

## **Electrical Safety by Design and Maintenance**

**Dennis K. Neitzel, CPE  
Director Emeritus  
AVO Training Institute, Inc.  
Dallas, TX**

### **Introduction**

Owners, operators, installers, and maintainers of commercial and industrial electric power systems and equipment, along with design consultants and manufacturers, should be concerned with the electrical safety aspects associated with these systems and equipment. Electrical safety must be an integral part of all electrical equipment and systems design and installations. An in-depth knowledge and understanding of all applicable codes, standards, and regulations is a must for electrical safety in design. Safety professionals and officers knowledgeable in electrical equipment and systems as well as electrical safety must be included in the planning and design phases of all projects to insure that safety is discussed and included in the design.

Electrical safety in design and maintenance is critical because there are approximately 400 electrocutions each year in industry, with more than half of them occurring at less than 600 volts. There are also more than 2000 people admitted to burn centers each year from arc flash-related burns. Additionally, over 800 people die annually due to fires caused by electrical faults, mainly due to faulty design, installation, or maintenance of the electrical equipment and/or systems. Each year, electrical mishaps account for thousands of people sustaining shock and burn injuries. Electrical failures also result in billions of dollars in property damage each year; the vast majority of these incidents could have been prevented by applying electrical safety in the design, installation and maintenance of the electrical equipment and systems.

Current standards and regulations place minimum requirements on electrical system designers, installers, and manufacturers, which yields functional, reasonably safe electrical installations. Knowledge of the electrical hazards will assist in going beyond the minimum requirements and providing a safe and reliable electrical power system.

Effective electrical preventive maintenance begins with good design. When designing a new facility, a conscious effort should be made to ensure optimum maintainability of the installed system and equipment. Design and installation of dual or redundant circuits, tie circuits, auxiliary power sources, and drawout protective devices make it easier to schedule maintenance activities and to perform the required maintenance work, with minimum interruption of production. Other

effective design techniques that should be considered include, but are not limited to, equipment rooms to provide environmental protection, grouping of equipment for more convenience and accessibility, and standardization of equipment and components.

## **Electrical Hazards**

In order to fully understand the electrical safety issues associated with design, installation, and maintenance, there must be an understanding of the hazards of electricity, identified through completing the electrical hazard analysis required by OSHA 1910.132(d)(1) and NFPA 70E Section 130.3(B)(1). One very important point to make here is that the physics of electricity are the same for everyone who has any kind of interface with electricity, even something as simple as plugging in an electrical appliance or portable tool; the physics are the same and do not change from the installer to the maintenance employee, or for that matter, anyone else.

The three main hazards of electricity are electrical shock, electrical arc flash, and electrical arc blast, along with the physiological effects on the human body. These hazards must be understood by everyone who designs, installs, maintains, or works on, near, or interfaces with electrical circuits and equipment. These hazards must be understood by designers to help them better understand what needs to be done and why, when it comes to designing hazards out and safety in.

Designing and installing electrical equipment and systems in accordance with applicable standards, such as the National Equipment Manufacturer's Association (NEMA), the National Electrical Code (NEC), the National Electrical Safety Code (NESC), the IEEE Color Book series for industrial and commercial power systems, and where applicable the Canadian Standards Association (CSA), the International Electrotechnical Commission (IEC), or the City and Guilds standards for design, manufacture, and installation of the electrical equipment and systems, will provide the minimum requirements for safety by design. Complying with these standards for design and installation, along with properly maintaining electrical equipment in its original condition can dramatically reduce the risk of the electrical shock and/or arc-flash hazards.

Adhering to safe work practices for personnel, along with complying with the maintenance recommendations for electrical equipment, provided by the Occupational Safety and Health Administration (OSHA), the National Fire Protection Association (NFPA; using NFPA 70E, *Standard for Electrical Safety in the Workplace* and NFPA 70B, *Recommended Practice for Electrical Equipment Maintenance*), the InterNational Electrical Testing Association (NETA) *Standard for Maintenance Testing Specifications for Electric Power Distribution Equipment and Systems* (MTS), and the NESC, along with the manufacturer's instructions, can significantly reduce the risk of a person making contact with energized conductors or circuit parts and can reduce the risk of an arc flash event occurring, as well as significantly increasing the reliability of the electrical equipment and system.

