Safely Lighting Hazardous Environments

An overview of hazardous environments and the lighting luminaires that protect them.

Lighting luminaires play a critical role in the safe, efficient and productive operation of any industrial facility or production process. Darkened, enclosed and round-the-clock operations rely on them exclusively for illumination. Daylight operations benefit from the additional and spot lighting they provide. However, facilities, such as petrochemical, refining and grain storage, require more from their lighting luminaires. In addition to providing light, luminaires for these industries must address and overcome the inherent challenges of hazardous environments.

Hazardous environment lighting luminaires are designed to specifically handle the highly corrosive elements, combustible dusts and flammable gases and vapors that are endemic to these industries. This whitepaper examines the distinct hazardous environments defined by global electrical codes, which luminaires are suited for them and technologies that are available to help keep them operating longer and safer. This information provides the foundation for achieving optimal plant safety and efficiency through proper lighting, safe electrical installation and operation.

Around the world, hazardous locations are broken down into different categories. Each category defines the type of hazard present, its explosive force and if its exposure is part of normal or abnormal facility operations.

Class of threats

The National Electric Code (NEC) and earlier editions of the Canadian Electric Code (CEC) define hazardous environment combustible dusts and flammable gases and vapors into three separate Classes. Class I locations are categorized by the flammable gases and vapors present in industries such as natural gas, petroleum and chemical.

Class II locations contain combustible dusts. These dusts can be carried aloft during pulverizing processes or compacted in storage centers. Combustible dusts are found inside plastic, pharmaceutical, coal and agricultural (grain and flour) processing locations.

Class III locations contain the ignitable fibers and flyings that are produced in the wood, cotton, and textile industries, among others.

Define the presence with divisions

NEC/CEC Divisions define hazardous environments by the amount of exposure to the gases, vapors, or dusts. Division 1 classifies hazardous atmospheres in which the flammable gas or vapor or combustible dust is present during normal operations or routine maintenance. The existing or potentially hazardous atmosphere must also be in the right mixture concentrations to be ignitable. Thus, proper ventilation can change a Division 1 location in to a Division 2 location.

Division 2 locations are where hazards are encountered only during an abnormal situation, such as equipment failure or a spill. Locations adjacent to Class I, Division 1 areas may be deemed Division 2, as well, to accommodate for the potential seeping of gases or vapors.

Groups within each class

Class ratings are further broken down into material groups, which identify the explosive characteristics of the material. The volatility of these groupings are based on MESG (Maximum Experimental Safe Gap) and MIC (Minimum Ignition Current).

Class I locations consist of Groups A, B, C and D:

- Group A, acetylene, features the highest outward pressure during an explosion
- Group B is hydrogen
- Group C is ethylene
- Group D is gasoline

Class II locations are divided into three Groups, E, F, and G in accordance with NFPA® 499.

- Group E is combustible metal dust such as aluminum and magnesium
- Group F consists of coal, printer ink powder and coke
- Group G features agricultural dusts such as cake mix, grain dust and flour

Class III locations are not broken down into groups.

Around the globe

The International Electrotechnical Commission (IEC) and European Committee for Electrotechnical Standardization (CENELEC) classifies hazardous locations into Zones, Groups and Gas Groups. The CEC and NEC include provisions for the Zone system in addition to the Division classification scheme. Zones are similar to the NEC/CEC Divisions, except that they classify three levels of the existence of hazardous atmospheres instead of two.

- Zone 0: hazardous atmospheres are continuously present
- Zone 1: hazardous atmosphere is often present
- Zone 2: hazardous atmosphere may accidentally be present

Equipment Groups are used to denote equipment used for the mining industry. Group I consist solely of mines. Group II encompasses every industry, but mining. The Atmosphere Groups of A, B, and C rate the pressure caused by an ignited gas, vapor or dust, much like the NEC/CEC Group. However, they are placed in the opposite order. Gas Group C, therefore, represents the extreme force of hydrogen and acetylene while Gas Group A denotes the less destructive forces of gasoline and natural gas.

Safely lighting facilities for the different Classes, Groups and Divisions requires engineering and manufacturing a variety of luminaire designs. Each design incorporates features that meet the specific rating criteria of the hazardous location.

Explosionproof luminaires for Class I, Division 1

Due to the ever-present condition of hazardous gases or vapors, luminaires placed in Class I, Division 1 locations must ensure that ignition is never allowed into the environment.

