

Arc Resistant Electrical Equipment in the Mining Industry

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History – Understanding Arc Flash

Electrical arcing injuries are the most common form of electrical injury in mining. MSHA data shows that 381 “non-contact electric arc burn” injuries occurred in the (US) mining industry from 1996 - 2005. Excerpt from NIOSH Paper by James C. Cawley, P.E., and Gerald T. Homce, P.E.

An arc flash is a sudden release of heat, light, sound, pressure, vapor, and molten material energy electric arc where a sustained flashover of electric current leaves its intended path and travels through the air from one conductor to another or to ground. The results are violent and when a human is in close proximity to the arc flash, serious injury and often death occurs.

Arc flash causes may include:

- Dust
- Dropping tools
- Accidental touch
- Condensation
- Material Failure
- Corrosion
- Faulty installation
- Loose connections
- Circuit Breaker failure

Three factors determine the severity of an arc flash injury:

- Proximity of the worker to the hazard and PPE
- Temperature
- Time for the circuit to interrupt

Equipment Standard

The mining industry is adopting standards for verification of arc resistant equipment designs to protect personnel and the entire mine the workforce in explosive mine atmospheres.

Standard mining electrical equipment is designed to withstand the mechanical forces generated by bolted faults on the load terminals until a power circuit breaker or other protective device can interrupt the fault current. However, this design is not capable of protecting against internal

arcing faults. During an arcing fault, the voltage at the fault location is essentially the system voltage and the fault energy is focused within the equipment. As temperatures rise to or above 35,000°F the metal parts vaporize and create thousands of pounds of impact force. The expanding plasma creates severe mechanical and thermal stress in the equipment, which can blow off top covers, panel, doors, and burn through the enclosure. Personnel located in this will be severely injured or worse, death will occur.

The ANSI/IEEE C37.20-2007 arc resistant conformance testing is almost identical to IEC 62271-200 (2001 annex AA) except time duration (500mSeconds versus 1 seconds).

ANSI/IEEE C37.20-2007 indicates that, “failure within a switchgear assembly, whether from a defect, an unusual service condition, lack of maintenance, or mis-operation, may initiate an internal arc. Arc Resistant Switchgear conformance standards were created to provide a means for electrical equipment manufacturers to verify that their designs provided an additional level of protection above standard electrical equipment. “

Standard equipment is designed assuming that everything is properly manufactured, installed, maintained and operates properly. It is not designed to be subjected to a circuit breaker that doesn't interrupt quickly enough when a loose connection is downstream.

Health and Safety Concerns

Arc exposure energy basics:

- Exposure energy is expressed in cal/cm²
- 1 cal/cm² Equals the exposure on the tip of a finger by a cigarette lighter in one second
- An exposure energy of only one or two cal/cm² will cause a 2nd degree burn on human skin

Occurrences involving human exposure to Arc Conditions

1. Surface Phosphate Mine – A miner was injured while preparing to add a 1000 ft. cable to a junction box on a 7,200 volt power circuit. The victim opened the junction box and placed the static grounding clamp assembly across the corner of the open junction box. The grounding clamp assembly fell into the junction box making contact with the energized conductors. An arc flash occurred severely injuring the miner.
2. October 10, 2010 - Michael A. Solomon, contract apprentice electrician, age 42, and two co-workers were seriously injured when an arc flash occurred. They were performing maintenance work on an electrical circuit breaker. The circuit breaker was in the “OFF” position but remained energized on the input side. They were all hospitalized. Solomon died on October 12, 2010, as a result of his injuries.
3. March 23, 2003 – Energy Plus, Inc. Number 50 Mine. A section foreman was using 2-phases of the 480 volt, resistance grounded, 225 amp output, on the section power center to detonate explosives during construction of a boom hole. This resulted in an

electrical arc flash that produced intense heat, resulting in serious burns to the victim's hands and face. The victim died on April 10, 2003 from complications due to these injuries.

4. October 12, 2006 – United Plant Mine. A 24-year old maintenance coordinator, with 1 year and 4 months mining experience, was fatally injured at an iron ore operation. The victim was troubleshooting an electrical fault in a high-voltage motor control center when a sustained arc blast occurred.
5. Burro Chiefe Copper Company – An electrical supervisor was fatally injured while testing a 480 volt electrical circuit breaker. An arc phase fault occurred at the breaker, resulting in an arc flash that injured the supervisor and two other miners. The supervisor died due to injuries sustained in the accident.
6. An electrical accident caused the death of one contract electrician and seriously injured two coworkers. They were installing ground fault indicator lights in a circuit breaker enclosure when an arc flash occurred. They were not aware the circuit breaker enclosure contained a bottom feed circuit breaker and had locked out the wrong disconnect.