### Electrical Shock

Electrical shock occurs when a person's body completes the current path between two energized conductors of a circuit or between an energized conductor and a grounded surface or object. Essentially, when there is a difference in potential (voltage) from one part of the body to another, current will flow.

The effects of an electrical shock on the human body can vary from a slight tingle to immediate cardiac arrest. The severity depends on several factors:

- Body resistance (wet or dry skin are major factors of resistance)
- Circuit voltage (50 volts to ground or more is considered by OSHA, IEEE, and NFPA as being hazardous voltage)
- Amount of current flowing through the body [determined by the circuit voltage divided by the body resistance  $I \text{ (current)} = E \text{ (voltage)} / R \text{ (resistance)}$ ]
- Current path through the body (if it passes through an vital organ it can be fatal)
- Area of contact
- Duration of contact

The “Shock Hazard Analysis” required by NFPA 70E Section 130.4 provides the guidance needed to determine the level of shock hazard (voltage). This analysis also determines the shock protection boundaries, as well as the approach limits for qualified and unqualified employees, along with the required shock protection PPE, i.e., rubber insulating gloves with leather protectors, rubber insulating sleeves, rubber insulating blankets, etc.

### Electrical Arc Flash

An electrical arc flash is the rapid release of energy due to an arcing fault of either phase-to-phase, phase-to-neutral, or phase-to-ground. Typically when one of these three conditions is initiated it will end up with all three occurring, because the air becomes a conductor due to ionization along with the plasma created from the vaporized metals, particularly copper. Simply put, an arc flash is a phenomenon where a flashover of electric current leaves its intended path and travels through the air from one conductor to another, or to ground. The results are often violent, and when a human is in close proximity to the arc flash, serious injury and even death can occur. Because of the violent nature of an arc-flash exposure, when an employee is injured, the injury is serious – even resulting in death. It’s not uncommon for an injured employee to never regain their past quality of life.

There are various studies on the causes of electrical injuries that show a large number these injuries involve burns from electrical arcs. There are actually three different issues with the arc flash hazard: the arc temperature; the incident energy; and the pressure developed by the arc. The main concern with the arc temperature, which can be as high as 36,000<sup>0</sup>F, is the flash flame and ignition of clothing. At approximately 203<sup>0</sup>F (96<sup>0</sup>C) for one-tenth of a second (6 cycles), the skin is rendered incurable or in other words a third-degree burn and at approximately 172<sup>0</sup>F (78<sup>0</sup>C) for one-tenth of a second (6 cycles) a person could receive a second degree burn. The incident energy threshold for the onset of a third degree burn is approximately 10.7 cal/cm<sup>2</sup> and the incident energy threshold for a second-degree burn is approximately 1.2 cal/cm<sup>2</sup>. As can be seen by this, it does not take a very high temperature or very much incident energy to cause severe injury, which can result in extreme pain and discomfort or even death to the worker.

The “Arc Flash Hazard Analysis” required by NFPA 70E Section 130.5 is used to determine the incident energy of an electrical arc, to establish the Arc Flash Boundary, and to determine the level of arc-rated clothing and PPE required for protecting employees.

### Electrical Arc Blast

Another major hazard of electricity is the rapid expansion of the air caused by an electrical arc. This occurrence is referred to as an electrical arc blast or, in other words, an explosion.

According to studies on the subject, the pressures from an electric arc are developed from two sources: the expansion of the metal in boiling and vaporizing, and the heating of the air by passage of the arc through it. Copper, when vaporized, expands by a factor of approximately 67,000 times; therefore one inch<sup>3</sup> of copper converts to 1.44 yards<sup>3</sup> of vapor instantly, which causes this rapid expansion and the resulting blast or explosion.

The arc flash coupled with the arc blast presents a very serious and dangerous situation for anyone working on or near, or otherwise interfacing with, the electrical equipment. While there is PPE for protecting employees from the shock and arc flash hazards there is no PPE for the arc blast hazard. The only thing that can be done for protection from the arc blast is to incorporate safe work practices that include correct body positioning when operating or otherwise interacting with the electrical equipment. A good practice is to never stand where the body would be in the direct “line-of-fire” should an arc flash/blast occur.

Ralph Lee’s paper, entitled “Pressures Developed by Arcs” (IEEE 1987), discusses methods that can be used to determine the amount of damage that a short circuit can cause in switchgear and the buildings where the switchgear is located.

