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Preventing Arc Flash Incidents in the Workplace

New requirements set forth by the NEC, IEEE, and OSHA enforce the need for more clearly defined workplace safety measures to protect workers against the hazards of arc flash

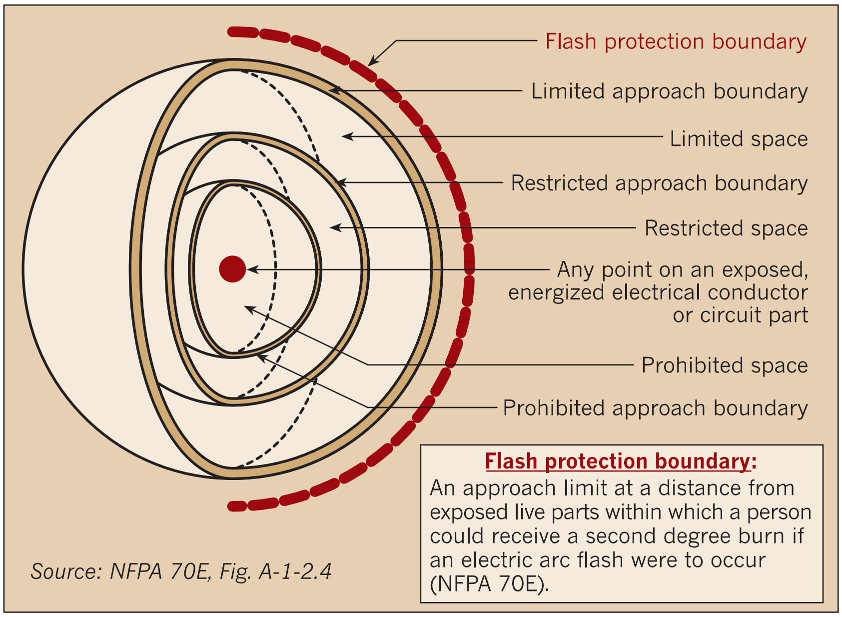

Fig. 1. It's generally accepted that a second degree burn results from exposure of an incident energy level of 1.2 cal/cm^2 or greater.

By George Gregory, Square D/Schneider Electric

Five to 10 arc flash explosions occur in electric equipment every day in the United States, according to statistics compiled by CapSchell, Inc., a Chicago-based research and consulting firm that specializes in preventing workplace injuries and deaths. This number doesn't even include cases in which the victim is sent to an ordinary hospital or clinic for medical treatment. Unreported cases and "near misses" are estimated to be many times this number. Instead, these incidents involve injuries so severe the victims require treatment from a special burn center.

The Occupational Safety and Health Administration (OSHA) has begun to aggressively monitor compliance with passage of the National Fire Protection Association's (NFPA) 70E standard, issued in 2000. In addition, electrical inspectors across the country are now enforcing a new labeling requirement set forth in the 2002 National Electrical Code (NEC). These requirements, along with guidelines published recently by the Institute of Electrical and Electronics Engineers (IEEE) in IEEE Standard 1584, Guide for Performing Arc Flash Hazard Calculations, help facilities personnel calculate the hazards of arc flash in different types of equipment in various power systems. What has emerged from this three-pronged approach is a new set of generally accepted best practices for preventing arc flash incidents in the workplace.

Early work on the subject. Arc flash first became a subject of serious study in the early ’80s, with the publication of a paper by Ralph Lee titled, “The Other Electrical Hazard: Electric Arc Blast Burns,” in the IEEE Transactions on Industry Applications. These early studies convinced several companies, particularly those in the petrochemical industry, that too many people were suffering injuries from arc flash incidents. These companies took steps to establish the first set of practices designed to better protect employees and electrical contractors working on energized electrical equipment.

While petrochemical companies were some of the first to recognize the need for additional steps to protect against arc flash hazards, the dangers apply to all electrical installations. Although the amount of energy released in an arc flash explosion may be greater for higher voltage installations found in some petrochemical and other industrial plants, the sheer volume of low voltage equipment in commercial and industrial facilities means that installations like these account for the greatest number of arc flash incidents.

