HIGH INTENSITY DISCHARGE (HID) LIGHTING

INTRODUCTION

Most lighting systems use incandescent or electric-discharge lamps. An incandescent lamp is a glass bulb containing a current-carrying filament in an inert gas. An electric-discharge lamp is a bulb or tube that contains two cathodes and a special gas or gas mixture through which an arc is maintained. Electric-discharge lamps include high intensity discharge (HID) lamps, fluorescent lamps and neon tubes. Fluorescent lighting is discussed in PRC.5.11.1.

Some HID lamps are shaped like ordinary incandescent light bulbs. Similarities end there. An HID lamp is a sealed, gas-filled arc tube surrounded by an outer glass envelope or bulb. The inner arc tube is constructed of quartz or a ceramic material and is designed to be durable under severe operating conditions. When the lamp circuit is energized, an arc forms between two coiled tungsten cathodes (one located at each end of the arc tube). The arc stream heats and pressurizes the gas, resulting in the emission of light.

The main types of HID lamps are metal halide lamps, mercury vapor lamps and high pressure sodium lamps. See Figure 1. Metal halide lamps are controversial because they are suspected of being the ignition source for several major fires. These lamps are frequently advertised by their trade names; the product literature sometimes avoids or limits use of the generic term, “metal halide.”

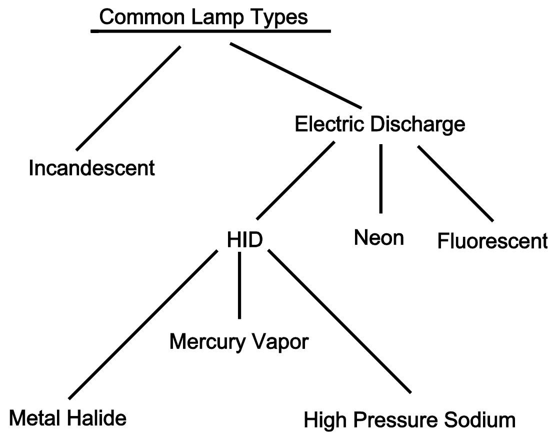

Figure 1. Common Lamp Types.

The gas in all three HID lamps, like the gas in a fluorescent tube, is mercury vapor. When the lamp is first lit, at low vapor pressures, much of the emitted energy is ultraviolet energy. Only a small amount of material is vaporized, so the lamp provides poor illumination. Continued operation of the lamp vaporizes more material, raises vapor temperature and pressure, and shifts much of the energy into the visible light range until the lamp shines at maximum brightness. This warm-up time can be several minutes (normally 4 min – 8 min). Once lit, upon a momentary loss of power, these lamps require sufficient time to cool down before restriking. The total lighting outage caused by a momentary power outage can be 5 min – 20 min.

Lamp efficiency and color rendering properties of mercury vapor lamps are unsuitable for many occupancies. When another metal, like metal halide or sodium, is added to the gas, lamp efficiency and color rendering characteristics improve. These added materials give the lamps their special names. Typical mercury vapor lamps produce a “white” light with a bluish tinge. Sodium lamps produce a red-orange-yellow light. Metal halide lamps, which produce a clean, white, “natural” light, are gaining in popularity and finding increasing usage in public buildings, businesses and industry.

Different operating characteristics can require different lamp and fixture constructions. As examples, ceramic arc tubes have replaced quartz arc tubes in high pressure sodium and certain metal halide lamps; and the typical metal halide HID fixture is constructed with barriers to contain hot lamp fragments in the event of an arc tube rupture.

The National Electrical Code (NEC) mandates rudimentary levels of protection and loss control for all electrical equipment. This guideline highlights and supplements selected NEC requirements as they apply to HID lighting fixtures. The purpose of this guide is to preserve property by reducing the frequency and limiting the spread of fires initiated by these fixtures.

POSITION

Do not use HID lighting systems where a lamp or fixture operating normally can contact, melt or ignite combustible materials. As an example, HID lighting may be acceptable in a display area if hanging or draped materials cannot accidentally contact the fixtures, and if fixture placement is such that fixed combustible materials will not be overheated.

Where HID lighting systems are desired, use only listed HID fixtures and comply with listing requirements. These requirements can include installation specifications for lamp orientation and fixture spacing. Lamp orientation specifications that limit lamp offset from the vertical position can be important to control lamp temperatures or pressures, or to maximize lamp life. Specifying spacing from building members, insulation and combustible materials might be necessary for proper heat dissipation and to prevent ignition of combustible materials.

If metal halide lamps are to be installed over an area where a fire can spread to cause a major property or business loss, comply with all of the following:

- **Fixtures**. Use only listed, metal halide HID fixtures with integral containment barriers. Barriers constructed of tempered or borosilicate glass are preferred.
- **Lamps**. Use lamps labeled as suitable for use in open fixtures. These lamps are reported by their manufacturers to contain a shrouded arc tube or a similar, double-containment feature to control shattering. It must be recognized, however, that manufacturers do not submit these lamps to listing agencies for verification of such claims.
- **Matching Lamps to Fixtures**. Use only lamps whose maximum operating temperatures are suitable for use with installed containment barriers and other fixture components. Additionally, comply with all lamp specifications provided by the fixture manufacturer.

