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Electric Arc Flash Protection: A Look to OSHA

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Introduction

Electricity is widely recognized as a serious workplace hazard, exposing employees to electric shock, electrocution, burns, fires, and explosions. Working on or around electric conductors and equipment can be particularly dangerous because electric energy cannot be sensed until contact is made.

Each year many employees suffer pain, injuries, and death from such accidents. According to the Bureau of Labor Statistics, 289 employees, or nearly one a day, were killed by contact with electric current in 2002.[1] According to the National Institute for Occupational Safety and Health, DHHS (NIOSH),[2] burns are the most common injury caused by electricity.

This paper addresses electric arc flash, what causes it, how to mitigate it, and how OSHA expects employers to protect employees from its effects. It also provides guidance about how OSHA might use NFPA 70E, the National Fire Protection Association's *Standard for Electrical Safety in the Workplace* in enforcement activities. Finally, this paper represents the views of the author, is not an OSHA policy document, and does not necessarily reflect the views of OSHA.

Electric Arc Flash

Electric arcs and the resultant flash and blast events occur when powerful, high-amperage currents arc through the air. Arcing is the luminous electrical discharge that occurs when sufficiently high voltage exists across a gap between conductors and current travels through the medium (air). Conditions such as unexpected dropping of tools or unexpected movement of the worker can initiate an arc at energized parts. Arcs can also be caused by a worker handling or causing a conductive object to move and often by equipment failure from abuse or fatigue. Temperatures as high as 35,000°F have been reached in arc-blasts.

Arc burns are the result of exposure to high temperatures produced by electric arcs proximate to a worker. Workers can also be subjected to the extreme force of the blast. If the electric current involved is great enough, electric arcs can start a fire. Extremely high-energy arcs can damage equipment, causing fragmented metal particles to fly in all directions. In atmospheres that contain

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[1] Bureau of Labor Statistics (BLS). 2002. *Census of Fatal Occupational Injuries, Table A-9* (retrieved February 7, 2012) (http://www.bls.gov/iif/oshwc/cfoi/cftb0163.pdf).

[2] *Electrical Safety: Safety and Health for Electrical Trades Student Manual*, Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication Number 2009–113, April 2009 (retrieved February 7, 2012) (http://www.cdc.gov/niosh/docs/2009-113/).

explosive gases or vapors or combustible dusts, even low-energy arcs can cause violent explosions.

According to DHHS (NIOSH),[3] the three primary hazards associated with an arc-blast are:

1. Arcing gives off thermal radiation (heat) and intense light, which can cause burns. Several factors affect the degree of injury, including the area of skin exposed and the type of clothing worn. Proper clothing, increased work distances, and overcurrent protection with quick fault clearing times can reduce the risk of such a burn.
2. A high-voltage arc can produce a considerable pressure wave blast. A person 2 feet away from a 25,000-amp arc feels a force of about 480 pounds on the front of the body. In addition, such an explosion can cause serious ear damage and memory loss due to concussion. Sometimes the pressure wave throws the victim away from the arc blast. While this may reduce further exposure to the thermal energy, serious physical injury may result. The pressure wave can propel large objects over great distances. In some cases, the pressure wave has enough force to snap off the heads of steel bolts and knock over walls.
3. A high-voltage arc can also cause many of the copper and aluminum components in electrical equipment to melt. These droplets of molten metal can be blasted great distances by the pressure wave. Although these droplets harden rapidly, they can still be hot enough to cause serious burns or cause ordinary clothing to catch fire, even if the employee is 10 feet or more away.

Burns suffered in electrical accidents can be very serious. These burns can be of three basic types: electrical burns, arc burns, and thermal contact burns.

Often, clothing, if it is flammable, ignites. When it ignites, it continues to burn until extinguished by an outside agent. Clothing has ignited, causing burn fatalities that would not have occurred if the clothing had been flame resistant. To appropriately protect employees from electric arc events, potentially exposed employees must use protective equipment that is designed and constructed for the part of the body to be protected and for the tasks to be performed. Arc-rated and nonconductive equipment manufactured and tested to ASTM standards[4] is available to protect workers from such dangers of injury from electric-arc blasts, including head and face protection from flying objects spewed from electric explosions. Clothing intended to protect from electric arcs is arc rated and has an arc thermal performance value (ATPV) as defined in ASTM F1959 / F1959M - 06ae1, the *Standard Test Method for Determining the Arc Thermal Performance Value of Materials for Clothing*. Specification for Arc and Flame-Resistant Rainwear, for protective raingear. The ATPV for clothing is given in a calories per centimeter rating established by ASTM testing means.