## **Electrical Safety Design Considerations**

With the above information concerning the hazards of electricity, the electrical equipment and systems engineers and designers are better equipped to design out the electrical hazards and design in electrical safety. There has been an increased effort over the last few decades to design electrical equipment with greater emphasis on safety, not only for the equipment and installation, but also for the personnel who operate and maintain, or otherwise interface, with the equipment.

Another consideration would be to include the maintenance supervisor and plant or facility engineer, along with the facility safety professional, in the design of electrical systems and equipment. These individuals are generally not considered or included in the design, when they should have an open line of communication with design engineering and supervision. Frequently, an unsafe installation or one that requires excessive maintenance can be traced to improper design or construction methods or misapplication of hardware and equipment. Everyone who can be affected by the design and installation of electrical equipment and systems should be consulted early in the design, preferably starting with the conceptual design phase of the project.

Although electrical systems are typically designed and installed according to the NEC, and other applicable standards, the real safety emphasis was placed on the design and installation of electrical equipment and systems when OSHA issued the Final Rule of 29 CFR 1910 Subpart S, *Electrical Standards*, 1910.302-308, *Design Safety Standards for Electric Utilization Systems*, on January 16, 1981. This regulation was recently revised and updated on February 14, 2007. This provided a Federal mandate on design and installation issues that related to the safety of employees working on, near, or with the electrical systems and equipment.

This emphasis increased for electrical equipment when OSHA published the Final Rule of 29 CFR 1910.147, *The Control of Hazardous Energy (lockout/tagout)* on September 1, 1989, which required that machines and equipment be manufactured with energy isolating devices (lockout/tagout). Effective energy isolation is a key to electrical safety because it provides a

means to deenergize the equipment so that it can be worked on in an electrically safe working condition. This regulatory requirement is quoted below:

OSHA 29 CFR 1910.147(c)(2)(iii) requires all electrical equipment be capable of being locked out. OSHA states: “*After January 2, 1990, whenever replacement or major repair, renovation or modification of a machine or equipment is performed, and whenever new machines or equipment are installed, energy isolating devices for such machine or equipment shall be designed to accept a lockout device.*”

Additional emphasis placed on electrical safety that would have a dramatic influence on the design, manufacturing, and installation of electrical equipment and systems has increased with the publication of OSHA 29 CFR 1910.331-.335, *Electrical Safety-Related Work Practices* on August 6, 1990; OSHA 29 CFR 1910.269, *Electric Power Generation, Transmission, and Distribution* on January 31, 1994 (OSHA Proposed Revision June 15, 2005); and the revisions of NFPA 70E, *Standard for Electrical Safety in the Workplace* over the past twenty years, that includes the 1995, 2000, 2004, 2009, and 2012, all of which are dedicated to electrical safety.

NFPA 70E, Informative Annex O, titled *Safety-Related Design Requirements*, provides some general design considerations for electrical systems that include:

- Owners, managers, and employers are responsible for performing an electrical hazard analysis during the design of electrical systems and installations in order to more effectively choose design options that would reduce or eliminate employee exposure to hazard risks and to enhance the effectiveness of electrical safety.
- Factors that have an impact on safety-related work practices to protect employees must be considered.
- The NFPA 70E, 130.3(B)(1), Electrical hazard Analysis results, should be used to compare design options and choices to facilitate decisions in the design of the electrical equipment and systems, and serve to:
  - Eliminate electrical hazards risk
  - Reduce frequency of exposure to electrical hazards
  - Reduce the magnitude and severity of hazard exposure
  - Enable the ability to achieve an electrically safe work condition as noted in the requirements of OSHA 29 CFR 1910.147, stated above. Also to enable the use of the electrical energy control requirements of NFPA 70E Article 120, *Establishing an Electrically Safe Work Condition* and OSHA 29 CFR 1910.333(b), *Working on or near exposed deenergized parts* for performing an electrical lockout/tagout.
  - Enhance the effectiveness of the electrical safety-related work practices
- Arc energy reduction is another consideration through the use of:
  - Zone-selective interlocking
  - Differential relaying
  - Energy-reducing maintenance switching with local status indicator
    - This feature sets the circuit breaker trip unit to a faster operating time, which will reduce the incident energy if an arc flash were to occur while the worker is working within the arc flash boundary.
  - High speed microprocessor based protective relaying
  - High speed optic sensors

Always keep in mind that no matter how fast the sensors or relaying are, the end device is still an electro-mechanical circuit breaker that can fail to open in the time specified. Mechanical devices, such as circuit breakers, must be maintained in accordance with the manufacturer's specifications. Even this is not a 100% guarantee, but it is the best we can do to minimize the risk of an unintentional time delay or total failure of the device. There is more information on this in the section titled Electrical Equipment Maintenance.

