated using a ballast that is designed for T8 lamp operation. T8 lamps are available in 2', 3', 4', 5', and 8' straight tubes, and 2' U-tubes with either the standard 6" leg spacing now available for retrofit, or the 1 5/8" leg spacing for new applications. Recently, T8 lamp/ballast systems have been introduced for replacing 8' 800mA high-output (HO) fluorescent systems.

All T8 lamps use tri-phosphor coatings that improve color rendering performance. T8 fluorescent lamps are generally available in two versions of color rendering: A thin triphosphor coat produces a color rendering index (CRI) in the 70s, and a thick triphosphor coat produces a CRI in the 80s (see definition of CRI in the glossary of the Fundamentals chapter). Standard "cool-white" lamps have a CRI of 62. When using T8 lamps, specify lamps with a CRI of 82-85 to yield maximum efficacy and improved color rendering. (Note, however, that special T8 lamps with a CRI *over 90* will *sacrifice* efficiency to achieve such unusually high color rendering.) The use of triphosphor coatings not only improve color rendering and boost efficacy, they reduce lumen depreciation over the lamp's life, resulting in further increases in overall system performance.

NOTE: "Advanced" T8 lamps are now available that provide higher CRI, longer life, and less lumen depreciation. These advanced T8 lamps have a CRI of 86, rated life of 24,000 hours (compared 20,000 for a standard T8), and only five percent lumen depreciation compared to 10 percent for standard T8 lamps.

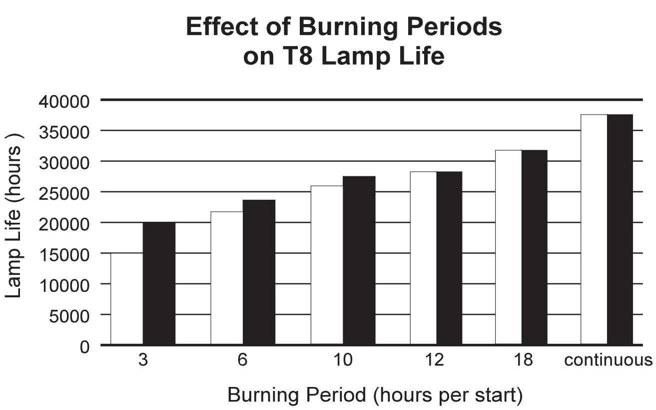
Refer to the performance tables at the end of this document for comparative data on light output, color rendering and system efficacy.

Qualifications

Because converting to T8 lamps requires new ballasts, the cost of new ballasts should be included in the project cost estimate. Consider installing electronic T8 ballasts for maximum efficiency.

Although T8 lamps are classified as rapid-start lamps, electronic ballasts can be designed to start these lamps in either the rapid-start or instant-start mode. There is a trade-off to consider when choosing between rapid-start and instant-start T8 electronic ballasts: T8 lamps operating on instant-start ballasts will produce about 6 percent more lumens per watt (more efficient), but may result in a reduction in lamp life. The amount of lamp life reduction depends on how frequently the system is switched on and off: At 3 hours per start, the lamp life reduction is 25 percent, but at 12 hours per start, the reduction is negligible. In most cases, the financial advantage of using the more efficient instant-start ballasts more than offsets the costs associated with reduced lamp life. However, when occupancy sensors will be used and frequent switching is expected, consider using rapid-start ballasts. Use the *ProjectKalc* analysis software to determine the effects of lamp life and efficiency on the total financial return.

For more information, refer to ***Lighting Answers: T8 Fluorescent Lamps****, Volume 1 Issue 1, National Lighting Product Information Program, April 1993. This document provides general performance information about T8 fluorescent systems.*



40W T10 Lamps

Definition

The T10 lamp is a high-efficiency, high lumen output (approx. 3700 initial lumens) F40 fluorescent lamp. The use of T10 lamps instead of standard 40-watt cool-white T12 lamps will increase light levels approximately 20 percent. The efficacy of the T10 lamp is comparable to that of a T8 lamp, assuming both types of lamps are operating on an electronic ballast. (T10 efficacy is a little greater than a 75 CRI T8 system, but less than an 85 CRI T8 system; refer to the tables at the end of this section).

Applications

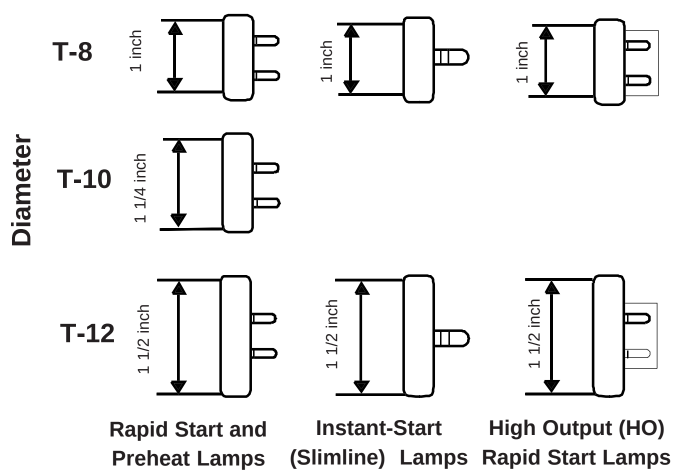
T10 lamps may be used with conventional T12 ballasts. (Note that T9 lamps are also available from one manufacturer that are compatible with both T12 and T8 ballasts, but the efficacy and light output values are less than dedicated T12 or T8 systems.)

Because T10 lamps have a color rendering index of 80 or more, they can improve the color rendering quality of the lighting system.

T10 lamps are currently available as straight four-foot lamps.

T10 lamps are commonly used for increasing light levels, usually after strategically removing one or more lamps from a multi-lamp luminaire and/or installing reflectors.

Another benefit of T10 lamp use is that they are rated to last 24,000 hours — 20 percent longer than most T8 and T12 lamps.



Qualifications

Although they are advertised as 40W lamps, they actually consume 42 watts. This added current may increase ballast temperature which could affect ballast life.

Conduct a trial installation to see the effect of the increased light output from these lamps. Remember to allow the lamps to “burn in” for 100 hours before measuring initial light levels. Refer to *Lighting Evaluations* for more guidance regarding trial installations.

For more information, refer to ***Lighting Answers: T10 and T9 Fluorescent Lamps****, National Lighting Product Information Program, Volume 2, Number 4, June 1995.*

40W T12 High-Lumen Lamps

Definition

These high-lumen triphosphor lamps are an alternative to T10 lamps for increasing light output and providing high color rendering. There are two versions of this unique T12 lamps: the 82 CRI lamps produce about 14 percent more light with no increase in energy consumption compared to standard cool-white 40-watt lamp; the 73 CRI lamps produce about 11 percent more light than standard cool-white 40-watt lamps. Although other triphosphor T12 lamps exist, these lamps utilize improved triphosphors to boost light output by about 7 percent over other triphosphor 40-watt lamps with the same CRI.

The high-lumen T12 lamps are available in both 40-watt and 34-watt versions.

Applications

High-lumen T12 lamps should be used where both an increase in light output and improved color rendering (CRI 70-82) are desired. In addition, these lamps have a rated life of 24,000 hours (as compared with the standard 20,000-hour life).

Qualifications

To achieve efficacies comparable to electronic T8 or T10 systems, operate high-lumen T12 lamps with electronic ballasts.

Reduced-Wattage T12 Fluorescent Lamps

Definition

The 34-watt “energy-saver” fluorescent lamp is essentially a standard 40-watt fluorescent lamp that is filled with an argon-krypton gas mixture (rather than just argon) that causes the lamp to draw only 34 watts.

Similar reduced-wattage versions exist to replace the following eight-foot lamps:

- 60W vs. 75W slimline
- 95W vs. 110W high-output (HO/800mA)
- 185W vs. 215W very-high-output (VHO/1500mA)

Applications

These lamps may be used to replace standard T12 lamps in spaces that are currently over-illuminated. This retrofit produces about 19 percent in energy savings and about a 19 percent reduction in light output. No ballast upgrades are required when converting to the energy-saver lamps.

Qualifications

Although the unit wattage is reduced, the resulting light output is also reduced. In addition to a lower rated lumen output, these lamps will lower the ballast factor from 94 to 87 when used with magnetic ballasts. The combination of these effects results in about a 19 percent reduction in light output. In 4-foot applications, energy-saver lamps do not increase the system efficacy; however, 8-foot enrgy-saver lamps do increase the system efficacy.

The 34W and 60W energy-saver lamps cannot be dimmed as easily as standard 40W and 75W T12 lamps, and they are more sensitive to temperature. The minimum starting temperature of 34W and 60W energy-saver lamps is 60°F. In addition, energy-saver lamps should not be used with preheat ballasts.

For maximum energy savings and efficiency in four-foot commercial applications, consider installing T8 or T10 lamps with electronic ballasts as an alternative. Refer to the lamp-ballast tables at the end of this section for listings of system wattages, ballast factors, lumen outputs, and system efficacies of various lamp-ballast systems.

25W T12 Lamps for Use with T8 Electronic Ballasts

Definition

One manufacturer produces 25-watt T12 lamps *specifically for use on T8 electronic ballasts*. The F25T12 lamp will reduce light levels by about 20 percent and energy consumption by about 17 percent when replacing F32T8 lamps operating on a full-output electronic T8 ballast. Initial rated lumens are 2300, the CRI is 72, and lamps are available in color temperatures of 3000K, 3500K, and 4100K.

Applications

These lamps enable users to correct overlit conditions which may result from installing full-output 32-watt T8 systems in place of 34-watt T12 systems. This simple lamp replacement is a far more economical approach to adjusting T8 system light levels than replacing the full-output T8 ballasts with partial-output ballasts. The light levels produced by a system using 25-watt T12 lamps with a full-output T8 electronic ballast is approximately equal to that of a system using 34-watt T12 lamps with an energy-efficient magnetic ballast.

Qualifications

Although this retrofit will reduce light levels to that of a 34-watt energy-saver T12 system, this upgrade is subject to potential “snap-back,” meaning that subsequent system relamping with 32-watt T8 lamps could result in lost energy savings and a return to unnecessarily high light levels. Snap-back can be avoided through proper maintenance practices and ongoing training of maintenance personnel.

FLUORESCENT LUMINAIRE UPGRADES

Delamping

Definition

Delamping is simply the removal of one or more lamps from a luminaire.

Applications

Two approaches to delamping may be used:

- *Uniform delamping* for reducing light levels throughout the space
- *Task-oriented delamping* to place more light directly in the work area and less light in the circulation areas

Relocating lamps so that they are centered on each half of the luminaire will improve light output and distribution, and will result in a more acceptable upgrade appearance.

Delamping may be combined with the use of higher output lamps, reflectors, lens upgrades, luminaire cleaning, and task lighting to minimize light output reduction.

In general, light levels are reduced in proportion to the number of lamps removed. However, in enclosed luminaires, delamping will result in a 5-10 percent increase in efficacy due to the cooler operating temperature and reduced lamp shadowing that results. Depending on ambient temperature, delamping an open strip luminaire may either increase or decrease efficacy.

Qualifications

If the remaining lamps are not relocated, the appearance of a delamped luminaire may not be acceptable.

Ballasts used for operating the removed lamps should be disconnected and removed from the luminaire. In addition, removing the unused sockets will prevent “snap-back” (re-installing lamps where they have been removed).

Delamping may not be feasible in series-wired two-lamp luminaires where the removal of one lamp extinguishes the other lamp. In such cases, consider installing partial-output (low ballast factor) electronic ballasts to operate both lamps at reduced wattage and reduced output.

Specular Reflectors with Delamping

Definition

Luminaire efficiency can be improved by 17 percent or more by removing one or more lamps and installing a specular “mirror-like” reflector in the luminaire behind the lamps. *(Efficiency can be improved by more than 17 percent when reflectors are installed in older luminaires where the finish is dull or has deteriorated.)*

Applications

Typically, the remaining two lamps in a 2’x4' luminaire are relocated to positions centered on each side of the luminaire for maximum utilization of the reflector. This enhances light output and distribution and will result in a more acceptable luminaire appearance.
The National Lighting Product Information Program measured the increase in luminaire efficiency achieved by specular reflectors in 2-lamp luminaires and reported the following average results:

Reflector Material	*Boost in Illumination*
new white reflector:	base case
anodized aluminum reflector:	5 percent increase
enhanced aluminum reflector:	15 percent increase
silver film reflector:	17 percent increase

The three factors that have the greatest affect on a reflector’s ability to improve luminaire efficiency are:

- reflector material
- reflector design (shape)
- efficiency of the base luminaire

Because it may be too expensive to replace older luminaires that have a dull or deteriorated finish, retrofit reflectors can be one of the most economical means for restoring the efficiency of an older luminaire.

As an alternative to specular reflectors, *white reflector retrofits* are available that can improve an older luminaire's efficiency while maintaining the original light distribution. These white reflectors can be significantly less expensive than specular reflectors.

All ballasts used for operating the removed lamps should be disconnected in order to save additional energy.

Reflectors may be combined with installation of higher output lamps, ballasts and/or improved lenses to minimize light output reduction (and in some cases, increase light output).

To maintain the increase in luminaire efficiency that results from a specular reflector installation, reflector surfaces should be cleaned at regular intervals.

Another application of specular reflectors is to modify a 2x2 luminaire by removing the two F40 U-lamps and installing a 2-lamp or 3-lamp UL-classified conversion to 2-foot 17-watt T8 lamps, electronic ballast, and specular reflector. This retrofit should be considered in applications where light output reductions are acceptable, yielding savings of over 60 percent.

Qualifications

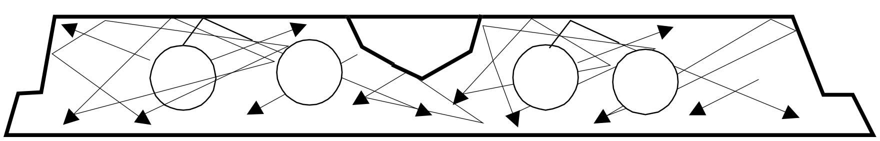
When installing reflectors and using 50 percent of the original lamps in 2'x4' troffers, maintained light levels are typically reduced by 30-45 percent (this assumes comparable conditions of luminaire dirt and lamp age). If existing luminaires show some surface deterioration (reduced efficiency that cleaning can't improve), reductions in light output resulting from installing reflectors and delamping will be lessened. To assess the performance of specular reflectors in your facility, set up a trial installation to compare the lighting in a room with clean, delamped luminaires to one with reflectors installed. (See *Lighting Evaluations* for specific procedures to follow for conducting a photometric evaluation both before and after a trial installation.)

Even a well-designed reflector may affect light distribution. Although it is possible to design reflectors that maintain the luminaire's original spacing criteria, most retrofit reflectors tend to concentrate the light distribution downward (refer to the glossary in *Lighting Fundamentals* for definition of spacing criteria). Although this concentration can reduce glare and brightness, it can also reduce the uniformity of illuminance throughout the space. To verify the reflector performance, install a trial installation and measure the variation of light levels at points directly underneath the luminaires compared to points between luminaires. Alternatively, ask your supplier for photometric data and check the values for spacing criteria.

