



Industry Arc Flash Event Results in Serious Burn Injuries

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On March 4, 2009, at the Jubail Project in Riyadh, Saudi Arabia, three workers were removing a 480-volt, molded-case circuit breaker from the bucket of an energized Motor Control Center (MCC) when an electrical arc flash occurred, severely injuring them. All three sustained first- and second-degree burns and were hospitalized following the accident.

The workers had been asked to obtain information about the breaker and tried to remove it to retrieve the information. They did not have an energized electrical work permit, were wearing no PPE other than their hardhats, and wore no arc-rated clothing. (Figure 1-1 shows their hardhats and the breaker on the floor of the utility room post-event.) The face and neck areas of two workers were badly burned, and one of them sustained burns to his hand (Figure 1-2). The third worker suffered scattered burns to his face (likely from molten debris). Figures 1-3 and 1-4 show the burn areas in the utility room where the MCC was located and the proximity of the MCC bucket to the wall. Figure 1-5 shows the inside of the MCC bucket after the event.

An arc flash can release a tremendous amount of concentrated radiant energy at the point of the arcing in a fraction of a second. The result is extremely high temperatures, a tremendous pressure blast, and shrapnel being hurled at velocities in excess of 700 miles per hour. Exposure to an arc flash frequently results in a variety of serious injuries and in some cases death. Workers have been injured even though they were 10 feet or more away from the arc center. Injuries can include damaged hearing and eyesight, as well as severe burns that can require years of skin grafting and rehabilitation.



Figure 1-1. Breaker and hardhats on the utility room floor post-event



Figure 1-2. Arc flash burn to worker's hand



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The workers in Riyadh were fortunate that their injuries were not more serious. They were severely burned primarily because they failed to apply fundamental Integrated Safety Management (ISM) principles to the task. When they realized that the requested breaker information could not be obtained without removing the circuit breaker, they should have stopped and modified the work plan and associated hazard analysis.

The designed controls for the identified hazard should have included, as a first option, the necessary actions to establish an electrically safe work condition before allowing a worker inside the arc flash protection boundary. If removing the hazardous

energy was not feasible, an energized electrical work permit that clearly described all barriers, including appropriate PPE, should have been developed and discussed with each of the workers. Many of the recent electrical events in DOE workplaces occurred when workers failed to recognize that the work scope or conditions were not bounded by the original work plan and hazard analysis.

Another important consideration when planning work is to minimize exposure to the extent possible. If the job that resulted in injury to the three Riyadh workers had been planned properly, it could have been done by a single worker while the



Figure 1-3. Utility room post-event



Figure 1-4. Burn on wall adjacent to MCC



Figure 1-5. Inside of MCC bucket after breaker was removed



others remained outside the hazardous zone. Applying As Low As Reasonably Achievable (ALARA) is a principle that applies to electrical hazards as well as to radiological hazards.

An event similar to this industry event occurred at the Stanford Linear Accelerator Center (SLAC) on October 11, 2004, when a subcontractor journeyman electrician received serious burns from an electrical arc flash. In that event, the electrician was installing a circuit breaker in an energized 480-volt electrical panel, also without a work permit, and wore a short-sleeved cotton/polyester shirt, leather gloves over voltage-rated gloves, safety glasses, and a hardhat. The arc flash ignited the electrician's clothing and knocked his safety backup, who was standing 2 or 3 feet behind him, to the floor. DOE conducted a Type A Accident Investigation following the accident. (ORPS Report SC-OAK--SU-SLAC-2004-0010)

Among the key deficiencies identified by the Type A Accident Investigation Board were the following.

- A pre-work hazards analysis form was not completed.
- There was no approved energized electrical work permit.
- The worker did not wear the appropriate flame-resistant (FR) clothing or all required PPE.
- No one in the SLAC management chain had been informed that the field supervisor had decided to install the circuit breaker in an energized panel.

The Board concluded that if proper permitting procedures had been followed, the work would not have been done. They also concluded that the severity of the injuries could have been significantly reduced or eliminated if proper FR clothing and PPE were used. The Type A Accident Investigation Report is available at http://www.hss.energy.gov/csa/csp/aip/accidents/typea/Type_A_Electrical_Arc_SLAC_20041011.pdf.

In two recent events at DOE sites, workers did not heed warnings about the potential for an arc flash and worked on or around arc-flash designated electrical equipment without wearing the appropriate PPE. Fortunately no one was injured in either event.

