**Dimming HID Lamps**

By Craig DiLouie, Lighting Controls Association

Published October 2004

High-intensity discharge (HID) lamp dimming has grown in popularity in recent years. Dimming HID lamps can result in energy savings, peak demand reduction and greater flexibility in multi-use spaces.

Dimming reduces energy costs by reducing the input power to the lighting system. It can be used to reduce peak demand and therefore reduce costly utility demand charges that can be a significant component of the total utility cost. And it offers greater flexibility to adapt spaces to different uses.

**HID Lamps**

HID light sources, ranging from 20W to 2000W in size, can be found in numerous applications, from retail to industrial to public spaces. It is estimated that there are more than 105 million HID lamps in operation in the United States. HID lighting systems consume 12% of all lighting electricity consumed by the commercial sector, 31% in the industrial sector, and 87% in all outdoor stationary applications—an average of 17% of all electricity consumed by all lighting systems in the United States (see Table 1).


<table>
<thead>
<tr>
<th>Estimated number of HID lamps/U.S.</th>
<th>Commercial 30.9 million</th>
<th>Industrial 15.2 million</th>
<th>Outdoor Stationary 54.9 million</th>
<th>All (Including Residential) 105.4 million</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average number of HID lamps/building</td>
<td>7</td>
<td>67</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Operating hours/day</td>
<td>10.1</td>
<td>13.9</td>
<td>11.3</td>
<td>11</td>
</tr>
<tr>
<td>Distribution of HID lamps/sector</td>
<td>2%</td>
<td>5%</td>
<td>75%</td>
<td>2%</td>
</tr>
<tr>
<td>Distribution of installed wattage/sector</td>
<td>11%</td>
<td>30%</td>
<td>83%</td>
<td>7%</td>
</tr>
<tr>
<td>Distribution of electricity consumed/sector</td>
<td>12%</td>
<td>31%</td>
<td>87%</td>
<td>17%</td>
</tr>
<tr>
<td>Distribution of lamp output (Terralumens-hour or trillions of lumens/hour)</td>
<td>3,068</td>
<td>2,320</td>
<td>4,677</td>
<td>10,097</td>
</tr>
</tbody>
</table>
HID lamps are similarly constructed in that they feature an arc tube of stress- and heat-resistant material that contains gases, metals and the electrodes. They are identified via the predominant distinctive metals contained in the arc tube: high-pressure sodium (sodium), mercury (mercury) and metal halide (metallic halides).

Figure 1. High pressure sodium lamp.

The arc tube is housed in a protective glass envelope. When starting voltage is applied to the electrodes from the ballast or ignitor, an arc is formed between them. Electrons in the arc stream collide with atoms of vaporized metals. The result of this action is the emission of light energy. Due to the high pressures of HID lamp operation, these wavelengths are concentrated in the visible light spectrum and therefore do not require a phosphor coating as a filter.

Of the three types of HID lighting, high-pressure sodium and metal halide are the most efficacious and offer the best color, limiting mercury’s use. Metal halide offers superior color quality with a bright white light, while most high-pressure sodium offer the greatest efficiency at the expense of color with an orangish light.

Figure 2. Metal halide lamp.

**Dimming Strategies**

Dimming can be employed in HID lighting systems to save energy, and enable the space to adapt to different uses, ambient conditions and time of day.

“HID dimming saves energy and thereby reduces owner operating costs,” says A. J. Glaser, President of the Lighting Controls Association and Colorado-based HUNT Dimming. “It also maximizes end-user satisfaction by providing proper light levels.”

**Save energy:** Dimming can be used to save energy during periods when the space is unoccupied but needs to stay lighted for safety and security reasons. Dimming can be achieved either manually via input from a switch or automatically via input from a control device. Automatic dimming can be set to respond to a preset schedule or variable ambient conditions such as occupancy and available daylight.

**Occupancy.** Dimming is a highly practical control method for saving energy with HID lighting systems to address periods of non-occupancy in spaces that must be constantly lighted.

High pressure sodium lamps can take 3-5 minutes to warm up; they take less than a minute to hot-restrike but don’t reach full light for 3-4 minutes. Metal halide lamps take 2-10 minutes to warm up and 12-20 to hot-restrike, while pulse-start metal halide lamps take 1-2 minutes.

Given these characteristics, it is not practical to shut off and restart the lamps based on occupancy if the space must be made usable again quickly. In these situations, the lamps must be operated continuously, resulting in energy waste.

In addition, most lamp manufacturers rate HID lamp life at a minimum of 10 hours per start. Any reduction in burn time per start below this minimum will result in shorter lamp life.

If the lamps are dimmed instead in response to a signal from an occupancy sensor or time-programmable controller
indicating the space is unoccupied, significant energy savings can occur during these periods, but the lamps will be able to achieve full light output quickly when the space becomes occupied again.