If lamps need to be relocated or if the reflector is being used as part of an electrical enclosure, specify only *UL-classified* reflectors and accessories that include installation instructions for your specific luminaire's make and model.

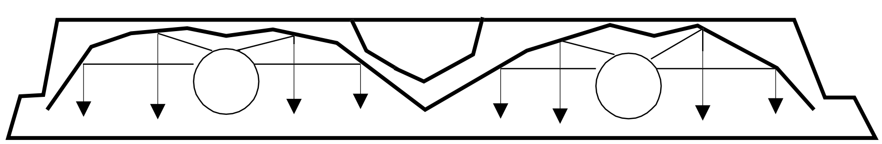
Check the design for accessibility to the ballast compartment.

Differences between manufacturers' reflector designs and materials can cause wide variations in reflector performance. *For independently measured performance data for specific name-brand reflectors, refer to* ***Specifier Reports: Specular Reflectors****, Volume 1 Issue 3, National Lighting Product Information Program, July 1992.*



Without Reflector

With Reflector



Fluorescent Power Reducers

Definition

Power Reducers (also called “current limiters”) are retrofit devices for fluorescent (and high-intensity discharge) luminaires that reduce light output with a nearly corresponding reduction in power consumption. (See high-intensity discharge (HID) upgrades section for discussion of HID power reducers.)

Applications

Most power reducers are designed to achieve a pre-set light output reduction — and energy savings — of 20, 33, or 50 percent. In addition, power reducers extend magnetic ballast life by reducing ballast operating temperature.

Power reducers enable light-output reductions as an alternative to delamping. They may be preferred to delamping in applications involving 2-lamp series-wired systems where the removal of one lamp will also extinguish the other lamp.

Power reducers may be installed directly inside the ballast compartment or installed as a companion lamp. The use of the companion lamp design is discouraged because it can be easily removed from the luminaire, eliminating future energy savings.

For maximum energy savings and efficiency in fluorescent systems, however, consider partial-output electronic ballasts as an alternative.

Qualifications

Power reducers do not improve the inherent efficacy of the lamp-ballast system. However, due to the relationship between operating temperature and fluorescent efficacy, slight increases in efficacy may result with power reducers installed in enclosed luminaires.

Power reducers may not be used with electronic ballasts.

Some power reducers increase total harmonic distortion in rapid-start systems to over 32 percent, which is considered an unacceptable level by most building engineers, utility companies, and ANSI. In addition, some power reducers can increase the lamp current crest factor to over 1.7 in rapid-start systems, which can void some lamp warranties. Check with the manufacturers of your lamps and ballasts to determine if the installation of power reducers will have any effect on their warranties.

Consider performing two comparative trial installations: Install power reducers and compare their measured performance against partial-output electronic ballasts. Verify that the resultant light levels will be satisfactory. Refer to *Lighting Evaluations* regarding trial installations.

Not all power reducers perform identically. For independently measured performance data for specific name-brand power reducers, refer to ***Specifier Reports: Power Reducers****, Volume 1 Issue 2, National Lighting Product Information Program, March 1992.*

Lens/Louver Upgrade

Definition

Luminaire efficiency can be significantly improved by replacing inefficient or deteriorated shielding materials. Clear acrylic lenses provide maximum efficiency, and new “low-glare” *clear* lenses provide this high efficiency AND good glare control. Deep-cell parabolic louvers also provide a good combination of efficiency and glare control.

Applications

The least efficient glare shielding materials — such as translucent diffusers or small-cell louvers — should be replaced with either clear acrylic lenses or large-cell parabolic louvers.

To determine impacts on visual comfort (glare control capability), refer to the product’s Visual Comfort Probability (VCP) data or perform a trial installation.

2-FOOT X 4-FOOT TROFFER SHIELDING MEDIA

Shielding Material	Efficiency Range (%)	VCP Range (%)
Standard Clear Lens	60-80	50-70
Low-Glare Clear Lens	60-80	75-85
Deep Cell Parabolic Louver	50-75	75-99
Translucent Diffuser	40-60	40-50
White Metal Louver	40-60	65-85
Small Cell Parabolic Louver	40-65	99

Visual comfort is improved when light emitted at higher angles is shielded.

Qualifications

Smaller cell parabolic louvers (2" or smaller cells) provide high visual comfort (>90) but reduce efficiency. Similarly, low glare *tinted* lenses also sacrifice efficiency in order to achieve high visual comfort.

If sufficient plenum space is available above the ceiling grid, deep-cell parabolic louver upgrades can be installed in many kinds of existing fluorescent luminaires. Alternatively, consider installing new deep-cell parabolic louver luminaires or retrofit with low-glare *clear* lenses.

New Efficient Luminaires

Definition

Instead of upgrading individual luminaire components, consider the labor savings and quality improvements that may be achieved by replacing existing luminaires with new luminaires that feature high-efficiency components such as T8 lamps, electronic ballasts, deep-cell parabolic louvers, and optional daylight-dimming controls.

Applications

Conditions that enhance the cost-effectiveness of new luminaires include:

★ where multiple luminaire component replacements are considered (new lamps, ballasts, reflectors, lenses, etc.)

★ where deep-cell parabolic louvers or indirect lighting systems are desired for combined efficiency and glare control

★ where the space will be remodeled or the luminaire locations will be changed

New luminaires should be considered in offices where computers are used. Luminaires in these areas should provide shielding of high-angle light which cause objectionable reflections in VDT screens, especially in large, open offices. The Illuminating Engineering Society (IES) has published their Recommended Practice No. 1 (RP-1) which addresses appropriate methods for lighting offices containing computer visual display terminals. Luminaires that meet the preferred glare shielding criteria of RP-1 have the following luminance (brightness) limits at specific angles.

Viewing Angle	*Maximum Luminance* *(preferred criteria)*
>55°	850 cd/m^2
>65°	350 cd/m^2
>75°	175 cd/m^2

Qualifications

Before installing new luminaires, ask a lighting designer to verify the correct number and spacing of the luminaires based on published photometric data and the desired illumination level.

Deep-Cell Parabolic Luminaires

Definition

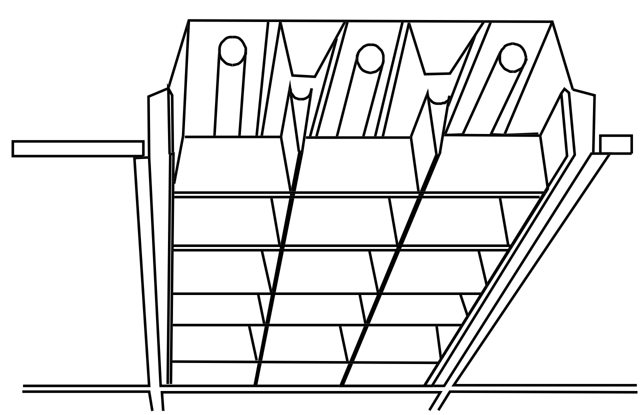
Deep-cell parabolic luminaires provide large-width louver cells (4-7 inches) to allow the light to efficiently exit the luminaire while providing glare shielding for high visual comfort. The vertical surfaces of these louvers are parabolic in shape, thereby eliminating any light loss resulting from interreflection within the louver.

Applications

Deep-cell parabolic luminaires are generally preferred in modern commercial spaces and particularly where visual display terminals are in use. Although the efficiency of deep-cell parabolic luminaires is typically less than that of lensed fixtures, the coefficient of utilization for the highest performing deep-cell luminaires may exceed that of standard lensed troffers. This advantage can be achieved by deep-cell luminaires that feature a “full chamber” design that aligns the parabolic louvers with a parabolic contour behind each lamp. More light is directed toward the visual task, and less light is absorbed by the walls in the room.

Typical Three-Lamp Parabolic Troffer

Source: CEC/DOE/EPRI



Qualifications

To achieve a high coefficient of utilization and high visual comfort, deep-cell parabolic luminaires may cause shadows to appear on the upper sections of walls, creating the “cave effect.” This aesthetic concern can be addressed with the use of accent lighting (e.g., wall sconces or wall-washers) or indirect luminaires (see below).

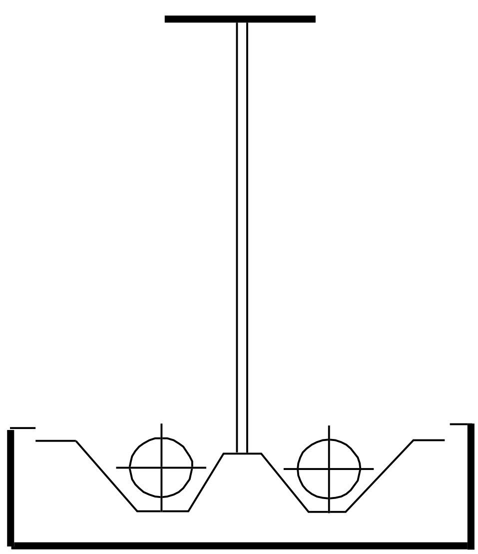
Indirect Luminaires

Definition

Indirect luminaires distribute at least 90 percent of the emitted light upwards to reflect off the ceiling, providing uniform, diffuse lighting on ceilings, walls, and tasks. Because the light sources are completely shielded from the view of occupants, indirect systems provide relatively high visual comfort. Compared with direct lighting systems, indirect lighting can create the illusion of a more spacious and pleasant environment because ceilings and walls are uniformly illuminated.

Applications

Indirect fluorescent lighting is an excellent application for offices with computers. Indirect luminaires provide a uniform lighting distribution on the ceiling and walls. This helps to eliminate the distracting glare of light sources on display screens. Properly installed, indirect luminaires meet the performance criteria of IES RP-1 for illuminating spaces with personal computers (see section above).



Indirect Luminaire Pendant Mounted

Another common application for indirect lighting is in partitioned spaces. Because the light reflected off the ceiling is more diffuse than light from direct systems, shadowing effects caused by the partitions are reduced.

Indirect luminaires are usually suspended from the ceiling, although some luminaires are available that can be directly mounted on systems furniture. Indirect lighting can also be used with compact fluorescent task lights for an energy-efficient task/ambient lighting system.

The combined use of both direct and indirect lighting can create a pleasing aesthetic effect. The direct lighting system can provide the needed ambient illumination in the interior area of a large space, while the indirect luminaires provide perimeter illumination and wall washing. Some purely indirect systems have been described as “washed out” or “bland” without the contrast-enhancing qualities of direct lighting. Also, consider the use of “direct/indirect” luminaires that provide both uplighting and downlighting from suspended luminaires.

Qualifications

Indirect systems yield a slightly lower workplane lumen efficacy (workplane lumens per system watt) than direct systems utilizing the same lamp-ballast combination. However, upgrading to a more efficient lamp-ballast combination can offset this decrease in efficacy.

A highly reflective ceiling is a must for indirect systems. Workplane lumen efficacy will significantly decline when ceiling reflectances are below 80 percent. In addition, walls should have a high reflectance (at least 50 percent reflectance).

Luminaire dirt depreciation is of major importance for successful indirect lighting systems. Indirect lighting systems are more susceptible to dirt depreciation because dust will settle on the lens or inside surfaces. Regular cleaning is strongly recommended to minimize the effects of dirt depreciation.

When installing indirect luminaires, mount them according to manufacturer’s specifications. The correct suspension distance is critical for indirect lighting system performance. If the sources are mounted too close to the ceiling, the resulting “hot-spots” will cause unwanted glare on computer screens. Suspending the luminaire too far from the ceiling will decrease the efficiency of the system.

Because indirect systems need to be suspended below the ceiling, areas with low ceilings may be unacceptable. In such areas, consider installing indirect systems that are specifically designed with a wide lighting distribution lateral to the lamp axis. User acceptance should first be evaluated in a trial installation.

Most indirect systems are installed in new construction and renovations, although retrofit indirect lighting kits are available. Indirect lighting is generally more expensive than direct systems, but check with local suppliers and contractors for installed costs in your area.

Task Lighting with Delamping

Definition

Significant energy savings and lighting quality improvements can be achieved by providing light sources at specific task locations while reducing ambient (overhead) lighting. The 50 footcandles that are normally needed for typical reading and writing tasks can be achieved with a task light that provides at least 25-30 footcandles and an ambient lighting system that provides only about 20-30 footcandles. Compact fluorescent task lighting with delamping increases visual comfort, saves energy, and provides users with greater control over their workstation illuminance.

Applications

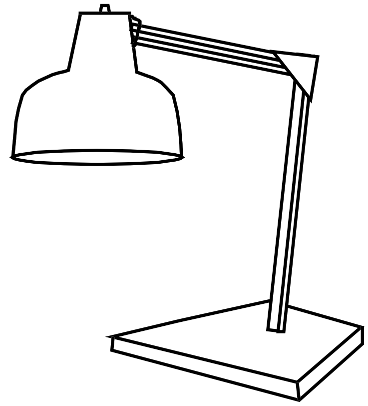
“Task/ambient” lighting designs are best suited for office environments with significant VDT usage and/or where modular furniture can incorporate task lighting under shelves. In other cases, desk lamps may be used to provide task illumination. Task lighting should also be incorporated into industrial applications such as inspection, assembly, and machine operation.

In most workplaces, a wide variety of visual tasks need to be performed. In addition, workers have varying visual capabilities and preferences. Task lighting can enhance user acceptance of the lighting system because task lights can be adjusted to provide higher levels of illuminance where the user chooses. In situations where older workers require higher light levels, an additional task light could be provided.

Qualifications

Energy savings result when the energy saved from reducing the ambient lighting load exceeds the added energy used for the task lights. In some cases, the use of incandescent task lights may add more load than can be eliminated from the ambient lighting system. Compact fluorescent task lights are very efficient sources for task lighting.

Non-adjustable task light strips that are permanently mounted under cabinet shelves can cause reflected



glare on work surfaces. To reduce reflected glare, specify compact fluorescent task lights that allow users to position the light to the side of the task.

When adding task lights, consider the electrical loads added to your distribution system. Be careful not to overload the amperage rating of your building circuits.

For more guidance on the use of task lighting, refer to ***Lighting Answers: Task Lighting for Offices****, Volume 1 Number 3, April 1994, National Lighting Product Information Program.*

Group Relamping and Cleaning with Delamping

Definition

Relamping and cleaning luminaires according to a schedule determined by lamp life, lumen depreciation characteristics, and ambient dirt conditions. Refer to *Lighting Maintenance* for a complete discussion of group relamping and cleaning.

Applications

Periodic group relamping and cleaning will significantly improve luminaire efficiency and reduce maintenance costs. The resulting increased light output from properly maintained luminaires may justify delamping, using current limiters, using partial-output electronic ballasts, or relamping with reduced-output lamps.

