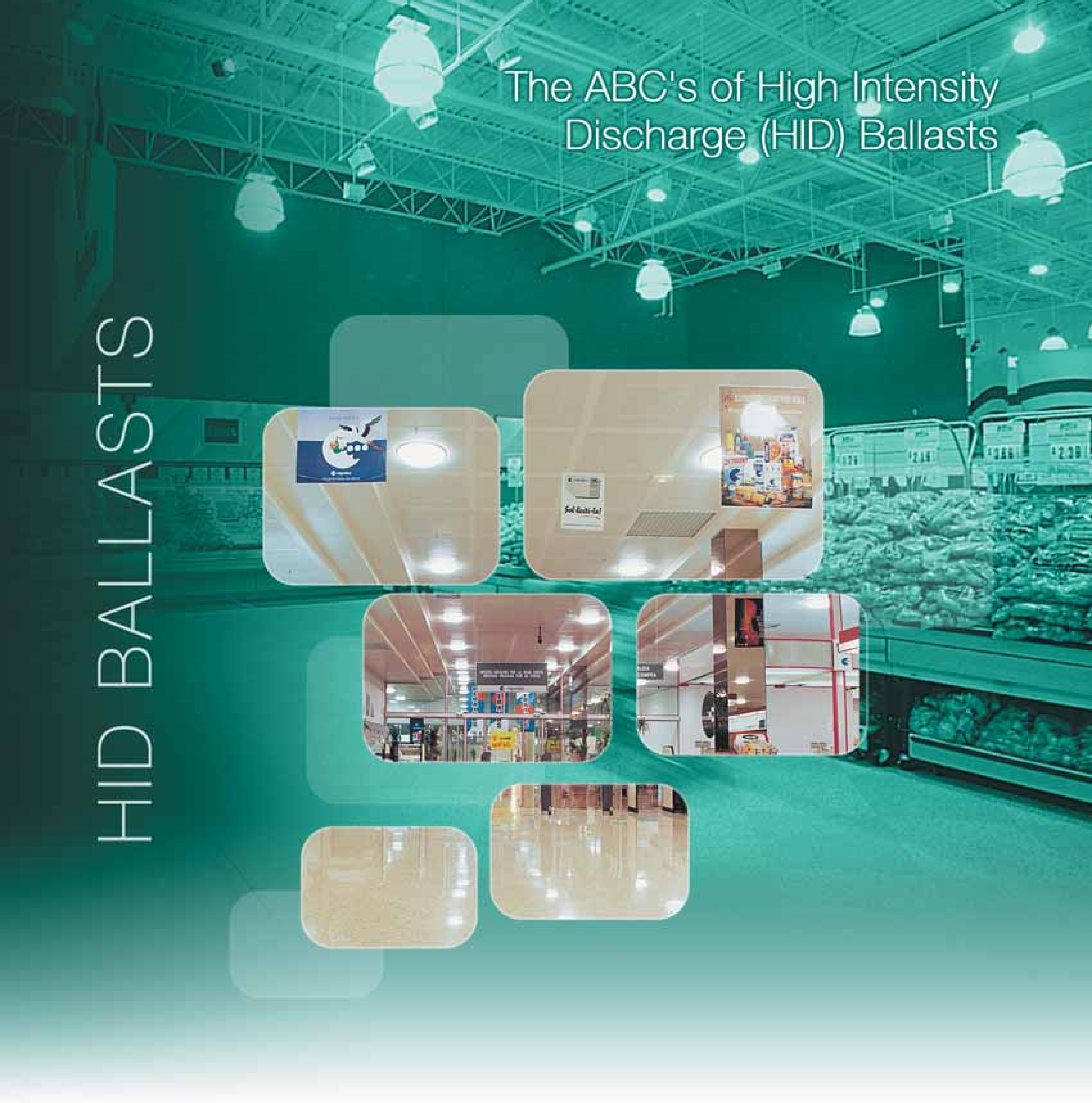
The ABC's of High Intensity Discharge (HID) Ballasts

HID BALLASTS



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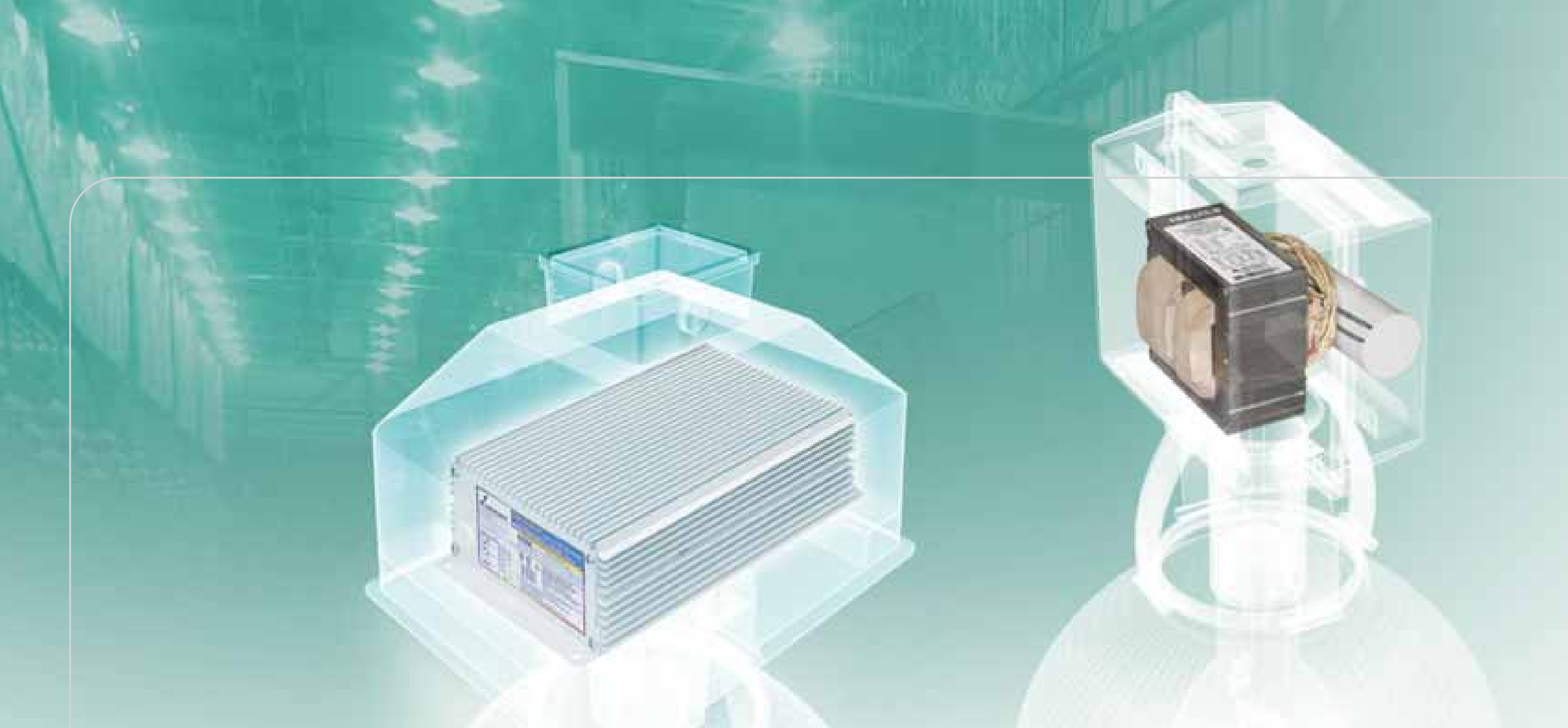


Introduction

This guide is written to help the reader understand, evaluate and specify HID ballasts, both magnetic and electronic. It starts with lamp and ballast basics and concludes with an explanation of the operating details and benefits of the fast-emerging electronic HID ballasts.

Metal halide high intensity discharge (HID) lighting has seen tremendous market acceptance since its development in the 1960s. In particular, metal halide has long dominated commercial and industrial applications such as high bay industrial and retail outdoor lighting due to its inherently high lumen output, high efficacy (efficiency), and superior quality white light. Alternative light sources for these applications were not as viable. Conventional fluorescent lighting had insufficient lumen output while incandescent lighting had poor efficacy. Other types of HID lightning such as high pressure sodium, low pressure sodium, and mercury vapor have poor color rendition, with high and low pressure sodium producing a yellowish light and mercury a bluish output. However, high pressure sodium, because of its high efficacy and long life is the dominant light source for much of outdoor lighting, especially roadway.

While metal halide's superior lumen output, crisp white light and efficacy propelled its market acceptance, it does have certain performance drawbacks. Its chief disadvantage is lumen maintenance – the lamp's ability to maintain light output over life. As with all HID light sources, until recently metal halide lamps were operated by electromagnetic ballasts – sound technology, but unable to optimize certain performance areas such as lumen maintenance and color control.

In the mid 1980s, lamp manufacturers began adding ignitors to the ballast circuit to start a new generation of metal halide lamps below 175W. These became known as pulse start lamps. By the mid 1990s, this technology was extended to the medium wattage lamps (175 – 400W) and later expanded up through 1000W and beyond. Pulse start metal halide lighting systems made measurable improvements in lumen efficiency and lamp life but the contribution to lumen maintenance and color stability enhancement was limited.

Concurrently, new fluorescent lighting systems were being developed, driven by electronic ballasts which improved lamp efficacy. Further, lamp manufacturers took advantage of the superior control rendered by electronic ballasts and were able to improve fluorescent lamps to minimize lumen depreciation and, with new phosphors, improve color rendition. Coupled with specially designed reflecting fixtures, these new fluorescent systems have become a viable alternative to HID in some applications.

Electronic ballasts have now been developed for metal halide, establishing new benchmarks in performance and energy savings, and reasserting metal halide's value. Lumen maintenance over conventional HID systems is improved significantly. For 400-watt lamps, the lumen maintenance rating is 85% to over 90% with the higher performance associated with longer burning hours (120+ hours per start) as compared to 65-75% for probe and pulse start lamps operating on magnetic ballasts. Equally important, as the lamps age, the rate of lumen depreciation is lessened, further widening the gap and extending useful lamp life closer to the full life rating. Fewer fixtures are required to provide the needed light, thus achieving significant energy savings. Some electronic HID ballasts also allow dimming, either continuous or step, using control devices such as photocells, relays and occupancy sensors.