Employers are able to calculate the incident arc energy and select appropriately ATPV-rated garments. The resultant value allows selection of protective apparel, because it correlates with ASTM F 1506 - 10a, the *Standard Performance Specification for Flame Resistant Textile Materials for Wearing Apparel for Use by Electrical Workers Exposed to Momentary Electric Arc and Related Thermal Hazards*, ASTM F1891 - 06, the *Standard Specification for Arc and Flame Resistant Rainwear*, and ASTM F2178 - 08, the *Standard Test Method for Determining the Arc Rating of Face Protective Products.*

Hazard Recognition

[3] Ibid.
[4] ASTM standards are available from ASTM International Standards, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959.

Prior to protecting employees with ATPV-rated clothing, insulating gloves, and the like, serious workplace hazards, such as electric shock, electrocutions, burns, fires, and explosions, must first be identified. This means that work area must be inspected for inadequate or inappropriate wiring, exposed electrical parts, overhead powerlines, overloaded circuits, wires with bad insulation, broken or damaged equipment, and electrical systems that are not properly grounded. Electrical hazards can be made worse if the worker, location, or equipment is wet.

Other considerations include evaluation of the method by which the intended work will be performed, including electric tools and electric equipment that are appropriate for the task.

Hazard Mitigation

It is also important to control the identified hazards. Using the wrong tool or personal protective equipment (PPE) is dangerous. For example, an incorrectly rated meter can explode or the ATPV rating of protective clothing could be inadequate for the exposure.

OSHA's preferred mitigation method for controlling electrically related hazards is to deenergize the electric circuits and equipment involved and to lock out the disconnecting means. This single safe work practice significantly reduces the likelihood of arc-flash burn injury by reducing employee exposure to electrical hazards. All circuits and equipment, including "deenergized" ones, must be treated as if they are energized until they are locked out and tagged, grounded, and confirmed.

To comply with OSHA's standards, a qualified person must confirm a de-energized state by use of a test instrument, before work is started. Further, to ensure a safe work environment, guard appropriately against contact with electric voltages and control electric currents.

OSHA'S Requirements for Protecting Employees

❑ Prevent Exposure to Live Electric Circuits and Parts by De-energizing Them

With limited exceptions, OSHA requires that live parts to which an employee may be exposed must be deenergized before the employee works on or near them. Energized circuit parts that operate at less than 50 volts to ground do not need to be deenergized if there will be no increased exposure to electrical burns or to explosions from electric arcs (§ 1910.333(a)(1)[5]).

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[5] 29 CFR 1910.333(a)(1) states:
"Deenergized parts." Live parts to which an employee may be exposed shall be deenergized before the employee works on or near them, unless the employer can demonstrate that deenergizing introduces additional or increased hazards or is infeasible due to equipment design or operational limitations. Live parts that operate at less than 50 volts to ground need not be deenergized if there will be no increased exposure to electrical burns or to explosion due to electric arcs.
Note 1: Examples of increased or additional hazards include interruption of life support equipment, deactivation of emergency alarm systems, shutdown of hazardous location ventilation equipment, or removal of illumination for an area.
Note 2: Examples of work that may be performed on or near energized circuit parts because of infeasibility due to equipment design or operational limitations include testing of electric circuits that can only be performed with the circuit energized and work on circuits that form an integral part of a continuous industrial process in a chemical plant that would otherwise need to be completely shut down in order to permit work on one circuit or piece of equipment.
Note 3: Work on or near deenergized parts is covered by paragraph (b) of [29 CFR 1910.333].

OSHA's preference for deenergizing electric equipment is based on NFPA 70E and on accident data. NFPA 70E—2012 under Section 100—*Definitions* defines an *Electrically Safe Work Condition* as "[a] state in which an electrical conductor or circuit part has been disconnected from energized parts, locked/tagged in accordance with established standards, tested to ensure the absence of voltage, and grounded if determined necessary."

In the preamble to the 29 CFR Part 1910 *Electrical Safety-Related Work Practices Final Rule* dated August 66, 1990, OSHA justified its preference for deenergizing stating that "[m]ore than ten percent of the fatalities listed in Table 2[6] were attributable, to the employer's failure to deenergize and lockout electric circuits or equipment."