Qualifications

Group relamping and cleaning makes the most sense in the following situations:

✓ high or remote fixture mounting locations
✓ dirty environments
✓ 800mA and 1500mA 8' fluorescent systems
✓ uniform hours of lighting operation
✓ retail, where aesthetics are important

INCANDESCENT UPGRADES

Wherever feasible, alternatives to the use of incandescent lamps should be pursued. With recent advances in compact fluorescent and halogen lamps, the continued use of standard incandescent lamps is difficult to justify.

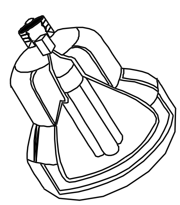
Compact Fluorescent Lamps

Definition

Compact fluorescent lamps (CFLs) are an energy-efficient, long-lasting substitute for the incandescent lamp. They are available in a wide variety of configurations beyond the most common twin-tube, quad-tube, and triple-twin-tube configurations. CFLs can be purchased as self-ballasted units or as discrete lamps and ballasts. Several retrofit adapters are available for convenient retrofit in existing incandescent sockets. Most CFL products are now manufactured with electronic ballasts which provide 20 percent higher efficacies as well as instant-starting, reduced lamp flicker, quiet operation, smaller size, and lighter weight.

Screw-In Compact Fluorescent

Source: CEC/DOE/EPRI



Applications

CFLs may be used in a variety of incandescent applications including downlights, surface lights, pendant luminaires, task lights, compact troffers, sconces, exit lights, step lights, and flood lights. Over the past couple years manufacturers have introduced CFLs that are designed to fit in the same physical space as an A-19 and A-21 incandescent lamp. These small size CFLs allow for upgrades to table lamps and small incandescent luminaires.

Qualifications

Because compact fluorescent lamps are not point sources (like incandescents or HID lamps), CFLs are not as effective in projecting light over distance. The light output from a CFL is much more diffuse, and lumens easily stray from the intended target in directional lighting applications. As such, these lamps may not be suitable in high-ceiling downlighting applications (ceilings higher than 15') or where tight control of beam spread is necessary. Note, however, that improvements in CFL reflector design are introduced each year. Perform a trial installation to verify CFL performance in high-ceiling areas.

Compact fluorescents are available in a wide range of color temperatures from 2700K to 5000K allowing the lamps to be used in a variety of applications. With the introduction of 2700 and 3000K CFLs in small and large sizes, almost every incandescent application can be upgraded with a CFL and still have the same look and "warmth" of an incandescent lamp.

Dimmable CFLs are available as part of a new luminaire installation and also as a retrofit. Complete fixtures are available that contain a dimmable CFL with a dimming ballast usually mounted on the exterior of the fixture (not as an integral part of the lamp). Retrofit dimmable CFLs are also available to be used on existing incandescent dimming circuits. Conference rooms with incandescent downlights are an excellent application for retrofit dimmable CFLs. Note: standard non-dimmable CFLs should not be installed on a dimming circuit due to risk of fire.

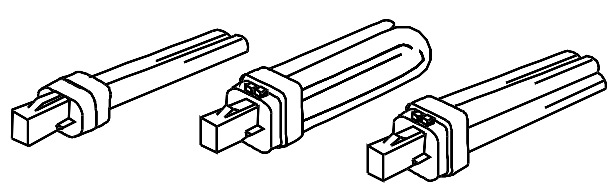
Some CFLs have difficulty starting when the ambient temperature drops below 40°F, while others are designed to start at temperatures below freezing. Refer to manufacturer specifications.

The light output of CFLs is significantly reduced when used in luminaires that trap heat near the lamp or when exposed to cold temperatures. However, when a mercury amalgam is included in the lamp's chemistry, the light output at temperature extremes is typically within 85 percent of maximum.

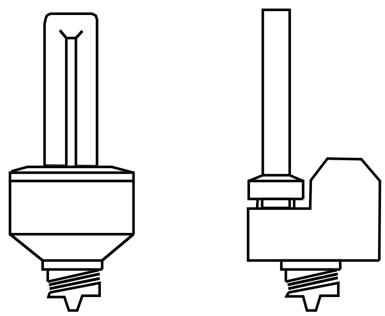
In addition, the *orientation* of the lamp can also significantly affect lumen output. Depending on the lamp design and ambient temperature, the light output in the base-down orientation may be up to 15 percent less than in the base-up position. Trial installations are recommended before purchasing large quantities.

Common Compact Fluorescent Lamp Types

Source: CEC/DOE/EPRI



Most lamps operating on magnetic ballasts require one to three seconds to start and rise to full output. Where instantaneous lighting is required, use compact fluorescent *electronic* ballasts or T5 rapid-start lamp-ballast systems.



Some compact fluorescent systems with electronic ballasts may be incompatible with occupancy sensors that utilize solid-state switches (triacs) instead of air-gap switches or relays. In these situations, the occupancy sensor may not function with electronically-ballasted lamps unless a ground wire is available. Check with your occupancy sensor supplier to verify compatibility.

The total harmonic distortion (THD) from most magnetically ballasted compact fluorescents is in the range of 15-25 percent. However, the THD from electronically ballasted compact fluorescents can be significantly higher. When using a relatively large number of electronically ballasted compact fluorescent lamps on a circuit, consider specifying “low-harmonic” electronic ballasts which produce less than 32 percent THD.

To achieve the compact size and low cost of compact fluorescent ballasts, many are produced with a normal power factor (NPF) rating. This causes the ballast to draw more current (amps), but not more energy (watts), than the high power factor type. When using a large number of NPF ballasts in a given location, consult your utility representative or a professional engineer to evaluate the impact of power factor on your utility bill.

For independently measured performance data for specific name-brand CFLs, refer to ***Specifier Reports: Screwbase Compact Fluorescent Lamp Products****, Volume 1 Issue 6, April 1993, and the* ***Update Specifier Reports on Screwbase Compact Fluorescent Lamp Products*** *published in 1994 and 1995, National Lighting Product Information Program. In addition, a Specifier Report on CFL downlights was published in 1995.*

Compact Halogen Lamps

Definition

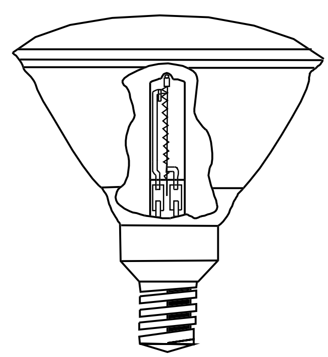
Compact halogen lamps consist of a small tungsten-halogen capsule lamp within a standard lamp shape similar to PAR lamps or general service A-type lamps. These lamps are adapted for use as direct replacements for standard incandescent lamps. Halogen lamps are more efficient, produce a whiter light, and last longer than conventional incandescent lamps.

Applications

As a general rule, compact halogen lamps should be considered for replacing incandescents wherever the more efficient compact fluorescents would not be a better choice. (See the qualifications listed under CFLs above.) Compact halogen lamps can be dimmed, their performance is independent of temperature and orientation, they project light efficiently over long distances, and they present no power quality or compatibility concerns.

Cut-Away View Showing Tungsten-Halogen Capsule Within a PAR Lamp

Source: CEC/DOE/EPRI



The best applications are in accent lighting and retail display lighting, especially where tight control of beam spread is necessary. Other good applications include high-ceiling downlighting and “instant-on” floodlighting. The use of specially-designed reflectors or an optional infrared (IR) coating applied to the halogen capsule can increase the efficacy of this light source by about 35 percent. Both PAR lamps and general service A-lamps are now manufactured using this thin film technology.

Compact halogen lamps may be used in full-range dimming applications, but constant dimming below 35 percent of full light output may reduce lamp life and efficacy.

Qualifications

Lamps with optional diodes (for improving lamp optics) can flicker and have adverse effects on dimming and power quality. Most manufacturers, however, have eliminated diodes from their lamp designs.

Due to their lower efficacy, compact halogen lamps should not be used in applications where compact fluorescent lamps would serve satisfactorily.

Although quartz capsules allow emissions of ultraviolet (UV) light, most compact halogen lamps are equipped with a glass cover or enclosure that blocks nearly all of the UV emissions. Note however that some compact halogen task lights, low-voltage halogen lamps, and linear quartz lamps may not be equipped with adequate UV protection.

*For independent performance test results for a wide variety of halogen and compact fluorescent reflector lamps, refer to **Specifier Reports: Reflector Lamps**, Volume 3 Number 1, October 1994, National Lighting Product Information Program.*

Exit Sign Upgrades

Definition

Exit sign upgrades offer the potential for huge reductions in energy and maintenance costs. The following light sources should be considered for replacing up to 40 watts of incandescent power consumption per exit sign:

Retrofit

✓ light-emitting diode (LED)
✓ low-wattage incandescent assembly
✓ compact fluorescent

New Exit Signs

✓ light-emitting diode (LED)
✓ electroluminescent
✓ tritium or self-luminous
✓ compact fluorescent

Applications

All emergency exit signs should illuminate 24 hours per day and be able to continue operation in the event of a power failure. Significant energy savings can be achieved by simply replacing or upgrading the exit signs with low-energy models.

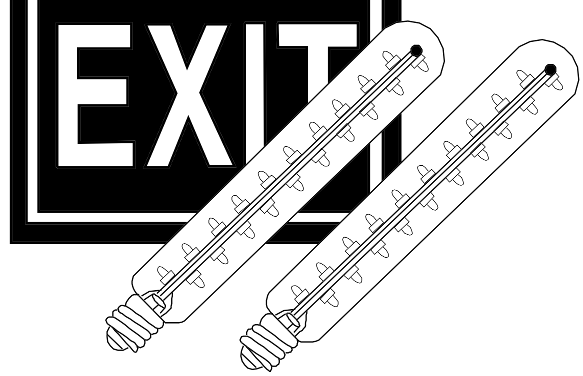
Common to all retrofit kits are adapters that screw into the existing incandescent sockets to make installation simple. However to avoid snap-back, retrofit kits are available for hard-wire installation. Whatever connection methods are used, installation is relatively easy, usually taking fifteen minutes or less per sign.

Of the **retrofit options**, *light-emitting diode (LED)* sources are the most energy efficient — only consuming two to five watts per exit sign kit. Combined with the extremely long rated life of LED sources, this option is one of the most economical retrofits based on life-cycle cost. One version of the LED retrofit consists of a pair of LED strips that adhere to the side panels of the exit sign enclosure. Alternatively, a simple screw-in LED “lamp” is available, consisting of a series of LEDs encased in a glass housing.

Another low-cost retrofit solution is the incandescent assembly which is a series of low-voltage, low-wattage, long-life incandescents that can be assembled in a variety of configurations such as a luminous rope or cluster. These devices simply screw into the existing incandescent sockets.

Although compact fluorescent lamps have been recommended for years as an energy-efficient retrofit for exit signs, their lamp life and efficacy are exceeded by the LED, EL, and low-wattage incandescent technologies discussed above.

Several choices exist for purchasing **new exit signs** with consumption of less than 5 watts. Among these choices, *tritium or self-luminous* sources are the most energy efficient, consuming no electricity. Note, however, that the spent tritium tubes must be disposed of as a radioactive waste. Other new fixture choices include LED, electroluminescent, and compact fluorescent.



To determine the most financially attractive exit sign upgrade, consider all of the costs that will occur during the life cycle, including installation, energy, maintenance, and disposal. The table below compares new fixture and retrofit options to an incandescent base case. Note that for new fixtures and retrofits, LED sources generally yield the highest net present value (NPV) or net profit. Use *ProjectKalc* and your specific financial assumptions to determine the life-cycle "net present value" of the benefits of replacing incandescents with one of these energy-efficient exit sign technologies. (See *Financial Considerations* for more information about financial analysis.)

Qualifications

Check with local building codes for accepted emergency exit sign illuminance options and accepted retrofit sources. Note that some exit sign technologies (such as electroluminescent) may not produce the required brightness during the entire life of the light source.

Verify that your new exit sign complies with Underwriters Laboratory Standard UL 924 and that your illumination sources are U.L. listed for use in your exit sign. To maintain the U.L. listing of retrofitted exit signs, use only *UL-classified* retrofit kits that are designed for your specific exit sign.
LED retrofit lamps and kits should not be used in panel-type exit signs (those with a single translucent panel where the word "exit" and the background are luminous). The red or green color of the LED source will distort the true color of the panel exit sign face, causing a reduction in letter contrast (visibility). Use only white sources in panel exit signs.

Reliability is of utmost importance for exit signs. For example, sources with a shorter life are more likely to be burned out when needed in an emergency situation. Of all the new technologies, LED sources have the longest rated life. Most claims state that LED sources will last 80 years, although some manufacturers claim a rated life of 25 years for their retrofit products. Self-luminous and electroluminescent sources also have relatively long life spans.

Note that the light output of electroluminescent light sources depreciates significantly over time. Request information about the lumen depreciation performance of the electroluminescent product that you are considering, and evaluate whether the *maintained* light output will be acceptable.

Exit Sign Technologies
Typical Performance

Source	Typical Wattage	Life (yrs)	Replacement Source	Annual Energy Cost ($)	Annual Maint. Cost ($)	Upgrade Cost
New Fixtures						
Incandescent	40	0.8	lamp	28.00	19.50	N/A
CFL	10	2	lamp	7.00	9.5	90.00
Electroluminescent	1	10	light panel	0.70	20.50	200.00
Self Luminous (Tritium)	0	10-20	tube console	0	10.50	247.00
LED	2-5	25+	circuit board	3.50	0	90.00
Retrofit Light Sources						
Reduced Wattage Incan.	8-18	10	light tube	5.60	4.00	30.00
CFL	10	2	lamp	7.00	9.50	30.00
LED	2	25+	LED kit	2.80	0	35.00

Note: Material, labor, energy costs and lamp performance can vary. Contact local suppliers for specific prices and performance data.

ASSUMPTIONS
- One-sided exit
- Ten year life used for tritium signs
- Maintenance costs based on materials and labor for source replacement on a spot relamping basis
- $0.08 per kWh, labor=$20 per hour
- Upgrade cost includes labor and materials
- Based on 1998 price data

Since tritium is radioactive, expired tritium tubes must be recycled or disposed of as radioactive waste. To insure proper disposal of the luminous tubes, manufacturers will label an address on the tube console that specifies where to send it for recycling (and purchase of replacement tubes).

*For more technical information, as well as independently measured performance data for specific name-brand exit signs, refer to **Specifier Reports: Exit Signs**, Volume 2, Issue 2, National Lighting Product Information Program, January 1994; **Specifier Reports Supplements: Exit Signs,** March 1998*

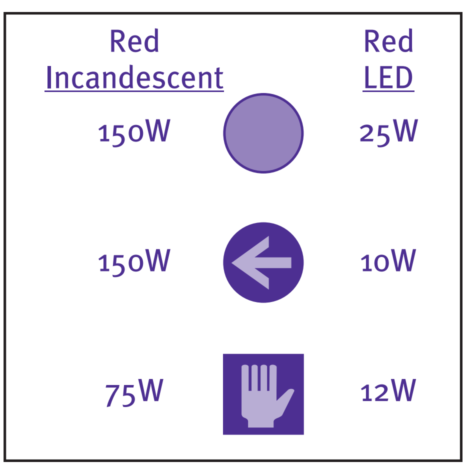
LED Traffic Lights

Definition

Instead of using high-wattage incandescent lamps in traffic signals, consider the new light-emitting diode (LED) traffic lights. Using over 85% less energy and lasting about five times longer than incandescents (about 44,000 hours), LED traffic lights can yield rapid financial returns for municipalities. Each "solid" LED traffic light consists of 400 to 700 LEDs; other configurations include directional arrows and pedestrian "hands." Typical solid-red and solid-yellow LED traffic lights can be purchased for $100-$150 per lamp. Solid-green can cost up to $400 per lamp.