Contents

HID Lamps: An Overview

There are four types of high intensity discharge lamps: mercury vapor, low pressure sodium, high pressure sodium and metal halide. All are electric arc discharge lamps. Light is produced by an arc discharge between two electrodes located at opposite ends of an arc tube within the lamp.

HID Lighting Characteristics

Each HID lamp type has its own characteristics that must be individually considered for any given lighting application.
There are four key parameters:

- *System efficacy [combination of lamp efficacy (lumen output per watt) and ballast efficiency]*
- *Lamp life*
- *Lumen maintenance*
- *Color rendition and control over life*

Mercury Vapor

Mercury vapor lamps are the least efficient HID source with an efficacy of 25 to 55 lumens per watt. As an early historical alternative to incandescent light, mercury vapor was more efficient and lasted 20-30 times as long. However, it has since lost viability against more efficient high pressure sodium and metal halide. Mercury vapor's color output is bluish, and lumen maintenance is only fair compared to other HID sources. Its strength is low cost, long life (in the range of 16,000 to 24,000 hours or more), and a wide range of wattages from 50 to 1000W. Today its most common applications are roadway lighting, competing with high pressure sodium, and low-cost area lighting. It has also found a strong niche in landscape applications where the bluish-green color is beneficial for illuminating foliage.

Low Pressure Sodium

Low pressure sodium lamps are grouped with other HID lamps, but in fact do not have a compact, high intensity arc. They are more like fluorescent lamps with a long, stretched-out arc. The lamps are the most efficient light source with an efficacy of 100 to 185 lumens per watt. However, color rendition is essentially non-existent because of the monochromatic yellow output. Consequently, low pressure sodium has never established itself beyond niche applications such as street and parking lot lighting. Low pressure sodium lamps range in size from 18 to 180W, average 14,000 to 18,000 hours of life, and have excellent lumen maintenance. Low pressure sodium lamps have the longest warm-up time among HID light sources, from 7 to 15 minutes.

High Pressure Sodium

High pressure sodium lamps have an efficacy of 80 to 140 lumens per watts, a long lamp life of 20,000 to 24,000 hours, and the best lumen maintenance among all HID light sources. Wattages range from 35 to 1000W and the warm-up time is from 3 to 4 minutes. The biggest drawback of high pressure sodium is the yellowish output, but it is acceptable for use in many industrial and outdoor applications (e.g., roadway lighting). High pressure sodium and metal halide are the mainstay lamps of the HID lamp group.

Metal Halide

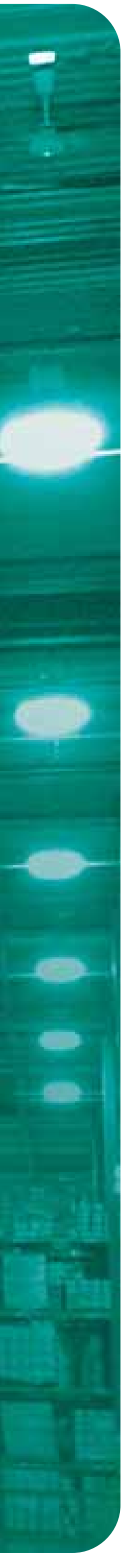
Metal halide lamps have an efficacy of 60 to 130 lumens per watt and have a warm-up time from 2 to 5 minutes. For general use, lamp wattages range from 20 to 1000W with a lamp life of 6,000 to 20,000 hours. Wattages from 1500 to 2000W are also used for sports lighting with lamp life ratings of 3,000 – 5,000 hours. Unfortunately, lumen maintenance is less than optimal relative to other light sources.

The advantage of metal halide is a bright, white-light output, making it highly suitable for commercial applications such as retail stores and all commercial and industrial installations where light color quality is important. While high bay fixture applications have been a predominant venue for metal halide, new electronic ballast technology is enabling expanded applications; in particular, low wattage metal halide is now being used for downlights and accent lighting in retail displays, and in lobbies and foyers. Low wattage metal halide, because of its "punch", is also commonly used for indoor commercial lighting for higher ceiling applications, such as airport terminals.

Pulse Start Metal Halide

Lamp manufacturers sought to improve upon traditional probe start metal halide lighting (175 – 1000W). They did so by changing the chemistry and increasing the fill pressure in the lamp arc tube to increase lumen efficacy (lumens per watt). However, with only a 600V peak starting voltage from the ballast, these new lamp designs would not start when used with traditional probe start ballasts. Advance introduced an ignitor as a component of the metal halide ballast to deliver a high voltage pulse directly across the lamp's operating electrodes to start the lamp – similar technology as that used for high pressure sodium and low wattage metal halide. The ignitor replaced the ballast's 600V peak voltage and eliminated the lamp's internal starting probe and its bi-metallic switch. Removal of the starting probe and switch from the arc tube construction allows for an optimized arc tube design and manufacturing process, making chemistry and fill pressure changes possible.

This technology improves the overall performance of metal halide. Lumen output per watt consumed can increase by 25% or more, depending on lamp wattage and burning cycle. Lumen maintenance is improved as much as 15%. Lamp life is extended, warm-up time is reduced to two minutes, and there is some improvement in color rendition.



Comparison to Fluorescent Lighting

Fluorescent lamps are based on the same electric discharge fundamentals, but the actual production of light is different. An invisible electric arc is established by the ballast between two electrodes on each end of the lamp which is filled with an inert gas and a tiny drop of mercury. The arc turns the liquid mercury into a vapor and the electrical current bombards the mercury atoms producing ultraviolet radiation. Whereas with HID the light is emitted directly by the arc stream, fluorescent lamps produce light by the arc-generated UV waves impacting a coating of white phosphor on the inside wall of the lamp – resulting in a diffused white light good for general lighting.

The newer T8 (1" diameter) and T5 (5/8" diameter) fluorescent lamps have an efficacy of 85 to 100 lumens per watt, good color rendition, and rated life ranging from 12,000 to 20,000 hours. Fluorescent lamps start and restrike almost instantly and the newer lamps have very good lumen maintenance. A major drawback of traditional fluorescent lamps is their large size for the amount of light produced. Larger lamp and fixture surface areas also accumulate more dirt than compact light sources such as metal halide and result in greater light losses over time.

Temperature sensitivity is another drawback. T8 fluorescent lamps are designed to operate optimally at a lamp ambient temperature of 25°C (77°F). Their efficacy declines on either side of that temperature, making them unsuitable for most outdoor applications (due to cold weather) and ceiling-mounted industrial applications (where heat build-up is a possibility).

T5 fluorescent lamps and the higher intensity T5/HO lamps have a smaller diameter than T8s, have better lumen efficiency and maintenance, and are operated most efficiently with a lamp temperature ambient of 35°C. However, the usable temperature operating range is extremely narrow. T5/HO lamps come in higher wattages and for similar length lamps provide roughly double the lumens of a T8 lamp. T8, T5 and T5/HO lamps are all driven with electronic ballasts.

Low wattage (5 – 42W) compact fluorescent lamps, introduced in the 1980s and through the 1990s as an energy-efficient alternative to incandescent lamps, are much smaller than standard linear fluorescent lamps, and are available in various sizes and bases.

High wattage compact fluorescent lamps (57 watts and above) have been developed which break through the low ceiling barrier of traditional fluorescent lighting. For example, Philips' PL-H 120W compact fluorescent lamp has an output of up to 9,000 lumens with excellent lumen maintenance. These lamps, like the T5 and T5/HO, are specifically designed for use with high frequency electronic ballasts.

Comparison to Incandescent Lighting

Incandescent lamps produce light by a wire or filament that is directly heated by a flow of current. The electrical resistance of the filament regulates the amount of power used, and thus no ballast is required. This simple operation coupled with its warm color rendition and low cost makes it the common type lamp for residential lighting. Dimming is also accomplished with very simple controls. However, efficacy is extremely low at 15 to 25 lumens per watt, and the life of a typical incandescent lamp is rated at 750 hours, neither of which is compatible with commercial, industrial, or outdoor applications.

HID Lamp Starting

Mercury vapor and traditional metal halide lamps (175 – 1500W) include an internal starting electrode, or "probe" within the arc tube. The ballast starts the lamp as well as regulates the current flowing through it. When the lamp is "turned on", a small arc is established between the starting electrode and the near-by operating electrode. This arc, in turn, initiates the main arc between the two operating electrodes. As the lamp warms up, the starting arc extinguishes. The warm-up period typically takes 5-7 minutes. With metal halide lamps, a bi-metallic switch within the lamp switches the starting electrode out of the circuit.

High pressure sodium, low wattage metal halide (< 175W), and 175 – 1000W pulse start metal halide also use a ballast to regulate the current through the lamp, but include an ignitor (also called a "starter") to send a high-voltage pulse directly across the operating electrodes to start the lamp. There is no starting probe in the lamp. After the lamp ignites, the ignitor automatically shuts off. It restarts each time power is turned on or if the lamp were to cycle off while operating.

Low pressure sodium lamps do not use a starting probe or an ignitor but are started from a relatively high voltage. This voltage is delivered directly across the full length of the arc tube by the ballast to the lamp at turn on (up to 600V).

Ballasts

The Purpose of the Ballast

The ballast is the power supply for arc discharge lamps. Its purpose, whether for HID or fluorescent, is to provide the proper starting and operating voltage and current to initiate and sustain the arc discharge between the two electrodes of the lamp. Electric discharge lamps have a negative resistance characteristic which would cause them to draw excessive current leading to instant lamp destruction if operated directly from line voltage. The ballast is therefore utilized to limit this current to the correct level for proper operation of the lamp.

Ballasts play a critical role in not only the operation of HID lamps but also the lamp performance. Ballast technology has continually developed to improve performance and life of lamps. The remaining sections of this booklet provide a historical overview of conventional electromagnetic ballast technology, introduce the latest electronic technology for HID lighting, and illustrate applications as a guide for the reader.