There is a new IEEE Std 1814 *Recommended Practice for Electrical System Design Techniques to Improve Electrical Safety* being developed that will address some of the common concerns related to safety by design. The following information is provided in order to provide a better understanding of this new standard; the Scope, Purpose, Need for the Project, and Stakeholders for the Standard is provided below:

**Scope:** This Recommended Practice addresses system and equipment design techniques and equipment selection that will improve electrical safety. The techniques in this Practice are intended to supplement the minimum requirements of installation codes and equipment standards. It does not include communications, programming, or life safety systems such as fire alarm and security.

**Purpose:** This Recommended Practice provides a "tool kit" of techniques to enable the system designer to specify equipment features, apply protective schemes, and make informed system installation design choices.

**Need for the Project:** There is currently no publication by an accepted standards entity that effectively communicates "electrical safety by design" concepts and their benefits. Current standards place only minimum requirements on electrical system designers and manufacturers that yield functional, reasonably safe electrical installations. There is a need to capture, in one location, the wealth of "electrical safety by design" concepts that have been published in recent IEEE papers and in other industry sources.

**Stakeholders for the Standard:** Owners, operators, installers and maintainers of industrial, commercial, power generation facilities, design consultants, and manufacturers.

The standard will address the following topics:

- System Design – General
- System Design – Operations & Maintenance
- System and Equipment Grounding and Bonding
- Power System Protection
- Electrical Equipment
- Environment (under consideration)
- Heat Tracing (under consideration)
- Labeling & Signage
- Lighting

Electrical equipment and systems must be designed such that there are no exposed energized conductors or circuit parts when they are under normal operating conditions. When energized

parts are exposed for maintenance purposes, they must be suitably guarded to prevent contact by personnel who are in the vicinity of the equipment or system.

A short-circuit current study must be performed in order to ensure that electrical equipment and systems have a sufficient interrupting rating for the available short-circuit current. This study should be evaluated at least every five years or after any system or equipment modifications to ensure that nothing has changed that would cause an increase in the available short-circuit current. High impedance devices such as current-limiting reactors can be installed in an electrical system to reduce the available short-circuit current. If these devices are installed, the coordination of the circuit protective devices must be verified and adjusted in order to prevent longer clearing times that may increase the available incident energy of an arc flash. Installing current-limiting devices requires a complete electrical equipment and system coordination study to ensure that all components work together to decrease electrical hazards, especially the arc flash hazard.

Manufacturers have designed electrical equipment, particularly metal-clad switchgear, to be “arc safe” or “arc resistant” in order to protect workers or operators when interfacing with the equipment (opening or closing the device). This type of equipment is designed with enclosure doors and latching mechanisms that are much more substantial than older equipment and are intended to help ensure that the door remains closed during an arc flash event. These enclosures also have a pressure relief venting mechanism on the top of the equipment that will open and vent the arc flash pressures and vapors up and through a duct system to a location outside of the electrical equipment room. This is a significant improvement for designing in electrical safety in the equipment.

This section of the paper has emphasized equipment and systems design used to minimize the electrical hazards to personnel. There is another major design issue that is all too often overlooked and that is the working space around electrical equipment. This working space includes the spaces required by OSHA 1910.303(g) and NEC Article 110, Part II for 600 volts or less and OSHA 1910.303(h) and NEC Article 110, Part III for over 600 volts. This work space must be designed into a facility in order to provide a safe working space for electrical workers who are required to maintain the equipment and operators who are required to operate (open or close) switches, circuit breakers, or otherwise interface with the equipment. This space must not be confused with the required electrical shock or arc flash boundaries, which must also be considered.