Applications

Red lights operate for more hours per year than green or yellow. (The average red light operates an average 60% of the time or nearly 5,300 hours per year.) In addition, some red traffic lights are larger and higher wattage than the other lights. For these reasons, about 85 percent of the potential energy savings from LED sources in traffic lights can be achieved by replacing the red lights.



The application with the greatest energy savings is replacing a 150-watt red incandescent directional arrow with a 9-watt red LED arrow. Other wattage comparisons are listed in the diagram below.

Limitations

Check with state vehicle codes for acceptance of LED traffic signals.

Verify that the LED light is compatible with the signal's controller. Some controllers may interpret the low-current condition of LED operation as a lamp "failure" and could switch the signal to a flashing-red mode.

Compact HID Sources

Definition

New manufacturing methods have produced low-wattage (<100-watt) versions of metal halide and high pressure sodium lamps.

Applications

Primarily intended for new construction or remodeling applications, compact high-intensity discharge (HID) lamps are point sources which lend themselves to projection and floodlight applications as well as general illumination.

Qualifications

All metal halide lamps are susceptible to lamp-to-lamp color differences and color shift over life.

Compact "white" high pressure sodium lamps offer improved color rendering (80-85 CRI) compared to standard HPS lamps, but after their "color life," the color quality becomes similar to standard HPS lamps (25 CRI). In addition, the maintained efficacy of white high pressure sodium systems is only 22-27 lumens per watt.

All HID lamps require warm-up and restrike periods, so frequent switching installations should not utilize these lamps.

*For independent performance test results for HID accent lighting systems, refer to **Specifier Report: HID Accent Lighting Systems,** October 1996 (Volume 4 Number 2).*

HID UPGRADES

The primary method for improving the efficiency of high-intensity discharge (HID) systems is to replace the light source with a more efficacious system. Other retrofit options include reduced-wattage HID lamps, retrofit reflectors, HPS lamps for mercury ballasts, and bi-level HID luminaire switching.

Conversion to High-Efficiency HID System

Definition

Existing high-bay or outdoor lighting systems that use incandescent, mercury vapor, or (in some cases) fluorescent lamps, may be replaced with metal halide (MH), high pressure sodium (HPS), or low pressure sodium (LPS) systems. These retrofits normally include a complete luminaire replacement, including the lamp, ballast and optical assembly. Refer to Lighting Fundamentals for a complete discussion of these lamps and their characteristics.

Applications

The most cost-effective upgrades involve replacing less efficient sources such as incandescent, HO/VHO fluorescent, or mercury vapor with MH, HPS, or LPS systems. This may involve a one-for-one luminaire replacement or a new layout of luminaires to take advantage of the different light distribution characteristics of HID luminaires.

Qualifications

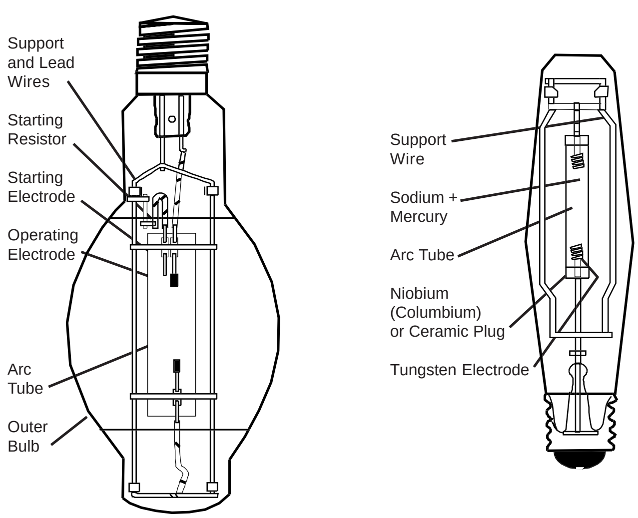
The selection of the HID luminaire should be based on the following criteria that pertain to the task:

- color rendering quality
- efficiency
- lamp life
- lumen maintenance
- light distribution

Refer to *Lighting Fundamentals* for a complete discussion of these characteristics.

Lamp Construction

Source: DOE: CEC/DOE/EPRI



Metal Halide High Pressure Sodium

High Performance Metal Halide Systems

Definition

For maximum efficacy (lumens/watt), consider the new high-performance pulse-start metal halide lamp/ballast systems. Pulse-start systems can achieve up to a 30 percent increase in maintained efficacy because of a change in the construction of the lamp's arc tube. The starting electrode normally used in a typical metal halide lamp is eliminated; a higher voltage pulse is supplied to the lamp using a special igniter in the ballast. The result is reduced lamp lumen depreciation. Some manufacturers have taken advantage of the removal of the starting electrode and redesigned the shape of the lamp's arc tube to further increase efficacy.

In addition to improved efficacy and reduced lamp lumen depreciation, other benefits of 'pulse-start metal halide systems include up to 60 percent reductions in lamp warm-up and restrike times, as well as improved color consistency. Restrike time for pulse-start MH is 2-4 minutes

Applications

To convert to this system, both the lamp and the ballast must be replaced. SuperCWA, regulated lag, and linear reactor type ballasts are available to operate pulse-start lamps. Pulse-start lamps and ballasts are available from several manufacturers in wattages from 150 to 400.

Pulse start lamps are excellent for interior and exterior applications. The increased color quality and shorter restrike characteristics lend the lamps to be practical for warehouses, gymnasiums, exterior lighting, indoor stadiums, and retail. For the most efficacious pulse-start system, specify a linear reactor ballast. A 350-

watt lamp on a linear reactor ballast (375 system watts) will provide comparable light levels to a 400-watt standard MH system (460 system watts).

Limitations

Although linear reactor pulse-start systems are the most efficacious they may be sensitive to voltage dips. In areas with frequent voltage dips consider using a regulated lag pulse-start system that can withstand a 50 percent voltage dip. SuperCWA pulse-start systems are good for a variety of general lighting applications but do not have the energy savings of a linear reactor system.

High-Bay Compact Fluorescent Luminaires

Definition

Compact fluorescent luminaires designed for relatively high mounting heights (up to 30'). Using large, specially designed reflectors, these luminaires typically house six to nine compact fluorescent lamps (either T4 quad-tube or T5 twin-tube).

Applications

The unique characteristics of compact fluorescent operation provide the following advantages of compact fluorescent luminaires over standard high-intensity discharge systems:

★ instant-on (no warm-up time)
★ instant-restrike
★ multiple light levels
★ high color rendering
★ high efficacy

Multiple light levels are provided by separately switching each of the 2-lamp or 3-lamp ballasts within the luminaire. Using a photosensor, the proper light output level can be determined automatically. The instant-on and instant-restrike performance allows for automatic on/off control using occupancy sensors.

Typical applications for these luminaires include sports arenas/gymnasiums, auditoriums, and warehouse aisles. The diffuse nature of fluorescent lighting increases the percentage of illuminance on vertical surfaces — an important consideration in manufacturing, warehousing, retail, and sport lighting.

Qualifications

Although compact fluorescent sources are relatively efficient in terms of lumens per watt, they are not as optically efficient has HID sources for directing light over long distances. To verify that the high-bay compact fluorescent luminaires will produce the required footcandles on the floor, ask for the luminaire's photometric data which tabulates the coefficient of utilization values for a variety of room geometries and room surface reflectances. In general, these luminaires will perform better in rooms with ceilings that are relatively low compared to the room length and width; they should not be considered for use in rooms with ceilings that are high in proportion to the room's length and width. Have a lighting specifier perform illuminance calculations for your specific application, based on independently measured photometric data. Do not rely on simplified lighting performance tables because they may not take into account the size and shape of the room in which the luminaires are to be located.

Reduced-Wattage (Energy-Saver) HID Systems

Definition

Reduced-wattage metal halide and high-pressure sodium systems are available that reduce energy consumption by up to 18 percent with corresponding reductions in light output. These upgrade technologies are available as reduced wattage retrofit lamps.

Applications

"Energy-saver" versions of metal halide and high pressure sodium lamps are available in 225-watt and 360-watt packages for directly replacing 250-watt and 400-watt lamps. In addition, 150-watt metal halide energy-saver lamps are available for replacing the 175-watt lamp.

Qualifications

In most cases, the reduced-wattage energy-saver lamps will also cause a corresponding reduction in light output. However, if a "universal-position" metal halide lamp is replaced with a "position-specific" energy-saver lamp (e.g., vertical base-up), then the light output would be comparable. A simple trial installation is suggested in order to compare the light output and quality of these new lamps. Remember to correct for lamp lumen depreciation when comparing the old and new lamps. Refer to *Lighting Maintenance* for a complete discussion of lamp lumen depreciation effects.

HID Power Reducers

Definition

Power reducers (also called “current limiters”) are retrofit devices for high-intensity discharge (and fluorescent) luminaires that reduce light output with a nearly corresponding reduction in power consumption. (See fluorescent upgrades section for discussion of fluorescent power reducers.)

Applications

Power reducers are designed to achieve a pre-set light output reduction — and energy savings — of 20 or 25 percent. In addition, power reducers extend HID ballast life by reducing ballast operating temperature. They should be considered as economic alternatives to panel-level HID system dimming (see controls upgrades section) if variable control of light output is not needed.

Qualifications

Power reducers are typically designed to work only with the more common CWA ballasts and HID lamp wattages of at least 175 watts. Lamp types that can be controlled include mercury vapor, metal halide, and high-pressure sodium.

Check with the manufacturers of your lamps and ballasts to determine if the installation of power reducers will have any effect on their warranties.

Trial installations are suggested to verify that light output reductions and energy savings are acceptable. Refer to *Lighting Evaluations* for guidance in performing and evaluating trial installations.

Retrofit HID Reflectors

Definition

Conventional HID reflectors can be retrofit or replaced with specular or clear reflectors in order to enhance luminaire efficiency.

Applications

In relatively clean environments, retrofit HID reflectors can increase illuminance on task surfaces without increasing energy consumption. In overlit situations, the efficiency improvement may allow some of the luminaires to be removed or de-energized. In addition, proper applications of retrofit reflectors can reduce glare.

Qualifications

The installation of retrofit reflectors may alter the lighting distribution from your existing HID luminaires. When evaluating a trial installation, check for uniformity of illuminance, visual comfort (glare), illuminance on vertical surfaces, color shift, and aesthetic effects such as darkness of ceilings and walls.

HPS and MH Lamps for Use on Existing Mercury Ballasts

Definition

High pressure sodium (HPS) and metal halide (MH) lamps are available that can be used in place of specific wattages of mercury vapor lamps, without requiring a ballast change.

Applications

These lamps provide an inexpensive means for significantly improving light output while saving up to 16 percent in energy consumption in existing mercury vapor luminaires.

Note that several manufacturers produce specially designed metal halide lamps that will operate on existing HPS ballasts for improving color rendering (65-70 vs. 22), but causing light output reductions of 33-50 percent.

Qualifications

Make sure that any retrofit lamp under consideration is UL-listed. Verify that the socket rating is compatible with the new lamp type.

Contact the manufacturer for a list of mercury ballast types for which their retrofit lamps are compatible.

For greater energy savings and wattage selection, consider replacing the mercury vapor luminaire with a new high-pressure sodium or metal-halide luminaire.

Conduct a trial installation to determine if resultant light levels and visual comfort will be acceptable.

For typical performance information, refer to the system performance tables included at the end of this booklet. Note that the actual wattage and lumen performance will vary depending on the specific mercury ballast that is used.

Capacitive Switching HID Luminaires (Bi-Level)

Definition

Capacitive switching (or “bi-level” or “hi/lo”) HID luminaires are designed to provide either full light output or partial light output based on inputs from occupancy sensors, manual switches, or scheduling systems. Capacitive-switched dimming can be installed as a retrofit to existing luminaires or, more commonly, as a direct luminaire replacement. Capacitive switching HID upgrades can be less expensive than installing a panel-level variable voltage control to dim the lights, especially in circuits with relatively few luminaires. In addition, it allows for control of individual luminaires, rather than entire circuits.

Applications

The most common applications of capacitive switching are occupancy-sensed dimming in parking lots, athletic facilities, and warehouse aisles. General purpose transmitters can be used with other control devices such as timeclocks and photosensors to control the bi-level luminaires.

Upon sensing motion, the occupancy sensor will send a signal (by powerline carrier, fiberoptic cable, or low-voltage wire) to the bi-level HID system that will rapidly bring the light levels from a standby reduced level to about 80 percent of full output, followed by a short warmup time between 80 percent and 100 percent of full light output.

Depending on the lamp type and wattage, the standby lumens are roughly 15-40 percent of full output and the standby wattage is 30-60 percent of full wattage. Therefore, during periods that the space is unoccupied and the system is dimmed, energy savings of 40-70 percent are achieved. Utility *cost* savings can be even greater depending on demand charges and time-of-use rates.

Qualifications

Lamp manufacturers do not recommend dimming below 50 percent of the rated input power. Check with your lamp supplier to determine whether the bi-level system will affect your lamp warranty.

For more information about continuous and bi-level HID dimming systems, refer to ***Lighting Answers: Dimming Systems for High-Intensity Discharge Lamps****, Volume 1 Number 4, September 1994, National Lighting Product Information Program.*

For a case study, order EPA’s **Application Profile – HID Bi-Level Switching ,** October 1996.

OCCUPANCY SENSORS

Reducing watts represents only half of the potential for maximizing energy savings. Reducing operating hours through automatic controls is the other half. Occupancy sensors are cost-effective devices that can ensure that the lights are energized only when occupants are present.

OVERVIEW

Occupancy sensors save energy by automatically turning off lights in spaces that are unoccupied. When motion is detected, the sensor activates a control device that turns on the luminaires. If no motion is detected within a specified period of time, the lights are turned off until motion is sensed again.

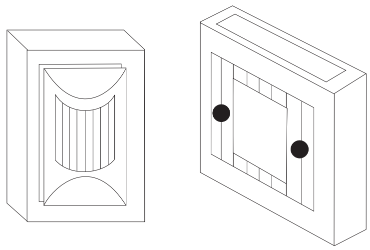
Occupancy sensors are suitable for a very wide range of lighting control applications and should be considered in every upgrade decision. Occupancy sensors may be installed to provide on/off control of incandescent or fluorescent loads as well as bi-level control of capacitive-switching HID luminaires (that idle in a low-output mode during periods of unoccupancy). Refer to the HID upgrades section for a complete discussion of capacitive switching HID luminaires.