These instances of human exposure provide useful evidence of the possible human health effects due to exposure to arc flash incidents.



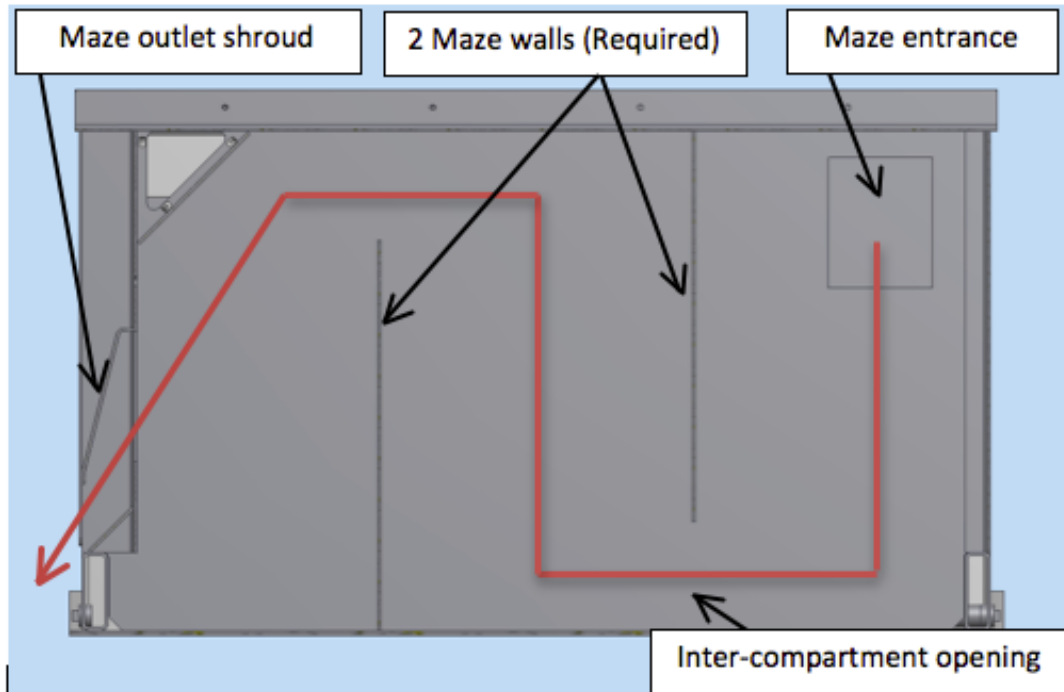
Arc Guard® Technology

Becker Global America offers ARCGUARD® technology, an arc resistant open type mining electrical equipment designed to eliminate arc flash potential and provide an additional degree of protection for personnel performing normal operating duties in proximity to the energized equipment. Such duties include opening or closing breakers, changing relay settings, programming PLC's, reading instruments or other activities that do not require cover removal. The standard features of the ARCGUARD® include:

- Protection to miners at the front, back, and sides of the equipment- 2B rating



- Performance tested to ANSI/IEEE C37.20-2007 at KEMA LABS
- Reinforced enclosure to withstand pressure from internal arcing faults
- Internal venting system with pressure dams and pressure vents to channel the flow of arc fault gases and vent these gases out the top of the gear and away from personnel
- Reinforced sealed top covers and panels
- Reinforced bolted covers
- Ventilation inlet/outlet shrouds



*Figure showing the pressure relief maze cross-section
Red arrow: Flow of the Arc fault gases*

Becker uses a proven technique to lengthen, cool and quench the arc plasma and vapor so the vapor leaving the unit does not harm personnel.

Due to Arc Resistant technology becoming available for all mining applications by Becker and the National Fire Protection Association making Above ground and Underground Mining responsible to follow NFPA70E in 2015, mining companies are requiring Arc Resistant electrical equipment. Other electrical equipment manufacturers are using questionable alternate techniques to provide unproven Arc Resistant equipment.



Arc Flash Relays Only

Arc Flash relays are a backup protection, but should **not be used as a primary means of protection**.

