Electrical Safety in the Mining Industry

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Introduction

The Mine Safety and Health Administration (MSHA) is responsible for the inspection and enforcement of the Federal Mine Safety and Health Act of 1977, and the associated parts of the Code of Federal Regulations Title 30, Parts 1 through 199, *Mineral Resources*. These regulations deal with all aspects of mine safety, including electrical safety. MSHA has the authority to issue citations and levy civil penalties for the violation of mine safety regulations. The mission of MSHA is to "enforce compliance with mandatory safety and health standards as a means to eliminate fatal accidents; to reduce the frequency and severity of nonfatal accidents; to minimize health hazards; and to promote improved safety and health conditions in the Nation's mines".

In addition to the electrical safety regulations developed by MSHA for the mining industry, there are requirements for electrical safety for all industries developed and issued by the Occupational Safety and Health Administration (OSHA) of the U.S. Department of Labor. The National Fire Protection Association also provides direction concerning electrical safety in NFPA 70E, *Standard for Electrical Safety in the Workplace*. Although the NFPA 70E standard does not apply directly to electrical installations in underground mines, as well as self-propelled mobile surface mining machinery and trailing cables, they do apply to all other electrical installations in the mining industry.

The MSHA and OSHA regulations, along with NFPA 70E, have been developed to assist the employer in protecting their employees who work on, near, or with electrical equipment and systems. These regulations and standards address electrical hazards analysis, safe work practices and procedures, and the personal protective equipment (PPE) required to protect employees from the hazards of electricity. In order to better understand why safe work practices and PPE are required, a brief description of the hazards of electricity will be provided.

Hazards of Electricity

All of the studies reviewed have revealed three major hazards of electricity, which are: 1) electrical shock, 2) electrical arc-flash and 3) electrical arc-blast. Each of these hazards will be addressed briefly and will include the physiological effects on the human body.

Electrical shock: It takes a very low value of current flowing through the human body to cause death or serious physical harm. Many studies have been performed in this area with different values of current that causes each effect. The following chart illustrates average values of current and the effects as taken from the published studies:

Current	Effect
1 mA	Barely perceptible
1-3 mA	Perception threshold (most cases)
3-9 mA	Painful sensations
9-25 mA	Muscular contractions (can't let go)
25-60 mA	Respiratory paralysis (may be fatal)
60 mA or more	Ventricular fibrillation (probably fatal)
4 A or more	Heart paralysis (fatal)
5 A or more	Tissue burning (fatal if vital organ)

MSHA, OSHA, and NFPA 70E, require employees who are exposed to the electrical shock hazard to be qualified persons. They also require the circuits or equipment to be deenergized and properly locked and tagged prior to work being performed. However, if the employees are required to work on circuits or equipment energized, they must use safe work practices and procedures, as well as the appropriate PPE.

MSHA 30 CFR 56.12022, *Authorized persons at major electrical installations*, states: **"**Areas containing major electrical installations shall be entered only by authorized persons." However, throughout the MSHA electrical regulations, it states: "Electrical work on all circuits and equipment…must be performed only by persons qualified…"

Since a qualified person is required by MSHA, OSHA, and NFPA, due to all three of the hazards of electricity, the definition will be provided here. According to the National Electrical Code, a *Qualified Person* is defined as: "One who has skills and knowledge related to the construction and operation of the electrical equipment and installations and has received safety training on the hazards involved."

Electrical arc-flash: There are two different issues with this hazard, the arc temperature and the incident energy. The main concern with the arc temperature is the flash-flame and ignition of clothing. At approximately 203^0F for one-tenth of a second (6 cycles), the skin is rendered incurable or in other words a third-degree burn. At only 1.2 cal/cm^2 of incident energy a person could receive a second-degree burn. It does not take a very high temperature or very much energy to cause extreme pain and discomfort or death to the worker. The wearing of many synthetic fabrics, such as acetate, nylon, polyester, and rayon either alone or in blends are prohibited by OSHA where an electrical arc might occur, unless the employer can demonstrate that the fabric has been treated to withstand the conditions that may be encountered. These materials, when exposed to flames or electric arcs, can ignite and continue to burn and will generally melt and adhere to the skin increasing the extent of the injury. In some cases 100% cotton will suffice, however in most cases involving electric arcs, clothing must be made of a flame resistant (FR) material in order to provide more