Most occupancy sensors have adjustable settings for both sensitivity and time delay. The sensitivity setting allows the user to fine tune the sensor for the activities that occur in the space to ensure that normal motion is detected without triggering responses to extraneous signals. The time delay setting refers to the amount of time that elapses with no motion detected before the luminaires are turned off. The time delay prevents the luminaires from switching off during intervals when people are actually in the room, but move too little or too slowly to be detected by the sensor.

Some occupancy sensors provide daylight switching with their occupancy switching control. A trial installation is recommended to assess user acceptance of this technology.

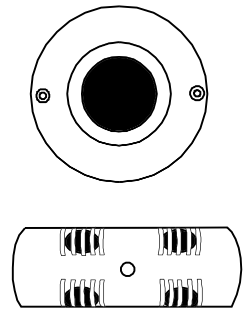
Wallbox Occupant Sensors

Source: CEC/DOE/EPRI



Ceiling-Mounted Occupant Sensors

Source: CEC/DOE/EPRI



MOUNTING LOCATIONS

Occupancy sensors are available in both ceiling-mounted and wall-mounted versions, utilizing either infrared or ultrasonic sensing technologies. In addition, workstation occupancy sensors have entered the market for automatically controlling workstation loads such as task lights, computer monitors, printers, and radios.

Wall-Mounted Sensors

Common applications for wall-mounted sensors include separately switched areas such as conference rooms, classrooms, individual offices, and storage rooms. Because these devices are mounted in existing light switch locations, check the coverage pattern provided by the sensor to see if it will adequately detect motion throughout the room. In addition, verify that the type of motion in the space will be detected, given the sensor type and location (see discussion of infrared and ultrasonic technologies below). In addition to the "automatic-on/automatic-off" occupancy sensors, other control options that are available with wall-mounted sensors include:

Manual-On/Automatic-Off

These sensors must be switched on manually to energize the luminaires; the unit automatically turns off the luminaires when motion is no longer detected.

Two-Level

For retrofit of dual switching systems (with two switches providing two levels of light), the user has the option to manually select either a "half-on" or "full-on" setting on the occupancy sensor.

Daylight Switching

These sensors can be calibrated to turn off the lights when ambient light levels reach a desired target. Some sensors will not allow the lights to turn off due to daylight contribution when occupants are present.

Ceiling-Mounted Sensors

Ceiling-mounted sensors should be used in areas where wall-mounted switches would be inadequate, such as corridors, rest rooms, open office areas, warehouse aisles, and spaces where objects obstruct the coverage of a wall-mounted sensor. These sensors are usually wired to a separate control module and one or more relays that perform the actual switching function in the ceiling plenum. Multiple sensors and lighting circuits can be controlled by one control module, but manufacturers specify a maximum distance between the sensors and the control module for reliable operation. Ceiling-mounted sensors are available in a variety of detection patterns to provide flexibility in mounting locations. With ceiling-mounted sensors in place, existing wall switches may be used to turn off the lights while occupants remain in the space.

MOTION SENSING TECHNOLOGIES

The two most common motion-sensing technologies used in occupancy sensors are passive infrared technology and ultrasonic technology. Either technology can be housed in ceiling-mounted or wall-mounted sensors. Some manufacturers combine these two technologies into one product, which is referred to as a hybrid or dual technology sensor. In addition, one manufacturer has introduced a dual-technology sensor that uses an infrared sensor and a microphonic (sound) sensor.

Passive Infrared Sensors

Passive infrared (PIR) sensors respond to motion between horizontal and vertical cones of vision defined by the faceted lens surrounding the sensor. As an occupant moves a hand, arm, or torso from one cone of vision to another, a positive "occupancy" signal is generated and sent to the controller. Because these cones of vision radiate from the sensor, a greater range of motion is required at a greater distance in order for the sensor to detect motion. Most PIR sensors are sensitive to hand movement up to a distance of about 10 feet, arm and upper torso movement up to 20 feet, and full-body motion up to about 40 feet. *Note that the PIR sensors require an unobstructed view of the motion and are much more sensitive to motion occurring perpendicular to the line-of-sight to the sensor*. Because infrared sensors require direct line-of-sight to the moving object, they will not perform properly in spaces where furniture, partitions, or other objects are between the sensor and the occupant.

Ultrasonic Sensors

Ultrasonic sensors emit and receive high-frequency sound waves in the range of 25-40 kHz, well above the range of human hearing. These waves reflect off objects and room surfaces, and the sensor measures the frequency of the waves that return to the receiver. If there is motion within the space, the frequency of the reflected waves will shift slightly; the change is detected by the receiver and the luminaires are turned on. Although ultrasonic sensors do not always require direct line-of-sight to detect motion, the space must be enclosed and must include hard surfaces for the reflected waves to eventually return to the receiver. *Ultrasonic sensors are much more sensitive to movement directly toward or away from the sensor, compared to lateral movements.*

QUALIFICATIONS

Occupancy sensors — when properly specified, installed, and adjusted — should provide reliable operation of lighting systems during periods of occupancy and should not disrupt normal business activity. Most causes of failed occupancy sensor installations can be linked to improper product selection and placement. By following the guidelines below, your occupancy sensor installation should provide significant energy savings.

Use professional services

The specification and placement of occupancy sensors should be performed by an experienced professional to ensure adequate occupancy sensing coverage. Occupancy sensor systems must be "tuned" after installation. This involves adjusting sensitivity and time delay settings as appropriate for the space. Most suppliers offer this post-installation service. As part of your agreement with your supplier, require a minimum 24-hour response time to address occupant complaints that may arise after the sensors have been installed and tuned. In some cases, the placement of sensors may need to be adjusted to provide reliable coverage.

Select products with adequate coverage areas

Specifiers should pay particular attention to the coverage area which defines the physical limits of the sensor's ability to detect motion. Most occupancy sensor manufacturers publish their coverage areas for the maximum sensitivity setting, although this may not be clearly stated in the product literature. In some cases, more than one occupancy sensor may be required in a space to extend the coverage area, as in the case of a large open office area.

Design sensor installations to avoid false signals

Both infrared and ultrasonic sensors are susceptible to activation by false signals.

False Signals for Ultrasonic Sensors

Ultrasonic sensors can be activated by vibrations (which, for example, may be caused by the starting of an air conditioner). Also, ultrasonic sensors can be activated by moving air and should not be used in areas where strong air currents exist. Ceiling-mounted ultrasonic sensors should be located away from ventilation diffusers.

False Signals for Infrared Sensors

Infrared sensors may be located in positions that allow the sensor to have line-of-sight into an adjacent corridor which could keep lights on unnecessarily. By applying a masking material to the appropriate facets of the PIR sensor's lens, this potential problem can be avoided. In addition, a mirrored image or direct sunlight may provide a signal to the PIR sensor that a space is occupied.

Select infrared or ultrasonic technologies based on room geometry and activities

Infrared

★ Requires line-of-sight; may not work well where partitions may block direct viewing of occupants

★ Magnitude of required motion is directly proportional to distance from the sensor

★ Least sensitive to motion toward and away from the sensor; most sensitive to motion lateral to sensor

★ Does not require an enclosed space; works well outdoors and in high-bay areas

Ultrasonic

- ★ Does not require line-of-sight in enclosed spaces; may require line-of-sight in large open office plans with fabric partitions
- ★ Magnitude of required motion increases with distance from the sensor
- ★ Least sensitive to motion lateral to the sensor; most sensitive to motion toward and away from the sensor
- ★ Requires an enclosed space; not for use outdoors or in high-bay areas

Energy Saving Potential with Occupancy Sensors
Source: EPA Green Lightd and ENERGY STAR Buildings

Application	Energy Savings*
Offices (private)	55%
Rest Rooms	70%
Storage Areas	56%
Conference Rooms	66%
Classrooms	61%

*Note: Figures are based on field data compiled during EPA's occupancy sensor outreach project with Green Lights and Energy Star Buildings Partners.

Verify compatibility with electronic ballasts

Mechanical relays typically used in older-technology occupancy sensors may become damaged by the relatively high in-rush currents that result from an occupancy sensor's making and breaking of electrical contact in electronically-ballasted fluorescent systems.

Mechanical relays that were commonly used with the earliest occupancy sensor models were rated for inductive and resistive loads, characteristic of magnetic and incandescent lighting systems, respectively. However, with the introduction of more complex harmonic filtering with electronic ballasts, the wave form generated when switching electronically ballasted fluorescent systems typically includes a combination of resistive, inductive, and capacitive loads. With the use of a triac, the switching system is protected in order to provide long life.

Contact your supplier to verify that their occupancy sensors are compatible with electronic ballasts.

Conduct a trial installation and evaluate the sensor's performance

Not all sensors perform comparably. Before purchasing a specific name brand of sensor, conduct a simple trial installation of all products under consideration — simultaneously. Follow the procedure below for conducting your test:

1. Install the ceiling-mounted sensors temporarily in a strategic location as suggested by the sensing coverage pattern.
2. Connect these sensors to a power supply. They should not, however, be connected to the lighting circuit.
3. Notice the LED indicator light that illuminates when the sensor detects motion. At various locations in the test room, perform several types of motions, varying the magnitude, speed, and direction of motion. Also, include a test that evaluates the sensor's ability to detect motion behind obstacles.
4. Note which sensors were most successful in detecting minor motion (both with and without obstacles), as well as which sensors were most affected by false signals.

For independently measured performance data for specific name-brand occupancy sensors, refer to ***Specifier Reports: Occupancy Sensors****, Volume 1 Issue 5, National Lighting Product Information Program, October 1992. A second report is to be issued in early 1997.*

SCHEDULING CONTROLS

In addition to occupancy sensors, scheduling controls are designed to help eliminate unnecessary use of lighting.

Timed Switching Systems

Definition

Timed switching controls can be installed to ensure that lighting systems are turned off or dimmed according to an established schedule. These devices range from simple wallbox electronic timer switches to programmable "sweep" systems.

Applications

Wallbox electronic timer switches can be installed in place of manual switches that allow the occupant to preselect a period of operating duration after which the lights will automatically shut off. These switches can be programmed to provide a warning signal before the lights are turned off.

Timeclocks can be used to control lighting systems with predictable operating periods, such as security lighting and corridors. In addition, more sophisticated scheduling controls can be programmed for facilities having different daily operating schedules.

Sweep systems are an advanced form of programmable switching control. These systems establish a programmed schedule for sequentially turning off lights throughout a floor or an entire building. A typical application is found in office buildings, where the systems ensure that lighting is not unnecessarily left on by the occupants. For example, if most of the occupants on a given floor normally leave by 6:00 pm, then the system will provide a warning signal (such as flicking the lights off and on) a few minutes prior to turning the lights off in the space. This warning signal allows any remaining occupants to override the scheduled lighting “sweep” in their location. This override may need to be repeated periodically until the space is unoccupied.

The components of a lighting sweep system include:

- The central processor which is capable of independently controlling several output channels; each group of luminaires to be controlled together is assigned to a single output channel.
- Relays are simple switches that are controlled electrically; they are series-wired to the controlled lighting zones and are controllable from the central processor.
- Overrides to the system can be activated by either a local override switch or a touch-tone telephone code.

Qualifications

Unlike occupancy sensors, scheduling systems do not have the flexibility to eliminate wasted energy consumption during normal business hours.

24-hour emergency lighting should be provided in areas with sweep systems to provide safe access to lighting control override switches.

Daylight Switching Systems

Definition

Photocells or scheduling systems may be used to automatically turn off lighting systems when sufficient daylight is available.

Applications

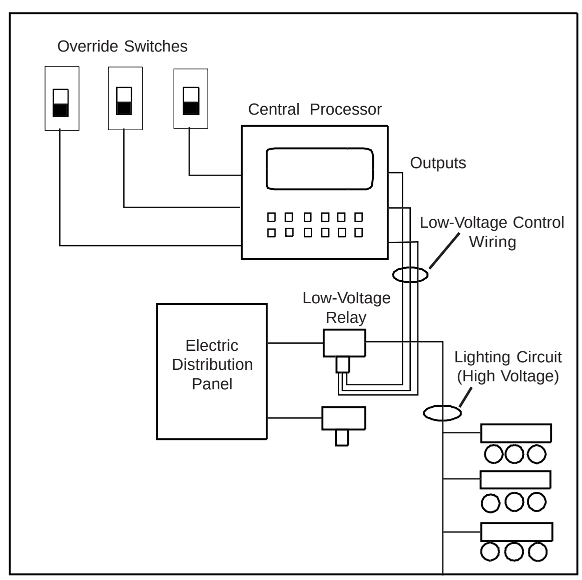
All outdoor lighting should be controlled using a daylight switching system. In many cases, photocells have been used to automatically provide “dusk-to-dawn” operation. The resulting operating hours under photocell control is typically 4,100 hours per year, because the lights are typically turned on about 20 minutes after sundown, and about 20 minutes prior to sunrise.
In applications where the outdoor lighting is not needed for dusk-to-dawn illumination, a timed switching system may be wired in series with the photosensor to switch off the circuit before dawn. For example, a retail establishment may require high-level parking lot illumination from dusk until one hour after closing — say 11:00 pm — after which the lighting system may be switched off by the timed switching system.

Compared to mechanical photocells, new solid-state electronic photosensors combine longer service life with more accurate daylight sensing to yield significant energy and maintenance cost savings.

As an alternative to photosensors, consider installing a microprocessor-based timed switching system for controlling outdoor lighting. Systems are available that predict seasonal dusk and dawn switching times and

Time Scheduling System Components

Source: CEC/DOE/EPRI



automatically switch the outdoor lighting systems according to this schedule. Such systems must have extensive battery back-up and memory in order to ensure that the "solar schedule" will remain properly programmed in the event of a power failure. Microprocessor-based daylight switching systems can also incorporate "pre-dawn" scheduled switching functions. Many systems provide the capability to program various lighting schedules over a multi-year period.

Qualifications

Mechanical timeclocks are not recommended for daylight switching control because they can be relatively inaccurate in scheduling on/off functions, and may get "off schedule" if not properly maintained.

Photocells should be properly calibrated and maintained to eliminate wasteful "day-burning."

Daylight switching indoors has been applied with varying degrees of success. Consider indoor daylight switching in common areas such as break rooms, corridors, and lobbies. In employee work areas, users may object to the use of automatic switching of the lighting system during daylight hours because it draws attention to sudden changes in illumination. However, adverse occupant reactions can be minimized if the sensor can be programmed to turn on the lights when the ambient light level drops to about 30 footcandles, and turn off the lights when the ambient light level climbs to about 65 footcandles. Still, the most successful indoor applications for daylighting control usually involve dimming instead of switching.

Some occupancy sensors provide daylight switching control in conjunction with their occupancy switching control. A trial installation is recommended to assess user acceptance of this technology.

For more information about photosensors, refer to: ***Specifier Reports: Photosensors,*** *Volume 6, Number 1, March 1998, National Lighting Product Information Program.*

DIMMING CONTROLS

Dimming controls can be used to vary the intensity of lighting system output based on ambient light levels, manual adjustments, and occupancy.

