Considerations for More Reliable Electrical Systems in Metals and Mining Facilities

White Paper

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The $925 billion global mining industry plays a vital role in economic growth and development. ① To do so, it relies heavily upon electrical equipment as the backbone of its operations. Yet no industry is harder on electrical equipment. Costly downtime, frequent maintenance, and accidents underscore the importance of specifying electrical equipment designed and engineered to perform without fail in mining's extreme environments.

In this whitepaper, we address the importance of reliable, durable, and safe electrical equipment to the day to day mining operations. Mining operators need to leverage the experience and innovation of electrical manufactures to drive safer, smarter, and more profitable mining — whether the operation is below ground, above ground, or a mineral processing facility. Without reliable electrical solutions, any mining operation comes to a standstill. Electrical lighting, fittings, controls, enclosures, plugs, receptacles, and distribution equipment must perform flawlessly no matter what the conditions.

A Historically Challenging Industry

Mining has changed significantly since the 19th century when simple manual tools were utilized, and underground workers relied on caged canaries as an early warning device for toxicities in the air. However, despite numerous technology innovations and stringent safety regulations, the mining process remains extremely demanding — both on workers and electrical equipment.

Mining is notorious for its occupational risks. These range from cave-ins and explosions, exposure to toxic air and coal dust, to blasting accidents, and run-ins with moving machinery. The environment is also punishing on the electrical equipment that mining companies rely upon to keep their operations up and running. At every stage in the mining process, electrical equipment is subjected to corrosive liquids, combustible dusts, grime, harsh chemicals, heavy vibration, power surges, and extreme temperatures — all while running continuously, around

the clock. If not properly engineered and diligently maintained, electrical equipment will fail, leading to costly production downtime.

Equipment reliability problems, employee safety incidents, and unplanned downtime are serious threats to the profitability of every mining operation. And they only add to the existing pressure to mine and process greater amounts of coal, metals, stone and other commodities – even as minerals become increasingly difficult to recover and as equipment, energy and labor costs rise.

Electrical Dangers

Modern mining would be impossible without electricity. Electrically powered equipment transports needed supplies, crushes and grinds rock, hauls raw materials, lights dark caverns, runs pumps and ventilation fans, and powers drills, cutting machines, dust collectors, and hoists.

Despite its vast utility, electrical power in a mine can also be extremely dangerous. The U.S. Bureau of Labor Statistics reports that mining has an electrical fatality rate eight to twelve times that of other U.S. industries. Mine Safety and Health Administration data shows one fatality for every 22 electrical-related injuries, compared with an average of one fatality for every 203 injuries for all other injury types. ②

Water is an ongoing danger with electrical equipment. Whether it's dredging, process water, dewatering and drainage systems, tailings ponds, or weather exposure, virtually every mining enterprise needs to operate electrical equipment in damp and wet locations. Because water and electricity don't mix, these locations require special attention to ensure safety as well as long-lasting serviceability.

Ignitable dust and gases pose a far greater danger. Even a small spark from an electrical lamp can ignite gas or swirling dust, setting off a chain of events leading to an explosion. Explosions can be triggered by everything from ventilation systems failing and poor rock dusting practices, to basic human error. Underground mining is inherently more susceptible to gas or dust explosions than strip, mountaintop, open pit, or other types of surface mining, although explosions do occur above ground.

Underground coal mining is particularly exposed to the dangers of methene gas and dust. Potentially explosive atmospheres can be found deep in caverns, continuous mining sections, coal crushing and screening operations, vehicle fueling stations, and many other locations in the mine. When a mixture of methane and air — also known as firedamp — in a coal mine explodes, the explosion can lead to the raising and burning of a coal dust cloud, which in turn produces a far more violent dust explosion. A tragic example of such a blast occurred on April 5, 2010, when a massive coal dust explosion at a West Virginia mine killed 29 miners. It was the largest mine disaster in the United States in 40 years. ③

Explosionproof Equipment

Improperly designed electrical equipment will ignite gases and dust, leading to both the explosions themselves and the subsequent collapse of mining structures. Due to this ever-present danger, certain areas of the mine are required to install explosionproof electrical equipment. These products are designed to withstand an internal explosion which can occur when enclosed devices produce arcs, sparks or generate heat that in turn ignite any gases or vapors trapped within the apparatus. Explosionproof equipment incorporates a flamepath that allows hot gases or vapors to safely cool before escaping into the surrounding atmosphere.