Technical Characteristics of Ballasts

Ballasts differ from one another in three key areas: energy efficiency, how much distortion they cause in a power waveform, and how much light a lamp produces when using them. Primary technical characteristics by which ballasts are measured and compared include:

Ballast Factor (BF)

A measure of light output with the lamp operated by a commercial ballast as compared to the light output of a lamp operated by a laboratory standard reference ballast.

$$\text{Ballast Factor} = \frac{\text{Commercial Ballast Light Output}}{\text{Laboratory Reference Ballast Light Output}}$$

Measuring HID light output requires a complex and expensive piece of equipment called an integrating sphere. Fortunately, lamp power and light output are related to each other on or close to a 1:1 basis. Thus, a faster method is to simply measure and compare lamp power between the commercial ballast design and the laboratory reference ballast.

ANSI (American National Standards Institute) specifications call for lamp operating power for a commercial ballast to be within ±5% of the rated lamp power for metal halide and ±7.5% for high pressure sodium and mercury vapor.

Technical Characteristics of Ballasts *continued*

Power Factor (PF)

A measure of the in-phase relationship between the AC source voltage and current which determines the current drawn by a ballast. Power factor is defined as a ratio of total system power to the product of the voltage and current delivered to the system:

$$PF = \frac{\text{Total Power}}{\text{Input Voltage x Input Current}}$$

High power factor ballasts, resulting from the input current and voltage being in phase with each other, require about half the AC current than would be required by an equivalent or "normal" low power factor ballast. A high power factor ballast is defined as one in which the power factor is greater than 0.9 (or 90%). Normal power factor ballasts have power factors in the 0.5 (or 50%) range. Ballast with power factors in the range of .80 to .89 (80% to 89%) are referred to as power factor corrected.

Lamp Current Crest Factor (CF)

Crest factor is a measure of the distortion level of the waveform of the current supplied by the ballast to the lamp. CF is the ratio of peak lamp current to the Root Mean Square (RMS) or "average" lamp current. Lamp currents with a high crest factor can cause material to erode from the lamp electrodes, reducing lamp life. The theoretical minimum value for crest factors for a magnetic ballast is 1.4 (sine wave). Most magnetic ballasts have CFs ranging from 1.5 to 1.7. The ANSI allowable limit is 1.8, except for mercury vapor lamps at 2.0.

Total Harmonic Distortion (THD)

A measure (in percent) of the distortion of the alternating current (AC) waveform from the nominal sine wave caused by operating a device such as a ballast and lamp. Excessive harmonic distortion on power lines can cause overheating of neutral wires, panelboards, transformers and capacitors.

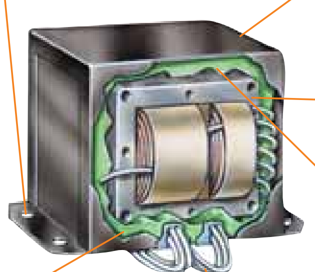
Typical magnetic ballasts have a THD in the range of 12-25%. Electronic ballasts, both HID and fluorescent, have THD values of 20% to less than 10%. With only minor exceptions, all of these values are considered very acceptable.

Magnetic Ballasts

Core & Coil

The electromagnetic, or “magnetic”, ballast is an inductor consisting of one, two, or three copper or aluminum coils assembled on a core (or “stack”) of electrical-grade steel laminations – commonly referred to as a core-and-coil ballast. This assembly transforms electrical power into a form appropriate to start and operate HID lamps. Ballasts for high pressure sodium and pulse start metal halide lamps also include an ignitor to start the lamp. The third major component is the capacitor, which improves the power factor, subsequently reducing current draw, and in some ballast circuits works with the core-and-coil to set the lamp operating wattage.

Typically, all three components – the basic open core-and-coil, capacitor, and ignitor – are assembled directly into the lighting fixture by the lighting luminaire manufacturer. However, some ballast core-and-coil assemblies are encased in a container to meet specific needs. A description of the various ballasts follows.

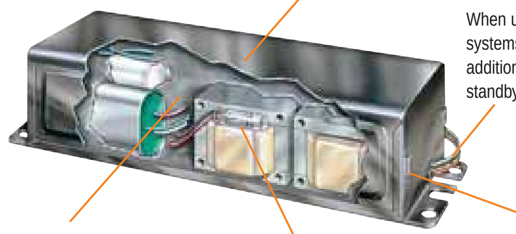


Encapsulated Core & Coil – The capacitor is mounted separately in the luminaire, as is the ignitor (where required). Applications include indoor installations such as offices, schools and retail stores, where ballast noise must be minimized. For a given application the fully-potted Core & Coil also runs about 10°C cooler than the open Core & Coil.

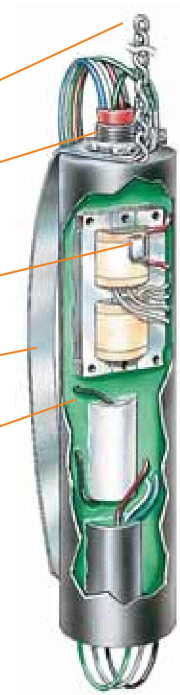
Indoor Enclosed – UL-Listed design for indoor use where the ballast must be mounted remotely from the luminaire, these ballasts are typically used in applications where the luminaire may be mounted where very high ambient temperatures may occur. The case contains the core-and-coil potted in heat-dissipating resin (Class H, 180°C max.) within the ballast compartment. The capacitor and ignitor (where used) are also included within the case.

Magnetic Ballasts *continued*

F-Can – Also UL-Listed for indoor use, primarily to minimize inherent ballast noise. F-Can ballasts are stand-alone products encased and potted in larger fluorescent ballast-style housings. F-Can ballasts utilize Class A (105°C rating, 90°C maximum case temperature) insulating materials for normal indoor ambients. Each ballast unit has an integral auto reset thermal protector, which disconnects the ballast from the power line in the event of overheating to protect the ballast and prevent the dripping of the asphalt fill. All ballasts include the capacitor within the housing. All models for high pressure sodium, and medium and low wattage pulse start metal halide ballasts also include the ignitor within the housing.



Outdoor Weatherproof – Ballasts are designed for remote mounting outdoors under all weather conditions. They may also be placed inside a pole base, but care must be taken to avoid areas prone to flood situations because weatherproof ballasts are not water-submersible. A Core & Coil, with capacitor and ignitor (where required) are firmly mounted to the heat-sink base. This assembly is then protected with an aluminum cover, gasketed and bolted to the base. The most common applications are billboard and road sign lighting.



Postline – Lantern-type fixtures mounted on slender poles often require ballasts which fit into the poles. Postline ballasts include a special, elongated Core & Coil encased and potted in high temperature resin (Class H, 180°C max.) in cylindrical housings of a diameter to accommodate being placed within 3” or 4” diameter poles. The capacitor and ignitor (where required) are included within the housing.

Line Voltages for HID Lighting

Today’s most widely used nominal input voltages for HID lighting systems in North America include 120, 208, 240, 277, 347 (Canada), and 480 volts, with 120 and 277 the most popular in the United States. Models are available which operate at only a single input voltage, but many are furnished as 120/277 dual-volt, 120/277/347 tri-volt, 120/208/240/277 QuadriVolt™, or 120/208/240/277/480 5-Tap™.

HID Magnetic Ballast Circuits

As stated previously, the ballast is the power supply for arc discharge lamps. If the input voltage to the ballast is not of the proper value for the lamp, the ballast must change or “transform” the voltage to the needed value. Secondly, the ballast must control the current to the lamp to the proper level. To accomplish these functions, the ballast employs one, two or three coils assembled on a “core” made up of electrical-grade steel laminations. The core-and-coil can act alone as a ballast or in concert with a capacitor. The various designs of the core-and-coil, and its arrangement with the capacitor, are called electrical ballast circuits. These circuits also include the addition of a third component – an ignitor or starter – that provides an additional “voltage spike” to aid in starting high pressure sodium and many of the metal halide lamps. A description of the various HID ballast circuits follows.

Reactor (R) – A single coil ballast can be used when the input voltage to a fixture meets the starting and operating voltage requirements of an HID lamp. In this situation, the reactor ballast performs only the current-limiting functions since the voltage necessary to initiate the ignitor pulses, and start and sustain the lamp comes directly from the input voltage to the fixture.

The reactor ballast is electrically in series with the lamp. There is no capacitor involved with the operation of the lamp. Because of that, the lamp current crest factor is desirably low, in the 1.4 to 1.5 range.

Without a capacitor, the reactor ballasts are inherently normal power factor devices (50%). Where necessary, to reduce the current draw during lamp operation, a capacitor may be utilized across the input line to provide high power factor (90%) operation, but the addition of the capacitor will not affect how the ballast operates the lamp.

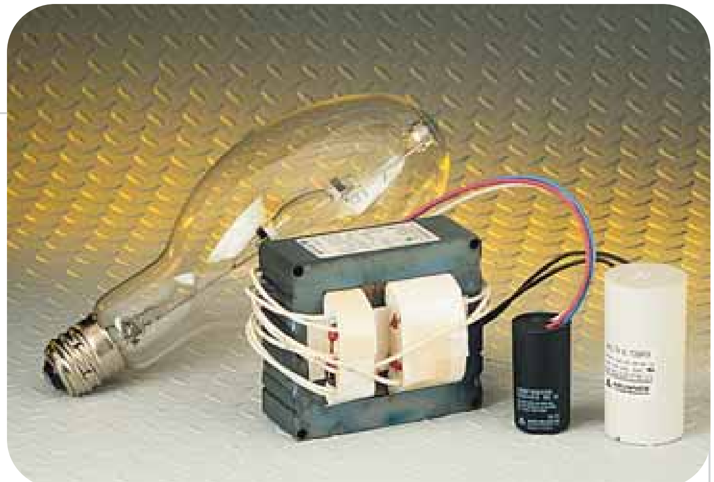
Reactor ballasts limit the number of fixtures that can be used on a circuit because they draw substantially more current during lamp starting (warm-up) and/or open-circuit operation (burned-out or missing lamp), than when the lamp is operating normally.

High Reactance Autotransformer (HX) – When the input voltage does not meet the starting and operating voltage requirements of the HID lamp, a high reactance autotransformer ballast can be used. In addition to limiting the current to the lamp, the ballast transforms the input voltage to the lamp's required level. Two coils, called the primary and secondary, are employed within the core. The operating characteristics are similar to the reactor.

The high reactance autotransformer ballast is also inherently a normal power factor (50%) ballast but can be corrected to a high power factor (90%) with the addition of a capacitor across the primary coil. As with the reactor ballast, the addition of this capacitor does not affect the lamp's operation.