Daylight Dimming & Lumen Maintenance Control

Definition

Daylight dimming systems consist of photosensors that are wired directly to specifically designed controllable (dimmable) electronic ballasts. Some manufacturers provide a photosensor to control every ballast, while others provide a single photosensor that can control many ballasts simultaneously. Because the control wiring can be run between the photosensors and the ballasts in the plenum above a dropped ceiling, retrofit applications can be feasible. The daylighting "zone" (consisting of the luminaires to be dimmed) is defined by the low-voltage wiring circuit which is independent of the power circuits. A manual adjustment on the photosensor allows users to select the light level to be maintained in both the absence of daylight and during the dimming process.

Applications

Ceiling-mounted photosensors should be installed a specific distance from window areas, according to manufacturer instructions. As daylighting becomes available, the photosensor will reduce the light output from the lamp-ballast systems that are directly connected to the photosensor via low-voltage wiring. The photosensor dims the luminaires in order to maintain the same light level that would normally be provided by the luminaires in the absence of daylight. However, the controllable ballasts are typically capable of reducing output down to 10-20 percent of full light output. When this minimum output level is reached, it is possible that increasing daylight contributions may further elevate light levels beyond the manually adjusted setpoint.

Because dimming (low-voltage) circuits are usually separate from existing power circuits, users have great flexibility in determining which luminaires will be controlled by the photocell. In general, retrofit installation costs are minimized if each dimming ballast is controlled with a low-cost, dedicated light sensor.

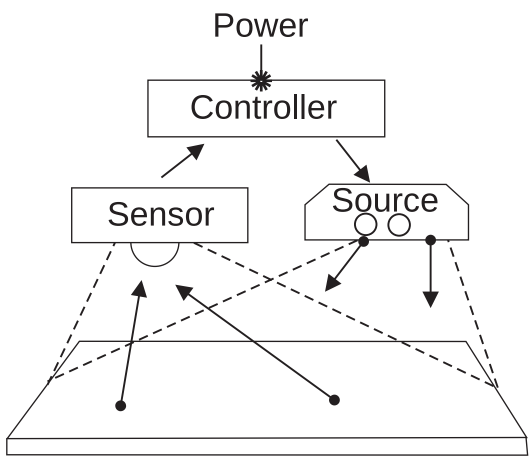
The same equipment used for daylight dimming may also be used in non-daylit areas for adjusting system light output to compensate for aging lamps and accumulated dirt on luminaires. This is known as lumen maintenance control. When lamps are new and luminaires are clean, the manual adjustment on the photosensor should be tuned to lower the illuminance by 25-30 percent — the amount of lamp lumen depreciation and luminaire dirt depreciation to be expected during the maintenance cycle. Over time as the lamps age and the luminaire collects dirt, the photosensor will require the controllable ballast to increase the system output in order to maintain the illuminance setpoint. In order for a lumen maintenance control strategy to save energy, the luminaires must be cleaned and relamped on a regular basis. See *Lighting Maintenance* regarding group maintenance strategies.

Light levels should be maintained in accordance with standards established by the Illuminating Engineering Society of North America. (Refer to *Lighting Fundamentals*.)

The introduction of *three-lamp* dimming ballasts has contributed to making dmming upgrades more cost-effective.

Daylighting Control System

Source: CEC/DOE/EPRI



Qualifications

The proper placement of photosensors is critical to the success of the daylight dimming installation. Follow manufacturer specifications carefully.

If architectural structures or partitions reduce the amount of available daylight in selected spaces within the daylighting zone, exclude the affected luminaires from daylighting control. Alternatively, if daylighting contributions vary widely within the daylighting zone, consider installing a daylighting system that provides a photosensor to control each luminaire.

To achieve sustained energy savings, be sure to adjust the photosensor so that the proper light levels are maintained. When daylight levels are low or nonexistent, reduce the light output by adjusting the tuning control on the photosensor to a point that is *below* your target workplane illuminance (have a light meter placed on the work surface). Then, increase the light output until the illuminance reaches your desired maintained light level.

When calculating energy cost savings expected from a dimming system, take into account the specific electric demand charge and rate structure; some rate schedules include a ratcheted demand charge that could negate cost savings resulting from reduced peak demand.

For independently measured performance data for specific dimming electronic ballasts, refer to ***Specifier Reports: Dimming Electronic Ballasts****, November 1995, National Lighting Product Information Program.*

Tuning

Definition

Using manual dimming controls, the light output from individual luminaires or groups of luminaires can be reduced to match the area's visual requirements. This is normally accomplished with either controllable electronic ballasts that have built-in adjusting switches or knobs, or with hand-held remote controls that communicate directly with one or more of the ballasts overhead. Alternatively the light level can be adjusted using a compatible manual dimmer control at the switch location.

Applications

The most common application of tuning is in spaces where the visual task changes frequently. (For example bookkeeping and VDT usage.) Other applications include adjusting light level for various occupants of a space based on age and visual task requirements — such as in a conference room.

Qualifications

Compact fluorescents and full-size fluorescents operating on magnetic ballasts require specialized dimming controls.

Panel-Level Dimming

Definition

This strategy involves installing a control system at the electric panel to uniformly control all luminaires on the designated circuits.

Applications

Circuit dimming can be controlled manually or by inputs from occupancy sensors, photosensors, timeclocks, or energy management systems. Panel-level dimming is a method for dimming HID systems as well as both electronically and magnetically ballasted fluorescent systems. Continuous dimming is accomplished using either a variable-voltage transformer or a wave modification device that reduces the power to the HID or fluorescent circuit.

For example, using photosensors in a warehouse with skylights, the high-pressure sodium lighting system could be uniformly dimmed in response to the available daylight from the skylights, saving substantial amounts of energy.

Another application would include a wholesale merchandising outlet that requires higher light levels during normal business hours, and reduced light levels during routine maintenance and stocking operations. The scheduling control system would automatically adjust the light levels based on the business operating schedule.

Qualifications

Slight reductions in efficiency result from dimming HID systems. Light output reductions are about 1.2 to 1.5 times the power reduction in metal halide systems and about 1.1-1.4 times the power reduction in high-pressure sodium systems. Manufacturers can provide the specific lumen-wattage performance curves for the specific systems being controlled.

Note that some panel-level dimming systems are incompatible with electronic ballasts. Check with the manufacturer to determine if their variable voltage system is compatible with electronic ballasts and whether the system introduces harmonic currents.

Dimming HID lamps below 50 percent power may result in a significant reduction in lamp life.

For more information about continuous and bi-level HID dimming systems, refer to ***Lighting Answers: Dimming Systems for High-Intensity Discharge Lamps****, Volume 1 Number 4, September 1994, National Lighting Product Information Program.*

DAY LIGHTING

Photovoltaic Systems

Definition

Photovoltaics are solid state semiconductor devices that convert light directly into (DC) electricity. Photovoltaic (or solar) modules usually employ a silicon-based material cut into wafers or chemically deposited in thin layers on glass, steel or other flexible materials and generate the most electricity when exposed to direct sunlight. Solar generated electricity can be used directly by a connected lighting system, stored in batteries, or “pumped” into the electric grid (grid-tied systems) for later use.

Applications

Photovoltaic systems are most commonly used to power remote (off-grid) lighting applications such as traffic signals, parking lots, streetlights, billboards, and transit shelter lighting. However, “remote” photovoltaic lighting can also be used in suburban areas for parking lots and other applications where the costs associated with running overhead or underground wires can be too expensive. All remote solar lighting systems require batteries for electric storage and to regulate the voltage of the solar array. Also, because electronic (DC) ballasts are available for fluorescent and HID lamps, the need for an (AC) inverter is eliminated, making the solar lighting system less costly.

A new application for photovoltaics and lighting is found with buildings that are connected to the electric grid (grid-tied). “Solar-assisted lighting” refers to systems specifically designed to offset the daytime lighting load through generated solar energy. These systems do not require batteries because the building lighting demand is generally coincident with the solar generation and the electric grid serves as a voltage regulator. However, if the system is deployed without batteries and the electric grid fails the system must shut down or risk damage to ballasts and solar modules. Some applications also use batteries to provide uniterruptable power supply (UPS). Also, some electronic AC ballasts will operate off a DC voltage allowing the elimination of the AC inverter.

Qualifications

Photovoltaics are most cost-effective in remote areas where the cost of extending a power line is very expensive. However, photovoltaics may be cost-effective for solar-assisted lighting applications depending on the rates paid for electricity or the need for emergency lighting. Solar-assisted lighting, with battery backup, is not less expensive than emergency lighting. However, the marginal additional cost is usually paid back in 8 - 10 years from energy savings based on $.10 per kWh and solar-assisted lighting does not require specially equipped lighting fixtures.

Active Daylighting Systems

Definition

A system consisting of a motorized sun-tracking mirror, a skylight, diffusing media, and an automatic lighting control. The sun-tracking mirror reflects sunlight through the skylight. This light is delivered to the building interior through a wide-angle diffuser. An automatic lighting control switches off the artificial lighting when sufficient daylighting is provided by the system.

Applications

The most economical applications are for one-story buildings in areas that receive a high percentage of sunny days (or bright cloudy days) and have relatively high peak demand charges and peak electricity rates. Systems are available for either new construction or retrofit. Daylighting systems also improve color rendering, reduce lighting maintenance costs, and potentially reduce air conditioning costs as well.

Qualifications

Verify vendor claims by visiting installations — check for workmanship, warranty service, demonstrated energy cost savings, and effect on illumination quality. Energy savings can be difficult to quantify, because they depend on local insolation data, equipment performance, and time-of-day energy use analysis. To mitigate financial risk with this upgrade, ask your supplier about performance guarantees.

PRODUCT REFERENCE INFORMATION

System Performance Tables

When performing lighting and energy calculations, refer to the performance tables on the following pages for listings of system wattage, ballast factor, lumen output, and maintained efficacy for your existing and proposed lighting systems. These tables address:

- ★ 2-lamp, 4-foot systems
- ★ 3-lamp, 4-foot systems
- ★ 4-lamp, 4-foot systems
- ★ 2-lamp, 8-foot systems
- ★ 2-foot systems
- ★ compact sources
- ★ directional lamps
- ★ HID systems
- ★ low pressure sodium systems
- ★ ANSI wattage correction factors
- ★ ANSI lumen correction factors

TYPICAL PERFORMANCE VALUES FOR 2-LAMP 4-FOOT SYSTEMS

Ballast Types / Lamp Types	Lamps per Ballast	Lamp Watts	System Input Watts	Lamp CRI	Initial Lamp Lumens	Lamp Lumen Deprec.	Ballast Factor	Maintained System Lumens	Maintained System Efficacy	Maintained Relative Lumens
Old Standard Magnetic										
2 - F40T12	2	40	96	62*	3050	0.87	0.94	4989	52	100%
	2	40	96	73	3200	0.90	0.94	5414	56	109%
	2	40	96	85	3300	0.90	0.94	5584	58	112%
2 - F40T12/ES	2	34	82	62	2650	0.87	0.87	4012	49	80%
	2	34	82	73	2800	0.90	0.87	4385	53	88%
	2	34	82	85	2900	0.90	0.87	4541	55	91%
2 - F40T10	2	40	101	82	3700	0.89	0.92	6059	60	121%
Standard EE Magnetic										
2 - F40T12	2	40	88	62*	3050	0.87	0.94	4989	57	100%
	2	40	88	73	3200	0.90	0.94	5414	62	109%
	2	40	88	85	3300	0.90	0.94	5584	63	112%
2 - F40T12/ES	2	34	72	62	2650	0.87	0.87	4012	56	80%
	2	34	72	73	2800	0.90	0.87	4385	61	88%
	2	34	72	85	2900	0.90	0.87	4541	63	91%
2 - F40T10	2	40	93	82	3700	0.89	0.92	6059	65	121%
2 - F32T8	2	32	70	75	2850	0.91	0.94	4876	70	98%
	2	32	70	85	3050	0.93	0.94	5333	76	107%
Magnetic Heater Cutout										
2 - F40T12	2	40	80	62*	3050	0.87	0.95	5042	63	101%
	2	40	80	73	3200	0.90	0.95	5472	68	110%
	2	40	80	85	3300	0.90	0.95	5643	71	113%
Partial	2	40	69	62*	3050	0.87	0.83	4405	64	88%
Output	2	40	69	73	3200	0.90	0.83	4781	69	96%
Ballast	2	40	69	85	3300	0.90	0.83	4930	71	99%
2 - F40T12/ES	2	34	66	62	2650	0.87	0.88	4058	61	81%
	2	34	66	73	2800	0.90	0.88	4435	67	89%
	2	34	66	85	2900	0.90	0.88	4594	70	92%
Partial	2	34	58	62	2650	0.87	0.81	3735	64	75%
Output	2	34	58	73	2800	0.90	0.81	4082	70	82%
Ballast	2	34	58	85	2900	0.90	0.81	4228	73	85%
2 - F40T10	2	40	84	82	3700	0.89	0.92	6059	72	121%
2 - F32T8	2	32	61	75	2850	0.91	0.86	4461	73	89%
	2	32	61	85	3050	0.93	0.86	4879	80	98%
Electronic Rapid Start										
2 - F40T12	2	40	72	62*	3050	0.87	0.88	4670	65	94%
	2	40	72	73	3200	0.90	0.88	5069	70	102%
	2	40	72	85	3300	0.90	0.88	5227	73	105%
2 - F40T12/ES	2	34	62	62	2650	0.87	0.88	4058	65	81%
	2	34	62	73	2800	0.90	0.88	4435	72	89%
	2	34	62	85	2900	0.90	0.88	4594	74	92%
2 - F40T10	2	40	75	82	3700	0.89	0.86	5664	76	114%
2 - F32T8	2	32	62	75	2850	0.91	0.88	4565	74	92%
	2	32	62	85	3050	0.93	0.88	4992	81	100%
	2	32	62	86	3200	0.95	0.88	5350	86	108%
Partial	2	32	54	75	2850	0.91	0.75	3890	72	78%
Output	2	32	54	85	3050	0.93	0.75	4255	79	85%
	2	32	54	86	3200	0.95	0.75	4560	84	92%
Extended	2	32	86	75	2850	0.91	1.28	6639	77	133%
Output	2	32	86	85	3050	0.93	1.28	7261	84	146%
	2	32	86	86	3200	0.95	1.28	7782	90	157%
Electronic Instant-Start										
2 - F32T8	2	32	58	75	2850	0.91	0.88	4565	79	92%
	2	32	58	85	3050	0.93	0.88	4992	86	100%
	2	32	58	86	3200	0.95	0.88	5350	92	108%
Extended	2	32	76	75	2850	0.91	1.15	5965	78	120%
Output	2	32	76	85	3050	0.93	1.15	6524	86	131%
	2	32	76	86	3200	0.95	1.15	6992	92	141%

NOTES: Lamp lumen performance varies among manufacturers.
Maintained performance includes effect of lamp lumen depreciation (@ 40% lamp life).
System wattages and lumens shown are based on ANSI test conditions; use correction factors at end of this section.
Sources: CEC/EPRI/DOE (1993) and manufacturer data

* Lamps no longer manufactured per Energy Policy Act of 1992.