The preamble further explained that:

Of the 13 workers killed, 9 appeared to be qualified for the task being performed. Obviously, none of the fatalities was caused by a deenergized circuit (though some fatalities involved circuits that were thought to be deenergized). For this reason, OSHA has not accepted the argument that a qualified employee can work on energized circuits as safely as he or she can work on deenergized circuits. Therefore, OSHA is not leaving it to the employer's discretion as to whether or not to deenergize electric circuits on the basis of convenience, custom, or expediency.

❑ Lock Out and Tag Out Circuits and Equipment

Obviously, electric equipment and circuits that are assuredly deenergized preclude the potential for electric shock or electric arc-flash hazards. Create a safe work environment by locking out and tagging out circuits and machines. Once the circuit has been shut off and de-energized, lock out the switchgear to the circuit so the power cannot be turned back on inadvertently. Then, tag out the circuit with easy-to-see signs or labels to identify to everyone the employees working on the circuit. Before beginning work, have qualified person test the circuit with a test instrument to make sure it is de-energized.

❑ Prevent Shocking Currents from Electrical Systems and Equipment by Grounding Them

Even though specific parts of the circuit have been deenergized and presumed to be safe, the installation of protective grounding provides assurance against any energized condition that could exist as a result of inadvertently induced voltage or unrelated voltage backfeed. Specifically, capacitors must be discharged and high capacitance elements must be short-circuited and grounded, if the stored electric energy might endanger personnel. Also, if work is to be performed near overhead lines, the deenergized lines must be grounded, or other protective measures must be provided before work is started. Arrangements to deenergize and ground them must be made with the person or organization (such as the electric utility) that operates or controls the electric circuits involved.

❑ Use Safety-Related Work Practices.

29 CFR 1910.333 sets forth the general requirement that safety-related work practices must be employed to prevent electric shock or other injuries resulting from either direct or indirect

[6] Table 2 is a general breakdown, by type, of fatalities and accidents that appeared to be indicate that an unsafe act was involved. Primary causes were use of equipment or material too close to energized lines, assuming an unsafe position, and failure to deenergize electric equipment.

electrical contacts, when work is performed near or on equipment or circuits which are or may be energized. The specific safety-related work practices must be consistent with the nature and extent of the associated electrical hazards.

OSHA's requirements for protecting employees working on electric circuits and equipment allow for three options: [*55 Federal Register 31984 – 32020, 32000* (August 6, 1990]

1. Deenergize the equipment involved (§ 1910.333((a)(1)) and lockout its disconnecting means (§ 1910.333(b)); or
2. Deenergize the equipment (§ 1910.333((a)(1)) and tag disconnecting means, if the employer can demonstrate that tagging is as safe as locking (§ 1910.333(b)); or
3. If it is not feasible to deenergize the equipment, work it energized (§ 1910.333(c)).

❑ Work on or Near Energized Electrical Systems and Equipment Where it is not Feasible to De-energize Them

When work is being done on or near energized circuits or parts, an unexpected condition, action, or human error can place the employee at risk of contacting hazardous voltages. Conductive parts can fall or tools could be dropped onto exposed (bare), energized circuit parts, or unexpected movement of the worker can initiate an arc at the energized circuit. However, deenergizing is not always required. OSHA realizes situations where it is necessary to work on or near exposed parts of electric circuits or equipment while the circuit or equipment remains energized.

OSHA recognizes two conditions under which circuits and equipment could remain energized: (1) If the employer can demonstrate that deenergizing would create additional or increased hazards or (2) if the employer can demonstrate that deenergizing is infeasible due to equipment design or operational considerations (Notes 1 and 2 to § 1910.333(a)(1)).

In most instances, however, OSHA expects that work can be scheduled to allow deenergization without interfering with the operation of facility or equipment. Moreover, the preamble to final Subpart S explains that Section 1910.333(a)(1) does not permit an employer to work on energized electric circuits or equipment simply "on the basis of convenience, custom, or expediency." [ibid.]

❑ Prevent Exposure to Live Electric Circuits Parts by Using Other Safety-Related Work Practices.

When it is necessary, under the limited exceptions to 29 CFR 1910.333(a)(1), to work on or near exposed energized parts of electric circuits or equipment, specific safety-related work practices must be used and must be consistent with the nature and extent of the associated electrical hazards. Paragraph (c) of § 1910.333 identifies the precautions to be taken to prevent accidents when work is performed on exposed live parts (involving either direct contact or by means of tools or materials) or near enough to them for employees to be exposed to any hazard they present. Requirements are given pertaining to work near overhead lines, illumination, confined work areas, conductive materials and equipment, portable ladders, conductive apparel, and housekeeping duties.