One weakness of both reactor and high reactance ballasts is their inability to regulate lamp wattage as the line voltage delivered to the fixture or ballast varies. For example, a simple 5% change in line voltage results in a 10-12% change in lamp operating wattage.

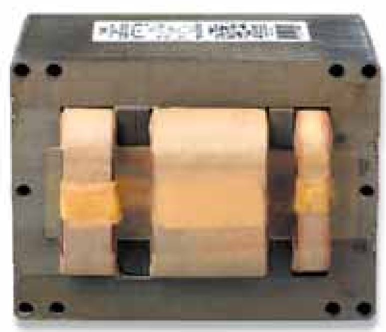
Magnetic Ballasts *continued*



Constant Wattage Autotransformer (CWA), also referred to as a "Peak Lead Autotransformer" – To correct the high current draw associated with reactor and high reactance ballasts, and to provide a greater level of lamp wattage regulation, the 2-coil CWA ballast was developed. It is the most commonly used ballast circuit for medium and high wattage (175 – 2000W) applications and typically represents the best compromise between cost and performance. The CWA is a high power factor ballast utilizing a capacitor in series with the lamp rather than across the input. The capacitor works with the core-and-coil to set and regulate the lamp current to the prescribed level.

The CWA ballast provides for greatly improved lamp wattage regulation over reactor and high reactance circuits. A ± 10% line voltage variation will result in a ± 10% change in lamp wattage for metal halide. The metal halide and high pressure sodium ballasts also incorporate wave shaping of the open circuit voltage to provide a higher peak voltage than a normal sine wave. This peak voltage (along with the ignitor when used) is used to start the lamp and control the lamp current crest factor (typically 1.60 -1.65).

With the CWA ballast, input current during lamp starting or open circuit conditions does not exceed the input current when the lamp is stabilized. CWA ballasts are engineered to tolerate 25-30% drops in line voltage before the lamp extinguishes (lamp dropout), thus reducing accidental lamp outages.



Constant Wattage Isolated (CWI) – The CWI ballast is a two-coil ballast similar to the CWA ballast except that it's secondary coil is electrically isolated from the primary coil. This isolated design prevents the socket screw shell from being energized on phase-to-phase input voltages such as 208, 240 and 480 volt inputs. The use of the CWI ballast for these voltages is a CSA safety requirement in Canada.

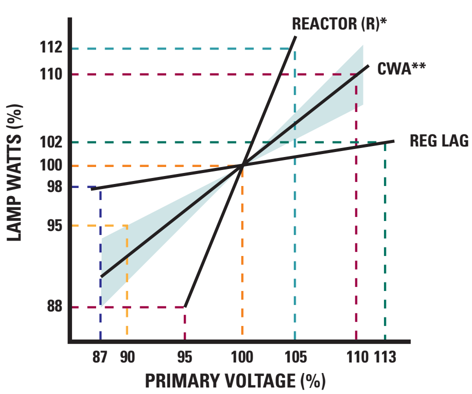
Regulated Lag (REG-LAG), also referred to as "Magnetic Regulator" or "MAG-REG" – This three-coil ballast circuit consists of a reactor ballast with a two-coil voltage regulator circuit all assembled on one core. The primary coil works with the tertiary coil and its capacitor to regulate the current through the reactor ballast and hence the lamp. Because a reactor is driving the lamp, the lamp current crest factor is typically 1.5, equal to that of single-coil reactor ballasts.

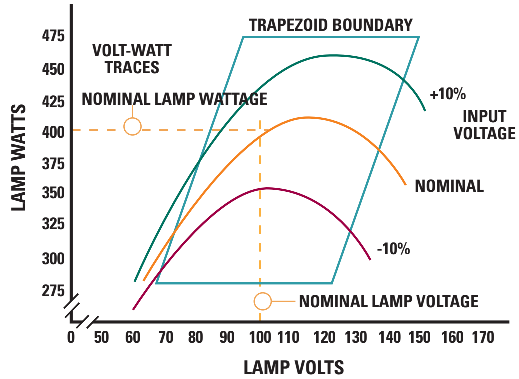
The reactor portion of the ballast is essentially isolated from line voltage variations and deviations from nominal. As a result, this circuit provides the best lamp wattage regulation (a ± 10% change in input voltage yields only a ± 4% change in lamp wattage) but carries an increase in ballast size, ballast losses and price.

Circuitry – Lamp Wattage Regulation Characteristics

One of the most important characteristics of each particular ballast circuit is the degree to which it controls the lamp wattage – and subsequently the light output when the input line voltage changes. The following chart compares the relationship of the three basic circuits as the input volts are changed. For example, the CWA line indicates that at 90% of line voltage, the ballast will operate the lamp at 90% of its nominal wattage. Similarly, at 110% of line voltage, the ballast will operate the lamp at 110% of nominal wattage.

The voltage of a typical mercury or metal halide lamp remains relatively constant throughout its operational life – for this reason, the lamp wattage regulation of these ballasts can be defined as a simple± percent. High pressure sodium lamps, however, see significant arc tube voltage increases during their operational life; therefore, the high pressure sodium lamp ballast must compensate for this changing lamp voltage (even with stable input voltages) to maintain constant lamp wattage. Consequently, a simple ± percent is not an adequate definition for high pressure sodium lamp regulation. Instead, a trapezoid, established by the American National Standards Institute (ANSI), is defined, which restricts the operation of the lamp to certain acceptable limits with respect to lamp voltage and resulting lamp operating wattage. The ballast is designed to operate a high pressure sodium lamp throughout its life within this trapezoid for any input voltage within the rated input voltage range of the ballast. The resultant value of the lamp's actual operating wattage over the life of the lamp when shown on a graph follows a rising-then-falling path called a volt-watt traces.





Pulse Start Metal Halide Ballasts

Pulse start metal halide ballasts meet the specific needs of pulse start lamps, they are not simply probe start metal halide ballasts with an added ignitor. Replacing the internal lamp-starting probe with an ignitor allows a separation of ballast starting and operating functions. The ignitor starts the lamp, then the ballast core-and-coil operates the lamp, allowing for optimization of both lamp and ballast performance.

The traditional CWA metal halide ballast, with its 600V peak open circuit voltage needed to start probe start metal halide lamps, creates a relatively high lamp current crest factor that compromises lamp performance. Focusing the ballast design solely on lamp operation lowers the lamp current crest factor – resulting in improved lamp life, lumen maintenance and color stability. Isolating lamp starting and operating functions also results in more efficient and cooler ballast operation, as the core-and-coil no longer needs to supply the 600V starting voltage. This lower open circuit voltage creates lower ballast losses, operates at lower temperatures, yields longer ballast life, and reduces maintenance and replacement costs, and the possibility of higher fixture ambient temperature ratings.

Optimized pulse start ballast and lamp systems boost maintained lumen output by roughly 15% as compared to probe start equivalents. Improving the quality and quantity of white light throughout lamp life provides energy savings, since lower wattage pulse start lamps produce the same light output as higher wattage probe start lamps. By achieving lumen maintenance of 75% versus 65% or less for probe start, pulse start lamps reduce light loss over life on the order of 20% compared to probe start metal halide. Fewer watts per square foot are required because consistently higher light levels are assured throughout lamp life.

Advance offers ballasts in Super Constant Wattage Autotransformer (SuperCWA), Linear Reactor and Regulated Lag circuits. SuperCWA ballasts, the pulse start version of CWA ballasts, are available in 150 to 1000W. Linear Reactor ballasts, for 277V applications, are available in 150 to 450W. Regulated Lag ballasts are offered in 175 to 450W for applications with long burning hours and/or heavy industrial applications with large power fluctuations to maximize lamp life, maintain lamps at their rated wattage, and minimize lamp dropouts due to voltage dips.

Electronic Ballasts

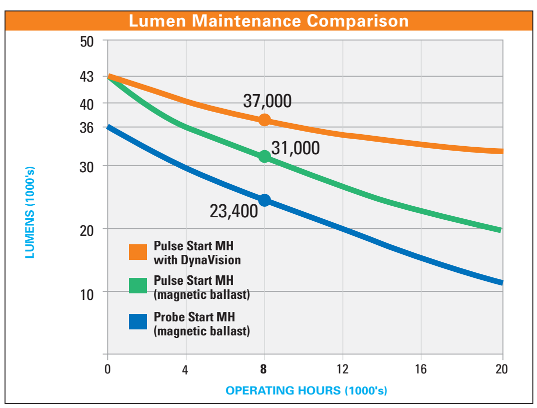
Why Consider Electronic HID Ballasts?

Just as electronic ballast technology enhanced fluorescent lighting systems, electronic HID ballasts bring significant performance improvements to metal halide lighting systems:

- *Higher efficiency*
- *Greater lumen maintenance*
- *Longer lamp life*
- *Enhanced color control*

Operational improvements are gained as greater efficiency and cooler running electronic ballasts lead to measurable energy savings. In addition, ballasts run quieter, weigh less, and have more compact footprints.

Improved lumen maintenance – the lamp and ballast system's ability to minimize light output depreciation over the life of the lamp – is the most fundamental and significant benefit of electronic HID ballasts, especially medium wattage (250 – 400W), high frequency ballasts such as Advance's DynaVision® ballast. At 8,000 hours of lamp life, DynaVision delivers a 30-50% improvement in lumen maintenance over conventional HID systems (magnetic ballasts driving probe start metal halide lamps) and a 20% or more improvement over pulse start systems. Conventional HID systems typically experience a 50-60% fall-off in light output over the published life of the lamp.



With more maintained lumens the overall fixture count can be significantly reduced. For example, repeated industry-standard lamp life tests show that a 400W electronic HID system produces at least 55% more mean lumens over a 400W probe start system with magnetic ballasts. Taking advantage of this performance benefit, the fixture count can be reduced by approximately 35% without sacrificing light levels. Fewer fixtures reduce installation costs and lead to dramatically lower operating costs in terms of both energy savings and maintenance. By maintaining higher light levels across the entire published life of the lamp, electronic HID ballasts also reduce the need for frequent re-lamping.

Dimming (to 50% lamp power) with lighting controls such as photocells, occupancy sensors, building management systems (BMS) and, in the future, digital addressable lighting interface (DALI) systems are also possible with Advance's DynaVision (medium wattage: 320W, 350W, 400W) and e-Vision® (low wattage: 20 – 200W) electronic HID ballasts.