TYPICAL PERFORMANCE VALUES FOR 3-LAMP 4-FOOT SYSTEMS

Ballast Types / Lamp Types	Lamps per Ballast	System Lamp Watts	Initial Input Watts	Lamp CRI	Lamp Lumens	Lamp Lumen Deprec.	Ballast Factor	Maintained System Lumens	Maintained System Efficacy	Maintained Relative Lumens
Old Standard Magnetic										
3 - F40T12	1.5	40	148	62*	3050	0.87	0.94	7483	51	100%
	1.5	40	148	73	3200	0.90	0.94	8122	55	109%
	1.5	40	148	85	3300	0.90	0.94	8375	57	112%
3 - F40T12/ES	1.5	34	134	62	2650	0.87	0.87	6017	45	80%
	1.5	34	134	73	2800	0.90	0.87	6577	49	88%
	1.5	34	134	85	2900	0.90	0.87	6812	51	91%
3 - F40T10	1.5	40	156	82	3700	0.89	0.92	9089	58	121%
Standard EE Magnetic										
3 - F40T12	1.5	40	134	62*	3050	0.87	0.94	7483	56	100%
	1.5	40	134	73	3200	0.90	0.94	8122	61	109%
	1.5	40	134	85	3300	0.90	0.94	8375	63	112%
3 - F40T12/ES	1.5	34	112	62	2650	0.87	0.87	6017	54	80%
	1.5	34	112	73	2800	0.90	0.87	6577	59	88%
	1.5	34	112	85	2900	0.90	0.87	6812	61	91%
3 - F40T10	1.5	40	142	82	3700	0.89	0.92	9089	64	121%
3 - F32T8	1.5	32	106	75	2850	0.91	0.94	7314	69	98%
	1.5	32	106	85	3050	0.93	0.94	7999	75	107%
Magnetic Heater Cutout										
3 - F40T12	2/T	40	120	62*	3050	0.87	0.95	7562	63	101%
	2/T	40	120	73	3200	0.90	0.95	8208	68	110%
	2/T	40	120	85	3300	0.90	0.95	8465	71	113%
Partial	2/T	40	104	62*	3050	0.87	0.83	6607	64	88%
Output	2/T	40	104	73	3200	0.90	0.83	7171	69	96%
Ballast	2/T	40	104	85	3300	0.90	0.83	7395	71	99%
3 - F40T12/ES	3	34	90	62	2650	0.87	0.83	5741	64	77%
	3	34	90	73	2800	0.90	0.83	6275	70	84%
(Partial Output)	3	34	90	85	2900	0.90	0.83	6499	72	87%
3 - F40T10	2/T	40	126	82	3700	0.89	0.92	9089	72	121%
3 - F32T8	2/T	32	92	75	2850	0.91	0.86	6691	73	89%
	2/T	32	92	85	3050	0.93	0.86	7318	80	98%
Electronic Rapid Start										
3 - F40T12	3	40	107	62*	3050	0.87	0.88	7005	65	94%
	3	40	107	73	3200	0.90	0.88	7603	71	102%
	3	40	107	85	3300	0.90	0.88	7841	73	105%
3 - F40T12/ES	3	34	92	62	2650	0.87	0.88	6087	66	81%
	3	34	92	73	2800	0.90	0.88	6653	72	89%
	3	34	92	85	2900	0.90	0.88	6890	75	92%
3 - F40T10	3	40	116	82	3700	0.89	0.92	9089	78	121%
3 - F32T8	3	32	90	75	2850	0.91	0.88	6847	76	92%
	3	32	90	85	3050	0.93	0.88	7488	83	100%
	3	32	90	86	3200	0.95	0.88	8026	89	108%
Partial	3	32	80	75	2850	0.91	0.75	5835	73	78%
Output	3	32	80	85	3050	0.93	0.75	6382	80	85%
	3	32	80	86	3200	0.95	0.75	6840	86	92%
Electronic Instant-Start										
	3	32	86	75	2850	0.91	0.88	6847	80	91%
	3	32	86	85	3050	0.93	0.88	7488	87	100%
	3	32	86	86	3200	0.95	0.88	8026	93	107%
Partial	3	32	75	75	2850	0.91	0.77	5991	80	80%
Output	3	32	75	85	3050	0.93	0.77	6552	87	88%
	3	32	75	86	3200	0.95	0.77	7022	94	94%

NOTES:

Lamp lumen performance varies among manufacturers.
Maintained" performance includes effect of lamp lumen depreciation (@ 40% lamp life).
Ballast factors for electronic ballasts can vary in range of 0.41-1.30 among manufacturers.
System wattages shown are based on ANSI test conditions.
Sources: CEC/EPRI/DOE (1993) and manufacturer data

* Lamps no longer manufactured per Energy Policy Act of 1992.

TYPICAL PERFORMANCE VALUES FOR 4-LAMP 4-FOOT SYSTEMS

Ballast Types / Lamp Types	Lamps per Ballast	Lamp Watts	System Input Watts	Lamp CRI	Initial Lamp Lumens	Lamp Lumen Deprec.	Ballast Factor	Maintained System Lumens	Maintained System Efficacy	Maintained Relative Lumens
Old Standard Magnetic										
4 - F40T12	2	40	192	62*	3050	0.87	0.94	9977	52	100%
	2	40	192	73	3200	0.90	0.94	10829	56	109%
	2	40	192	85	3300	0.90	0.94	11167	58	112%
4 - F40T12/ES	2	34	164	62	2650	0.87	0.87	8023	49	80%
	2	34	164	73	2800	0.90	0.87	8770	53	88%
	2	34	164	85	2900	0.90	0.87	9083	55	91%
Standard EE Magnetic										
4 - F40T12	2	40	176	62*	3050	0.87	0.94	9977	57	100%
	2	40	176	73	3200	0.90	0.94	10829	62	109%
	2	40	176	85	3300	0.90	0.94	11167	63	112%
4 - F40T12/ES	2	34	144	62	2650	0.87	0.87	8023	56	80%
	2	34	144	73	2800	0.90	0.87	8770	61	88%
	2	34	144	85	2900	0.90	0.87	9083	63	91%
4 - F32T8	2	32	140	75	2850	0.91	0.94	9752	70	98%
	2	32	140	85	3050	0.93	0.94	10665	76	107%
Magnetic Heater Cutout										
4 - F40T12	2	40	160	62*	3050	0.87	0.95	10083	63	101%
	2	40	160	73	3200	0.90	0.95	10944	68	110%
	2	40	160	85	3300	0.90	0.95	11286	71	113%
Partial	2	40	138	62*	3050	0.87	0.83	8810	64	88%
Output	2	40	138	73	3200	0.90	0.83	9562	69	96%
Ballast	2	40	138	85	3300	0.90	0.83	9860	71	99%
4 - F40T12/ES	2	34	132	62	2650	0.87	0.88	8115	61	81%
	2	34	132	73	2800	0.90	0.88	8870	67	89%
	2	34	132	85	2900	0.90	0.88	9187	70	92%
Partial	2	34	116	62	2650	0.87	0.81	7470	64	75%
Output	2	34	116	73	2800	0.90	0.81	8165	70	82%
Ballast	2	34	116	85	2900	0.90	0.81	8456	73	85%
4 - F32T8	2	32	122	75	2850	0.91	0.86	8922	73	89%
	2	32	122	85	3050	0.93	0.86	9758	80	98%
Electronic Rapid Start										
4 - F40T12	4	40	141	62*	3050	0.87	0.87	9234	65	93%
	4	40	141	73	3200	0.90	0.87	10022	71	100%
	4	40	141	85	3300	0.90	0.87	10336	73	104%
4 - F40T12/ES	4	34	117	62	2650	0.87	0.83	7654	65	77%
	4	34	117	73	2800	0.90	0.83	8366	72	84%
	4	34	117	85	2900	0.90	0.83	8665	74	87%
4 - F32T8	4	32	116	75	2850	0.91	0.87	9025	78	90%
	4	32	116	85	3050	0.93	0.87	9871	85	99%
	4	32	116	86	3200	0.95	0.87	10579	91	106%
Partial	4	32	101	75	2850	0.91	0.75	7781	77	78%
Output	4	32	101	85	3050	0.93	0.75	8510	84	85%
	4	32	101	86	3200	0.95	0.75	9120	90	92%
Electronic Instant-Start										
4 - F32T8	4	32	111	75	2850	0.91	0.85	8818	79	88%
	4	32	111	85	3050	0.93	0.85	9644	87	97%
	4	32	111	86	3200	0.95	0.85	10336	93	104%
Partial	4	32	101	75	2850	0.91	0.79	8195	81	82%
Output	4	32	101	85	3050	0.93	0.79	8963	89	90%
	4	32	101	86	3200	0.95	0.79	9606	95	96%

NOTES: Lamp lumen performance varies among manufacturers.
"Maintained" performance includes effect of lamp lumen depreciation (@ 40% lamp life).
Ballast factors for electronic ballasts can vary in range of 0.41-1.30 among manufacturers.
System wattages shown are based on ANSI test conditions.
Sources: CEC/EPRI/DOE (1993) and manufacturer data

* Lamps no longer manufactured per Energy Policy Act of 1992.

TYPICAL PERFORMANCE VALUES FOR 2-LAMP 8-FOOT SYSTEMS

Ballast Types / Lamp Types	Lamps per Ballast	Lamp Watts	System Input Watts	Lamp CRI	Initial Lamp Lumens	Lamp Lumen Deprec.	Ballast Factor	Maintained System Lumens	Maintained System Efficacy	Maintained Relative Lumens
Old Standard Magnetic										
2 - F96T12	2	75	173	62*	6100	0.88	0.94	10092	58	100%
	2	75	173	73	6425	0.94	0.94	11354	66	113%
	2	75	173	85	6600	0.94	0.94	11664	67	116%
2 - F96T12/ES	2	60	138	62	5500	0.88	0.87	8422	61	83%
	2	60	138	73	5750	0.94	0.87	9405	68	93%
	2	60	138	85	5900	0.94	0.87	9650	70	96%
2 - F96T12/HO	2	110	257	62*	8900	0.87	0.94	14557	57	144%
	2	110	257	73	9200	0.90	0.94	15566	61	154%
	2	110	257	85	9400	0.90	0.94	15905	62	158%
2 - F96T12/HO/ES	2	95	227	62	8000	0.87	0.87	12110	53	120%
	2	95	227	73	8350	0.90	0.87	13076	58	130%
	2	95	227	85	8600	0.90	0.87	13468	59	133%
2 - F96T12/VHO	2	215	450	62	13500	0.75	0.94	19035	42	189%
2 - F96T12/VHO/ES	2	185	390	62	12500	0.75	0.87	16313	42	162%
Standard EE Magnetic										
2 - F96T12	2	75	158	62*	6100	0.88	0.95	10199	65	100%
	2	75	158	73	6425	0.94	0.95	11475	73	114%
	2	75	158	85	6600	0.94	0.95	11788	75	117%
2 - F96T12/ES	2	60	128	62	5500	0.88	0.90	8712	68	86%
	2	60	128	73	5750	0.94	0.90	9729	76	96%
	2	60	128	85	5900	0.94	0.90	9983	78	99%
2 - F96T12/HO	2	110	237	62*	8900	0.87	0.95	14712	62	146%
	2	110	237	73	9200	0.90	0.95	15732	66	156%
	2	110	237	85	9400	0.90	0.95	16074	68	159%
2 - F96T12/HO/ES	2	95	197	62	8000	0.87	0.88	12250	62	121%
	2	95	197	73	8350	0.90	0.88	13226	67	131%
	2	95	197	85	8600	0.90	0.88	13622	69	135%
2 - F96T12/VHO	2	215	440	62	13500	0.75	0.95	19238	44	191%
2 - F96T12/VHO/ES	2	185	380	62	12500	0.75	0.88	16500	43	163%
Magnetic Heater Cutout										
2 - F96T12/HO	2	110	210	62*	8900	0.87	0.89	13783	66	137%
	2	110	210	73	9200	0.90	0.89	14738	70	146%
	2	110	210	85	9400	0.90	0.89	15059	72	149%
2 - F96T12/HO/ES	2	95	177	62	8000	0.87	0.86	11971	68	119%
	2	95	177	73	8350	0.90	0.86	12926	73	128%
	2	95	177	85	8600	0.90	0.86	13313	75	132%
Electronic										
2 - F96T12	2	75	136	62*	6100	0.88	0.89	9555	70	100%
	2	75	136	73	6425	0.94	0.89	10750	79	107%
	2	75	136	85	6600	0.94	0.89	11043	81	109%
2 - F96T12/ES	2	60	110	62	5500	0.88	0.88	8518	77	84%
	2	60	110	73	5750	0.94	0.88	9513	86	94%
	2	60	110	85	5900	0.94	0.88	9761	89	97%
2 - F96T12/HO	2	110	209	62*	8900	0.87	0.90	13937	67	138%
	2	110	209	73	9200	0.90	0.90	14904	71	148%
	2	110	209	85	9400	0.90	0.90	15228	73	151%
2 - F96T12/HO/ES	2	95	174	62	8000	0.87	0.88	12250	70	121%
	2	95	174	73	8350	0.90	0.88	13226	76	131%
	2	95	174	85	8600	0.90	0.88	13622	78	135%
2 - F96T8	2	59	106	75	5800	0.91	0.85	8973	85	89%
	2	59	106	84	5950	0.91	0.85	9205	87	91%
Partial	2	59	99	75	5800	0.91	0.78	8234	83	82%
Output	2	59	99	84	5950	0.91	0.78	8447	85	84%
2 - F96T8/HO	2	86	160	85	8200	0.90	0.88	12989	81	129%
	2	86	186	85	8200	0.90	1.00	14760	79	146%

NOTES:
Lamp lumen peformance varies among manufacturers.
Maintained performance includes effect of lamp lumen depreciation (@ 40% rated life).
System wattages and lumens shown are based on ANSI test conditions; use correction factors at end of this section.
Sources: CEC/EPRI/DOE (1993) and manufacturer data

* Lamps no longer manufactured per Energy Policy Act of 1992.

TYPICAL PERFORMANCE VALUES FOR 2-FOOT SYSTEMS

22.5" T5 Compact Fluorescents
24" T8 Straight Fluorescent Lamps

FB40T12 and FB31T8 U-lamps perform essentially the same as F40T12 and F32T8 straight lamps, respectively. Refer to the 4-foot table (2-lamp and 3-lamp) for representative values for FB40T12 and FB31T8 lamps.

