# MULTIPLE HAZARDS OF ARCING FAULTS



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## I. THE COSTS OF ARC FLASH

Based on previous statistics, it's expected that the explosive energy released during arcing faults will send more than 2,000 American workers to burn centers this year. Most of these people will not have been properly warned of the hazards associated with arc flash nor will they have been adequately trained in how to protect themselves.

Although injuries from arc flash are not the most frequent work related injuries, the costs to industry and to society are high. Arc flash exposure can result in severe disfiguring burns and can be a life-changing event for those affected. The monetary cost of a single arc flash incident can easily exceed $1 million per incident and includes not only medical expenses, but the costs of equipment replacement, downtime, and insurance. While the potential for arc flash has existed for as long as plants have been powered by electricity, several factors have pushed arc flash prevention and protection to the forefront.

The first is a greater understanding of arc flash hazards and the risks they pose to personnel. Research has now begun to quantify the energy and forces unleashed by arc flash events and has led to the development of standards to better protect workers. Some of the more significant changes have been within NFPA 70E, Standard for Electrical Safety in the Workplace, which identifies other standards that have evolved to address the arc flash hazard.

OSHA is using NFPA 70E, the industry's consensus standard for electrical safety, to judge whether or not an employer has "acted reasonably" in protecting workers from arc flash hazards. In many cases, OSHA investigations of arc flash events have resulted in substantial fines being imposed on employers.

## II. THE EXPLOSIVE NATURE OF AN ARC FLASH

The many hazards created by arcing faults in today's industrial power systems arise from two factors: the tremendous amounts of energy that can be delivered to such arcs and the workers' close proximity to them.

The development of a high-current arcing fault is like an explosion. When an arcing fault is being established, current begins passing through ionized air. Large volumes of ionized gases, along with metal from the vaporized conductors, are rapidly expelled. As the arc runs its course, electrical energy continues to be converted into extremely hazardous forms of energy.

Many events occur in less than 0.2 seconds but can create:

- Blinding light
- Intense heat
- Thermoacoustic effect
- Molten metal
- Toxic gases
- Shrapnel
- Contact with energized components

*Blinding Light*

As the arc is first established, an extremely bright flash of light occurs. Although it diminishes as the arcing continues, the intensity of the light can cause immediate vision damage

and increases the probability for future vision problems.

*Intense Heat*

The electrical current flowing through the ionized air creates tremendously high levels of heat energy. This heat is transferred to the developing plasma, which rapidly expands away from the source of supply. Tests have shown that heat densities at typical working distances can exceed 40 cal/cm$^2$. Even at much lower levels, conventional clothing ignites, causing severe, often fatal, burns. At typical arc fault durations, a heat density of only 1.2 cal/cm$^2$ on exposed flesh is enough to cause the onset of a second-degree burn. According to Annex K of NFPA 70E "Arc Flashes can and do kill at distances of 10 feet."

*Thermoacoustic Effect*

As the conductive element that caused the arc is vaporized, the power delivered to the arc fault rises rapidly. Rapid heating of the arc and surrounding air corresponds to a rapid rise in surrounding pressure. The resultant shock wave can create impulse sound levels well beyond OSHA's allowable limits. Forces from the pressure wave can rupture eardrums, collapse lungs, and cause fatal injuries.

*Molten Metal*

As the arcing fault develops, the magnetic fields created by the currents force the arcs away from the source until they reach a barrier or the end of the conductors. At high fault current levels, plasma jets are formed at these "electrodes." Hazards from vaporized and molten electrode material, ejected at high velocity from these jets, can extend for several feet. Since the molten metal is typically over 1000° C, it's a potential ignition source for conventional clothing.

*Toxic Gases*

Toxic combustion by-products and copper oxides formed when the cooling metal vapors combine with oxygen, are also expelled into the atmosphere during an arc fault. The image below shows a large volume of mostly copper oxides seen after the conclusion of an arc fault of 0.1 second duration.

*Shrapnel*

The force of the explosion can cause a significant amount of shrapnel to be accelerated away from the source. These fragments can impact a nearby worker at high velocity, resulting in physical trauma.

*Contact with Energized Components*

The explosive nature of an arc fault increases the possibility that an energized conductor or components will make contact with workers in the area, subjecting workers to additional harm.

**III. SOME TYPICAL CAUSES OF ARC FLASH**

- Accidental contact with energized parts including dropped tools.
- Inadequate short circuit ratings
- Tracking across insulation surfaces
- Improper work procedures
- Wiring errors
- Contamination, such as dust on insulating surfaces
- Corrosion of equipment parts and contacts
- Improper work procedures.

**IV. WHAT IS YOUR RESPONSIBILITY?**
Personnel responsible for electrical safety should stay up to date on the latest OSHA standards and all relevant consensus standards. Four major industry standards that address electrical safety as it applies to arc flash hazards are:

*OSHA Standards*
OSHA regulations make it clear that, with very few exceptions, equipment must be deenergized before employees work on or near it. When employers must make exceptions to the above, the regulations also make it clear that it is the employer's responsibility to evaluate the workplace for hazards and protect workers from these hazards. This requires:

- A hazard/risk assessment for the electrical hazards associated with energized work
- Selection of appropriate personal protective equipment (PPE) and flame resistant (FR) clothing

*NFPA 70E*
OSHA standards don't provide details on how to conduct an electrical hazard assessment or how to select PPE. For guidance on compliance, you need to look to industry consensus standards.

NFPA 70E, Standard for Electrical Safety in the Workplace, developed by the National Fire Protection Association, is one of the foremost consensus standards for electrical safety. It covers employee protection from the electrical hazards of shock, arc flash and arc blasts.

Although it is only referenced in OSHA 29 CFR Subpart S, Appendix A, NFPA 70E is considered by OSHA to be the recognized industry standard for electrical safety. In a standard interpretation of the relevance of NFPA 70E, OSHA states:

Industry consensus standards, such as NFPA 70E, can be used by employers as guides to making the assessments and equipment selections required by the standard. Similarly, in OSHA enforcement actions, they can be used as evidence of whether the employer acted reasonably.

And while the 2004 edition of NFPA 70E emphasizes that working on live parts is "the last alternative work practice," it contains extensive requirements for "working on or near electrical conductors or circuit parts that have not been put into an electrically safe work condition." When such work is to be done, NFPA 70E requires an Electrical Hazard Analysis with specific requirements for the analysis of shock and flash hazards. Other sections of the standard provide guidance on selecting the proper PPE.

*IEEE Standard 1584TM-2002 Guide for Performing Arc Flash Hazard Calculations*
As implied by its title, IEEE Standard 1584 provides techniques for designers and facility operators to apply in determining the arc flash-protection boundary and arc flash incident energy for PPE selection.

*NFPA 70: National Electrical Code®*
While the National Electrical Code (NEC® 2014) has traditionally addressed proper installation techniques intended to prevent fire, electrocution, and shock hazard, Section 110-16, Flash Protection, was added in the 2002 edition of the NEC. This section requires markings on switchboards, panelboards, industrial control panels, and motor control centers to warn qualified persons of potential arc flash hazards.