Analysis of explosionproof equipment requirements in a new mine must be performed at every phase, from basic engineering to commissioning. Updating hazardous area drawings is also required each time modifications or expansions are made to a mine. This is not the duty of a single engineer, but a multi-disciplinary job performed by several trained professionals familiar with a mine's processes, equipment, and operations. Given the dangerous nature of mining, analysis of equipment requirements and area classifications is a highly complex exercise that requires knowledge of local regulations, applicable standards, electrical codes, company specifications, and general industry benchmarking.

To achieve certification from the U.S. Mine Safety and Health Administration (MSHA), all designs and specifications for electrical equipment and accessories must

be submitted for approval. Electrical equipment will be regularly inspected once it is installed to ensure it is being maintained in accordance with the Federal Mine Safety and Health Act of 1977 (Mine Act), as amended, and MSHA's standards. ④

At Emerson, we take the challenge of protecting hazardous environments seriously. Many of the safety innovations that have become standard in today's explosionproof equipment were pioneered by engineers developing Appleton™ brand electrical products. For explosionproof protection in mining operations, Appleton products offer:

- *Strength: Appleton explosionproof products are robustly constructed of the best materials to exceed the rigorous hydrostatic pressure testing requirements for NEC, CEC, ATEX, and IECEx installations.*
- *Thermal management and testing: Appleton LED luminaires and other heat producing products are designed and tested to provide extremely conservative temperature ratings, so you can install them in hazardous environments with confidence.*
- *Design and construction: State-of-the-art safety functions, precision machined flamepaths, increased safety products, and other features and options ensure mining operators will have access to the safest electrical solution to protect people, property, and profits.*

Electrical Safety Requirements

Ensuring electrical equipment meets the highest local and international safety standards and certifications for harsh and hazardous locations is paramount to keeping workforces safe. Specifying the correct electrical equipment for a mine also improves productivity and reduces operating costs.

Most countries today have mining laws and regulations that address electrical safety issues. These standards apply to all electrical equipment in and around the mine, running the gamut from protective gear and communication devices to heavy-duty motors and lighting, to switchboards and instrument controls.

The National Electrical Code (NEC), or NFPA (National Fire Protection Association) 70, is a United States standard for the safe installation of electrical wiring and equipment. Article 500 of the NEC establishes the basis for classifying locations where fire or explosion hazards can exist due to flammable gases, flammable liquid–produced vapors, combustible liquid–produced vapors, combustible dusts, or ignitable fibers and flyings. Explosive liquids are rare in mines other than in and around fueling stations. As highlighted previously, the most common dangers in mines are dust and gases.

NEC/CEC Area Classification

Classes	Divisions	Groups
Class I: Gases Areas in which flammable gases or vapors in the air, in sufficient quantities to ignite or explode. **Class II: Dust** Areas in which combustible dust may be suspended in the air or accumulates on electrical equipment in quantities sufficient to ignite or explode. **Class III: Fibers** Areas in which easily ignitable fibers or flyings are present. Typically fibers and flyings are not suspended in the air, but can collect around machinery or on lighting fixtures.	**Division 1: Always Present** Areas in which ignitable concentrations of hazards exist under normal operation conditions and/or where hazard is caused by frequent maintenance or repair work or frequent equipment failure. **Division 2:** Not Normally Present Areas in which ignitable concentrations of hazards are normally in closed containers or closed systems. Hazards may be present due to accidental rupture or breakdown of such containers or systems.	**Class I: Gases** Group A - Acetylene Group B - Hydrogen Group C - Ethylene Group D - Propane **Class II: Dusts** Group E - Electrically conductive dust Group F - Carbonaceous dust Group G - Agricultural and polymer dust

Powertite™ Series Pin and Sleeve Plugs, Connectors, Receptacles

AJBEW Cast Junction Boxes

NEC 500 requires the installation of Code compliant equipment that has been tested and approved for specific hazards. Depending on the level of threat, hazardous or "classified" locations are categorized by the NEC in terms of Classes, Divisions, or Zones, and into Groups depending on the nature of the hazardous substance. Those substances may be grouped (Group A, B, C, or D) according to the ignition temperature of the substance, its explosion pressure, and other flammable characteristics.