To do this, engineers calculate that the gas or vapor has successfully leaked into the interior of the luminaire and has ignited. To prevent ignited gases or vapors from propagating to the surrounding atmosphere, explosionproof luminaires feature engineered flamepaths. The flamepaths vent burned gases from an explosion to the surrounding atmosphere only after the gas has traveled within the luminaire's flamepaths long enough to cool. Cooled gases are released from the flamepaths at temperatures that will not ignite the surrounding flammable atmospheres. Depending on the luminaire's design and application, these flamepaths can be incorporated into ground joints, threaded joints, labyrinth-paths, close tolerance shafts, interlocking concentric rings and precision acme/conical threads.

Encapsulated and Flameproof Luminaires for Zone 1 Applications

Two common ATEX/IECEx Protection Concepts for Zone 1 environments include Flameproof (d) and Encapsulation (ma and mb). Flameproof construction contains and vents the explosion using engineered flamepaths similar to

Class I: Flammable Vapors & Gasses *(Volatile gas or vapor present in sufficient quantity to produce ignition or explosion)*		**Class II: Combustible Dusts** *(Combustible dusts present in sufficient quantity to present a fire or explosion hazard)*		**Class III: Fibers & Flyings** *(Easily ignitable fibers or flyings present but not likely to be suspended in the air)*
Group A	Acetylene	Group E	Metal Dusts	
Group B	Hydrogen	Group F	Carbon Dusts - Coal	
Group C	Ethylene	Group G	Grain Dusts	
Group D	Gasoline			

Figure 1 Summary of NEC/CEC Classes and Groups

Explosionproof construction. Encapsulation construction keeps the flammable substances out by sealing LED arrays and drivers using common potting polymer systems, such as epoxies, silicones and polyurethanes. The characteristics of LED light sources and supporting electronic components are particularly well suited to the application of encapsulation to isolate both electrical connections and heat sources from the intrusion of gases. ①

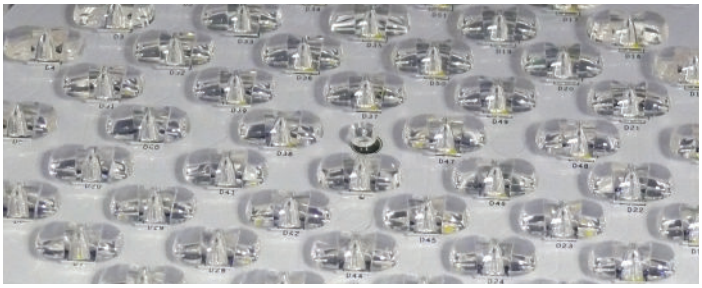
Enclosed & gasketed luminaires for Class I, Division 2 & Class II / Zone 2, 20, 21 and 22

Class I, Division 2/ Zone 2 luminaires must be gasketed to prevent the hazardous atmosphere from entering the luminaire's interior. As such, enclosed and gasketed luminaires are most suitable for this environment. Class II/ Zone 20, 21, and 22 luminaires also must function under a blanket of explosive dust as grain silos and other agricultural and mineral processing plants position lights where they can get covered by dust or grains for extended periods of time. These conditions mandate that enclosed and gasketed luminaires prevent dust ingress and keep temperatures low. Internal control components need to be engineered to radiate less heat. Surfaces need to be contoured to prevent the accumulation of dust on the luminaire and reduce blanketing. If not engineered properly exterior light temperatures can soar.

Temperatures to a "T"

Every hazardous atmosphere has a temperature that, if exceeded, will cause the flammable or combustible to ignite. Accordingly, this temperature, called the "T" rating, is a critical safety benchmark. Hazardous location lighting luminaires must run cooler than the ignition temperature of the surrounding atmosphere. Per the "T" rating chart (Figure 2), T1 rated luminaries can only be used in locations where the atmosphere needs a temperature greater than 450° C to ignite. Conversely, T6 rated luminaires run the coolest and can be used in very volatile environments where temperatures cannot exceed 85° C.

The "T" rating for a luminaire is the temperature of the hottest spot on or in the luminaire depending on the luminaires' Class or Zone rating. Whether the "T" rating is recorded on or in the luminaire depends on whether it is an explosionproof, flameproof, encapsulated or enclosed and gasketed. For explosionproof, flameproof and encapsulated luminaires, the "T" ratings are measured on the exterior of the luminaire. This is due to the explosionproof, flameproof or encapsulated luminaire's ability to disarm any explosion caused within the interior of the luminaire. Therefore, the exterior temperature of the luminaire becomes the forerunning concern. Class II,



Encapsulation construction of LED Arrays

Silicone rubber gaskets seal out moisture, dirt and dust. Stays flexible, withstands extreme temperatures.