❑Use Appropriate Personal Protective Equipment and Insulated Tools

OSHA requires that workers be provided with personal protective equipment (PPE). This equipment must meet OSHA requirements and be appropriate for the parts of the body that need

protection and the work performed. There are many types of PPE: rubber gloves, insulating shoes and boots, face shields, safety glasses, hard hats, arc-thermal-performance-value (ATPV) rated clothing, etc. Even if regulations did not exist requiring the use of PPE, there would still be every reason to use this equipment. PPE helps keep employees safe. It is the last line of defense between the employee and the hazard.

OSHA's present requirements in Subpart S, *Safety-Related Work Practices*, are based on NFPA 70E-1983, which did not at that time include specific provisions for ATPV-rated clothing [protective equipment]. Although more recent versions of NFPA 70E have included such body protection provisions, OSHA has not conducted rulemaking proceedings to update Subpart S by adopting comparable provisions specifically related to the use of ATPV-rated clothing to protect against arc-flash hazards. OSHA's existing Subpart S, therefore, does not include a specific requirement for the use of ATPV-rated clothing.

However, arc-flash hazards are addressed in the OSHA electrical safety-related work practices standards. For example, with respect to arc-flash burn hazard prevention, the general provisions for the Selection and use of work practices contained in §1910.333(a)(1) generally require deenergization of live parts before an employee works on or near them — i.e., employees must first render electric equipment safe by completely deenergizing it by means of lockout and tagging procedures. This single safe work practice significantly reduces the likelihood of arc-flash burn injury by reducing employee exposure to electrical hazards — i.e., exposure is limited to the act of shutting down the equipment and when the qualified employee verifies, by use of a test instrument, a deenergized state.

When employees perform work on energized circuits, as permitted by §1910.333(a)(1), tools and handling equipment that might make contact with exposed energized parts must be insulated in accordance with §1910.335(a)(2)(i). This work practice also reduces the likelihood of employee injury caused by an arc blast.

Arc-flash hazards are also addressed in §1910.335(a)(1)(v), Safeguards for personnel protection, which requires that personal protective Equipment (PPE) for the eyes and face be worn whenever there is danger of injury to the eyes or face from electric arcs or flashes or from flying objects resulting from an electrical explosion. In addition, paragraph (a)(2)(ii) of §1910.335 requires, in pertinent part, the use of protective shields, barriers, or insulating equipment "to protect each employee from shocks, burns, or other electrically related injuries while that employee is working . . . *where dangerous electric heating or arcing might occur*" (emphasis added). The §1910.335(a)(2)(ii) safeguard selected — shield, barrier, or insulating material — must fully protect employees from electric shock, the blast, and arc-flash burn hazards associated with the incident energy exposure for the specific task to be performed. However, in situations where a fully protective safeguard could be used as an alternative, OSHA will, under its policy for *de minimis* violations,[7] allow employers to use, instead, safeguards that are not fully protective, provided that the employer implements additional measures. The supplemental measures, which could include the use of arc-rated FR clothing appropriate to the specific task, **must fully protect** the employee from all residual hazardous energy (e.g., the resultant thermal effects from the electric arc) that passes the initial safeguard.

[7] Under the current OSHA policy on *de minimis* violations, employers are allowed to comply with the most current consensus standards applicable to their operations, rather than with the OSHA standard in effect at the time of inspection, **when the employer's action provides equal or greater employee protection**.

Where there is no §1910.335(a)(2)(ii) safeguard that would fully protect against the hazards, an employer is still obligated under the Occupational Safety and Health Act of 1970 to take reasonable steps that will protect the employee to the degree possible.[8] As noted in the previous paragraph, the protection provided by a safeguard that is not fully effective can be augmented through use of other safety measures such as FR clothing and other appropriate PPE.

OSHA recommends that employers consult consensus standards such as NFPA 70E-2004 to identify safety measures that can be used to comply with or supplement the requirements of OSHA's standards for preventing or protecting against arc-flash hazards. For example, Section 130.3 of the NFPA standard establishes its own mandatory provisions for flash-hazard-analysis[9], which sets forth the criteria to define a flash-protection boundary and the personal protective equipment for use by employees within the flash-protection boundary. The goal of this provision is to reduce the possibility of being injured by an arc-flash. The analysis is task specific and determines the worker's incident-energy exposure (in calories per square centimeter). Where it has been determined that work will be performed within the flash-protection boundary, NFPA 70E specifies that flame-resistant clothing and PPE use either be based on the pre-determined incident-energy exposure data or be in accordance with the *Hazard/Risk Category Classifications* and *Protective Clothing and Personal Protective Equipment (PPE)* matrix tables contained in Sections 130.7(C)(15) and (C)(16), respectively.

