DEADLY AND PREVALENT

To Decrease Fatalities and Injuries, Electrical Shock Safety Needs a Jolt of Change

SAFETY REPORT

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Introduction

Electrical shock is incredibly dangerous. Not only is it dangerous, but it is also a common occurrence where resulting injuries—if not fatal—can lead to lifelong complications. More than 90 % of electrical fatalities among US workers are due to electrical shock [1]. This number does not even account for the substantial proportion of injuries and fatalities that are often misclassified under a different cause of death. And yet, regardless of a worker's years of experience or what their safety training taught them about electrical shock (if their safety training addressed electrical shock at all), many—if not most—workers' actions demonstrate that they do not seem to take electrical shock hazards seriously. It is for this reason that companies and safety professionals must ensure that Prevention Through Design always remain at the forefront of their electrical safety approach.

This year, we surveyed more than 400 people whose job is either involved in safety (such as safety professionals or consultants), or work directly with electricity. We wanted to better understand the reasoning behind why electrical workers often take unsafe actions, and the challenges safety professionals and consultants experience when trying to keep these workers safe.

Safety professionals seemingly face an uphill battle with electrical safety. For starters, most safety professionals do not come from an electrical background, and yet they are responsible for conducting most electrical safety courses [2]. Additionally, there seems to be a widespread notion among those electrical workers we surveyed that the more experience they have, the less of a need there is for PPE and de-energizing equipment before working on it. One electrical worker, for example, said they do not always wear PPE where code requires it because of their "amount of experience [and] history with safe handling of live conductors."

This report will tie in outside research with the goal of helping us understand why Prevention Through Design (also commonly called Safety by Design) is the best way to ensure nobody is injured or killed while on the job. Oftentimes, electrical hazards can easily be designed out or controlled with the right equipment, and yet, despite those available technologies and the electrical codes in place, electrical injuries and fatalities continue to happen. And contrary to widespread belief, these injuries and fatalities are not on the decline.

Acronyms

ac	alternating current
BLS	Bureau of Labor Statistics
CFOI	Census of Fatal Occupational Injuries
dc	direct current
EGFPD	equipment ground fault protection device
EHS	environmental health and safety
GFCI	ground-fault circuit interrupter
NEC	National Electrical Code
OSHA	Occupational Safety and Health Administration
PPE	personal protective equipment
SPGFCI	special-purpose ground-fault circuit interrupter

Why Companies Must Take Electrical Shock Mitigation, Prevention Through Design More Seriously

An electrical shock is a sudden violent response to electrical current flowing through any part of a person's body.

It wasn't until recent years that we began to learn that what we typically dismissed as "just a shock" can actually have a long-term impact on the body [3]. Even minor shock injuries can result in life-altering and debilitating symptoms. Oftentimes, electrical shock victims are not aware that the symptoms they experience—such as fatigue, depression, or weakness—are the result of what was "just a minor shock" incident from years before.

Electrical injury often leads to neurocognitive function problems, affecting the victim's speed of mental processing, attention, concentration, and memory. [4], [5]. "Even without visible burns, electrical shock survivors may face long-term muscular pain and discomfort, fatigue, headache, problems with peripheral nerve conduction and sensation, inadequate balance and coordination, and other additional symptoms" [3]. There are a subset of cases among minor electrical shocks that went unnoticed that manifested long-term disability with peripheral pain, loss of strength and coordination, and a variety of other problems that interfered with daily activities of the victim [3].

Q Have you ever experienced electrical shock while on the job?

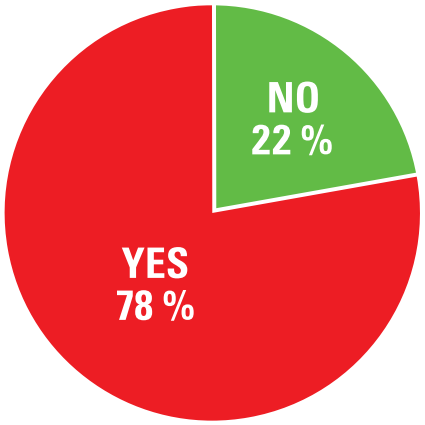


FIGURE 1. Most respondents have been electrically shocked while on the job, half of which by more than 220 volts.