Some ballasts also incorporate microprocessor-based technology, providing even more comprehensive lamp and ballast parameter control and a solid platform for future development of both lamp and ballast.

Lamp manufacturers recommend low frequency electronic ballasts to drive the new generation of ceramic metal halide lamps. These ceramic lamps have superior color rendition and can potentially maintain that consistent color over the full lamp life. However, as color is a function of lamp wattage, the ballast must be able to maintain lamp wattage precisely at its rated point throughout the entire life of the lamp. Low frequency electronic HID ballasts, such as Advance's e-Vision line, constantly measure and adjust the lamp current to keep the lamp operating at its rated wattage, optimizing delivery of the ceramic lamp's superior color properties. This makes metal halide a viable energy-saving and longer-life choice for many applications previously lit by either tungsten halogen or incandescent sources, such as retail display lighting. The sharp, crisp light from metal halide because of near point-source arc tubes also compares favorably against fluorescent lamps where the light is spread out over the length of the fluorescent tube.

Electronic Ballasts for Fluorescent Lighting

In the 1980s, ballasts were introduced for fluorescent lamps using solid-state electronic components in place of the traditional core-and-coil transformer, greatly improving the efficiency of lighting systems. Electronic ballasts are able to shape the input voltage waveform to fit the needs of the lamp. They also operate the lamps at higher frequencies, as opposed to magnetic ballasts which operate lamps at 60Hz (in North America), the same frequency as the input. Raising the frequency at which power is applied to fluorescent lamps allows both the lamps and ballasts to operate more efficiently. Lumen efficiency is increased, and ballast loss is reduced. Operating frequencies for fluorescent lighting are in the range of 20-90 kHz, but most newer ballasts are in the 45-60 kHz range to avoid interference issues with other electronic equipment.

Electronic Ballasts for HID Lighting

Electronic ballasts for HID lighting were introduced in the late 1990s, bringing a number of improvements over magnetic HID ballasts. Because metal halide is the most prevalent HID light source used in the industrial and commercial market, the majority of electronic HID (e-HID) ballasts in today's market are designed for metal halide lamps, though e-HID ballasts are available for select high pressure sodium wattages. The discussion in this guide, however, will focus on the predominant metal halide e-HID ballasts.

While magnetic ballasts operate and deliver power to the lamps at the input voltage frequency of 60 Hz, the standard alternating current/voltage in North America, electronic HID ballasts convert the 60 Hz input to operate the lamps at higher frequencies. This results in significant improvements in the system.

The Merits of Electronic HID Ballasts

Electronic HID ballasts address and significantly improve the entire ballast and lamp system with respect to:

- *Lumen maintenance*
- *Lamp life*
- *Lamp and ballast efficiency*
- *Lamp color quality and control*

Resulting benefits include:

- *Fewer or lower wattage fixtures*
- *Better quality of light in that nearly-level, white light is provided over the life of the lamps*
- *Lower operating costs with respect to energy and lamp replacement*

In addition, the ballasts provide much quieter operation due to solid-state components rather than core-and-coil assemblies, which can produce humming due to the vibration of the core's steel laminations.

Electronic HID ballasts also have compact footprints and are lighter weight, providing flexibility for fixture designers and retrofit applications.

Certain electronic HID ballasts include universal and/or multi-voltage input, multi-wattage capability, end-of-lamp life detection and shutdown, thermal protection shutoff and auto-reset, dimming and control interfacing, and other features.

Lamp Operating Frequency

Electronic HID ballasts function much like electronic fluorescent ballasts: electronic components shape the voltage and current wave-forms to best meet the needs of the lamp, operating the lamps at higher frequencies. However, due to certain characteristics of metal halide lamps, the operating frequencies are not in the same 20-90 kHz range used for fluorescent lamps. Because of the compact shape and size of the arc tubes used in metal halide lamps, these operating frequencies can create acoustic resonance – a phenomenon that can destroy lamps immediately. Instead, electronic HID ballasts operate at either very low frequencies (100-400 Hz) for low and higher wattage lamps or very high frequencies (100-130 kHz) for the higher wattage lamps.

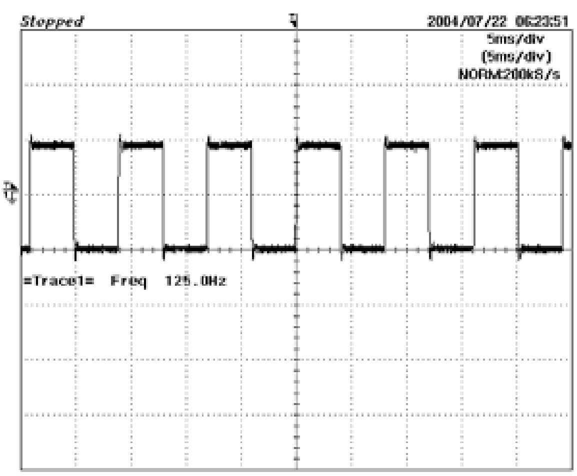
Acoustic Resonance

Much like a wine glass can "sing" if carefully rubbed with a moistened finger, the electric arc within the arc tube can change from its straight, stable profile to an oscillating sine wave if operated within certain frequency ranges. This phenomenon is known as acoustic resonance. Because the arc is no longer centered within the diameter of the arc tube, the arc tube wall will overheat where the arc is closer. This overheating can typically destroy the arc tube, often in short order.

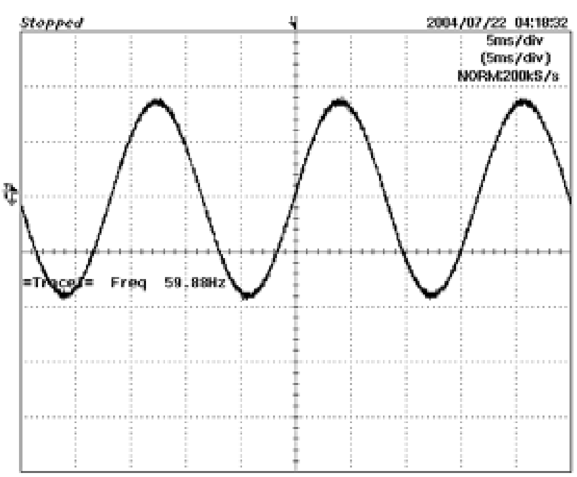
Electronic Ballasts for Low Wattage Metal Halide Lamps

Low Frequency Electronic HID Ballasts for Low Wattage Lamps

As the geometry of the arc tube gets smaller, the high-frequency level required to avoid acoustic resonance increases. A 70W metal halide lamp, for example, could require an operating frequency of 500 kHz or more to avoid acoustic resource. Such frequencies can essentially create a broadcast transmitter, leading to electromagnetic interference (EMI), radio frequency interference (RFI), and FCC issues. Popular low wattage (20 to 150W) metal halide lamps have very small, cylindrical ceramic arc tubes. Consequently, to avoid acoustic resonance, low wattage HID lamps are operated on very low frequencies in the range of 100-400 Hz. Most e-HID ballasts in the low wattage range operate the lamps with a low frequency square wave current waveform. The square wave allows for the lamp current crest factor to approach 1.0, something not possible with magnetic ballasts.



Low frequency square wave crest factor approaches 1.0



Sine wave crest factor = 1.4

Lamp Rectification for Ceramic Lamps

Low wattage ceramic lamps are subject to a possible, but very infrequent phenomenon associated with lamp end-of-life called lamp rectification. As ceramic lamps age, the ceramic material of the arc tube erodes. Eventually the arc tube integrity is breached when a small hole is formed in the arc tube wall and the hot ionized gases within the arc tube leak out to within the outer bulb. Normally when this happens, the lamp simply goes out and needs to be replaced. However, under certain conditions, because power is still being applied to the lamp by the ballast, the arc can re-establish itself outside the arc tube. This creates the potential for physically destroying the lamp, cracking or breaking the outer glass envelope.

In addition, the current waveform of this external arc is highly asymmetrical, meaning there are direct current (DC) elements within the arc. Core-and-coil magnetic ballasts are alternating current (AC) devices and cannot control DC currents. As the DC components increase uninhibited, the excessive over-current destroys both the lamp and the ballast. While some magnetic ballasts incorporate thermal protection and other safeguards to address potential rectification, electronic ballasts are specifically designed to monitor for rectification indicators, such as erratic lamp voltage, and automatically shut down before there is any damage to the lamp or ballast.

Electronic Ballasts Recommended for Ceramic Lamps

Electronic ballasts are unarguably the best choice for driving ceramic low wattage metal halide lamps because of their optimal maintenance of the ceramic lamps' superior color properties. Ceramic arc tube lamps have high color rendering indices (CRIs) typically over 90, efficacies of 90 or more lumens per watt, and color stability within ±200°K over life.

Color temperature is a function of lamp arc tube operating temperature. As lamps age, the intrinsic voltage of the lamp arc tube changes. In turn, with magnetic ballasts, the actual lamp operating wattage changes, causing the arc tube temperature to change and result in shifts of the color temperature and CRI. Electronic ballasts constantly measure the lamp wattage and via feedback are able to maintain lamp wattage precisely at its rating (e.g. 70 watts) throughout the entire life of the lamp.

Electronic ballasts also keep the arc lamp precisely at wattage over very large swings or deviations of the incoming line voltage from nominal. Keeping the arc lamp right at its rated wattage regardless of the shifts in lamp voltage or line voltage ensures that the arc tube is always operating at its design temperature and subsequently, the high color performance of the lamp is maintained over the life of the lamp.

For these reasons, lamp manufacturers recommend electronic ballasts for ceramic metal halide lamps.

e-Vision®: The Advance Ballast for Low Wattage Metal Halide

The Advance e-Vision electronic ballasts are designed for the operation of low wattage metal halide lamps: 20, 39, 50, 70, 100, 150,175 and 200 watt pulse start. The electronic design provides benefits in quality and efficiency of system operation, with input watt savings of approximately 20% on 39-watt systems and 10% on 100-watt systems.

e-Vision ballasts also provide true constant lamp wattage regulation compared to magnetic ballasts, optimizing lamp color stability over life and reducing lamp-to-lamp color variations.

e-Vision electronic ballasts are inherently smaller and lighter than equivalent magnetic ballasts typically used in HID applications. This provides fixture designers with increased flexibility in designing lower-profile fixtures and allows simple retrofitting into existing fixtures. Further flexibility in fixture design is provided by the metal enclosure used for e-Vision, transferring heat away from sensitive internal components and thereby permitting use in higher in-fixture ambient temperatures.