As a worldwide manufacturer of electrical products, Emerson continually strives for new and better solutions to ensure electrical installations are safer, more productive, and more reliable. To learn more about our Appleton products and hazardous locations, we offer educational resources to our customers online at go.bluevolt.com/AppletonGroup/s/.

Under International Electrotechnical Commission (IEC) practices, each hazardous location is typically identified by a Zone designation. IEC Zones are defined by the relative risk of the atmosphere becoming explosive. Zones 0, 1, and 2 cover the frequency of exposure within the area to explosive gases. 0 being the most continuous, and 2 being least likely. Likewise, Zones 20, 21, and 22 cover the frequency of exposure within the area to combustible dusts.

The IECEx system is the international version of the IEC standards for hazardous locations and is currently accepted in several countries. You should also be aware of the ATEX directive (ATmospheres EXplosibles) that consists of two EU (European Union) directives which address minimum safety requirements for both equipment and the workspace within an environment which has been identified as having a potentially explosive atmosphere. The original Directive 94/9/EC dictated specific safety requirements for manufacturers of equipment intended for installation in potentially explosive atmospheres. Directive 2014/34/UE replaced 94/9/EC and updated/expanded the declaration of conformities and examination certificates equipment is required to have, in addition to improved product markings for better traceability and manufacturer identification.

Appleton electrical solutions by Emerson meet or exceed global certifications for harsh and hazardous environments. We recognize the importance of having lighting, power distribution, control, and fittings solutions that are correctly certified for specific geographic locations and environments. Whether your geography requires NEC, CEC, ATEX, or IECEx certification, our regulatory involvement, technical expertise, and range of Appleton electrical products solve the challenges of outfitting mining and processing facilities.

After a study is done to determine the Class, Zone, Division and Group areas within your applications – through a third party or by plant engineers – our sales team can specify the exact Appleton electrical products you need from our diverse and comprehensive family of solutions, all tested to perform in corrosive atmospheres, extreme temperatures, locations with heavy vibrations, and explosive areas.

Appleton ATX™ FELED Series Nonmetallic LED Luminaires

CEC/ATEX/IECEx Zone Classification

- IEC publication 60079-10 uses Zones to define the guidelines for classifying hazardous areas.
- CEC Section 18 uses Zones to define the guidelines for classifying hazardous areas.

Gases	Dusts
Zone 0: Areas where explosive gas atmosphere is continuously present or present for long periods of time.	**Zone 20**: Areas in which a combustible dust, as a cloud, is present continously or frequently during normal operations in sufficient quantities to produce an explosive mixture.
Zone 1: Areas where explosive gas atmosphere is likely to occur in normal operation or can be expected to be present frequently.	**Zone 21**: Areas in which a combustible dust, as a cloud, is likely to occur during normal operations in sufficient quantities to produce an explosive mixure.
Zone 2 : Areas where explosive gas atmosphere is not likely to occur and if it does, it will only be present for a short period of time.	**Zone 22** : Areas in which a combustible dust, as a cloud, is not likely to occur, but may occur infrequently and persist for only short periods of time.

