Facing Up to the Arc Challenge

You have to do something to protect your body from equipment failures because procedures and experience won't protect you in every circumstance.

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It's no big deal. I've worked with 277V a hundred times. I know what I'm doing."

It is commonly thought that low-voltage electrical arc accidents are harmless "poofs" as long as there is no electrical contact, and often this is true. The problem with low-voltage accidents is that the great majority are without consequence.

While working on electrical equipment, an industrial electrician or maintenance worker may hear a screw fall into bus work followed by a dramatic flash, which happens to be a quick clearing electric arc offering only a scare. Or a utility worker may plug in a meter and see an arc flash caused by a broken clip falling between the phase and the ground, which happens to cause a one cycle (1/60 of a second) arc. This also is a dramatic flash, but with little consequence under most exposure conditions. Both of these scenarios are deceiving.

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Sometimes when an arc flash does occur at higher amperage, low-voltage nodes, there are major multi-phase flashes that can cause a serious burning incident, especially for unprotected skin and from potential ignition of flammable work clothing. Unfortunately, these more common "poofs" give workers a false sense of confidence the arc energies talked about by the safety professional will not happen to them or are not actually available in their system. But the worst-case scenario can and does happen.

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Two Arc Incidents: Mark and Vitor

Mark was installing a meter at his utility. He followed his company's safe work procedures by verifying the fuses on the load-side of the selfcontained meter socket were open and that no ground shorts were present. Because other meters in the bank were still energized, he suited up with his flame-resistant PBI-Kevlar shirt, Class O rubber gloves with leather protectors, and safety glasses.

As he installed the meter, there was an arc flash. Later accident investigation was inconclusive about the cause, but many think it was a broken or faulty spring clip used for tension for the jaw in the meter base. This clip fell between phases of the energized meter socket near the one being installed. Mark did nothing wrong, and the direct work area was deenergized.

From viewing photos of the PBI shirt and the gloves, Mark received from 2-15 cal/cm² over parts of his upper torso (see the photos accompanying this article). When the meter flashed, Mark received second-degree burns on his face. His safety glasses protected his eyes and the area of his face they covered, but the uncovered area caused Mark to spend three days in a hospital burn unit.

Mark's commitment to wearing the proper PPE saved his life. If he had been wearing a non-FR cotton shirt or a polyester cotton blend shirt, this accident--which resulted in a few weeks off work--would have meant years of recovery and operations.

Vitor was working in a motor control center (MCC) when an arc flash occurred. From looking at the PPE and clothing Vitor was wearing, he received an amount of energy similar to Mark's on his upper torso. Most of this energy was focused on the faceshield and upper arm.

Vitor was wearing a Nomex coverall over his cotton uniform, a faceshield with a Nomex knit balaclava hood underneath it, safety glasses, and Kevlar gloves. The major difference between the two men was the use of a faceshield and hood.

Adequate Clothing, Training Paid Off

Even without an electrical contact, the two workers in this case study could have died from burns resulting from an ignited work uniform, but both companies had provided training and arc-resistant clothing for the work hazard. A worst-case arc energy scenario for low-voltage electric arcs occurred in these two accidents. Their arcs most likely went phase-to-phase and had sufficient fault current and clearing times to ignite non-FR clothing, had it been worn. During the electrical arc, both Mark and Vitor were exposed to as much as 15 cal/cm² at several points on their bodies.

Both of the workers were highly skilled, experienced, and trained for the job they were doing. Their companies had assessed the job hazard and provided adequate clothing for the hazard the workers faced. This is why the results of the incidents were limited to little injury, and none of the injuries caused permanent damage.

Equipment failures happen. Though rarely expected, they are one of the main causes of arc flashes. Human error alone outweighs equipment failures in causing arc flashes, but in the cases of Mark and Vitor, evidence suggests it was very difficult to prevent an equipment failure. The incidents' causes could not be confirmed for certain, but PPE made a big difference in the results. Mark's company now requires a faceshield for installing or replacing these meters. Vitor's company has used his incident to encourage workers to use their new PPE scheme based on NFPA 70E.