Degree C	Degree F	ID #
351-450	664-842	T1
326-350	619-662	350
301-325	574-617	325
281-300	538-572	T2
261-280	502-536	T2A
231-260	448-500	T2B
216-230	421-446	T2C
201-215	394-419	T2D
181-200	358-392	T3
166-180	331-356	T3A
161-165	322-329	T3B
136-160	277-320	T3C
121-135	250-275	T4
101-120	214-248	T4A
86-100	187-212	T5
85	185	T6

Hazardous Lighting - "T" Rating

Division 1 T-codes are also measured on the exterior of the luminaire. Enclosed & gasketed luminaires measure their "T" ratings on the inside. If a hazard is accidentally released into the atmosphere and reaches inside the luminaire, it will not ignite assuming the luminaire's "T" rating is below that of the hazard.

Keeping your cool in hazardous atmospheres

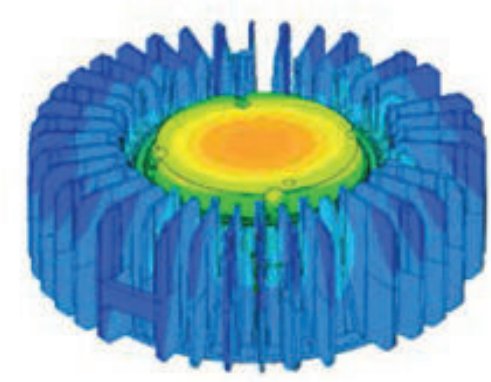
A light that lasts longer is safer for the production line and the maintenance crew. It provides more light over its lifetime and reduces the potential of a maintenance-related accident by stretching out the amount of time between servicing. Simply put, cooler running luminaires stay lit longer. That's why it is important to design and manufacture enclosed and gasketed and explosionproof luminaires that reduce the amount of heat they produce.

Thermal Design

When it comes to LED luminaires, reliability begins with good thermal design. Product designs need to take into consideration such facets as placement of LED drivers and LED array boards and the thermal design needed to draw heat away from the internal components and direct it out through the casting. Reliable LED luminaire designs emphasize thermal performance first and foremost to provide long term field reliability. Extensive thermal simulation during the design process ensures driver electronics and LED semiconductor devices operate within their thermal limits even at the fixture's maximum rated ambient temperature. No failure-prone fans or other active thermal management devices are employed. These designs optimize housing thermal conduction, maximize radiating surface areas, and employ strategically placed thermal conduction breaks to balance heat flows within each LED fixture (Patent Pending). Choose luminaires that deliver rated illumination through their full ambient operating temperature range to make sure your facility is safely lit even when the going gets hot.

Complex engineering made simple

The seemingly simple look of hazardous location lighting can often cause work crews to underestimate the environments that they work in and the engineering of these luminaires. This is reinforced by surveys that show maintenance practices usually do not follow standard guidelines. 80% of the time, HID luminaires are relamped with the electrical power on. In the 20% of the time that the power is turned off, 69% of the relamping happens as soon as the power is shut off. This does not allow the proper amount of time for many luminaires to cool. Utilizing LED technology eliminates these safety hazards posed by improper relamping procedures. However, research also shows that 32% of gaskets and seals are not inspected and maintenance crews are "pretty sure" the gaskets are properly sealed only 55% of the time. Also, 95% of the time, luminaires are maintained only after the unit fails ②. Again, LED luminaires eliminate these risks by removing the need for maintenance altogether. And features that reduce the need to open the luminaire, such as separate wiring compartments, further reduce the risk of compromised seals.



Appleton Mercmaster LED Generation 3 Thermal Simulation

New risks, however, have arisen with the use of LED retrofit lamps. Care must be taken to ensure that any retrofit lamp used in a hazardous location has been tested and certified for use in that fixture. New labels must be provided to identify a retrofitted luminaire complete with correct wattage and T-code information. Retrofit lamps that require disconnecting the existing ballast violate warranty and pose additional concerns.

When specifying luminaires for hazardous locations, look for innovative features that speed maintenance and ensure the integrity of those luminaires remains uncompromised. The industry standard, hinged mounting hood design provides the easiest installation with the most flexibility, often allowing many different mounting types with one standard luminaire body. For an easy upgrade to LED, crews can quickly unscrew a nut and swing open the luminaire with one hand; easily replacing the existing ballast tank with a brand-new LED driver housing. Certified adapters on the market today even provide for simple conversion from one manufacturer's luminaire to another, offering additional flexibility.