Mercmaster™ LED Generation 3 Series Luminaires

PlexPower™ Series Panelboards

The Cost of Unplanned Downtime

Due to the adverse conditions of mining operations, electrical equipment must not only be properly certified, but well-built both electrically and mechanically. If it is not, unplanned downtime is the consequence. As the mining industry continues to mature and commodity prices remain low, the negative impact of unplanned downtime on the bottom line will only increase. This is one reason a typical mine spends 35 to 50 percent of its annual operating budget on preventive maintenance and repairs. ⑤

Mining, metals, and other heavy industrial companies lose 23 hours per month of production time to machine failures at an average cost of $187,500 (USD) per hour. This amount can go much higher depending on the time it takes to get the equipment fixed, as well as the size of the mining company, and the number of machines that failed, malfunctioned, or are no longer operational. A standard mine works 24/7 throughout the year, for years to decades, so even short intervals of unplanned downtime can have significant financial impacts. ⑥

The best starting point for mine operators to maximize machine uptime and availability is to specify the most reliable electrical equipment available. This is the proactive approach, focusing on avoiding issues instead of trying to repair them.

At Emerson, we understand that reliability is key to improving operational efficiency and reducing expensive maintenance costs. Our Appleton electrical products reduce total life cycle cost by minimizing unplanned downtime with superior product designs and materials, while simultaneously lowering the need for planned downtime for maintenance.

How Mining Equipment is Damaged

Mining exposes electrical equipment to multiple environmental challenges that can bring about failures and downtime. Losses are exacerbated by the fact that critical pieces of electrical equipment often take a long time to replace.

Below are the most common and costly reasons for electrical equipment to go non-functional:

- Corrosion: Mining sites expose electrical equipment to highly corrosive conditions due to the presence of corrosive liquids, corrosive and abrasive ores, high levels of humidity and corrosive fumes and gases. Corrosion of electrical products in mining, ore processing and refining operations can compromise safety and often leads to expensive downtime for maintenance or replacement.
- Vibration: Negative effects of vibration are prevalent throughout the industrial world, particularly in mining where heavy earth-moving equipment, blasting, and off-road vehicles are necessities. Mining equipment-induced vibration places a significant burden on electrical equipment. It will eventually damage components and loosen connections that cause downtime and potentially, injuries to employees.
- Water: Electrical products in mines must be reliably sealed against ingress even under hose-down water pressures. They must provide appropriate safety features to protect people and equipment. And they must minimize the chance of failure due to improper installation or accidents.
- Dust: Dust is an especially destructive agent to electrical equipment. In addition to accelerating corrosion, dust acts as insulation, preventing heat from escaping. Dust can contain oils, organic materials, minerals, and chemicals, all of which can diminish equipment reliability and life span. Dust will accumulate inside unsealed equipment, creating problems with conductivity, moisture ingress, electrical shorts, increased arcing and carbon tracking, and ultimately, premature failure. Worse, dust is combustible. Underground or on the surface, explosions are possible anywhere ignitable dust is present — from crushers and mills, to cleaning processes and conveyors, to transportation railways and more.

Conduit Outlet Boxes

- Extreme temperatures: Minerals are mined all over the world. Coal mines can reach brutally cold temperatures of -45 °C (-50 °F) while salt mines in Ethiopia have ambient temperatures above +54 °C (+130 °F). Both extremes can have negative effects on electrical equipment, especially heat. Excess heat in enclosures makes components work harder, shortening their lifetime. Replacing electrical components more frequently than normal will increase maintenance costs and downtime.

PlexPower™ Factory Sealed Enclosed Disconnect Switches

LED Lighting in Mines

Proper lighting is fundamental to the safety of underground mines. Worker's lives literally depend on it. Yet factors such as low ceilings, shadowing, low reflectivity, narrow tunnels and corridors, and explosive atmospheres makes providing adequate, glare-free illumination in mines difficult. Mines have traditionally relied upon long-established light sources such as incandescent bulbs, fluorescent tubes, and high-intensity discharge (HID) lamps. Inadequate lighting poses major safety risks within mines. Poor lighting decreases employee alertness and reaction time, leading to accidents. It also makes it nearly impossible to see dangerous obstacles or detect damage to vital equipment, further compromising safety. Worse, luminaires not engineered for hazardous underground areas like coal wash plants, reclaim tunnels, and conveyor systems where flammable gases

How Emerson Protects Equipment

Emerson manufactures Appleton brand products to keep mining operations running safely and efficiently. High design standards, superior materials, and top tier components are all used to ensure our Appleton electrical products meet the long-term performance requirements of the global mining industry. Not every electrical equipment manufacturer understands the unique and often unpredictable challenges of mining and mineral processing, and not every supplier has the commitment to developing and manufacturing equipment to address these challenges, Emerson does.

