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Guidelines on the Application of Dimming to High-Intensity Discharge Lamps

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Preface

With the increasing emphasis on energy efficiency, attention is being focused on the application of control systems that include dimming functions for High-Intensity Discharge (HID) lighting systems for both indoor and outdoor lighting. Complicating matters is that the lamps, ballasts, and control systems may be designed by different companies and may have compatibility issues. The exact performance of any HID dimming system or of the lamp on that system is dependent upon the specific dimming methodology employed with specific ballasts and lamps.

These guidelines are meant to impart general information and considerations in the design and application of such systems. Contact the manufacturers of the lamps, ballasts, and dimming systems for specific recommendations.

It is further recommended that the user, lighting designer, or specifier evaluate any new proposed combination of components as a system in a field test to ensure that the combined performance of the system is acceptable.

Additionally, policy makers who reference or cite these guidelines should carefully analyze the three sub-sections: high-pressure sodium, metal halide, and mercury vapor. A thorough reading of each section will reveal that HID systems respond differently to dimming, between and among the HID family types, and that recommendations for one family cannot be assumed to apply to others.

A General Statement

HID lamps are designed to keep the lamp electrodes and discharge tube wall operating within a specific temperature range in order to maintain the proper vapor phase concentrations of discharge tube additives for good lamp performance. Because dimmed operation of HID lamps causes the discharge vessel to operate below ideal thermal conditions, users may experience degradation of efficacy and life if the starting and operating recommendations below are not followed. For this reason, control or occupancy detection systems capable of instant off-on operation are not desirable for HID lamps.

The effect of dimming on HID lamp life is dependent on how long lamps are operated in the dimmed mode, the type of dimming system, and how deeply lamps are dimmed. Lamp and ballast systems should meet the requirements of the appropriate American National Standards Institute (ANSI) specifications for both starting and operating lamps at full/rated power. Magnetic ballast dimming systems may not be capable of maintaining recommended ANSI specifications in the dimmed mode. Failure to meet the required sustaining voltage may cause premature lamp dropout and shortened life.

In general, satisfactory, efficient operation of HID lamps that does not harm lamp life or introduce the risk of accelerated lumen depreciation can best be achieved by operating the lamp in accordance with the recommended dimming levels in this paper.

The information below represents some practical guidelines for considering an energy-saving HID dimming system. Ideal applications of these energy-saving systems include parking garages, warehouses, shipping docks, street lights, supermarkets, ball fields, factories, and security lighting. They are also used in conjunction with daylight lighting systems to conserve energy. Concerns such as color shift and lamp performance have been expressed regarding the use of HID lamps on dimming systems. Since these are application dependent, tradeoffs in color and performance should be weighed in the overall benefits calculation of energy reduction.

Common Types of Lamp Dimming Systems

There are two basic categories of lamp dimming systems in common use:

(A) Step-level (including bi-level) power reduction, typically associated with magnetic ballasts
(B) Continuous or variable dimming, typically associated with electronic ballasts

Not all systems will provide the same performance with all HID lamps, and not all systems are optimized for all HID lamps. Consequently, lamp and ballast manufacturers should be contacted to confirm that lamp/ballast combinations are compatible.

A. Step-Level

Step-level systems generally operate by increasing the capacitive impedance of a magnetic ballast to reduce the lamp current and therefore the lamp wattage. These systems are often used in conjunction with occupancy detection systems. In a typical application, infrared or ultrasonic occupancy sensors are utilized to detect motion in the controlled area. During the period in which motion is detected by the sensors, the lamps operate at full power. With the absence of local activity over a certain period of time, a switching mechanism in the system reduces the lamp power to a predetermined wattage.

Step-level systems should not drop below the reduced lamp wattage specification when using an ANSI reference lamp at the lowest recommended ANSI input voltage for a particular magnetic ballast type. See the sections specific to high-pressure sodium and metal halide for more detail.