If occupation of the space is predictable, then timers or other time-programmable controllers may be used to deliver the control signal to dim the lamps. If occupation of the space is not predictable, then occupancy sensors may be used.

_Daylight harvesting._ Dimming can be used to adjust light levels based on available daylight via input from a photocell.

_Peak demand reduction._ Dimming can be scheduled using a time-programmable controller during times of peak demand, shaving the facility’s peak demand and potentially reducing utility demand charges.

**Flexibility:** HID lighting systems are fixed output systems, but spaces may require different light levels because they are used for multiple purposes. Dimming makes the lighting system flexible and adaptive to different uses of the space.

A school gym, for example, can be dimmed to provide suitable lighting for sports, social events, maintenance and other uses. A wholesale outlet can be dimmed during maintenance and stocking operations. Spaces can also be dimmed to provide lighting for safety and security.

**Dimming Technologies**

HID lamps can be dimmed using step-level or continuous-dimming systems.

**Step-level dimming:** Step-level dimming enables wattage reduction, usually at 100% and a step between 100% and 50% of rated power, causing step-level dimming systems to often be called two-level or bi-level dimming systems. However, some systems, often called tri-level dimming systems, can operate at three fixed light levels.

Step-level dimming is ideal for saving energy and providing lighting for safety and security during hours of non-occupancy. Tri-level dimming provides this benefit but offers a greater degree of flexibility to address multiple uses of the space.

**Figure 3. Step-dimming energy-saving application in a warehouse.** When the space is occupied, the lamps are at full input power and light output (left). When the space is not occupied, an occupancy sensor sends a signal to the dimming system, which dims the lamps while reducing input power (right). Photo courtesy: Thomas Lighting, Inc.

This dimming method usually employs a constant-wattage autotransformer (CWA) magnetic ballast with one or two additional capacitors added to the circuit, depending on whether the ballast provides bi- or tri-level dimming. Relay switching of the capacitors results in additional impedance, which reduces the lamp current and the wattage. The capacitor circuit configuration may be a parallel or series connection.

Step-level dimming is achieved based on input from manual switches, scheduling devices, occupancy sensors and photocells. When the space is occupied, the lamp is brought from its reduced light output to about 80% of light output, followed by a brief warm-up time between 80% and 100% of light output.

Step-level dimming systems using the capacitive-switching method (magnetic dimming ballast) are generally less expensive than continuous dimming systems and are often more cost-effective than HID dimming panels for applications with relatively few fixtures. This type of dimming system also allows individual fixture control. It is suitable
for retrofit; in addition, fixtures are available with a dedicated occupancy sensor and dimming ballast, suitable for direct fixture replacement.

Ideal applications for step-dimming include spaces that may be unoccupied for long periods of time but still need to be lighted, such as parking lots, warehouses, supermarkets and malls. High pressure sodium lamps are typically used for parking lots and warehouses, while metal halide lamps are typically used for supermarkets and malls. Step-level dimming systems work with all HID lamp types.

Depending on the lamp type and wattage, in a bi-level dimming system, the Low level may be 15-40% of light output and 30-60% of wattage. During dimming periods, therefore, energy savings as high as 40-70% can result.

A typical application for step-level dimming is a warehouse. When the space is unoccupied—as determined either by an occupancy sensor to detect variable occupancy, an operator with access to a high/low switch, or a timer or other scheduling system—the lamps are dimmed to an energy-saving level. Besides saving energy, the lower light level setting provides minimum lighting for safety and security. During periods of occupancy, the lamps are brought back to full light output.

In outdoor applications such as parking lots, an added bonus of dimming is a reduction in spill light that may impact adjacent properties.

**Continuous (line-voltage) dimming:** A number of technologies are available for smooth, continuous reduction of lamp wattage, including panel-level HID dimming and relatively new electronic HID ballasts. Ideal applications include anywhere it is advantageous to adapt the lighting system to a wide range of light levels to meet various space uses, such as airports, lobbies, classrooms, industrial facilities, sporting arenas, gymnasiums and auditoriums. With the exception of industrial buildings, metal halide lamps are typically used for most of these types of applications. Continuous dimming is also ideal for daylight harvesting by enabling the HID lamp output to be tuned to maintain a constant light level in the space.

**Panel-level HID dimming.** This method is used by control systems installed at the electrical panel that reduces the power supplied to the circuit. These control systems accept inputs from occupancy sensors, photocells and time-programmable systems.

The control system may be one of three types:

- **Variable-step transformer:** Variable-step transformers reduce the voltage supplied to the load, reducing light output and electrical input. They typically operate with existing CWA ballasts. They can reduce rated power down to 50%. While they have little impact on power quality, reducing voltage can affect lamp and ballast performance, according to the Lighting Research Center.