complete protection. Incident energy is a radiant energy that can pass through the clothing fabric (even if it is FR material) and could ignite underclothing or burn the skin. The Flash Hazard Analysis, as required by NFPA 70E, must be performed in order to determine the level of hazard and the appropriate PPE for the available incident energy. As with the shock hazard, PPE should be the last option. The best practice is to engineer out the hazards.

Some considerations for engineering out the hazard are to:

1. Perform a complete lockout/tagout, test, and ground if necessary. (PPE is required while performing these functions but can be removed once this procedure is completed.)
2. Install electrical equipment that will either contain or properly vent the arc flash and blast pressure.
3. Use current limiting devices such as current limiting reactors or current limiting fuses to limit the available short-circuit current in the electrical system.
4. Use remote operating controls for circuit breakers so the operator does not have to stand at the equipment to open or close it.
5. Use extensions on the racking mechanism of circuit breakers that extends through the cubicle door so the breaker can be racked in and out with the door securely latched closed.

Electrical arc-blast: The pressures developed by an electrical arc can be extremely high. One study noted that copper, when vaporized, expands at a factor of 67,000 times which one expert stated was the same expansion as dynamite. Doors or covers must be securely latched before operating a switch or circuit breaker. Technicians or operators must place their body in the safest position before operating the equipment. Flash suits will protect against the flash/flame and incident energy hazards of the arc-flash but may not protect against the pressures of the arc-blast. There are several issues to think about with an electrical arc-flash and arc-blast:

- Copper expanding when vaporized is similar to dynamite releasing:
  - Dynamite releases energy in microseconds
  - Arc releases energy in milliseconds
  - 1 MW of power = 1 stick of dynamite (1/3 lb. of TNT)
- An electrical arc is a multi-hazard event:
  - Electrical Arc
    - Flash/flame temperature
    - Incident energy
  - Electrical Blast (explosion)
    - Fragmented metal
    - Molten metal
    - Vaporized metal (plasma)
    - Pressure

There are several engineering considerations that must be taken into account with the arc-flash and arc-blast hazards. These include, but are not limited to, up-to-date electrical protective device coordination studies, up-to-date short-circuit analysis, flash hazard analysis, and regularly scheduled preventive and predictive maintenance and testing programs for the electrical protective devices.

Preventive Measures and Equipment

By far the safest way to work on electrical equipment and circuits is to deenergize, lock, and tag them. In fact MSHA and OSHA point out very clearly that this is their preference. Energized work is to be performed only as a last resort, when it is infeasible to deenergize. OSHA 29 CFR 1910.331-.335, *Electrical Safety-Related Work Practices.* addresses the requirements for working on, near, or with exposed energized electrical circuits or equipment that are energized at 50-volts or more to ground. OSHA defines energized work as: "work performed on exposed live parts (involving either direct contact or contact by means of tools or materials) or near enough to them for employees to be exposed to any hazards they present."

With regard to deenergize work, MSHA 30 CFR 56.12017 states: "Power circuits shall be deenergized before work is done on such circuits unless hot-line tools are used. Suitable warning signs shall be posted by the individuals who are to do the work. Switches shall be locked out or other measures taken which shall prevent the power circuits from being energized without the knowledge of the individuals working on them. Such locks, signs, or preventative devices shall be removed only by the person who installs them or by authorized personnel."

Working on or near exposed energized circuits and equipment can be extremely dangerous if proper safe work practices are not utilized. Energized work should be done only after all other avenues, which would allow the work to be done deenergized, have been exhausted. With this said, it is necessary to recognize that in some cases, it may be more hazardous to deenergize than to work the system energized. Such circumstances could include shutting down an emergency alarm system, shutting down the ventilation system to a hazardous location, shutting down systems for life support equipment, or turning off the lights to a process area. Energized work would also be required for diagnostic testing or troubleshooting. Under these conditions, the work must be performed by qualified persons only, using proper safe work practice procedures, personal protective equipment, and protective measures in order to perform the work safely.