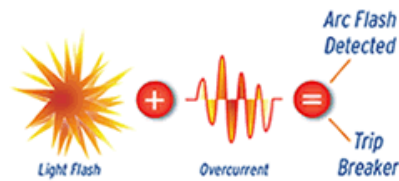
ANSI/IEEE C37.20-2007 indicates that, “Even when arc-resistant construction is specified, it is strongly recommended that supplemental power system protection is provided. This supplemental protection should limit the total energy that can be delivered in the event of internal arcing faults. This protection can be provided in a variety of ways, depending on the nature of the system. Among the forms of protection that may be appropriate are current limiting fuses, current-limiting circuit breakers, zone differential or bus differential relaying, ground differential protection, **or arc-sensing systems sensitive to light or pressure effects that**

accompany internal arcing faults. The objective of such protection must be to cause the interruption of all sources of power to the arcing fault **in a time interval that is shorter than the rated arcing duration** capability demonstrated by the tests contained within this document.”

One problem is that the fiber-optic cable can become crimped or broken completely. Another problem is that it will take the upstream Circuit Breaker at least 50-60m Seconds to trip, if it trips at all. A relay is a secondary Arc Flash backup only.

High-Speed Detection

Arc-flash light sensing and overcurrent protection detect arc-flash hazards and send a trip signal to the breaker in as fast as 2 ms.