- *Corrosion: Salt, sulfur compounds, ammonium nitrate and many other corrosive substances are commonly found in and around mining operations. Appleton electrical products feature corrosion-resistant materials and finishes that significantly extend product life, therefore lowering long-term costs while minimizing maintenance needs and maximizing productivity. Stainless steel hardware is standard on all Appleton products intended for use in corrosive environments. Some products feature stainless steel designs for added corrosion-resistance such as our Appleton PlexPower™ Series. Our copperfree aluminum products feature our gray epoxy powder coat finish which is electrostatically applied for complete uniform protection. The majority of Appleton iron products come standard with our triple coat finish which provides in an unsurpassed barrier to harmful corrosion and other environmental elements. In addition, Emerson has durable nonmetallic Appleton electrical products for the ultimate in corrosion-resistance.*
- *Vibration: Appleton electrical products are designed to withstand the heavy vibration created by mining equipment and to survive impacts from falling ores, accidental collisions, and general rough handling. Appleton LED Luminaires have shockproof designs and the highest quality electronics. Exterior features, such as captive hardware and integral redundant die cast safety retention points, help protect workers from luminaire parts falling into work areas and production processes.*
- *Water: Mining is a wet, dirty job. That's why Appleton products are protected by impervious materials and rugged gaskets designed for long-term effectiveness and to resist degradation under harsh mining conditions. Positive grounding, ground fault protection, impact resistant glass, recessed and interlocked receptacles, NEMA 4X covers and many other options are available to keep water out of the electrical system and protect against accidents.*
- *Extreme temperatures: Emerson offers a broad line of Appleton products with ambient temperatures suitable for use in extremely hot and cold climate areas inside or outside mines. Heat producing products are designed and tested to provide extremely conservative temperature ratings, so you can install them in hazardous environments with confidence.*
- *Dust: Appleton dust-ignitionproof equipment seals dust out to prevent accumulation and combustion. Surface temperatures remain well below the ignition point of the surrounding dust/air mixture, even if a dust blanket builds up on the equipment and causes it to run at a higher temperature than its nominal rating. Heat-generating equipment is designed and tested to avoid overheating and ignition due to dust clouds or layers.*

are present, can ignite explosions. And when you consider that the greatest percentage of accidents (53%) occur when employees are maintaining or repairing light bulbs or light fixtures ⑦, upgrading a mines legacy lighting system — or when designing a new facility — Light-Emitting Diode (LED) lighting solutions provide many benefits.

LED luminaires are a brighter, safer solution than legacy light sources. Quality LED luminaires have a longer life span — often approaching 100,000 hours (10+ years) — and provides improved visual perception. Effectively converting an operation to LED can provide a compelling return on investment (ROI) in terms of energy savings, reduced long term maintenance and improved facility safety. However, be aware of LED retrofit lamp kits. Always check the hazardous location certifications on the kit you are planning to invest in. Installing some LED retrofit kits will void the manufacturers certifications, turning an explosionproof or dust-ignitionproof luminaire, into an ordinary location one.

Adding dimming functionality to the lighting system will increase luminaire lifetime and energy savings. Greenhouse gas emissions associated with LED luminaires is considerably lower than legacy lighting sources. Upgrading to LED lighting will enhance energy efficiency of your mine by up to 60 percent, increase employee productivity and comfort, lower maintenance costs, and improve safety by reducing injuries, fatalities, and other health hazards.

LED lighting is the most eco-friendly lighting technology available today, both in terms of energy efficiency and in controlling light pollution. Minimizing light pollution is a major deciding factor for many mining operations, especially in South America where there is a high concentration of copper mines. For instance, Chile has very strict light pollution standards (DS43) requiring warmer color temperatures and extreme shielding to eliminate uplight. ⑧ Unlike incandescent, HID, or fluorescent lighting, LED lighting is highly focused, so it reduces the unwanted scattered light in the environment. Light only goes where it is needed with no waste. Look for manufacturers that offer Dark Sky Friendly luminaires, approved by the International Dark Sky Association, to reduce light trespass and skyglow. Typically, accessories can be added to a luminaire to minimize light pollution in certain mounting configurations.