B. Continuous or Variable

Line voltage continuous dimming systems work by changing the primary voltage to the ballast with a variable voltage transformer or by electronically modifying input voltage and current waveforms (also known as ¯phase control). Continuous dimming can also be achieved by employing electronic low or high frequency switching circuits or by combinations of electronic and mechanical devices (so-called ¯hybrid systems) to modify the lamp power. These systems can reduce lamp wattage continuously. Questions on line voltage lamp dimming should be directed to individual lamp or controller manufacturers.

High-Pressure Sodium

There are several common high-pressure sodium (HPS) lamp technologies, including standard, non-cycling, TCLP-compliant, and internal ignitor types. Additionally, there are some quartz MH and ceramic MH lamps that offer enhanced color characteristics (CRI, CCT) for specific applications that are designed for retrofit operation on HPS ballast systems. All HPS and HPS retrofit lamps meet the same recommendations for starting and dimming operation.

Most HPS lamps are approved for dimming in any orientation, but operation on magnetic or electronic ballasts may make a difference. The lamp manufacturer should be consulted to determine performance expectations for specific applications and control systems.

It is recommended that HPS lamps be started and operated in the full power mode, i.e., at rated wattage, for a minimum of 15 minutes before dimming. This is necessary to clean the arc tube of deposits from starting that would raise arc voltage and promote internal reactions within the alumina tube. If an interruption to the ballast input voltage should occur, the lamp may extinguish and require several minutes to re-ignite. The timing circuit should be reset for 15 minutes only after the lamp has restarted. If the input voltage activates the timer, then 20 minutes is recommended before dimming is resumed.

For a continuous type dimming system, the reduced wattage recommendation for HPS lamps must be achieved with a ballast meeting the recommended ANSI specifications for starting and operating a reference lamp. Step-level systems should not drop below this minimum wattage specification when using a reference lamp at the lowest recommended ANSI input voltage for a particular magnetic ballast type. Line voltage dimming systems may not be capable of maintaining the minimum ANSI open circuit voltage in the dimmed mode. Failure to provide sufficient sustaining voltage may cause premature lamp dropout and short life.

Users should be aware that for some HPS lamps, and particularly for retrofit quartz and ceramic MH lamps designed to operate on HPS ballasts, there may be changes in lamp color temperature, color rendering, and luminous efficacy with dimming. As a general guideline, when dimmed below the wattage value in Table 1 for sustained periods, there is an increased likelihood of poor lumen maintenance and shorter lamp life.

Additionally, HPS lamps, aged approximately 15,000 hours, are susceptible to dropout when rapidly dimmed. This could be misconstrued by the user as a failed lamp, when in fact if allowed to cool, the lamp will re-light and operate at rated wattage for its rated life in an undimmed mode. To reduce the potential for dropout due to rapid dimming, it is recommended that dimming rates be slowed to approximately 1.5 minutes from full light to maximum dimmed condition, while maintaining sufficient sustaining voltage.

For more information, see Table 1.

Table 1
Recommended Dimming Levels See Note 1

Lamp Type	Wattage Range and Burn Position	Maximum Recommended Percent Dimming
High-Pressure Sodium	All wattages in all positions	Down to 50 percent rated lamp wattage See Figure 2 for effect on lamp lumens
Retrofit Quartz Metal Halide, Ceramic Metal Halide, and Specialty HPS (i.e., internal ignitor, etc.)	Consult with the lamp manufacturer for specific details about allowable dimming, wattage range, and burn position of these lamp types when operated on HPS ballasts with specific control systems.	

Metal Halide

There are several common types of metal halide (MH) lamps, including pulse start ceramic MH (CMH), pulse start quartz MH (QMH), and probe start quartz MH. There are also some specialty lamps such as those with internal ignitors or starting aids that are designed to operate on probe start and pulse start ballasts.

It is recommended that metal halide lamps be started and operated at full power, i.e., at rated wattage, for a minimum of 15 minutes before dimming. If an interruption to the ballast input voltage should occur, the lamp may extinguish and require several minutes to re-ignite. The timing circuit should be reset for 15 minutes only after the lamp has restarted. If the input voltage activates the timer, then at least 20 minutes is recommended before dimming is resumed. This recommendation includes lamp types that are started with the assistance of internal starting aids, e.g., a starting probe, as well as those that require external high voltage ignitors.