On March 31, 2009, at Brookhaven National Laboratory, a worker failed to use proper arc-flash precautions and wear appropriate PPE when he placed a lockout/tagout on a 440-volt load center breaker. The breaker had been identified as arc-flash category "Dangerous" and was labeled DANGER, ARC FLASH HAZARD, HAZARD/RISK CATEGORY DANGEROUS, ENERGIZED WORK PROHIBITED. The worker who placed the lockout/tagout did not understand that the label meant that the breaker could not be operated in an energized condition. He assumed that the labeling applied only to opening the cabinet and working on or near exposed conductors. There was no injury or electrical shock from this event, but there was a potential for a serious injury. Investigation is ongoing. (ORPS Report EM--BHSO-BNL-BNL-2009-0004)

On November 14, 2008, at the Savannah River Site, a DOE Facility Representative saw a vendor retrieve an instrument from the low voltage area of an electrical panel and look into the open door of another electrical panel. Both 480-volt panels were arc-flash labeled. The vendor was not wearing appropriate PPE in either case. Investigators determined that the apparent cause of this event was that the vendor misunderstood site requirements (i.e., Safe Practices On or Near Electrical Conductors or Live Parts). He was also confused about the arc flash PPE required when opening the 480-volt panel door to gain access to the 24-volt electrical panel, which is interlocked to the 480-volt panel and which is not arc-flash labeled. (ORPS Report EM-SR--SRNS-SIPS-2008-0004; final report issued January 29, 2009)



Choosing and wearing proper PPE are critical as final barriers in preventing injuries from an electrical arc flash. Arc flash clothing is made from materials that have an Arc Thermal Performance Value (ATPV), which is defined as the amount of heat energy (calories/cm²) the fabric will absorb or deflect. A heat flux of 1.2 cal/cm² is considered to be the amount of heat required to produce the onset of a second-degree burn to unprotected skin. National Fire Protection Association (NFPA) Standard 70E, *Standard for Electrical Safety in the Workplace*, requires PPE used for arc flash protection to be worn inside the boundary where an exposure to 1.2 cal/cm² would be experienced should an arc flash occur.

All parts of the body that may be exposed to an arc flash should be covered by the appropriate type and quality of PPE. The following is a list of the PPE and clothing that should be worn when working on energized panels.

- V-rated gloves with leather protectors
- V-rated tools
- Non-melting or untreated natural-fiber T-shirt and underwear
- FR pants and shirt (8 calorie/cm²) or FR coverall over cotton long-sleeved shirt and pants
- Safety glasses and hearing protection
- Double-layer switching hood (with FR face shield)
- Leather work shoes

OSHA regulations in 29 CFR 1910.333(c)(2), “Work on Energized Equipment,” state that “only qualified persons may work on electrical circuit parts or equipment that has not been de-energized” and that they “shall be capable of working safely on energized circuits and shall be familiar with the proper

use of special precautionary techniques, personal protective equipment, insulating and shielding materials, and insulated tools.” (http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=standards&p_id=9910)

With regard to PPE, OSHA requirements state the following.

1910.335(a)(1)(i) — 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 for the work to be performed.

1910.335(a)(1)(v) — Employees shall wear PPE 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. (http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=standards&p_id=9912)

In addition, NFPA 70E-2000, *Electrical Safety Requirements for Employee Workplaces*, provides guidance in determining the severity of potential exposure to arc flash and selecting protective equipment. Equations for calculating incident energy and flash protection boundaries are provided in NFPA 70E and in IEEE 1584-2002, *IEEE Guide for Performing Arc-Flash Hazard Calculations*.

The Center of Excellence for Electrical Safety, which was developed by the Energy Facility Contractors Group (EFCOG) Electrical Safety Task Group through a collaborative effort with DOE and the National Nuclear Security Administration, can provide additional information on electrical arc flash. The website is hosted by Los Alamos National Laboratory and can be accessed at <http://www.lanl.gov/safety/electrical/>.



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These events illustrate the dangers associated with an electrical arc flash. Workers should never perform work on energized electrical equipment without an energized electrical work permit that clearly identifies the hazards and appropriate controls. Wearing the correct PPE can reduce the potential for serious burns, and flame-resistant clothing and required PPE should always be worn if there is any chance that an arc flash could occur. Workers must understand that labels indicating that the danger of an arc flash exists are posted to ensure that appropriate precautions are taken when working on equipment so labeled. Pre-job briefings, facility procedures, and training programs should emphasize the danger of electrical arc flash while working on or near energized equipment.

KEYWORDS: Arc flash, burns, injury, PPE, industry event

ISM CORE FUNCTIONS: Analyze the Hazards, Develop and Implement Hazard Controls, Perform Work within Controls