Of the 163 people we surveyed this year who work directly with electricity, 78 % said they have experienced an electrical incident while on the job (see **Figure 1**).

When we consider how even a minor shock incident can impact a person for the rest of their life, it's hard to not feel disheartened from this survey's result.

Why Electrical Shock Incidents Are More Serious Than the Data Reflects

No one is immune from an electrical incident, regardless of their trade. According to data from OSHA, 64 % of all electrical fatalities occur in non-electrical occupations [6]. Thus, companies still have a high risk of fatal incidents from electrical shock occurring regardless of any requirements for electrical work to be done by only qualified workers.

Contact with an energized machine, tool, appliance, or light fixture is the second most common activity resulting in electrocution for non-electrical workers. The most common cause of electrical worker fatalities is contact with wiring, a transformer, or other electrical components {burdge].

The best safety training available cannot prevent human error from happening. And that is not to say there are countless trades and occupations that use electricity everyday by way of various tools and appliances—for most of which electrical safety training is not practical, but electrical hazards are still present.

This is all the more reason to use the Hierarchy of Controls to prevent accidents and focus on methods that are higher up on the pyramid.

Electrical injuries are particularly underrepresented in occupational injury and fatality data because they often are classified as a different type of incident. For example, if a worker is electrically shocked while using a ladder to change a light fixture and then falls from the ladder, the fatality is classified as being due to a fall, not electricity.

Another reason the industry lacks awareness of the prevalence of worker electrical fatalities is due to little-known inconsistencies between OSHA and the Bureau of Labor Statistics (BLS) data sets.

The Let-Go Threshold: The Line Between Injury and Death

The let-go threshold is when a person is experiencing an electrical shock and loses their ability to let go of the object. This can oftentimes make the difference between life and death.

Alternating current (ac) repetitively stimulates nerves and muscles that cause sustained contraction of the muscles. When a person's muscles contract, their grip tightens, which will remain contracted as long as contact with the energized object is maintained. Once the current passes through the heart, the victim will likely experience ventricular fibrillation which usually causes brain damage and cardiac arrest. Ventricular fibrillation may occur with exposure to voltage as low as 50 mA to 120 mA [5].

Of the worker electrical fatalities that occurred between 2011 and 2017, OSHA's data sets only included 74 % of those reported by the BLS Census of Fatal Occupational Injuries (CFOI) [7].

The CFOI data, however, cannot be used by researchers to understand the context behind these incidents because BLS divides the information surrounding the incidents into separate reports, rather than provide a single comprehensive set of data like that of OSHA. For example, the 2018 CFOI includes a data set that will tell us how many workers died due to electricity and another set for the number of fatalities among electricians, but because they are separate sets, we cannot determine how many of the electricians died due to electricity. This lack of comprehensive data reporting prevents researchers from analyzing the data to understand the context of these incidents, such as whether a fatality incident that is classified as a fall was the result of an electrical shock, for example.

The perception that electrical fatalities are on a steady decline is somewhat of a myth due to improper classifications of injury and cause of death, how BLS presents its fatality data, and unaccounted incidents in OSHA's injury and fatality data sets.

When Incidents Are Prevalent, a Better Approach is Necessary

Near miss incidents "provide a window to examine the quality of electrical safety competency and effectiveness of the electrical safety program for an organization" [2].

Sixty-eight percent of the 10 survey respondents reported a near miss electrical incident within the previous five years. "These results," [2] said, "particularly the frequency of near electrical misses, should challenge the industry to prioritize electrical safety in safety programs, especially with the frequency of electrical incidents no longer decreasing. One area to start is to ensure near-misses are being reported and corrective action is put in place."