The best way to prevent arc flash incidents from occurring is to de-energize equipment before beginning work. The new industry standards are designed to protect workers and the workplace in the few instances where turning off the power could create a greater hazard to people or processes than leaving it on. These standards place responsibility on employers and facility owners for establishing safe practices to protect their workers against arc flash incidents.

The goal of these standards is to keep electrical workers free from the hazards of shock, electrocution, arc flash, and arc blast. It’s important, therefore, to understand the requirements set forth in the standards for employee safety, the importance of an electrical safety program, the responsibilities of employer and employee, and the processes and best practices set forth in various industry standards and regulations.

Industry standards governing arc flash prevention. Four separate industry standards establish practices for the prevention of arc flash incidents:

- OSHA 29 Code of Federal Regulations (CFR) Part 1910, Subpart S
- NFPA 70-2002, National Electrical Code
- NFPA 70E-2000, Standard for Electrical Safety Requirements for Employee Workplaces (**Fig. 1**).
- IEEE Standard 1584-2002, Guide for Performing Arc Flash Hazard Calculations

OSHA is an enforcer of safety practices in the workplace. Its 29 CFR Part 1910.333 states, in part, “Safety related work practices shall be employed to prevent electric shock or other injuries resulting from either direct or indirect electrical contacts.” Although a number of related requirements are included in several OSHA standards, the administration’s field inspectors also carry with them a copy of NFPA 70E and use it to enforce safety procedures related to arc flash. NFPA 70E might be thought of as a “how to” standard. It provides guidance on specific steps that must be taken to comply with the more general statements made in the OSHA standards.

NFPA 70E and the 2002 NEC state that facilities must provide:

- A safety program with defined responsibilities.
- Calculations for the degree of arc flash hazard.
- Personal protective equipment (PPE) for workers.
- Training for workers.
- Tools for safe work.
- Warning labels on equipment.

A new requirement in the 2002 NEC (110.16) states, “Switchboards, panelboards, industrial control panels, and motor control centers that are in other than dwelling occupancies and are likely to require examination, adjustment, servicing or maintenance while energized shall be field marked to warn qualified persons of potential arc flash hazards. The marking shall be located so as to be clearly visible to qualified persons before examination, adjustment, servicing or maintenance of the equipment” (**Fig. 2** at right). This label, designed only to warn of potential hazards, is a field marking and isn’t provided by equipment manufacturers. Future revisions of the NEC are expected to require equipment owners to place other information on the label as well, including the equipment’s flash protection boundary, its incident energy level, and the required personal protective equipment (PPE) necessary to safely work on the equipment.

The danger zone for arc flash conditions is different for different types of equipment and is established in part by the voltage of the system. Typically, the higher the voltage, the larger the danger zone. To make it easier for facilities to determine the danger zone—identified as the flash protection boundary—for each piece of equipment, IEEE Standard 1584 provides definitive calculation steps in support of NFPA 70E. It also outlines a method for calculating the anticipated incident energy level so the facility owner can make an informed decision about the level of PPE that those who work on the equipment must wear.

An Arc Flash Defined

Think of an arc flash as a short circuit through the air. In an arc flash incident, an enormous amount of concentrated radiant energy explodes outward from electrical equipment, creating pressure waves that can damage a person’s hearing, a high-intensity flash that can damage their eyesight, and a superheated ball of gas that can severely burn a worker’s body and melt metal. The pressure waves can also send loose material like pieces of damaged equipment, tools, and other objects flying through the air.

Fig. 2. A warning label must be placed on any piece of electrical equipment that may remain energized during maintenance or repair.

Determining PPE Hazard Risk Category

Category	Cal/cm^2	Clothing
0	1.2	Untreated cotton
1	5	Flame retardant (FR) shirt and FR pants
2	8	Cotton underwear, FR shirt, and FR pants
3	25	Cotton underwear, FR shirt, FR pants, and FR coverall
4*	40	Cotton underwear, FR shirt, FR pants, and double-layer switching coat and pants

*Output category for personal protective equipment (PPE)

Source: NFPA 70E, Table 3-3.9.3

As the incident energy level increases so does the protection level of a worker's clothing.

What is an electrically safe work condition? Both OSHA standards and NFPA 70E require that equipment be placed in an electrically safe work condition before employees or electrical contractors work on or near them. Essentially, this means that equipment must be de-energized and that verification must be made that the equipment is truly de-energized before it's worked on.

