Shedding Light on Arc-Tube Rupture

In High Intensity Discharge (HID) lamps, light is produced by passing current through a vapor at relatively high pressure, in contrast to the extremely low pressure characteristics of fluorescent lamp operation. HID lamps are generally chosen for applications where substantially high light output, together with long reliable life and high lamp efficacy are required.

There are three types of HID lamps: High Pressure Sodium, Mercury Vapor and Metal Halide. They are of different design and construction, and vary greatly in their light color output. Often insurance companies do not realize the differences among these lamps, or the extremely rare event of an arc-tube rupture, which is a prime concern discussed later in this article. High Pressure Sodium (HPS) Lamps emit a gold colored light because of the sodium vapors contained within the lamp. HPS lamps are constructed differently than mercury vapor and metal halide lamps, therefore HPS lamps do not stand the risk of arc-tube rupture. Mercury Vapor Lamps emit a blue colored light. There is a chance that mercury vapor lamps can experience arc-tube rupture, however it is small because their arc tubes operate at temperatures of 600-800º C and under contained pressures of 3-5 atmospheres. Metal Halide Lamps' ability to deliver the increasingly preferred white light has made them the HID lamp of choice for many applications, resulting in the overwhelming success of these systems in the marketplace. The National Electrical Manufacturers Association (NEMA) estimates that there are close to 40 million metal halide systems installed in North America alone, with the vast majority being in commercial and industrial applications. There is a small chance that these lamps can experience arc-tube rupture. The arc tubes in these lamps operate at temperatures of 900-1100º C and under contained pressures of 5-30 atmospheres.

Metal Halide Lamps consist of a clear quartz arc tube enclosed in a gas-filled hard glass outer bulb. The arc tube contains mercury, together with other metals in iodide form, which serve to improve the color appearance, color rendering properties and luminous efficacy of the lamp in comparison to standard mercury lamps. Quartz is used as the arc tube material in metal halide lamps because of its ability to withstand the extremely high temperature and pressure which build up during lamp operation. However, even with an arc tube constructed of the most durable materials, there is still a small chance of non-passive failure, or arc-tube rupture.

The most likely cause of a rupture of a quartz tube is the creation of stresses during lamp life resulting from crystallization within the arc tube body. This phenomenon in quartz is called devitrification. This process, by which some sections of a quartz arc tube become crystalline while adjacent regions remain in the amorphous state, gives rise to regions of different thermal expansion. When regions of different thermal expansion are created within the same quartz arc tube, the quartz becomes weakened and may crack. If a crack propagates through the quartz arc tube after the arc tube has reached full operating wattage where the pressure is between 5-30 atmospheres, it may rupture with enough force to fracture the outer bulb. However, despite the millions of metal halide systems currently in use and the over 100 million sold over the last 10 years, there are very few reported instances of property damage claims resulting from the rupture of a metal halide lamp system.

Since metal halide lamps operate at elevated internal pressures compared with most other general purpose light sources, manufacturers have historically provided explicit instructions on their proper use. There is a misconception that only lamps from certain manufacturers can suffer arc-tube rupture, however this is false. There is a chance, albeit small, of an arc-tube rupture occurring, regardless of the lighting manufacturer. The small, but existing, possibility of a

rupture is why all lamp manufacturers provide strongly worded warning statements with metal halide lamps. One example states,

> The arc tubes of Metal Halide Lamps are designed to operate under high pressure and at temperatures up to 1000º C and can unexpectedly rupture due to internal or external factors such as a ballast failure or misapplication. If the arc tube ruptures for any reason, the outer bulb may break and pieces of extremely hot glass might be discharged into the surrounding environment. If such a rupture were to happen, there is a risk of personal injury, property damage, burns and/or fire. Certain shrouded lamps that will retain all the glass particles should inner arc tube rupture occur are commercially available.