- **Variable-reactor:** This device keeps voltage constant but reduces current, enabling a reduction in rated power down to 30%.

- **Waveform modification:** Also called “wave choppers,” these electronic control systems reduce the RMS voltage to the load to reduce rated power down to 50% by chopping a part of each voltage cycle. They are used for control of both HID and fluorescent magnetic systems. They are compact and light controls, but can reduce power quality as well as lamp and ballast performance, according to test conducted by the Lighting Research Center. Some devices reduce the light output almost immediately rather than a smooth, gradual reduction, which is perceptible to occupants.

**Electronic HID ballasts.** Electronic dimming ballasts for HID lamps are now available in new fixtures and provide continuous dimming, typically from 100-50% light output for metal halide and 100-30% light output for high pressure sodium lamps so as to preserve lamp life. In addition to dimming, they are designed to operate at a higher efficacy, improved color control, less stroboscopic effect, and harmonic distortion under 20%.

While generally not cost-effective for retrofit, electronic HID ballasts can yield significant energy savings in a new fixture. They are interoperable with occupancy sensors, photocells and time-programmable systems. The signal can be transmitted along the power circuit or low-voltage wires.
“The big trend is more control,” says Glaser. “Sophistication in job design necessitates having the ability to vary the environment in precise increments and to exact levels. Continuous, variable control down to 50% provides this.”

**Dimming Controls**
The dimming signal can be created using one of three types of controls:

- Manual, either local or remote switch
- Automatic, used in conjunction with occupancy sensors or photocells
- Time-programmable, either timers or scheduling systems

Dimming systems can be configured to control a single or multiple zones.

The occupancy sensor detects motion and sends a signal to the control system using the power line, low-voltage wire or fiber-optic cable.

**Related Issues**
There are a number of technical issues related to dimming HID lamps that lighting professionals should be aware of when specifying an HID dimming system. These issues relate to light output, efficacy, lumen depreciation, service life and color.

**Efficacy:** The ratio of reduction in wattage to reduction in light output is not proportional with panel-level and step-dimming control systems. Light output will be reduced further than the wattage reduction. In general, light output reductions are about 1.2-1.5 times the power reduction for metal halide lighting systems, and about 1.1-1.4 times the power reduction in high pressure sodium lighting systems. See Table 2 for changes in efficacy for a 400W coated metal halide lamp.

**Table 2. Changes in efficacy for a 400W coated metal halide lamp. Efficacy is defined as the relative light output divided by relative system input power. Source: Lighting Research Center.**

<table>
<thead>
<tr>
<th>System Input Power (W)</th>
<th>Relative Efficacy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>439</td>
<td>100</td>
</tr>
<tr>
<td>393</td>
<td>91</td>
</tr>
<tr>
<td>354</td>
<td>82</td>
</tr>
<tr>
<td>302</td>
<td>79</td>
</tr>
<tr>
<td>260</td>
<td>67</td>
</tr>
<tr>
<td>247</td>
<td>59</td>
</tr>
</tbody>
</table>

**Figure 4. Light output versus system input power for a 400W coated metal halide lamp. Source: Lighting Research Center.**
Dimming below 50%: When HID lamps are dimmed below 50% of rated power, they may experience degradation in service life, efficacy, color and lumen maintenance, or they may extinguish. Dimming below 50% of rated power, in fact, may reduce high pressure sodium and metal halide lamp life by 90%. As a result, dimming below 50% may void lamp warranties.

NEMA recommends that the maximum recommended dimming level is 50% rated lamp wattage for both metal halide and high pressure sodium lamps. NEMA further recommends that the lamps should be operated at full power for at least 15 minutes prior to dimming (unless the lamp is extinguished from a voltage interruption and the input voltage activates the timer, in which case 30 minutes is recommended before dimming.)

Compatibility: Some panel-level dimming systems are not compatible with electronic ballasts. Self-extinguishing lamps are not recommended for use with dimming systems. Some manufacturers recommend that metal halide lamps be operated base-up to preserve lamp life. Some panel-level dimming systems introduce harmonic currents into the electrical system.

Flicker: Dimming HID lamps, particularly high pressure sodium lamps, can make flicker more visible.

Color: HID lamps can experience a color shift during dimming and also a reduction in color rendering ability. Metal halide lamps are most susceptible to changes in lamp color characteristics.

Clear metal halide lamps, for example, will shift to a higher color temperature or cooler appearance during dimming, from white to blue-green. When a clear metal halide lamp is dimmed to 50% of rated power, color temperature can increase 1500K, according to the Lighting Research Center.