Appleton LED luminaires by Emerson are robustly built to deliver superior durability to outlast the toughest mining conditions, from area to task, flood to emergency. Proprietary finishing techniques protect and seal our luminaires to resist corrosion, while gaskets keep damaging water and dust on the outside. Their designs optimize housing thermal conduction, maximize radiating surface areas, and employ strategically placed thermal conduction breaks to balance heat flows.

Many Appleton LED luminaires can easily retrofit into existing Appleton mounting hoods by simply replacing the legacy ballast body with a new LED driver housing. In some cases, retrofit adapters are available to retrofit Appleton LED luminaires to select existing competitor mounting hoods — without changing the hazardous location certification — reducing labor costs required by modifying existing conduit and wiring infrastructure. Replaceable drivers extend the lifetime of the luminaire. Appleton LED luminaires offer field replaceable lenses and globes, increasing the usefulness of our solutions to exceed the requirements of any lighting application.

Emerson offers a WirelessHART™ connected LED lighting solution. Our Appleton Mercmaster Connect LED with integrated motion and illuminance sensor is available in a range of dimmable lumen output options in a rugged, corrosion-resistant housing. The optional Plantweb™ Insight Connected Lighting Application provides map based commissioning of the lighting system and real-time information about lighting usage, energy consumption calculations, and maintenance priorities. Customers utilizing Rosemount measurement devices can easily incorporate connected lighting into a facility.

To ensure interior components of the luminaire remain protected, impact tests are performed to safety standards after material aging and temperature cycling to verify robust enclosure performance. A 6kV surge suppression circuit prevents damage caused by surge energy, extending the life of your lighting installation. Appleton LED luminaires address and overcome the inherent challenges of hazardous environments with a wide range of models featuring excellent T ratings, Ingress Protection (IP) ratings, and compliance with NEC, CEC, ATEX and IECEx hazardous location standards.

By employing only the highest-grade components Appleton LED luminaires maximize usable light that is both comfortable and appropriate for the application. They provide energy efficient and environmentally friendly, high quality white light with better visibility, no startup delay, no degradation in lighting quality due to on/off cycles, and no end-of-life cycling. Models are available with low-profile designs making them extremely easy to position and install in confined spaces, reducing the possibility they will be damaged by mining equipment.

Upgrading to Appleton LED Luminaires can also have a positive sustainable impact on our environment. Lower energy costs, lower maintenance and less waste equals a greener future. Plus, Emerson is a proud member of the International Dark Sky Association. Many of our LED designs, including our Appleton Mercmaster™ LED Generation 3 Series, have earned the Dark Sky Fixture Seal of Approval.

In Conclusion

Mining sites have multiple processes taking place in a single, broad location. Each part of the process demands unique electrical solutions to keep processes running with minimal downtime while eliminating worker accidents. The electrical equipment installed must be reliable, durable, and safe — whether the operation is below ground, above ground, or a mineral processing facility. It's about safety, of course. But it's also about productivity and profitability for mining companies under constant pressure to produce more – even as minerals become more difficult to recover and as equipment, energy, and labor costs rise out of sight. You can't afford reliability problems, safety incidents, or unplanned downtime. That is why you need a manufacturer whose electrical products are designed to be the most rugged, corrosion-resistant, and dependable in the world.

Emerson has a long history of providing mining operations with reliable, purpose-built, heavy industrial grade Appleton electrical equipment essential to improving operational efficiency, creating a safer work environment, and reducing maintenance costs. Our Appleton electrical products perform in environments subject to extreme temperatures, electrical disturbances, and dust, while running 24/7/365. In areas of the mine where hazardous gases, liquids, and vapors could be present, along with combustible dusts, Appleton hazardous location products are certified by international standards for safe operation. For more information visit us at www.appleton.emerson.com.

Footnotes

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