Because of the risk of arc-tube rupture, several lighting manufacturers have developed a new technology in effort to thwart the possibility of injury and property damage by arc-tube rupture. By developing a thick quartz tube that shrouds the arc tube, the chance of injury from a rare arc-tube rupture is greatly lessened. The quartz shroud of these protected lamps encompasses the arc tube and contains any quartz fragments that result from an arc-tube rupture. The shield of the protected metal halide lamps has sufficient mass to decrease the momentum of the arc tube fragments so that no quartz pieces go through the outer jacket. Should a protected metal halide lamp suffer arc-tube rupture, the shroud would catch the broken glass and let if fall harmlessly to the bottom of the lamp. This eliminates the need for an enclosed fixture. The protective shroud is not standard on every metal halide lamp. The metal halides that come with a protective shroud are generally designated MP metal halide lamps. The manufacturers who offer MP metal halide lamps do so for several reasons. First, they generally provide more safety than their unprotected counterparts, giving customers an option as to the degree of safety they want. The quartz shroud safely contains the glass particles in the event of an arc-tube rupture, which significantly decreases the chance of injury and damage. Second, the addition of a protective inner quartz shroud allows MP metal halide lamps to be used in open style fixtures. The benefits of an open fixture is an increase in light output and greater ease when relamping. Third, the protective shroud reduces ultraviolet (UV) output compared to standard metal halide lamps. UV emissions are reduced by over 70% in the protective shrouded metal halide lamps. The MP metal halide lamps do not eliminate the small chance of an arc-tube rupture, however the quartz shroud will contain the explosive force in such an event. The shroud will prevent the outer glass bulb from breaking and allowing hot glass and quartz particles to escape into the surrounding areas.

HID lamps, including metal halide and MP metal halide lamps, can be plastic-coated for safety purposes. A quality plastic coating is designed to safely contain the glass particles and phosphors should a lamp be broken. However, some safety coating manufacturers claim that their plastic coating can withstand an arc-tube rupture, safely containing the particles of hot quartz and glass. This is simply false. In the event of an arc-tube rupture, the arc-tube superheats and explodes at a pressure of 50 pounds per square inch (50 p.s.i.). That pressure alone is enough to penetrate any plastic coating. In addition, the extremely high temperatures of the glass would easily burn through the plastic coating. The glass particles that would be blown out of a lamp in an arc-tube rupture are as high as 1000º C (1832º F). Purchasing agents, maintenance workers, insurance inspectors and end-users alike should be wary of any safety coating manufacturer that states their coating will contain the glass particles in the event of an

arc-tube rupture. A quality, safety plastic coating together with an MP metal halide lamp would offer the greatest possible protection on the market.

There are two main precautions metal halide users can take to reduce the chance of an arc-tube rupture: practice a minimum amount of shut down time and relamp fixtures at or before the end of rated life. In systems that operate on a continuous basis, meaning 24 hours a day, seven days a week, metal halide lamps should be turned off at least once a week for a minimum of 15 minutes. When any lamp, be it a fluorescent or metal halide, approaches its end of life, it doesn't start as easily as when it was new. Since an arc-tube rupture is more likely to occur when a lamp approaches its end of a life, the shut down time decreases the chance the lamp will restart, thus decreasing the chance of an arc-tube rupture. Failure to turn off lamps for the minimum recommended time may increase the chance, albeit small, of an arc-tube rupture. Another precautionary measure is to relamp fixtures at or before the end of rated life. Again, as the lamps approach their end of life they become slightly more likely to experience arc-tube rupture, therefore relamping fixtures at or before the end of their recommended life further decreases the chance of an arc-tube rupture.

Although these precautions can reduce the chance of an arc-tube rupture, the event, although unlikely, can still occur. These precautions can decrease the chance of an arc-tube rupture incident. Over 100 million metal halide lamps have been sold over the last 10 years, and there are very few reported instances of property damage claims resulting from the rupture of a metal halide lamp system. With the necessary precautions they can be safely used with only the smallest chance of incident ever occurring. The safest metal halide lamp would be a protective shroud metal halide and a high quality, protective plastic coating. A lamp of this type would protect people, products and worksites from harm should an arc-tube rupture occur, or if the lamp was simply dropped and broken. Overall, metal halide lamps continue to provide long reliable life and the most efficient source of white light for HID applications.

Sources:

NEMA, "Best Practices for Metal Halide Lighting Systems," www.nema.org.
Philips Lighting, "Guide to High Intensity Discharge Lamps."
Osram Sylvania, "Engineering Bulletin: High Intensity Discharge Metalarc® Lamps."