There are exceptions for cases in which an employer can demonstrate that de-energizing the equipment would introduce additional hazards or in which the work can't be done with the system de-energized. For example, shutting down a ventilation system for a hazardous location could introduce additional hazards to those working in the work zone. With careful planning, however, work can almost always be done with equipment de-energized.

Placing equipment in an electrically safe work condition involves a number of steps, including turning off the electrical supply, locking it off, and taking measurements to verify that the system is indeed de-energized. These steps have to be taken before the equipment is in a safe condition, meaning that appropriate protective precautions, including the use of PPE, are necessary during the de-energizing process.

As set forth in NFPA 70E, Part 2, workers must take the following steps to ensure an electrically safe work condition exists:

- Find all possible sources of supply.
- Open disconnecting device(s) for each source.
- Where possible, visually verify device is open.
- Apply lockout/tagout devices.
- Test voltage on each conductor to verify that it's de-energized.
- Apply grounding devices where stored energy or induced voltage could exist or where de-energized conductors could contact live parts.

PPE must be worn when any of this work is conducted within the established flash protection boundary for that equipment (**See Table**).

Performing a flash hazard analysis. NFPA 70E requires facility owners to perform a flash hazard analysis prior to allowing a worker to work on energized equipment. The analysis is necessary for determining the flash protection boundary distance and the type of PPE required. To establish this information, an incident energy calculation is generally necessary.

The flash protection boundary is an imaginary sphere that surrounds the potential arc point "within which a person could receive a second degree burn if an electrical arc flash were to occur," according to NFPA 70E. This standard also defines the incident energy level as "the amount of energy impressed on a surface, a certain distance from the source, generated during an electrical arc event."

NFPA 70E doesn't specifically require or exclude any method of analysis. Tables and guidelines within the standard provide enough information to perform the analysis without other source material. The relatively simple approach in NFPA 70E may be satisfactory when facility owners lack the time or the capability to perform a more focused analysis. However, the values shown in the NFPA 70E tables represent only one condition of fault current and duration of the arc event. For input values different from that condition, PPE category values can be higher. A point not generally understood is that incident energy may actually increase in a low-fault current situation, which isn't reflected in the table.

More accurate calculations that take into consideration the true operating conditions of a specific facility can be performed using the methods outlined in IEEE Standard 1584. The more accurate the analysis, the more likely that proper preventive measures can be taken. The incident energy exposure level associated with a specific task, for example, determines the type of PPE an electrician needs to wear while working on equipment.

IEEE Standard 1584 establishes nine steps in the analysis process:

- Collect system and installation data.
- Determine modes of operation.
- Determine bolted fault current.
- Determine arc fault current.
- Find protective device characteristic and arc duration.
- Document system voltages and equipment class.
- Select working distances.
- Calculate incident energy.
- Calculate the flash protection boundary.

Calculations made using these guidelines are more likely to be accurate because they're based on a large number of tests. When installation data is known, the spreadsheet calculations are easy. Results can also be easily modified for variations of circuit layouts or changes in working conditions. The disadvantages of these guidelines are that they require detailed equipment specifications and operating characteristics and the use of a computer or good calculating skills.

The guidelines provide a number of shortcuts that provide quick calculation for low-voltage circuit breakers, including MCCBs, ICCBs, and LVPCBs. These shortcuts don't require detailed time current characteristics, but are meant to represent any manufacturer's equipment. They apply to thermal-magnetic, magnetic only, and electronic trip units.

No substitute for safety. It isn't possible to overstate the importance of establishing an electrical safety program. Arc flash is a serious hazard that can be devastating to those exposed to it. It can also cause lengthy downtime to repair or replace severely damaged equipment.

The requirements of NFPA 70E can help plant and facility managers and other users of electricity to understand how to reduce the probability of an arc flash event and its effects. The seriousness of these hazards is demonstrated by stepped-up efforts by OSHA to ensure compliance with new industry standards, which can help reduce workplace injuries, prevent damage to equipment, and increase uptime for any company.

Gregory is the manager of industry standards-circuit protection of Square D/Schneider Electric in Cedar Rapids, Iowa.

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