Other NFPA 70E, Article 130 provisions, such as the justification for work through the use of an energized electrical work authorization permit, and the completion of a job briefing with employees before they start each job, additionally decrease the likelihood that exposure to electrical hazards would occur.

Summary

OSHA’s preferred mitigation procedure for controlling electrically related hazards, including electric arc flash, is to deenergize the electric circuits and equipment involved and to lock out the disconnecting means. This single safe work practice significantly reduces the likelihood of arc-flash burn injury by reducing employee exposure to electrical hazards.

OSHA’s requirements for protecting employees working on electric circuits and equipment allow for three options: [*55 Federal Register 31984 – 32020, 32000* (August 6, 1990)]

1. Deenergize the equipment involved (§ 1910.333((a)(1)) and lockout its disconnecting means (§ 1910.333(b)); or
2. Deenergize the equipment (§ 1910.333((a)(1)) and tag disconnecting means, if the employer can demonstrate that tagging is as safe as locking (§ 1910.333(b)); or
3. If it is not feasible to deenergize the equipment, work it energized (§ 1910.333(c)).

Create an electrically safe work condition by doing the following:

❑ Lock out and tag out circuits and machines;

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[8] To establish all of the elements of the affirmative defense of impossibility, an employer who can show that compliance with the terms of a standard is impossible under the circumstances must also show that it used alternative measures to protect employees, or that there were no such control measures.

[9] This flash hazard analysis information represents recognized good engineering practice and can be useful guidance for both OSHA personnel and employers applying the provisions contained in the electrical safety-related work practice standards contained in 29 CFR §§1910.331 through 1910.335.

❑ Verify circuits are de-energized before starting work;

❑ Treat all conductors—even "de-energized" ones—as if they are energized until they are locked out and tagged;

❑ Prevent exposure to live electrical parts by isolating them;

❑ Prevent exposure to live wires and parts by using insulation;

❑ Prevent shocking currents from electrical systems and equipment by grounding them;

❑ Exercise caution when working on or near exposed energized conductors and equipment; and

❑ Use appropriate personal protective equipment and insulated tools.

Bibliography

Bureau of Labor Statistics (BLS). 2002. *Census of Fatal Occupational Injuries, Table A-9* (retrieved February 7, 2012) (http://www.bls.gov/iif/oshwc/cfoi/cftb0163.pdf).

Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH). April 2009. NIOSH Publication Number 2009–113, *Electrical Safety: Safety and Health for Electrical Trades Student Manual* (retrieved February 7, 2012) (http://www.cdc.gov/niosh/docs/2009-113/).

Lee, Ralph H., "Electrical Safety in Industrial Plants," *IEEE Transactions on Industry and General Applications*, Vol. IGA-7, Jan. /Feb. 1971. 10-16.

National Fire Protection Association (NFPA). 2012., *Standard for Electrical Safety in the Workplace* (NFPA 70E). Quincy, MA: National Fire Protection Association.

Lee, Ralph H., "The Other Electrical Hazard; Electric Arc Blast Burns," *IEEE Transactions on Industry Applications*, Vol. IA-18, No. 3, May/June 1982.

Lee, Ralph H., "Pressures Developed by Arcs," *IEEE Transactions on Industry Applications*, Vol. IA-23, No. 4, July/Aug. 1987. 760.

Occupational Safety and Health Administration (OSHA). February 14, 2007. 29 CFR 1910, Subpart S, *Electrical Standard* (retrieved February 7, 2012) (http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10135).

Occupational Safety and Health Administration (OSHA). August 6, 1990. 29 CFR 1910.331, *Electrical Safety-Related Work Practices* (retrieved February 7, 2012) (http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9908).

Occupational Safety and Health Administration (OSHA). September 1, 1989. 29 CFR 1910.147, "*Control of Hazardous Energy Source (Lockout/Tagout)*, (retrieved February 7, 2012) (http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9804).

Occupational Safety and Health Administration (OSHA) letter of interpretation dated November 14, 2006. *OSHA requirements for warning signs and protection from electric-arc-flash hazards and compliance with NFPA 70E-2004* (retrieved February 7, 2012) (https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=INTERPRETATIONS&p_id=25557).

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