Lamp manufacturers restrict the operating positions of lamps with starting probes to the base-up position when they are used on dimming systems. This restriction originates from consideration of the operating temperature of the bimetal switch that is used with the starting probe. Failure of the bimetal switch to operate at its design temperature in the dimmed mode may cause premature lamp failure. Consult the lamp manufacturer before operating probe start lamps in other than vertical base up positions.

Quartz and ceramic pulse start MH lamps are commonly available that require external ignitors for starting and do not utilize probes and switches. These lamps may be dimmed in any position that the lamp manufacturer recommends for a particular wattage. NEMA recommendations are listed in Table 2.

Users should be aware that quite often, there is a color shift when dimming MH lamps. The amount and effect of the shift can differ from one type to another. The bulk of available public data is for QMH. The following examples best represent QMH lamps: With a clear lamp, the color will change toward a higher correlated color temperature (CCT). With sufficient dimming, the source will appear as a clear mercury lamp of approximately 5000K-6000K in CCT versus the typical 3000K-4000K for the common MH lamps. See Figure 1 for the average shift in CCT and the corresponding decrease in lamp power that may be expected in dimming a clear 400W probe start MH lamp. For a phosphor coated lamp, the color temperature increase may not be as drastic. For example, a 3700K coated lamp may increase to only 4000K with dimming. In addition, there will be a reduction in lamp efficacy and color rendering.

Self-extinguishing T-type MH lamps and retrofit HPS lamps designed to operate on MH ballasts are not recommended for use with dimming systems.

Table 2
Recommended Dimming Levels and Positions See Note 1

Lamp Type	Wattage Range and Burn Position	Maximum Recommended Percent Dimming
Quartz Metal Halide, probe start	All wattages: Base up position only	Down to 50% rated lamp wattage
Quartz Metal Halide, pulse start	≤150W: Universal operating position with some exceptions (see individual manufacturer specification)	Down to 60% rated lamp wattage
	>150W: Universal operating position with some exceptions (see individual manufacturer specification)	Down to 50% rated lamp wattage
Ceramic Metal Halide pulse start	<150W: Universal operating position with some exceptions (see individual manufacturer specification)	Down to 70% rated lamp wattage
	≥150W: Base up and vertical positions (see individual manufacturer specification)	Down to 60% rated lamp wattage
Specialty MH (i.e., retro-fit, internal ignitor, etc.)	Consult with the lamp manufacturer for specific details about allowable dimming, wattage range, and burn position of these lamp types on specific control systems.	
Self-extinguishing T-type Lamps	These lamps are not recommended for use with any dimming system.	

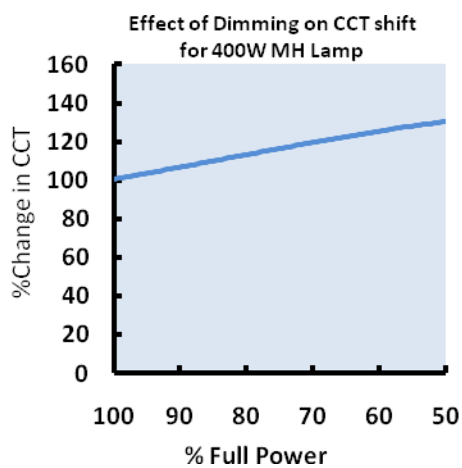

Figure 1
CCT Shift for QMH Lamp

Note 1 The reduced wattage recommendation for HID lamps must be achieved with a ballast meeting the recommended ANSI specifications for starting and operating a reference lamp at rated lamp power. Magnetically and electronically ballasted dimming systems should not drop below these wattage specifications when using a reference lamp at the lowest recommended ANSI ballast input voltage. Dimming systems may not be capable of maintaining sufficient sustaining voltage in the dimmed mode. This may cause premature lamp dropout and short life. Older lamps may be prone to dropout during dimming. Consequently, a slower rate of dimming is recommended. Magnetic lag and regulated lag ballast dimming is not recommended.