Ballast Protection Schemes

e-Vision ballasts incorporate a multi-faceted ballast protection scheme:

Automatic lamp power control

- *Prevents under- and over-driven lamps and resulting thermal stress during high-line and low-line conditions and as the lamp ages.*

Automatic lamp monitoring

- *Shuts system down if the lamp fails to ignite or the lamp voltage is low or erratic.*

Power control fault monitor

- *Shuts system down if power control within the ballast is lost.*

Output short-circuit protection

- *Protects the ballast if lamp leads are shorted together.*

Internal fusing

- *Shuts system down in the event of an unexpected internal ballast failure.*

Auto-reset thermal protection

- *Shuts system down if high thermal conditions are encountered. If temperatures return to normal, the ballast resets itself and restarts the lamp. If conditions are still too hot as the ballast and lamp warm up, the system will shut down again. This cycling will repeat until the excessive thermal condition is eliminated.*

Voltage Flexibility

Versatility is provided by Advance's IntelliVolt® technology.
The e-Vision ballast can operate with any nominal input voltage from 120 through 277V, 50 or 60Hz, and does not require separate taps or leads.

Ballast-to-Lamp Distance

Using typical wiring methods and materials, the maximum e-Vision ballast-to-lamp distance is 5 feet. Longer distances are possible if special consideration is given to using lower capacitance wire between the lamp and ballast.

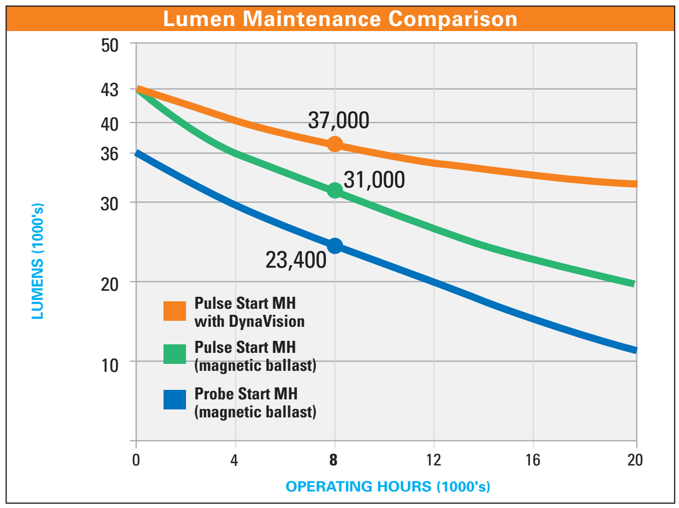
Electronic Ballasts for Medium Wattage Metal Halide Lamps

High Frequency Electronic HID Ballasts for Medium Wattage Lamps

Just as electronic ballasts for low wattage ceramic lamps provide critical lamp parameter control, electronic ballasts for medium wattage lamps (250 to 400W) serve a similarly critical function. Metal halide lamps are made with either quartz or ceramic arc tubes, with ceramic arc tubes, the newer technology, providing significantly better color performance.

With low wattage lamps, regardless of the arc tube material, the e-HID lamp operating frequencies are low, in the 100 to 400 Hz range, to avoid acoustic resonance as well as EMI and RFI issues. With medium wattage lamps, having their larger arc tubes, it is possible to operate lamps at higher frequencies (100-200 kHz) without acoustic resonance and remain well below the threshold of EMI and RFI frequencies (~ 500 kHz and above).

For quartz arc tubes, operating at these higher frequencies brings significant advantages with respect to lamp performance and ballast design. However, for ceramic arc tubes, it was found that there were still arc stability issues, and thus the low frequency square wave was still the best operating scenario for these lamps.



DynaVision®
The Advance Ballast for Medium Wattage Metal Halide

The Advance DynaVision electronic ballast, designed for the operation of 320, 350 and 400W quartz arc tube, pulse start metal halide lamps, provides dramatic lumen maintenance improvement. Conventional HID systems (magnetic ballasts driving probe start metal halide lamps) typically experience a 50% to 60% fall-off in light output over the published 20,000 hr. life of the lamp. This leads to higher fixture counts and resultant higher energy costs and excessive maintenance costs associated with frequent re-lamping all to compensate for the excessive lumen deprecation. Comparatively, Advance's DynaVision high frequency electronic ballast delivers 56-58% more lumens at the 8,000-hour mean design point over magnetic probe start ballasts, and a 19% gain over magnetic pulse start performance.

The lumen maintenance improvement is due in part to a significant lessening of electrode erosion and resultant arc tube blackening.

Design options for HID applications are broadened with the use of DynaVision electronic ballasts. Fewer fixtures can be utilized to achieve desired light levels.

Alternatively, for light distribution uniformity, the same or lesser fixture count as conventional systems can be used, but the fixture can be equipped with lower wattage lamps. For example, 320-watt pulse start lamps operating on DynaVision ballasts can be used instead of conventional 400-watt probe start lamps operating on magnetic ballasts.

With conventional probe start systems, light output from 0-8,000 hours starts out significantly above the mean value – as a result, the user pays for unnecessary lumens. Further, the light output decline after 8,000 hours may result in unsatisfactory light levels.

With DynaVision, after a small initial lumen drop-off, the lamp lumen maintenance curve is almost level. Light levels are maintained over the life of the lamp, resulting in fewer fixtures and longer times between lamp changes.

Case History: 10-Year Overall Cost of Ownership = 36% Reduction

Consider an example of lighting a new 300 ft. x 300 ft. retail space with a 24 ft. ceiling to a minimum illumination level of 100 foot-candles at a work-plane height of 30 inches. Never has a new technology had the potential to contribute so significantly to the bottomline. Even with DynaVision's higher initial cost, the savings over a 10-year operating cycle can be as high as 36%, as the following model illustrates:

	400W Probe Start Magnetic CWA	400W Pulse Start Magnetic SCWA	400W Pulse Start Electronic DynaVision®
Mean Lumens per Lamp	23,400	31,000	37,000
Input Watts per Fixture	458	452	425
Number of Fixtures Required	462	352	295
Fixture Cost, each	$150	$175	$275
Lamp Cost, each	$15	$25	$25
Fixture Cost, total	$69,300	$61,600	$81,125
Lamp Cost, total	$6,930	$8,800	$7,375
Installation Labor	$23,100	$17,600	$14,750
Installation Materials	$138,600	$105,600	$88,500
Total Installed Cost	**$237,930**	**$193,600**	**$191,750**
Savings	———	18.6%	19.4%
Annual Energy Costs (@ $0.10/KWH)	**$105,798**	**$79,552**	**$62,688**
Savings	———	25%	41%
10 Year Lamp Replacements and Cleanings	**$46,200**	**$44,000**	**$36,875**
Savings	———	5%	20%
10 Year Cost of Ownership	**$1,342,110**	**$1,033,120**	**$855,500**
Savings	———	23%	36%
Savings vs. 400W Probe Start	———	$308,990	$486,610

DynaVision ballasts are UL-listed and have an ambient temperature rating of 55°C max, providing a high degree of application flexibility.

Installation Versatility

Installation versatility is provided on two levels:

Tri-wattage operation. One ballast operates three different lamp wattages: 320W, 350W, or 400W.

IntelliVolt® technology. The DynaVision ballast can operate with any nominal input voltage from 200 through 277V, 50 or 60Hz, and does not require separate taps or leads.

DynaVision ballasts also include an integral 120V/250W power output with integral relay for operating a quartz auxiliary lamp. The relay keeps the quartz lamp on until the HID lamp relights and reaches 50% power. The quartz lamp is connected directly to this output and no other control device is necessary.

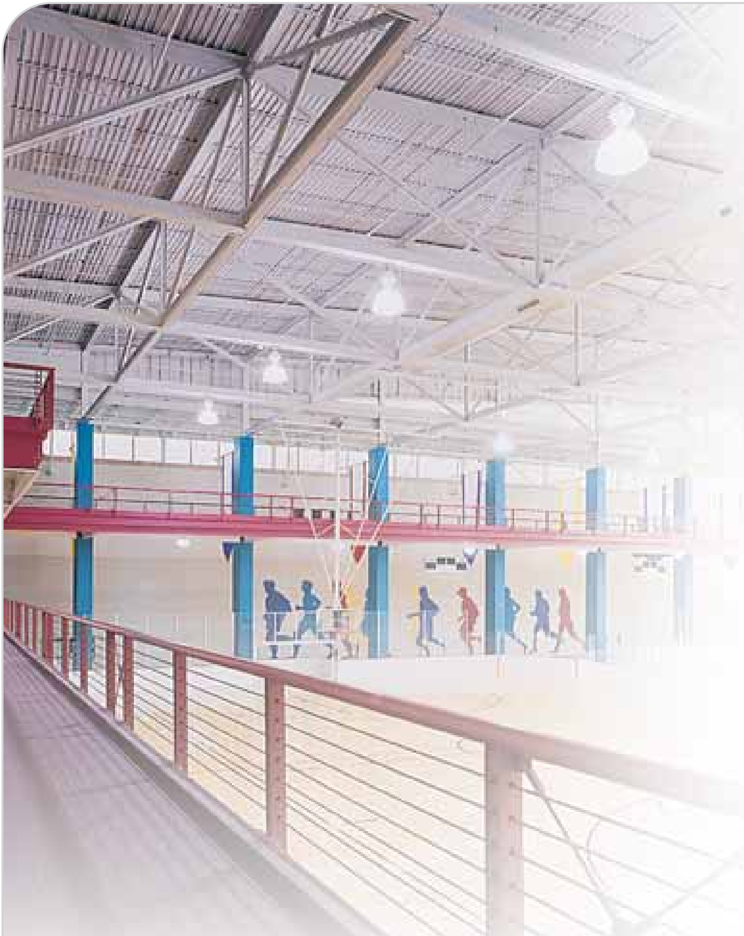
Ballast-to-Lamp Distance

Remote DynaVision ballast-to-lamp mounting distance is 15 feet maximum.