Ballast Types / Lamp Types	Lamps per Ballast	Lamp Watts	System Input Watts	Lamp CRI	Initial Lamp Lumens	Lamp Lumen Deprec.*	Ballast Factor	Maintained System Lumens	Maintained System Efficacy
Old Standard Magnetic									
2 - F20T12 (preheat)	2	20	50	62	1200	0.87	0.94	1963	39
Standard EE Magnetic									
2 - F20T12 (preheat)	2	20	46	62	1200	0.87	0.94	1963	43
2 - F17T8	2	17	43	75	1325	0.91	0.93	2243	52
	2	17	43	85	1400	0.93	0.93	2422	56
2 - FT40T5	2	40	91	82	3150	0.90	0.93	5273	58
Electronic Rapid Start									
2 - F17T8	2	17	37	75	1325	0.91	0.92	2219	60
	2	17	37	85	1400	0.93	0.92	2396	65
Partial	2	17	27	75	1325	0.91	0.75	1809	67
Output	2	17	27	85	1400	0.93	0.75	1953	72
3 - F17T8	3	17	52	75	1325	0.91	0.92	3328	64
	3	17	52	85	1400	0.93	0.92	3594	69
4 - F17T8	4	17	70	75	1325	0.91	0.92	4437	63
	4	17	70	85	1400	0.93	0.92	4791	68
2 - FT40T5	2	40	74	82	3150	0.90	0.87	4933	67
3 - FT40T5	3	40	106	82	3150	0.90	0.90	7655	72
Electronic Instant-Start									
2 - F17T8	2	17	33	75	1325	0.91	0.90	2170	66
2 - F17T8	2	17	33	85	1400	0.93	0.90	2344	71
3 - F17T8	3	17	47	75	1325	0.91	0.92	3328	71
3 - F17T8	3	17	47	85	1400	0.93	0.92	3594	76
4 - F17T8	4	17	62	75	1325	0.91	0.90	4341	70
4 - F17T8	4	17	62	85	1400	0.93	0.90	4687	76
2 - FT40T5	2	40	71	82	3150	0.90	0.90	5103	72
3 - FT40T5	3	40	101	82	3150	0.90	0.88	7484	74

NOTES: Different manufacturers of 22.5" lamps provide rated wattages of 38, 39, or 40 watts.
Maintained performance includes effect of lamp lumen depreciation.
System wattages and lumens shown are based on ANSI test conditions; use thermal correction factors included at the end of this section.
Sources: CEC/EPRI/DOE (1993) and manufacturer data

*@ 40% life

TYPICAL PERFORMANCE VALUES FOR COMPACT SOURCES
(non-directional sources)

Lamp Types	Lamp Watts	System Watts	Initial Lamp CRI	Maintained Lamp Lumens	Maintained System Lumens	System Efficacy	Rated Life
Incandescents (Reference)							
A19	25	25	100	215	215	9	1000
A19	40	40	100	495	495	12	1000
A19	60	60	100	860	860	14	1000
A19	75	75	100	1180	1180	16	750
A19	100	100	100	1720	1720	17	750
A23	200	200	100	4010	4010	20	750
TB19 (halogen)	50	50	100	830	830	17	2000
TB19 (halogen)	90	90	100	1680	1680	19	2000
TB19 (halogen/film)	60	60	100	1400	1400	23	2000
Integral Units / Electronic							
Enclosed / Non Vent	-	16	82	800	650	41	10000
Enclosed / Vented	-	18	82	1100	950	53	10000
Open Quad Tube	-	15	82	900	765	51	10000
Open Quad Tube	-	20	82	1200	1020	51	10000
Open Quad Tube	-	26	82	1500	1275	49	10000
Triple Twin/U-Tube	-	15	82	900	750	50	10000
Triple Twin/U-Tube	-	20	82	1200	1020	51	10000
Triple Twin/U-Tube	-	25	82	1520	1290	52	10000
Quadruple Twin-Tube	-	28	82	1750	1475	53	10000
T-4 Twin-Tube / Preheat Magnetic							
	5	9	82	225	216	24	10000
	7	11	82	360	324	29	10000
	9	13	82	540	432	33	10000
	13	17	82	810	792	47	10000
T-4 Quad Tube / Preheat Magnetic							
	9	13	82	540	440	34	10000
	13	17	82	774	756	44	10000
	18	25	82	1125	1070	43	10000
	26	31	82	1620	1540	50	10000
Circline / Electronic Adapter							
6.1" diam.	-	13	84	950	800	62	12000
6.4" diam.	-	20	84	1450	1250	63	12000
8.2" diam.	-	22	84	1750	1475	67	12000
8.9" diam.	-	30	84	2400	2050	68	12000
2-D / Electronic Adapter							
4.0" diam.	-	22	82	1300	1100	50	10000
4.3" diam.	-	39	82	2780	2375	61	10000
Spiral Integral Units							
	-	9	85	400	340	38	10000
	-	11	85	600	510	46	10000
	-	15	85	900	765	51	10000
	-	20	85	1200	1020	51	10000
	-	23	85	1450	1232	54	10000
	-	26	82	1560	1326	51	10000

NOTES: Lamp lumen performance varies among manufacturers.
Maintained performance includes effect of lamp lumen depreciation (@40% rated life).
Sources: 1993 Advanced Lighting Guidelines; manufacturer data.

TYPICAL PERFORMANCE VALUES FOR DIRECTIONAL LAMPS

Lamp Types	System Watts	Avg.System Lumens	CBCP Candelas	Beam Degrees	Rated Life
Incandescents					
R30	45	485	N/A	N/A	2000
R30 / Krypton	60	775	510	65	2000
R30	75	900	470	72	2000
ER30	50	replaces 100W in deep cans			2000
ER30	75	replaces 150W in deep cans			2000
ER40	120	replaces 250W in deep cans			2000
R40	75	890	N/A	N/A	2000
R40	100	1190	N/A	N/A	2000
PAR38/ES/Spot	65	675	5900	14	2000
PAR38/ES/Flood	65	675	1750	30	2000
PAR38/Spot	75	765	4400	17	2000
PAR38/Flood	75	765	1750	33	2000
PAR38/ES/Spot	85	930	6800	15	2000
PAR38/ES/Flood	85	930	2000	37	2000
PAR38/ES/Spot	120	1370	9200	18	2000
PAR38/ES/Flood	120	1370	3600	30	2000
PAR38/Spot	150	1740	12000	16	2000
PAR38/Flood	150	1740	3100	36	2000
Compact Halogen					
PAR30/Wide Flood	50	670	800	55	2000
PAR30/Spot/IR	50	1000	19500	7	3000
PAR30/Flood/IR	50	1000	2400	33	3000
PAR30/Spot	75	1100	15000	11	2000
PAR30/Flood	75	1100	2500	36	2000
PAR30/Wide Flood	75	1100	2500	36	2000
PAR38/Spot/IR	60	1150	18500	10	3000
PAR38/Flood/IR	60	1150	3650	29	3000
PAR38/Spot	75	1070	18400	8	2500
PAR38/Flood	75	1070	4000	26	2500
PAR38/Spot	90	1270	18500	10	2000
PAR38/Flood	90	1270	4000	30	2000
PAR38/Wide Flood	90	1270	1500	55	2000
PAR38/Spot/IR	100	2000	30000	10	3000
PAR38/Flood/IR	100	2000	5500	33	3000
Compact Fluorescent					
Integral/Reflector/Quad	15	540	315	70	10000
Integral/Reflector/Quad	17	720	N/A	N/A	10000
Integral/Reflector/Quad	20	810	335	80	10000

Notes: CBDP = center beam candlepower, the maximum luminous intensity (in candelas)
Beam angle = the angle in which the luminous intensity is at least 50% of the maximum value.

Sources: Manufacturer Literature

TYPICAL PERFORMANCE VALUES FOR HID SYSTEMS

Lamp Types	Lamp Watts	System Watts	Lamp CRI	Initial Lamp Lumens	Maintained System Lumens	Maintained System Efficacy	Rated Life
Mercury Vapor (MV)							
2 1/8" Diameter (Coated)	50	67	50	1575	1250	19	16000
2 1/8" Diameter (Coated)	75	92	50	2800	2250	24	16000
3" Diameter	100	120	15	4200	3200	27	24000
3 1/2" Diameter	175	206	15	7900	7400	36	24000
3 1/2" Diameter	250	284	15	12100	10500	37	24000
4 5/8" Diameter	400	458	15	22500	17500	38	24000
7" Diameter	1000	1050	15	60000	45000	43	24000
2 1/8" Diameter	35	50	65	2500	1900	38	7500
Metal Halide (MH)							
2 1/8" Diameter	35	50	65	2500	1900	38	7500
2 1/8" Diameter	50	67	65	3500	2550	38	5000
2 1/8" Diameter	70	90	65	5500	4000	44	7500
2 1/8" Diameter (ceramic tube)	70	90	83	6200	4960	55	7500
2 1/8" Diameter	100	127	65	9000	6390	50	15000
2 1/8" Diameter (ceramic tube)	100	127	83	9500	7600	60	10000
2 1/8" Diameter	150	195	65	13500	10200	52	15000
2 7/8" Diameter (1)	175	210	65	15000	12000	57	10000
3 1/2" Diameter (1)	250	293	65	23000	18000	61	10000
4 5/8" Diameter (1)	400	458	65	40000	32000	70	20000
7" Diameter (1)	1000	1080	65	115000	92000	85	12000
7" Diameter (1)	1500	1620	65	155000	140000	86	6000
MH Retrofit for MV Systems	325	383	65	28000	18200	48	20000
MH Retrofit for MV Systems	950	1030	65	100000	80000	78	12000
MH Retrofit for HPS Systems	250	300	65	18000	13500	45	10000
MH Retrofit for HPS Systems	400	465	65	40000	30000	65	20000
Energy-saver MH	150	185	65	13500	10200	55	10000
Energy-saver MH	225	268	65	19000	14300	53	10000
Energy-saver MH	360	418	65	35000	26300	63	10000
Super MH (2)	150	not avail.	65	15000	11300	n/a	15000
Super MH (2)	200	not avail.	65	21000	15800	n/a	15000
Super MH (2)	350	375	65	36000	27000	72	15000
150W Pulse-Start (Linear Reactor Blast)	150	170	65	15000	11300	66	15000
200W Pulse-Start (Linear Reactor Blast)	200	218	65	21000	15800	72	15000
350W Pulse-Start (Linear Reactor Blast)	350	375	65	36000	27000	72	20000

Note: Linear Reactor ballasts may not be suitable for all pulse-start lamp applications. Check with manufacturer for proper ballast specifications.

Lamp Types	Lamp Watts	System Watts	Lamp CRI	Initial Lamp Lumens	Maintained System Lumens	Maintained System Efficacy	Rated Life
High Pressure Sodium (HPS)							
Standard HPS	35	45	22	2250	2025	45	24000
Standard HPS	50	65	22	4000	3600	55	24000
Standard HPS	70	95	22	6400	5450	57	24000
Standard HPS	100	130	22	9500	8550	66	24000
Standard HPS	150	195	22	16000	14400	74	24000
Standard HPS	250	300	22	28000	27000	90	24000
Standard HPS	400	465	22	51000	45000	97	24000
Standard HPS	1000	1100	22	140000	126000	115	24000
Energy-saver HPS	225	275	22	27500	24800	90	24000
Energy-saver HPS	360	425	22	45000	40500	95	24000
Deluxe HPS	70	95	60	4400	3960	42	15000
Deluxe HPS	100	130	60	7300	6570	51	15000
Deluxe HPS	150	195	60	12000	10800	55	15000
Deluxe HPS	250	300	65	23000	20700	69	15000
Deluxe HPS	400	465	65	37500	33750	73	15000
White HPS	35	45	70	1250	1000	22	10000
White HPS	50	65	70	2300	1725	27	10000
White HPS	100	130	70	4700	3520	27	10000
HPS Retrofit for MV Systems	150	195	25	15000	13500	69	24000
HPS Retrofit for MV Systems	215	265	25	20200	18600	70	24000
HPS Retrofit for MV Systems	360	425	25	45000	40500	95	24000

NOTES TO HID LAMP TABLE:

(1) High-output lamps designed for specific vertical or horizontal orientation and produce 10-25% more light than universal-orientation lamps.
(2) Requires external igniter in ballast.

Many other variations of HID lamps exist that are not included in the table, including coated lamps,various outer jacket sizes, various color temperatures, enclosed vs. open fixture rated, directional lamps,double-ended lamps, and instant restrike lamps.

NOTES TO HID TABLE (cont'd)

The lumen output and lamp life of some metal halide lamps are affected by burning position. Consult lamp manufacturer catalogs for application-specific performance data.

HID lamps are available with or without phosphor coatings. Unless otherwise noted, the data shown are for clear lamps.
Coatings on MV lamps provide CRI of 50, average.
Coatings on MH lamps provide CRI of 70, average.
Coatings on HPS lamps do not improve CRI, but reduce direct glare.
Coatings can reduce lamp output by up to 15%, particularly in lower-wattage lamps; consult manufacturer data.

Maintained performance includes effect of lamp lumen depreciation (@40% rated life).
Lamp life ratings are based on 10 hours per start.

Sources: 1993 Advanced Lighting Guidelines; manufacturer data.

TYPICAL PERFORMANCE VALUES FOR LOW PRESSURE SODIUM SYSTEMS

Lamp Types	Lamp Watts	System Watts	Initial Lamp CRI	Lamp Lumens	Maintained System Lumens	Maintained System Efficacy	Rated Life
Low Pressure Sodium (LPS)							
8-inch LPS	18	36	0	1800	1800	50	14000
12-inch LPS	35	60	0	4800	4800	80	18000
17-inch LPS	55	80	0	8000	8000	100	18000
21-inch LPS	90	125	0	13500	13500	108	18000
30-inch LPS	135	178	0	22500	22500	126	18000
44-inch LPS	180	220	0	33000	33000	150	18000

NOTES: Maintained performance includes effect of lamp lumen depreciation (@40% rated life).
Lamp life ratings are based on 10 hours per start.

Source: Manufacturer data

APPROXIMATE ANSI THERMAL CORRECTION FACTORS: WATTAGE

Source: CEC/DOE/EPRI

	Parabolic	Lens	Air Return	Strip
40W/T12/Magnetic	0.92	0.91	0.99	1.00
34W/T12/Magnetic	0.98	0.95	1.00	1.00
40W/T12/Electronic	0.94	0.92	0.99	1.00
34W/T12/Electronic	1.00	0.97	1.02	1.00
T8/Magnetic	0.95	0.92	0.98	1.00
T8/Electronic	0.94	0.90	0.98	1.00

Note: Luminaires (except strip fixtures) are assumed to be recessed in grid ceiling.
Thermally corrected wattage = ANSI wattage x correction factor

APPROXIMATE ANSI THERMAL CORRECTION FACTORS: LUMENS

Source: CEC/DOE/EPRI

	Parabolic	Lens	Air Return	Strip
40W/T12/Magnetic	0.96	0.96	1.11	1.00
34W/T12/Magnetic	0.98	0.95	1.09	1.00
40W/T12/Electronic	0.97	0.97	1.09	1.00
34W/T12/Electronic	0.99	0.97	1.07	1.00
T8/Magnetic	0.98	0.96	1.07	1.00
T8/Electronic	0.98	0.95	1.08	1.00

Note: Luminaires (except strip fixtures) are assumed to be recessed in grid ceiling.
Thermally corrected lumens = ANSI lumens x correction factor

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