Figure 2 illustrates the potential lamp wattage and color shift of a clear 400W probe start MH lamp. Though many MH products respond to dimming with a color shift in this manner, not all do. The values included in Table 1 and Table 2 for rated lamp power can be translated into percent lumen output as shown in Figure 2.

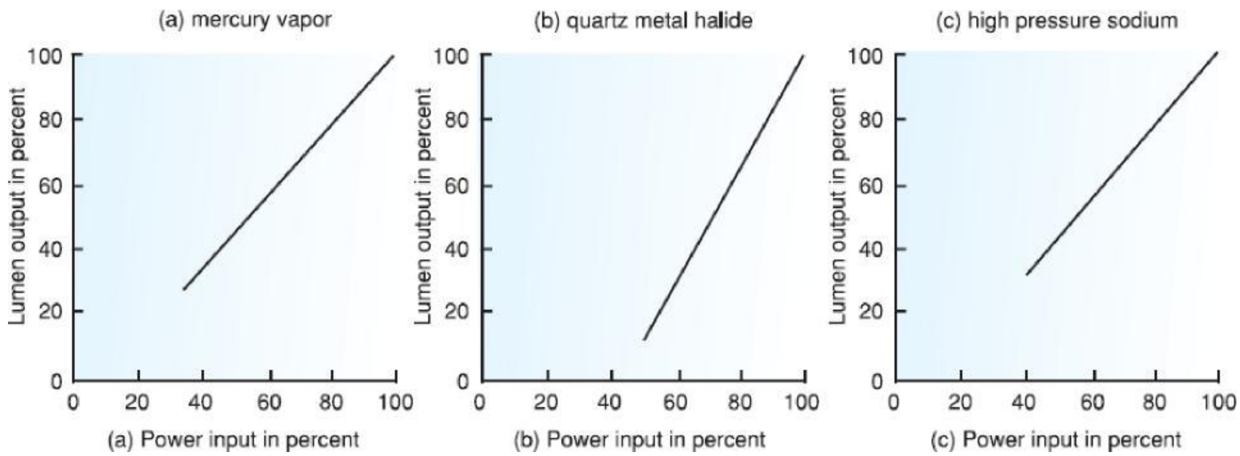

Figure 2
Lumen output vs. power output for high-intensity discharge lamps: (a) mercury vapor; (b) quartz metal halide; and (c) high-pressure sodium.
(Source: IESNA Handbook)

Mercury Vapor

Mercury Vapor lamp ballasts for general purpose lighting were regulated in accordance with EPAct 2005 and can no longer be manufactured in or imported into the United States. However, certain types of specialty mercury vapor systems are still in use and could feasibly be dimmed. Specialty applications include UV curing, microscopy, photo-polymerization, circuit board fabrication, fiber optic illumination, and other scientific uses.

In general, it is recommended that mercury vapor lamps be started and operated at full power, i.e., at rated wattage, for a minimum of 15 minutes before dimming. If an interruption to the ballast input voltage should occur, the lamp may extinguish and require several minutes to re-ignite. The timing circuit should reset for 15 minutes only after the lamp has restarted. If the input voltage activates the timer, then 20 minutes is recommended before dimming is resumed.

Questions regarding the dimming of specialty mercury vapor systems should be directed to the manufacturer.

References

D. Smith and H. Zhu, ¯Properties of High Intensity Discharge Lamps Operating on Reduced Power Lighting Systems, *Journal of the IES*, Vol. 22, No. 2: pp. 27-39, 1992.

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Dimming of Philips Metal Halide Lamps, *Philips Lighting Technical Bulletin*, June 1992.

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High Intensity Discharge Lamp Dimming, *General Electric Technical Bulletin*, August 2010.

IESNA Handbook, 9th Edition, pp. 6-54 and 6-55, 2000

NEMA LSD 25-2008 *Best Practices for Metal Halide Lighting Systems, Plus Questions and Answers about Lamp Ruptures in Metal Halide Lighting Systems.*

R. G. Gibson, ¯Dimming of Metal Halide Lamps, *Journal of the IES*, Vol. 23, No. 2: pp. 19-23,

1993. §