Ballast Protection Schemes

DynaVision ballasts incorporate a multi-faceted ballast protection scheme:

- ***Automatic lamp power control***
  Prevents under- and over-driven lamps and resulting thermal stress during high-line and low-line conditions. In very low-line conditions (greater than -10%), the HID lamp is dimmed to prevent ballast damage.
- ***Automatic lamp monitoring***
  Shuts system down if the lamp fails to ignite or the lamp voltage is low or erratic.
- ***Power control fault monitor***
  Shuts system down if power control within the ballast is lost.
- ***Output short-circuit protection***
  Protects the ballast if lamp leads are shorted together.
- ***Internal fusing***
  Shuts system down in the event of an unexpected internal component failure.
- ***Active thermal protection***
  Dims the HID lamp if extreme thermal conditions are encountered in an attempt to cool itself down and if severe conditions persist, the system is shut down.



Precise Dimming Control, Daylight Harvesting and Occupancy Sensing

Dimming of high wattage metal halide lamps with DynaVision electronic ballasts is a much more viable and controlled application than dimming with traditional magnetic ballasts. With magnetic CWA ballasts, dimming is a rudimentary step-dimming process, where a relay connects or disconnects a secondary capacitor to achieve either 100% or 50% lamp power. With DynaVision's microprocessor control, 0-10V continuous dimming with a continuous array of lamp powers between 50% and 100% is achievable.

This sophistication can allow full advantage of daylight harvesting using any compatible 0-10V dimming control. Control devices such as relays and occupancy sensors may also be used. The microprocessor intelligence ensures the required 15-minute lamp warm-up at full power before the lamp is allowed to dim, regardless of the level of the 0-10V signal.

The dimming capability and precise control rendered by electronic HID ballasts form a basis for even further sophisticated lumen control. One example is load shedding if the ballasts are tied into the facility's energy management system. Another intriguing possibility under industry evaluation involves reducing the initial power to the lamp and slowly increasing it as the lamp ages and/or dirt accumulation on the lamp increases, maximizing lumen control and efficiency and essentially harvesting lumens for future use.

Microprocessor Technology

The microprocessor technology employed in the DynaVision ballast provides a state-of-the-art platform enabling precise control and optimum operation of the ballast/lamp system. Expanded dimming control is one deliverable achieved by microprocessor control, as detailed below. Additionally, microprocessor technology provides extremely straightforward integration into other controls such as building management systems.

Advance Reliability and Industry Leadership

Advance is the industry leader in the design, development, manufacture, and sale of fluorescent and HID ballasts and LED drivers for commercial, industrial and institutional lighting. Since the first Advance ballast was manufactured in 1945, Advance has built a reputation for excellence through its dedication to quality and R&D, its long-standing relationships with leading lamp and lighting system manufacturers, and its emphasis on customer satisfaction. Throughout its 60+ years of operation, Advance ballasts and drivers have provided the benefits of reliability, versatility, energy efficiency, and long service life in millions of lighting installations worldwide.

Advance is also a proactive participant and leading presence within a broad range of industry associations and governmental agencies that regulate performance and safety standards for lighting and other energy related products.

Glossary

Alternating Current – Current that passes from the generator first in one direction and then the other, alternatively. Commercial power is generated using alternating current: 60hertz (cycles/second) in North America and 50hertz in Europe, Asia and Africa. South America, the Middle East and Japan have a mix of both 50 and 60hz power, depending on the location.

Ampere – The unit of measurement of electrical current flow of either D.C. or A.C. in a circuit

ANSI – (American National Standards Institute) Non-profit organization that generates voluntary product performance standards for many U.S. industries. ANSI Standard C82.1 applies to electromagnetic ballasts, both HID and fluorescent

ANSI Codes – These are 3-letter codes assigned by the American National Standards Institute. They provide a system of assuring mechanical and electrical interchangeability among similarly coded lamps from various manufacturers.

Arc – Intense luminous discharge formed by the passage of electric current across a space between electrodes.

Arc Tube – The "vessel", either quartz or ceramic within an HID lamp, which surrounds the arc and holds the electrodes in place.

Autotransformer Ballast – A type of ballast circuit that includes a transformer to change the input voltage up or down to meet the voltage requirements of the lamp. The output windings of the transformer, called the secondary, share a portion of the primary winding.

Ballast – Device, power supply, for starting and regulating (operating) HID and fluorescent lamps.

Ballast Factor – Measure of light output from lamp operated by a commercial ballast as compared to a laboratory standard reference ballast. Ballast factor .94 means ballast produces 94% of light produced by ANSI C82.2 reference ballast operating same lamps.

Ballast Losses – Power that is used by a ballast in performing its function. This power is "lost" as it is not converted into lamp energy. Ballast losses are dissipated as heat.

Base, Lamp – That part of the lamp (light bulb) that fits into the lamp holder (socket).

Canadian Standards Association (CSA) – Association that generates product performance and safety standards for many Canadian industries.

Capacitor – A device consisting of two electrodes (metal or metalized surfaces) separated by a dielectric (insulator) to store electrical energy. Capacitors both "correct" the power factor of a ballast from normal to high, and in some ballast circuits work with the core-&-coil to set the operating wattage of the lamp. Capacitors today incorporate two interleaved layers of metalized poly film wound in a compact roll and then assembled into a plastic or metal housing. Depending on the capacitor's construction, the roll is left dry or immersed in oil as a finishing process.

Centigrade – Celsius temperature scale where 0°C = 32°F and 100°C – 212°F

Chromaticity – Chromaticity is a method of describing the "color" of a lamp's light output. It references the CIE standard chromaticity diagram and is expressed as "x" and "y" coordinates on the diagram. See also Color Temperature.

Circuit, Ballast – The design and electrical arrangement of the core-and-coil in combination with a capacitor (when it is used) to ballast an HID lamp. The five basic ballast circuits are: reactor (R), high reactance (HX), constant wattage autotransformer (CWA), constant wattage isolated (CWI), and regulated lag (reg lag, mag reg)

Coil – Windings of copper or aluminum wire surrounding the steel core in ballast that when powered create magnetic flux within the core, or, conversely, in the presence of magnetic flux, create power.

Color Rendering Index (CRI) – An international system used to rate a lamp's ability to render an object's color. The higher the CRI (0-100 scale), the truer colors are rendered. CRI differences among lamps are not usually significant (visible to the eye) unless the difference is more than three to five points.

Color Temperature – The term used to describe the "whiteness" of a lamp's light output. Color temperature is expressed in degrees Kelvin (°K) because it is related to the physical temperature of the filament in incandescent lamps. A higher temperature color (such as 4000°K and higher) describes a visually cooler, bluer source. A lower temperature (such as 3000°K and lower) describes a visually warmer, redder source. Typical color temperatures are 2800°K (incandescent), 4000°K (metal halide and cool white fluorescent), 5000°K (daylight), and 2300°K (high pressure sodium). See also Chromaticity.

Core – Component of electromagnetic ballast or transformer that is surrounded by the coil. Core is comprised of steel laminations or solid ferrite material.

Core and Coil Ballast – Another term for an electromagnetic ballast.

Crest Factor – Ratio of peak current or voltage to the RMS or "average" current or voltage of an AC waveform. The most common application of crest factor is in reference to the lamp operating current. For magnetic ballasts lamp current crest factor of 1.4 to 1.8 are typical. For electronic ballasts crest factors as low as 1.0 are theoretically possible.

Direct Current – Voltage available from a battery supplies a current that is constant with time when connected to a load.

Discharge Lamp – A lamp that utilizes an electric Arc (current discharge) between two electrodes to generate light (lumens). HID and fluorescent lamps are discharge lamps. An incandescent lamp is not a discharge lamp as it uses a metal filament heat by the electric current passing through it to generate light.

Efficacy (lamp, system) – Light output (lumens) per unit of power consumed (watts). Lamp efficacy is lamp light output divided by lamp power (lumens/watt). System efficacy (also lumens/watt) is lamp light output divided by the sum of the lamp power plus the ballast losses.

Efficiency (of a ballast) – The ratio (in watts) of the lamp operating power divided by the total power (lamp power plus ballast losses).

Electrode – Metal filaments that emit electrons in an HID or fluorescent lamp. Negatively charged free electrons emitted by one electrode are attracted to the positive electrode (anode), creating an electric current or arc between electrodes.

Electromagnetic Ballast – A ballast that uses a "Core & Coil" assembly to transform and control electrical current and voltage to start and operate HID and fluorescent lamps.

Electromagnetic Interference (EMI) – Electrical interference (noise) generated by electrical and electronic devices. Levels generated by high frequency electronic devices are subject to regulation by Federal Communications Commission (FCC).

Glossary

Energy – Energy is produced when a current flows from a source of voltage into a load. Energy is the product of voltage "V", current "A", and Power Factor.

Federal Communication Commission (FCC) – The U.S. federal agency that is charged with regulating electrical interference emissions of the electromagnetic spectrum. The regulation entitled, "Part 18" deals with electromagnetic interference (EMI) from all lighting devices operating at frequencies higher than 9 kilohertz (kHz). Electronically ballasted fluorescent lamps and some operate in the range of 24-200 kHz. Most electronically ballasted HID lamps operate at lower frequencies (100 to 400Hz) but may generate higher frequencies within their circuitry. These higher frequencies are also subject to Part 18 limitations.

Footcandles (fc) – Measure of light level on a surface being illuminated. Defined as one lumen of light per one square foot of surface area.

Frequency – Rate of alteration in an AC current. Expressed in cycles per second or Hertz (Hz).

Harmonic – An integral multiple of the fundamental frequency (60 Hz) that becomes a component of the current (see Harmonic Distortion).

Harmonic Distortion – Produced by a ballast or other device (computers, printers, fax machines, etc.), harmonic distortion is the distortion of an AC waveform from its original sine wave shape caused by line current components operating at multiples of the fundamental 60hz frequency (harmonics). The odd triplet harmonics (thirds [180hz], ninths [540hz], etc.) may result in large currents on the neutral wire in a 3-phase wye, 4-wire power system. Total harmonic distortion is the combined effect of all of the harmonic distortion expressed as a percentage. See Harmonic Distortion.

Hertz (Hz) – Unit used to measure frequency (cycles per second) of alternating of current or voltage.