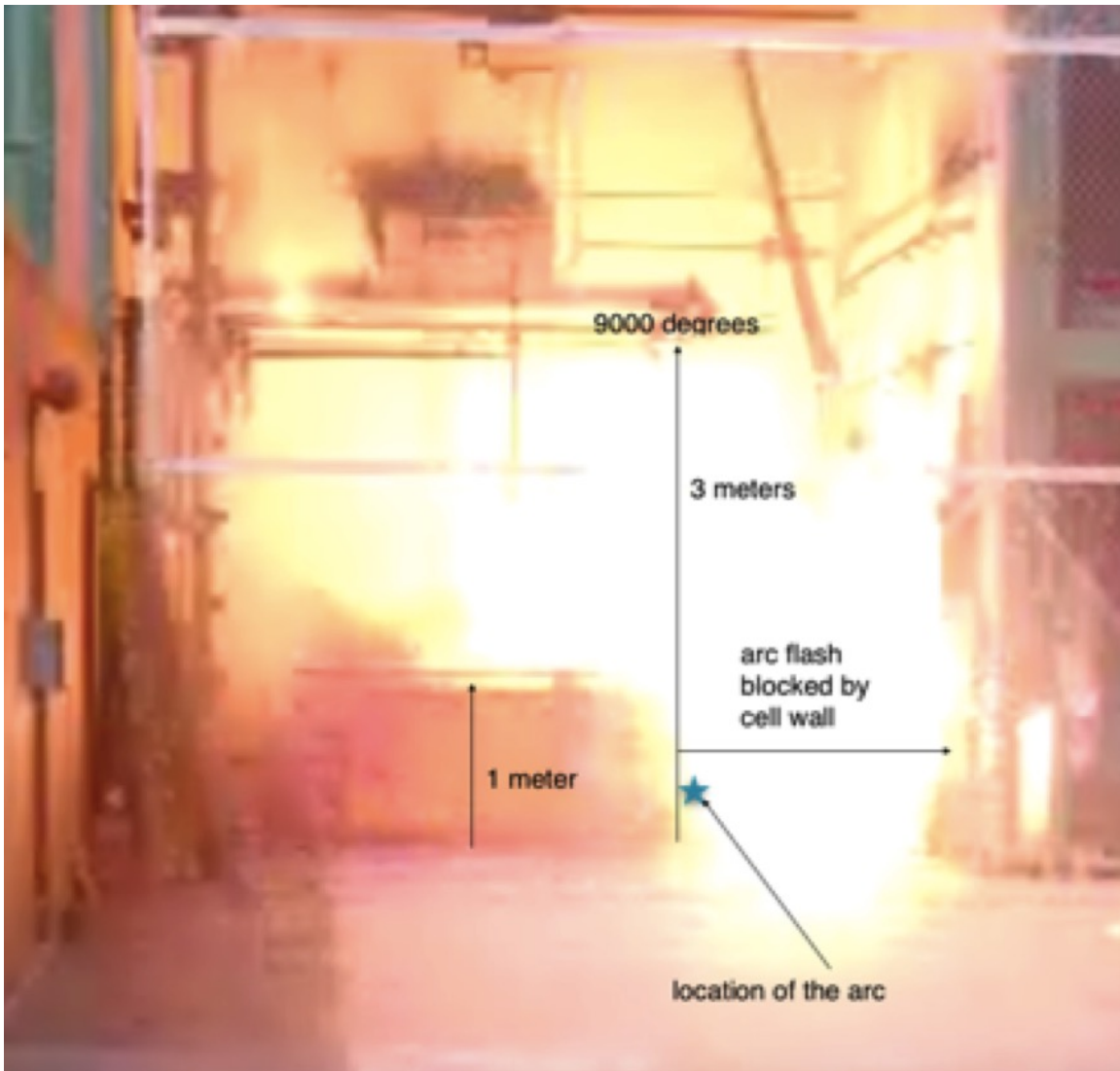


Remote Operators

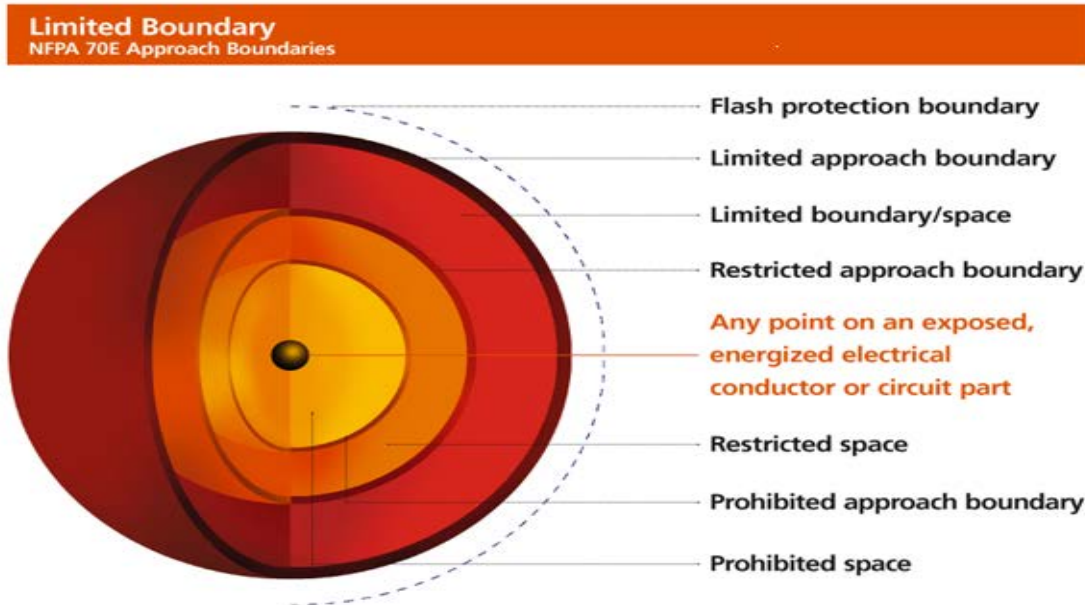
Remote Operators do not qualify a unit as Arc Resistant. It is not a recommended practice for a Miner to use a Remote Operator to operate equipment and consider this a safe practice for mining equipment without proper PPE. Low roof conditions and potentially ventilation pushing vapor make the situation even worse. Testing has proven that arc plasma and molten metal travels **greater than 12 meters** during an arc flash event.



Based on this distance it is also proven that fatal burns can occur at these distances and is not recommended to use remote closing in place of arc resistant build equipment. This alternate choice can result in injury, death, equipment replacement costs, and accident litigation costs. The worker must understand boundary limitation each time operating on the equipment.



The National Fire Protection Association (NFPA) has developed specific approach boundaries designed to protect employees while working on or near energized equipment. These boundaries are:



The limited boundary is for unqualified personnel. No unqualified person may approach any exposed energized conductor any closer than the limited approach boundary. The limited approach boundary is determined by referring to Table 2-1.3.4 in NFPA 70E – Page 51. (2000 Edition. Note that in the 2000 Edition NFPA has added the concept of movable or fixed conductors. In 2000 edition unqualified workers may approach non-moving conductors (fixed buswork for example) more closely than those which may move (overhead lines for example).

Vents

Vents provide the first direction the vapor and plasma escapes from the unit, but as seen in empirical testing this may be the first point where the **unit actually erupts**. Also, personnel may be standing in front of the vents, which would be catastrophic. That is why Arc Resistant equipment is categorized. For example the Becker ARCGUARD® is categorized as Type 2B which means arcing does not cause holes in the freely accessible front, sides, and rear of the enclosure, where miners may work safely at zero distance.



Conclusion

In conclusion, a physical boundary of zero around electrical equipment that has been subjected to testing is the safest option for mine personnel. Additional levels of protection are great, but only as secondary levels of protection and not primary protection. When it comes to protecting the workforce a proven solution integral to the equipment is the best.



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