MSHA does not address specific electrical protective equipment for performing energized work; however, they do require protective equipment to be utilized for all hazardous conditions. MSHA 30 CFR 56 and 57.15006 require that "special protective equipment and special protective clothing shall be provided, maintained in a sanitary and reliable condition, and used whenever hazards of

process or environment, chemical hazards, radiological hazards, or mechanical irritants are encountered in a manner capable of causing injury or impairment." Note that this requirement is intended to cover situations where normal and ordinary work clothing and safety equipment is not adequate.

OSHA has similar requirements for protective clothing and equipment in 29 CFR 1910.132(d) which requires a hazard assessment and equipment selection:

> "(1)The employer shall assess the workplace to determine if hazards are present, or are likely to be present, which necessitate the use of personal protective equipment (PPE). If such hazards are present, or likely to be present, the employer shall:
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> (i) Select, and have each affected employee use, the types of PPE that will protect the affected employee from the hazards identified in the hazard assessment;
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> (ii) Communicate selection decisions to each affected employee; and,
>
> (iii) Select PPE that properly fits each affected employee.
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> (2)The employer shall verify that the required workplace hazard assessment has been performed through a written certification that identifies the workplace evaluated; the person certifying that the evaluation has been performed; the date(s) of the hazard assessment; and, which identifies the document as a certification of hazard assessment."

These MSHA and OSHA requirements are both fairly generic with regard to hazard assessments and selection of personal protective equipment. OSHA 29 CFR 1910.335, *Safeguards for personal protection*, is somewhat more specific with regard to the electrical hazards and PPE requirements. OSHA makes several statements in 1910.335 with regard to protecting employees from electrical hazards. These statements are as follows:

> "Employees working in areas where there are potential electrical hazards shall be provided with, and shall use, electrical protective equipment that is appropriate for the specific parts of the body to be protected and for the work to be performed."
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> "Employees shall wear nonconductive head protection wherever there is a danger of head injury from electric shock or burns due to contact with exposed energized parts."
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> "Employees shall wear protective equipment for the eyes or face wherever there is danger of injury to the eyes or face from electric arcs or flashes or from flying objects resulting from electrical explosion."
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> "When working near exposed energized conductors or circuit parts, each employee shall use insulated tools or handling equipment if the tools or handling equipment might make contact with such conductors or parts."

> "Fuse handling equipment, insulated for the circuit voltage, shall be used to remove or install fuses when the fuse terminals are energized."
>
> "Ropes and handlines used near exposed energized parts shall be nonconductive."
>
> "Protective shields, protective barriers, or insulating materials shall be used to protect each employee from shock, burns, or other electrically related injuries while that employee is working near exposed energized parts which might be accidentally contacted or where dangerous electric heating or arcing might occur."

All of these quotes address protecting employees from the hazards of electricity. NFPA 70E further breaks this down into specific requirements for a Shock Hazard Analysis and a Flash Hazard Analysis, along with the appropriate PPE and safe work practices required to protect employees from these hazards.

Summary

In resolving the issues in electrical safety in the mining industry, a path must be followed that will lead to a comprehensive analysis of the problems and hazards that exist or may exist and provide a quantified value to ensure the selection of appropriate personal protective equipment and clothing as well as safe work practices and procedures. An analysis of all three hazards; electrical shock, electrical arc-flash, and electrical arc-blast must be completed and steps taken to prevent injuries and fatalities.

Regulatory agencies and standards organizations have long recognized the need to analyze the hazards of electrical work and plan accordingly to mitigate the hazards. Unfortunately, many in the electrical industry have chosen to "take their chances", largely because nothing bad has yet to happen. As more information becomes available on the economic and human costs of electrical accidents, it is hoped that more in the industry will recognize the need for systematic hazard analysis, and an electrical safe work program that emphasizes hazard identification and abatement.

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