Preventing Equipment Failures

Let's look at what can be done about equipment failures:

1. Inspect parts before reassembling or installing.
2. Perform proper and preventative maintenance. Manufacturers usually have specific maintenance procedures, but if instructions are not available you may choose to use NETA's Maintenance Testing Specifications for Electrical Power Distribution Equipment and Systems, 2001 edition (www.netaworld.org).
3. Be aware of the energy levels of the equipment involved. Using NFPA 70E can simplify this, or you can do a hazard assessment using ArcPro v2.0 Software (www.hdelec.com) or IEEE 1584-2002, IEEE Guide for Arc Flash Hazard Calculations (www.ieee.org).
4. Identify the proper, safe work practices for the job and think through the accident scenarios. Sometimes, doing a job with a shotgun stick or using a hot stick shield like a Safety Shield (www.garyguard.com) can prevent hazardous energy and molten metal from reaching the worker.
5. Identify and wear adequate PPE for the job. Voltage-rated gloves and proper protectors or arc-rated gloves when shock hazard is not present, faceshield and/or hood (if needed), flame-resistant shirt and/or trousers, and proper work shoes. Clothing made of many materials have been arc tested and have been shown to protect workers in arc exposures. Some faceshields are *not* adequate for the electric arc. Arc testing with ASTM F2178 gives assurance of the arc rating, but make sure the faceshield is adequate for the exposure. (Most companies choose to use flash hoods that cover the facepiece when exposed to HRC 3 in the NFPA 70E standard.) Pay special attention to products that have FR (Flame Resistant or Flame Retardant) as part of their label. They should be rated for electric arc, or they may not be adequate. Many winterwear and rainwear materials can retard flame but are inadequate in the electric arc. Look for testing to the following standards: ASTM F1506, F1891, F2178, or F1959. These standards indicate the materials are arc resistant. Other standards for flame resistance alone may not be adequate. Most PPE, including fall protection harnesses, rainwear, winterwear, voltage-rated gloves (contact the author for a recent study from W.H. Salisbury on arc tests of voltage-rated gloves), clothing, and flash suits have been arc tested, and standards are being worked on or have been established for these items.

Be aware of the energy levels of the equipment involved. Using NFPA 70E can simplify this, or you can do a hazard assessment.

When Proper Equipment is Crucial

You have to do something to protect your body from equipment failures because procedures and experience won't protect you in every circumstance. Equipment *will* fail, whether because of being used past its life expectancy, being used in applications it was never designed for, having defective parts, or because of inadequate or improper maintenance.

The level of protection obtained by wearing PPE made all the difference in these two worst-case scenarios. A person wearing a non-FR shirt in these arc scenarios could have died from a clothing ignition. The energy levels could have ignited the heaviest cotton shirt and severely burned the worker. A common, lightweight poly-cotton shirt would have ignited and melted into the worker's skin. But the companies had thought out their apparel policy; both companies had provided comfortable, flame-resistant clothing with adequate arc resistance to provide a barrier from second-degree burn for the workers' upper torsos.

Vitor had an advantage over Mark in that his company had implemented NFPA 70E for its electricians. (NFPA 70E excludes utilities from its scope.) This policy, and Vitor's commitment to follow it, prevented him from receiving a burn. Like Mark, he had followed procedures and had assessed the job to avoid injury, but equipment failures are not as predictable as the behavior of highly skilled workers.

Looking at the equipment or knowing the arc energies, you couldn't tell which of these accident scenarios would have caused the greater injury. The incident arc energies were very similar on these secondary sources. Both were caused by secondary voltages in the 120V to 480V range. Each incident resulted in an arc that created energy from 2-15 cal/cm² at different parts of the worker's body.

Many electricians and utility workers think these voltages are harmless, but from an arc flash perspective, nothing could be further from the truth. Both of the workers involved in these accidents lived: one with no scarring but with a painful burn injury, while the other walked away from the accident. But it's important to remember that either worker could have died or been much more severely burned in these accidents had he been wearing a non-FR cotton or poly-cotton uniform or not wearing safety glasses and/or a faceshield or flame-resistant clothing.

Growing Awareness of 70E

OSHA has been regulating the clothing worn by electric utility workers since 1994. In 2000, the National Fire Protection Association released 70E, a consensus standard that guides industrial electricians for voltages less than 600V. During interviews with electricians in training classes, we are amazed how many electricians haven't heard of NFPA 70E--but the awareness is growing.

Mark was performing a routine reinsertion of a meter in a deenergized socket in a meter bank. The meter was fed from a 277/480V bank. Before installing the meter, he verified the fuses were open on the load-side of the meter socket and that no ground short was present. The fault blew the fuse in a 2500 KVA transformer, which is about 70 KA fault current. The energy exhausted out of the meter base Mark was working on and three others on his left side. Some sort of failure in the switchgear was the likely cause, but nothing Mark did precipitated this incident. Vitor was performing predictive maintenance on an energized 440v switchbox when a flashover occurred. Because he was wearing the prescribed PPE, he was uninjured.

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Skilled workers and good work procedures are not enough to protect personnel from on-the-job injuries, especially in electrical arc exposures. Know the standards and follow through with their implementation. Wear the proper PPE, such as voltage-rated gloves.

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