Rugged Reliability

Hazardous location luminaires need to be able to withstand the toughest environments on earth from the deserts of Saudi Arabia, to off shore platforms, and the North Slope of Alaska. In these dangerous environments dependable lighting is essential to keeping workers safe. Reliable lighting is key to improving operational efficiency and reducing expensive maintenance costs. Choose a luminaire manufacturer with a commitment to reliability; beginning with a rigorous process, where designs are qualified to perform in environments beyond the worst

expectations relative to corrosive atmospheres, extreme temperatures, heavy vibration, and electrical disturbances.

Corrosion Resistance

Hazardous locations and corrosion go hand in hand. Gases inherently present in these environments eat away at surfaces and require protection beyond the capabilities of low cost luminaires. Unlike liquid paint, powder coating uses an electrostatic process to apply a finish to metallic parts in a dry state. Correct surface preparation and application quality are essential. Once applied, the finish should be heat-cured to create a finish that is thicker, tougher, and more even on all outer surfaces and edges. Epoxy powder coat products last longer, thus reducing callbacks, lowering total installation and operation costs. Preferred luminaires should be suitable for use in wet locations and undergo rigorous testing procedures that comply with Marine Outside Type (Salt Water).

Reliable Protection

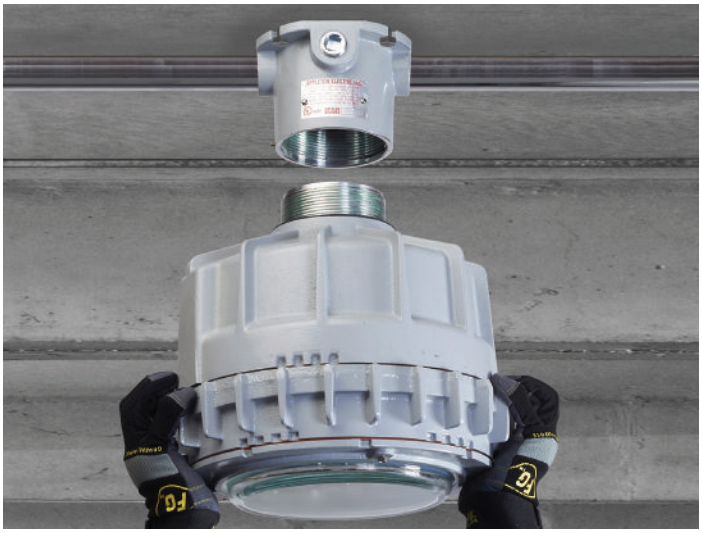
Careful gasket design is essential to keeping water and dust on the outside. Critical to the reliability, gasket seals must be tested to the stringent application requirements encountered in heavy industrial and hazardous applications. ISO accredited third-party laboratories conduct gasket performance testing according to ASTM-D-395. Manufacturers should also conduct extended duration product life tests exceeding product operating specifications and verifying long term field reliability. Aging tests include thermal endurance spanning -50°C to +120°C (-58°F to +248°F), humidity levels of 95% RH, and continuous Ultra Violet (UV) exposure. Top grade gasket material composed of high performance closed cell silicone foam and superior low compression set characteristics deliver years of reliable service in the toughest environments on the planet.

The Devil is in the Detail

Explosionproof luminaire flamepaths are frequently viewed as simple threads. However, each thread is tuned precisely to contain, shape and control an explosion caused by the rated hazard. The threads for Class I, Division 1 luminaires for Group A and B have more robust flamepaths to handle the more violent explosions of detonated acetylene and hydrogen.

Explosionproof luminaires should employ acme double lead threads and pre-lubrication to ensure a quick, tight seal without the possibility of galling or seizing, even in the most corrosive environments. This negates the need for added lubrication or elbow grease in tight spots. Wireless mounting designs simplify installation and minimize the time worker's spend in Division 1 locations. These

Appleton Mercmaster™ LED Generation 3 Luminaire | Enclosed and Gasketed



Appleton Code•Master™ LED Factory Sealed Luminaires | Explosionproof

mounting hoods are easily wired by simply attaching two wires to the connection block. This allows the luminaire to be installed, replaced or moved to a safer location for servicing without exposing wiring to a hazardous environment. There are no bare wires that can spark or wire nuts to handle.

Safely lighting the way

Lighting in hazardous locations is a necessity and a potential danger. Knowing the facility environment, combustible composition and luminaire application enables the proper lighting design for a safe and productive working environment.

Footnotes:

① *More information can be found in the "Use of Light Source Encapsulation in IECEx/ATEX Zone 1 Hazardous Locations" white paper, available on Emerson.com.*

② *Haley, Mike et al. "Benefits and concerns with NEC® Section 501.1 inreference to Zone 2 lighting in Division 2 areas." IEEE Paper No. PCIC-2004-47. 7 pages.*

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