## **Electrical Equipment Maintenance**

Maintenance, lubrication and testing are essential to ensure proper protection of equipment and personnel. NFPA 70E Section 205.1 requires all persons who maintain electrical equipment to be a qualified person and Section 205.3 requires electrical equipment to be maintained according to the manufacturer’s instructions or industry consensus standards such as NFPA 70B, *Recommended Practice for Electrical Equipment Maintenance*) and the InterNational Electrical Testing Association (ANSI/NETA) *Standard for Maintenance Testing Specifications for Electric Power Distribution Equipment and Systems* (MTS). Section 205.4 of NFPA 70E also requires that the maintenance, tests, and inspections be documented. With regard to personnel protection, NFPA 70E requires that a shock hazard analysis and an arc flash hazard analysis be performed before anyone approaches exposed electrical conductors or circuit parts that have not been placed

in an electrically safe work condition. In addition it requires shock protection boundaries and an arc flash boundary to be established.

All arc flash hazard analysis calculations, for determining the incident energy of an arc, and for establishing an arc flash boundary, require the arc clearing time, available short-circuit current, and the distance from the potential arc to the worker. The clearing time is derived from the engineering protective device coordination study which is based on what the protective devices are supposed to do. If, for example, a low-voltage power circuit breaker had not been operated or maintained for several years and the lubrication had become sticky or hardened, the circuit breaker could take several additional cycles, seconds, minutes, or longer to clear a fault condition. The following is a specific example:

Two Arc Flash Hazard Analyses will be performed using a 20,000-amp short-circuit with the worker 18 inches from the arc:

1. Based on what the system is supposed to do:
  - 0.083 second (5 cycles)
2. Due to a sticky mechanism the breaker now has an unintentional time delay:
  - 0.5 second (30 cycles)

***Example #1:***

$E_{MB}$  = maximum 20 in. cubic box incident energy, cal/cm<sup>2</sup>

$D_B$  = distance from arc electrodes, inches (for distances 18 in. and greater)

$t_A$  = arc duration, seconds

F = short circuit current, kA (for the range of 16 kA to 50 kA)

(1)  $D_A = 18$  in.

(2)  $t_A = \mathbf{0.083}$  second (**5** cycles)

(3) F = 20kA

$$\begin{aligned} E_{MB} &= 1038.7D_B^{-1.4738} t_A [0.0093F^2 - 0.3453F + 5.9675] \\ &= 1038 \times 0.0141 \times 0.083 [0.0093 \times 400 - 0.3453 \times 20 + 5.9675] \\ &= 1.4636 \times [2.7815] \\ &= \mathbf{3.5 \text{ cal/cm}^2} \end{aligned}$$

NFPA 70E, 130.5(B)(1) requires arc-rated clothing and other PPE are to be selected based on this incident energy -level exposure. Therefore the arc-rated clothing and PPE must have an arc rating of at least 3.5 cal/cm<sup>2</sup>.

***Example #2:***

$E_{MB}$  = maximum 20 in. cubic box incident energy, cal/cm<sup>2</sup>

$D_B$  = distance from arc electrodes, inches (for distances 18 in. and greater)

$t_A$  = arc duration, seconds

F = short circuit current, kA (for the range of 16 kA to 50 kA)

(1)  $D_A = 18$  in.



(2)  $t_A = 0.5$  second (30 cycles)

(3)  $F = 20$ kA

$$\begin{aligned} E_{MB} &= 1038.7 D_B^{-1.4738} t_A [0.0093 F^2 - 0.3453 F + 5.9675] \\ &= 1038 \times 0.0141 \times 0.5 [0.0093 \times 400 - 0.3453 \times 20 + 5.9675] \\ &= 7.3179 \times [2.7815] \\ &= \mathbf{20.4 \text{ cal/cm}^2} \end{aligned}$$

NFPA 70E, 130.5(B)(1) requires arc-rated clothing and other PPE to be selected based on this incident energy-level exposure. Therefore the arc-rated clothing and PPE must have an arc rating of at least 20.4 cal/cm<sup>2</sup>.

If the worker is protected based on what the system is supposed to do, in this case 0.083 second or 5 cycles, and an unintentional time delay occurs, and the time is increased to 0.5 second or 30 cycles, the worker could be seriously injured or killed because he/she was under protected. As can be seen, maintenance is extremely important to an electrical safety program. Maintenance must be performed according to the manufacturer's instructions in order to minimize the risk of having an unintentional time delay, or complete failure, of the operation of the circuit overcurrent protective device(s).