NOTE: The double-safeguard approach (using lamps designed to prevent shattering, and using fixtures designed to prevent the escape of shattered lamp fragments) is recommended because metal halide lamps are not tested for listing by independent listing agencies; no test standard has been developed that can reliably predict lamp failure modes or avoid the causes of nonpassive failures; fires have reportedly been caused by lamp failures in both open fixtures and in fixtures with barriers; reliable control is needed over lamp replacements; future “designated” lamp availability for a listed fixture cannot be assured; and there are questions as to whether existing plastic and metal barriers provide reliable containment for today’s lamp temperatures.

Replace existing metal halide lamp fixtures if they are not designed to reliably contain hot, metal halide lamp fragments and if they are located over an area containing combustible materials and subject to a major fire loss. (As previously described, listed HID fixtures containing integral tempered or borosilicate glass containment barriers may be considered acceptable.) Alternately, modify existing fixtures by installing tempered or borosilicate glass containment barriers or enclosures. Consult the original fixture manufacturer when planning modifications. Use the manufacturer's listed components and retrofit kits, if available.

Properly maintain HID fixtures. For metal halide lamps placed in "continuous operation," make provisions for a weekly, 15 min, shutoff. Lamps shut off at least once per week and allowed to cool are reportedly less likely to rupture while operating.

Replace metal halide lamps at or before the end of rated life. To accomplish this in a cost effective manner, consider maintaining records of lamp operating hours and implementing group relamping and cleaning practices. Tracking individual lamp operating hours may be difficult and impractical. Group relamping before the end-of-life is a preferred cautionary measure.

- One recognized maintenance practice is to group relamp metal halide lamps when they have reached about 70% of their rated life; beyond that point, the probability of failure is especially high.
- Typically, rated life of an HID lamp is a prediction based on a 50% probability of failure for given service conditions. This probability is set by statistical analysis. Theoretically, if 100 metal halide lamps are kept in an energized circuit for the duration of their rated life of 12,000 h (500 days of continuous operation), 50 lamps will be found to have failed. If they failed by rupturing, then 50 opportunities for ignition of nearby combustibles occurred unless special precautions were taken to prevent this ignition.
- One manufacturer's lamp mortality curves show a **20% failure rate for lamps reaching 50% of rated life**. This means out of 100 metal halide lamps, 20 opportunities for ignition can occur by the time the lamps are half-way through their rated service life. While not all will fail violently, some might.
- No definitive failure-mode rates are published, however, one manufacturer suggests that **less than one violent rupture occurs in 100,000 failures**. Regardless, multiple incidents occur every year, and with increasing metal halide lamp use, the number and frequency of these incidents will grow.

Comply with section 410-73(f) of the NEC regarding the protection of HID fixtures:

> *Recessed high-intensity discharge fixtures shall be thermally protected and shall be so identified. Where fixtures, whether recessed or otherwise, are operated by remote ballasts, the ballasts shall also be thermally protected. Exception: Recessed high-intensity discharge fixtures identified for use and installed in poured concrete.*

Comply with section 410-54(a) of the NEC regarding electric-discharge lamp auxiliary equipment:

> *Auxiliary equipment for electric-discharge lamps shall be enclosed in noncombustible cases and treated as sources of heat*.

Comply with applicable environmental regulations when disposing of lamps containing mercury vapor, ballasts containing polychlorinated biphenyls (PCBs) and other materials considered hazardous to the environment. Where possible, use a waste handling organization licensed to recycle mercury, lead and other lamp wastes.

Certain HID lamps can cause ultraviolet radiation damage if operated when the outer glass envelope of the lamp is broken or punctured and the arc tube continues to operate. Replace these lamps or at least remove them from service whenever the protective glass cover is damaged. Some special lamps automatically shut down when the outer envelope is broken.

DISCUSSION

When investigating fire losses caused by HID lighting, important issues include the sequence of events; environment in the vicinity of the electrical system; housekeeping around the fixture; fixture construction and maintenance; listings and approvals for the fixture, lamps and ballast; thermal protection for the ballast; circuit fusing; power quality; and manufacturer’s recommendations. When a loss investigation addresses these items, a need for equipment design changes, code changes or changes in installation requirements may become apparent. The information may be of interest to manufacturers, code authorities and testing labs. Unfortunately, fires resulting from electrical system problems often destroy evidence that identifies sources of ignition.

The Metal Halide Problem

Although any type of HID lamp can fail violently, metal halide HID lamps have been identified as the likely cause of ignition in recent, major fires. The number of losses attributed to metal halide HID lighting fixtures continues to grow. The characteristics of the gas, and the lamp’s high operating temperature and pressure, appear to have caused the fracture of tubes, expulsion of hot quartz fragments and ignition of nearby combustibles. The root causes of ruptures are not known. Possibilities include off-specification tube thickness, accumulated tube stress, off-specification or inadequate quality power, and increasing gas pressures and component temperatures as the lamp grows older.