High Intensity Discharge (HID) Lamp – A discharge lamp containing an arc tube in which the active elements within (mercury, sodium, etc.) becomes vaporized (a gaseous state) within the electric arc stream to produce light.

High Power Factor – A ballast where the Power Factor is corrected to 90% or greater by use of a capacitor.

High-Pressure Sodium (HPS) Lamp – The generic name for HID lamps that contain an amalgam (mix) of a high proportion of sodium along with mercury as the active elements within the arc tube. All HPS lamps require an electrical high-voltage pulse from an ignitor or “starter” (within the ballast circuit) to start the lamp. The efficacy performance of HPS lamps is excellent, in the rage of 90 to 125 lu/w. The lamp color is dominantly yellow, and the resultant CRI’s are in the low 20’s

Hot Restart Time – If the power to an operating HID lamp is turned off and then immediately turned on, the HID lamp does not re-light immediately like an incandescent lamp. The time it takes the lamp to restart and reach 90% of its light output after going from on-to-off-to-on is referred to as the Hot Restart (or Restrike) Time. Typical restart times are 1-2 minutes for HPS and 5-20 minutes for Metal Halide.

Ignitor (starter) – A device used within the ballast circuit to generate high-voltage electrical pulses needed to start high pressure sodium and some metal halide lamps

Input Voltage – The voltage from the incoming power line to the ballast or fixture.

Inputs Watts – The total power input to the ballast that includes lamp watts and ballast losses. The total power input to the fixture is the value to be used when calculating cost of energy and air conditioning loads.

Kilowatt Hour (kwh) – The standard measure of electrical energy and the typical billing unit used by electrical utilities for electricity. A 100-watt lamp operated for 10 hours consumes 1000 watt-hours (100w X 10hrs) or 1 kilowatt-hour of electrical power. If the utility charges $.10/kWhr, then the electricity cost for the 10 hours of operation would then be 10 cents (1kWhr X $.10/kWhr).

Laminations – Layers of steel, making up the ballast "core" that is surrounded by the coils in a core & coil ballast.

Lamp – The lighting industry term for lightbulb. It refers to the complete assembly including the internal parts as well as the outer bulb or tube and base(s).

Lamp Current – The current delivered to the lamp by the ballast to generate light.

Lamp Current Crest Factor – Ratio of peak lamp current to RMS or "average" lamp operating current. See "Crest Factor."

Lamp Watts – The power consumed by the lamp to generate light.

Light – Radiant energy that can be sensed or seen by the human eye. Visible light is measured in lumens.

[Average Rated] Life – The median time it takes for a lamp to burn out. For example, a typical incandescent lamp is expected, on average, to burn for 1,000 hours. Based upon continuous testing of lamps in laboratories, the 1,000-hour rating is that point when 50% of the test samples have burned out and 50% are still burning. Unless otherwise noted fluorescent (linear and compact) rated life assumes 3 hours average operating time per start. HID rated life assumes 10 hours average operating time per start.

Low Pressure Sodium (LPS) Lamp – The generic name for HID lamps that contain a small dose of sodium as the active element within the arc tube. Low pressure sodium lamps are in fact not “high intensity discharge” lamps like mercury or metal halide, as the sodium vapor pressure is quite low, similar to the mercury vapor pressure in a fluorescent lamp. With efficacies measured in the rage of 200 lu/w, low pressure sodium lamps have the highest efficacy of all the discharge lamps. However, they are a monochromtic light source as the light output is only yellow. No other colors are present within the spectrum. As a result there is no CRI value associated with these lamps.

Lumens/Watt [lpw], also Luminous Efficacy – The measure of the efficacy (efficiency) of a lamp. The amount of light (lumens) produced by each lamp watt. Efficacy is easily calculated by dividing the lumen output of a lamp and by the lamp watts. For example, a 400w-watt metal halide lamp producing 36,0000 initial lumens has an initial efficacy of 90 lumens per watt.

[Initial] Lumens – Initial light output of a new lamp. For HID lamps the initial lumen rating is based on the light output of the lamp after it has be seasoned (burned or "aged") for 100 hours.

[Mean] Lumens – Lamp light output (lumens) measured at 40% of rated lamp life for fluorescent, compact fluorescent and metal halide lamps and 50% of rated life for mercury and HPS lamps.

Lumen Maintenance – A measure of how well a lamp maintains its lamp output as it ages. Lumen maintenance can be displayed as a curve showing light output (lumens) as a function of time (lamp age), or as one number: the percent of initial lumens at the mean lumens point. See also Mean Lumens.

Luminaire – A complete lighting fixture consisting of a lamp (or lamps), ballast (or ballasts) as required together with the parts designed to distribute the light, position and protect the lamp, and connect them to the incoming power.

Mercury Vapor Lamp – The generic name for HID lamps that contain a small dose of mercury as the active element within the arc tube. Mercury vapor lamps were the earliest of the general-purpose HID lamps. Efficacies are in the range of 35-55 lu/w. Color rendition is poor with CRI's in the 45 to 50 range.

Metal Halide (MH) Lamp – The generic name for HID lamps that contain a mix of mercury and salts of one or more "halides", speciality metals such s sodium, scandium, dysprosium, cesium and others. The addition of the halides improves the lumen efficacy and color rendering over plain mercury vapor lamps. Efficacies are in the 60-100 lu/w range, and the color rendering index is typically 65. See Probe Start and Pulse Start MH.

National Electric Code (NEC) – A nationally accepted electrical installation code developed by the National Fire Protection Association to reduce the risk of fire.

NOM – Laboratory that sets safety standards for building materials, electrical appliances and other products for Mexico.

Non-PCB Capacitor – A capacitor that contains no polychlorinated biphenyls (PCBs) and meets EPA requirements.

Normal Power Factor – Ballasts with power factor less than 90% that do not incorporate capacitors to provide for power factor correction.

Open Circuit Voltage [OCV] – The voltage measured at the lamp socket (HID or CFL) or across the lamp holders (fluorescent) when the lamp is not present. The open circuit voltage is generated by the ballast and is needed to start a lamp when power is turned on.

Operating Position or Burn Position – The orientation of an HID lamp in a lighting fixture such as base up, base down, horizontal, or universal. The light output, operating life, and sometimes the safety of many HID lamps are affected by the burning position of the lamp. To maximize the performance of a particular lamp, it will often be designed and designated for a particular burning position. Mercury, high pressure sodium, and most low wattage metal halide lamps may be operated in any burning position and still maintain their rated performance specifications. These are called universal burning position lamps. Medium and high wattage metal halide and low pressure sodium lamps, however, are optimized for performance in specific burn positions.

PCB (oil) – Polychlorinated Biphenyl oil. The type of oil formerly used in ballast capacitors and indoor oil-filled transformers. While this oil was used because of its flammability temperature was high, the PCBs within the oil are a chemical pollutant and therefore were banned for use by the EPA in 1979.

Potting – Material used to completely surround and cover components of some magnetic and electronic ballasts. Potting compound fulfills functions of protecting components, dampening sound, and dissipating heat.

Power – The amount of energy consumed or needed by a device (ballast, lamp, or ballast plus lamp) to perform its function. Power is measured in watts. Power consumed over time is expressed as kilowatt-hours: thousands of watts consumed over time (hours).

Power Factor – The measurement of the in-phase relationship between the AC source voltage and current that determines the current drawn by the ballast. High power factor ballasts require less AC operating current operating at the same wattage than equivalent lower power factor ballast. Formula: Power Factor equals Input Watts (lamp plus ballast) divided by the product of Line Volts times Line Amps (Volt Amps or VA).

Probe Start Metal Halide – The generic name for Metal Halide lamps that utilize a small "probe" electrode within the arc tube to start the lamp, similar to that of mercury vapor lamps. Initially all of the metal halide lamps were "probe start", but this starting method proved inadequate for the newer, technically improved lamps that began to emerge in the mid-80s.

Pulse Start Metal Halide – The generic name for metal halide HID lamps that require an electrical high-voltage pulse from an ignitor or "starter" (within the ballast circuit) to start the lamp. Newer, improved metal halide lamps, with different chemistries and higher arc-tube fill pressures, required a high-voltage "pulse" from the ignitor to establish the arc, hence the name "pulse-start". Efficacies were measurably improved over "standard" probe start metal halide lamps. Typical values are in the range of 80-100 lu/w. The color rendering index of 65 is similar to probe start MH.

Regulation, lamp wattage – The measure of the ability of a ballast or ballast circuit type to control (regulate) a lamp's operating wattage as the input voltage varies from nominal. Regulation is expressed in percent as % : %, and is the ratio of the percent change in line voltage (input voltage) and the resultant percent change in lamp wattage. The ability to regulate lamp wattage as the line voltage varies from nominal varies from circuit type to circuit type. Reactor and high reactance circuits have a regulation ratio of 5% : 12% or 5:12, meaning that a 5% change in line voltage results in a 12% change in lamp wattage. CWA and CWI circuits have a regulation ratio of 10:10. RegLag circuits have a regulation ratio of 10:4. See also Circuit, Ballast.

Total Harmonic Distortion (THD) – The combined effect of all of the harmonic distortion on the AC waveform produced by a ballast or other device expressed as a percentage. Excessive levels of THD can create large currents on the neutral line of a 3-phase wye 4-wire power system. See Harmonic Distortion.

Transients – High voltage and resultant high current surges through an electrical system caused by lightning strikes to nearby transformers, overhead lines or the ground. May also be caused by switching of large motors or other electrical loads, as well as by short circuits or utility system switching. Can lead to premature failure of ballasts or other electrical devices.

Underwriters' Laboratories (UL) – A not-for-profit organization in the US that generates product performance and safety standards for electrical equipment, building materials, and other products. End-use products such as lighting fixtures, fully encased ballasts, and home appliances are examples of UL Listed products and bear the UL logo. Components such as HID open core-&-coil ballasts, electrical insulating materials are UL Component Recognized products and bear the UL Component Recognition logo. Can we add these actual logos? Ditto CSA & NOM

Voltage – A measurement of the electromotive force (electrical pressure) in an electrical circuit or device expressed in volts. Voltage can be thought of as being analogous to the pressure in waterline.

Watt – The unit of measurement of electrical power. Electrical power is the product of the voltage to a device: ballast, lamp, lighting fixture, etc., times the current through that device, times the power factor of that device.

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