Maintenance is more than just performing the required preventive or predictive maintenance that is recommended by the manufacture. Other maintenance practices related to electrical safety include, but are not limited to:

- Effectively closing unused openings in electrical equipment and devices, such as:
  - When conduit is removed from an enclosure – plug the hole with an approved plug
  - When a molded case circuit breaker is removed from a panelboard, the opening must be closed using a panel compatible snap in device
  - When a low-voltage power circuit breaker is removed from the enclosure the opening in the door must be effectively closed
- All electrical panels (includes power and control panels), receptacles, light switches, junction boxes, conduit bodies, etc. must have the covers securely and properly installed (all screws or bolts installed and/or all latches securely fastened)
- All electrical panels must have danger signs installed and maintained, as identified below:
  - 600 volts or less OSHA and NFPA requires: *“Entrances to rooms and other guarded locations containing exposed live parts shall be marked with conspicuous warning signs forbidding unqualified persons to enter.”* This would require a sign that states: **“WARNING–HAZARDOUS VOLTAGE–UNQUALIFIED PERSONNEL KEEP OUT”** or similar.



- Over 600 volts OSHA and NFPA requires: *“The entrances shall be kept locked unless they are under the observation of a qualified person at all times; and permanent and conspicuous warning signs shall be provided, reading substantially as follows: “DANGER–HIGH VOLTAGE–KEEP OUT”*



- The work space around electrical equipment must be maintained clear as required by OSHA and NFPA: *“Working space required by this subpart may not be used for storage. When normally enclosed live parts are exposed for inspection or servicing, the working space, if in a passageway or general open space, shall be suitably guarded.”*

Many of the electrical equipment maintenance tasks require the equipment to be placed in an electrically safe work condition for effective safety prior to working on it. There are other maintenance tasks that might specifically require or permit equipment to be energized and in service while the tasks are being performed. Examples include taking voltage or current readings, troubleshooting, taking an oil sample from a transformer or oil circuit breaker for analysis, observing and recording operating characteristics such as temperatures, load conditions, corona, noise, or performing thermographic surveys while the equipment is under normal load and operating conditions. Coordinating maintenance and inspection with planned or scheduled production outages can provide an added safety environment for employees and may also provide a means to avoid major disruptions of operations.

When performing the required maintenance and testing of electrical equipment there are two sets of values or readings that must be recorded, namely the “as-found” and “as-left” values. The

as-found tests are tests performed on equipment when initially installed and before being energized or after it has been taken out of service for maintenance but before any maintenance work is performed. The as-left tests are tests performed on equipment after preventive or corrective maintenance has been completed and immediately prior to placing the equipment back in service. When equipment is taken out of service for maintenance, performance of both an as-found and an as-left test is highly recommended. The as-found tests will show any deterioration or defects in the equipment since the last maintenance period and, in addition, will indicate whether corrective maintenance or special procedures should be taken during the maintenance process. The as-left tests will indicate the degree of improvement in the equipment during the maintenance process and will also serve as a benchmark for comparison with the as-found tests during the next maintenance cycle.

## **In Summary**

Each of the three hazards of electricity (electrical shock, electrical arc-flash and electrical arc-blast) has its own unique characteristics that require special attention to hazard assessments, electrical safety programs and procedures, personal protective equipment, and the design, installation, and maintenance of electrical equipment and systems.

Personnel safety should be a primary consideration in electrical systems design and in establishing safety-related work practices when performing preventative maintenance for electrical systems and equipment. Maintenance must be performed only by qualified persons trained in safe maintenance practices and the special considerations necessary to maintain electrical equipment. Safe work practices must be instituted and followed to prevent injury or death to those who are performing tasks, as well as others who might be exposed to the hazards. Among the hazards associated with working on energized electrical conductors or circuit parts are hazards of electricity, any of which may result in severe injury or death to the employee(s). Preventive maintenance should be performed only when equipment is in an electrically safe work condition.

Equipment should always be deenergized for all inspections, tests, repairs, and other servicing. Where maintenance tasks must be performed when the equipment is energized, provisions are to be made to allow maintenance to be performed safely as required by NFPA 70E, *Standard for Electrical Safety in the Workplace*. For the purposes of this paper, deenergized means the equipment has been placed in an electrically safe work condition in accordance with NFPA 70E, Article 120, OSHA 1910.147, and 1910.333(b) requirements.

The best way to avoid exposure to electrical hazards is to keep as far away as possible from electrical equipment and systems that have exposed energized parts or where the electrical equipment is being operated or maintained.

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