The severity of loss caused by the rupture of metal halide lamps depends on the protection and arrangement of buildings and occupancies, including manual firefighting efforts and combustible continuity and loading. One fire, thought to have been initiated by a hot metal halide arc tube fragment, resulted in considerable fire spread and smoke damage. The fire was deep-seated in the top level of storage, and it filled the warehouse with smoke. The fire department, in trying to find the seat of the fire, shut off sprinkler protection to see where the flames were located.

Lighting is only one of many possible sources of ignition. Losses can be reduced not only by controlling sources of ignition, e.g., by reducing the frequency of arc tube ruptures and using fixtures designed to contain such ruptures, but also by limiting and protecting nearby combustibles from possible sources of ignition. Effective loss control must also recognize that certain occupancies cannot safely use a metal halide lamp because of the high operating temperatures of the lamp and fixture.

The pressure in a quartz arc tube in a metal halide lamp can reach 70 psi (4.8 bar). The temperature can reach 1100°C (2000°F). Operating temperatures and pressures have become higher as lamp technology has improved. Major metal halide lamp manufacturers have issued product specification literature and bulletins to warn users of the possibility of non-passive failure (violent rupture) of these lamps. Experience supports manufacturers’ concerns, and fires have resulted. The use of metal halide lamps appears to heighten fire risk.

For these reasons, listed metal halide lighting fixtures typically have integral barriers to contain and prevent the discharge of large, hot, arc tube fragments that result from lamp rupture while operating. However, not all listed fixtures have these barriers. Metal halide lamp fixtures without barriers can be listed if they are labeled to be used only with special lamps marked for use in such fixtures. But at a later time, if someone inadvertently uses the wrong bulb or deliberately purchases cheaper lamps not designed to control fragmentation, the hazard increases and the fixture listing is void.

In other cases, barriers may become ineffective as newer, hotter replacement lamps are introduced. UL allows tempered glass, borosilicate glass, plastic, aluminum, wire-mesh and other barrier constructions if they pass specified tests. However, extremely hot arc tube fragments can be emitted from a fixture to create a risk of injury and fire if the lighting fixture contains:

- a plastic, aluminum or other barrier that can melt at operating bulb temperatures;
- a plain-glass covering that can shatter; or,
- a mesh barrier with openings large enough to allow the passage of fragments containing sufficient heat to ignite combustibles with which they come into contact.

Bulb selection must be matched to the specific fixture to avoid problems created by high fragment temperatures and velocities. Similarly, other components, including lens coverings, can contribute to damage or injury as the glass shatters or plastic component melts and burns. Listing and labeling requirements make fixture suppliers, installers and owners aware of these complex issues.

In one major loss suspected to have been caused by metal halide fixtures, the fixtures were not UL listed. They did not have containment barriers and the lamps were not shatter-resistant. However, other losses suggest even listed fixtures and newer materials do not eliminate this fire threat. As one manufacturer's representative stated, the use of newer, ceramic arc tubes does not eliminate the possibility of violent ruptures.

Some manufacturers suggest that by turning metal halide lamps off at least once per week for at least 15 min, units approaching the end of their useful life will fail to restart. They imply this action will prevent violent lamp failures. The theory is that if a lamp is near the point of failure, an arc will not restrike when power is restored. Similarly, NFPA 70B is being revised to include a new requirement for these lamps. It states, "In continuously operating systems, turn lamps off once per week for at least 15 min. Failure to do this increases the risk of rupture." This position is widely held, but scientific evidence is lacking. No proof exists that shutting off a lamp weekly prevents its rupture later in that week.

Although UL 1572 addresses construction of metal halide lighting fixtures, no UL standard exists to test or specify the construction of metal halide lamps for safe operation. UL's standards do not test lamp failure modes. UL relies on manufacturers' tests to specify the acceptability of a lamp for open fixtures, and to match lamps with suitable listed fixtures. UL limits itself to testing the design of lamp fixtures, but **does not list metal halide lamps**. As an example of how lamps and fixtures must be matched, one lamp manufacturer states, "lens/diffuser (barrier) material must be able to contain fragments of hot quartz or glass (up to 1100°C). If in doubt, contact your fixture manufacturer."

AXA XL Risk Consulting prefers the use of listed metal halide fixtures with integral, tempered or borosilicate glass barriers that complete the fixture enclosure. These types of glass are less likely to melt, shatter or split and release hot arc tube fragments.

AXA XL Risk Consulting recommends compliance with manufacturer's guidelines, use of listed equipment, selection of lamps to match fixtures, and implementation of weekly shut-offs (if not done automatically, anyway.) These are simple precautions that may help reduce the frequency of metal halide HID lighting fires. Additionally, well protected facilities have loss control programs that protect against the spread of fire and smoke damage in the event ignition does occur.