Color rendering may also be affected; when a clear metal halide lamp is dimmed to 50% of rated power, the Color Rendering Index (CRI) value may decline from 65 to 45. Coated metal halide lamps experience a much smaller shift and a smaller reduction in CRI than clear lamps.

High pressure sodium lamps can also be affected, typically experiencing a 50-200K reduction in color temperature when they are dimmed, appearing more yellow, while CRI experiences a minimal change.
**Alternative Solutions**
Facility owners and operators can achieve energy savings with HID lighting without dimming, by considering power reducers, low-wattage HID lamps, and low-bay fluorescent T5 lighting systems.

**Power reducers:** Powers reducers, or current limiters, are retrofit devices that can be wired to control an HID ballast or can be installed at the electrical panel to control an entire HID circuit. They are typically designed to work with common CWA ballasts and lamps at least 175W in size. Ideal for overlighted spaces where variable light levels are not needed, they can achieve a preset reduction of 20-25% rated power and may extend ballast life by reducing ballast case operating temperature. Reduced-wattage and lower output HID lamps can also be used to retrofit existing fixtures in such applications, as an alternative to power reducers. Although power reducer manufacturers claim that their devices result in little or no reduction in perceived light output, light output will in fact be reduced. It is recommended that lighting professionals conduct a trial installation and measure light levels and wattage before and after installation of the given power reducer.

**Fluorescent T5 or T5HO systems:** T5HO lamps have been incorporated into a new type of low-bay (>15 ft.) fixture. This 4- or 6-lamp, instant-on/restrike, high-lumen-maintenance, high-CRI, 20,000- or 28,440-lumen fluorescent fixture has become a popular energy-saving alternative to metal halide in industrial facilities, warehouses, gymnasiums, etc. All things being equal, the T5HO fluorescent is more efficient than metal halide, provides better color rendering and consistency, and has instant-on and instant-restrike, with the tradeoff that more lamps and fixtures would be required to light the space, and the fluorescent lamps may not perform as well in cold environments. An interesting side benefit of T5 low-bays is that they can double for emergency lighting.

**Latest Solutions**
Below are several of the latest HID dimming solutions offered by members of the Lighting Controls Association.

**Advance Transformer:** Advance Transformer recently introduced Dynavision, a new microprocessor-based electronic ballast for the operation of pulse-start metal halide lamps. Because of DynaVision's ability to maximize lamp lumen maintenance over life, a variety of cost saving opportunities is possible through energy savings and reduced re-lamping and maintenance. In a scenario where the number of fixtures is unchanged, a DynaVision ballasted 320W lamp could be substituted to produce lumen levels at or above those provided by a 400W probe-start system. The result is a substantial reduction in watts per square foot.

*Figure 5. Dynavision from Advance Transformer.*

Alternatively, energy savings can be achieved with DynaVision by reducing the number of fixtures utilized, thanks to the ballasts' ability to maintain lumen levels over lamp life. A DynaVision ballast will operate either a 320W, 350W or 400W pulse-start metal halide lamp, from any manufacturer, at its rated wattage level. DynaVision ballasts also feature Advance IntelliVolt technology, permitting operation on different voltage systems, ranging from 200V to 277V.

Other important DynaVision features include continuous 0-10V dimming, down to 50% of lamp power, and the ability to directly control a quartz auxiliary lamp up to 250W.

**HUNT Dimming:** HUNT Dimming offers the Simplicity Series Digital Dimming Systems, designed to simplify contractor installation by utilizing a compact, lightweight design and minimal wiring requirements, and also designed to maximize owner benefits with simplified programming and ease of use.
The Simplicity Series wall-mounted control stations include LCD touchscreens which provide visual and intuitive digital lighting control for single location operation, monitoring and programming of all lighting zones; pushbutton control stations which -100 bi-level HID controllers from The Watt Stopper.

Both controllers are designed to operate 175-1000W HID lamps operated on CWA-type ballasts. The DM-105 installs on new or existing fixtures and requires a bi-level capacitor, which is installed inside the fixture. It requires four wires. The DM-100 mounts directly onto the HID fixture or at a remote location using two wires. Both work with a 24VDC controlling device, such as an occupancy sensor, photocell or time switch, and switches HID lighting between high and low. Both utilize a dual capacitor and capacitor switching to achieve bi-level control. Multiple modules can be linked together and then be controlled from one device.

ULTRAWATT: ULTRAWATT's PowerGate Intelligent Lighting Management System (PGi) offers digital panel-level HID dimming. The PGi system features a custom cabinet design connected to existing lighting circuit breakers and is ideally suited for retrofit applications. Control cards can be accessed, from either local or remote location, through proprietary PC-based software for fine-tuning the lighting system according to time, occupancy, or utility requirements. Analysis of the systems operations can also be used in conjunction with facility maintenance programs.