Industry reports say that electrical fatalities have steadily declined since NFPA 70E became required. However, this belief is based on a linear trendline, which can be misleading because it is not the best way to understand data that fluctuates from year to year. Last year, we used a 2-year sliding average of these fatality rates and reported that the electrical fatality rate among workers has nearly flatlined since the rate sharply dropped in 2007. Under a linear model, this sharp drop is largely responsible for the common belief that electrical fatalities are currently on the decline (see **Figure 2**).

Unfortunately, the electrical fatality rate has not improved since last year's report. With 2019's rate being the highest since 2011, the 2-year sliding average is no longer flatlined (see **Figure 2**). It is increasing—or at least beginning to.

In 2007, OSHA published 29 CFR Part 1910, subpart S, which was the first revision to OSHA's general industry electrical standard in 25 years. The basis of the updates was NFPA 70E-2000 (the previous version used the 1979 edition of NFPA 70E and safety design requirements for electrical installations, such as expanded requirements

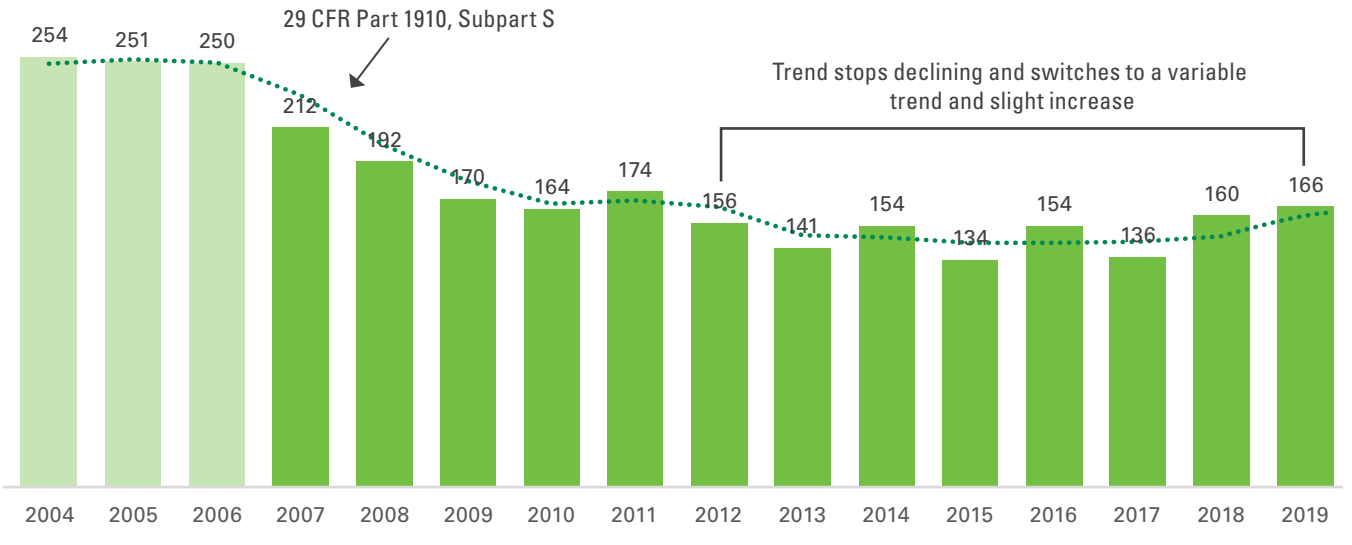


FIGURE 2. Number of US electrical fatalities began to flatline across the last decade [13].

for ground-fault circuit interrupters (GFCI) protection of temporary wiring used for maintenance and repair purposes (§ 1910.304(b)(3)(ii)) [8]. Upon OSHA's requirement for companies to follow better electrical safety designs, the number of electrical fatalities sharply dropped.

In the years following this sharp drop—after most states had adopted the new safety standard, the rate of fatalities began to flatline. It is no longer accurate to say the electrical fatality rate is declining in the United States. Thanks to the historical addition of requirements for GFCIs in certain applications and other electrical requirements, the fatality rate is not as high as it once was. However, the current fatality rate reveals that there is still more work to be done. There are more applications where GFCIs are not yet required by the NEC, but have the potential to save many lives due to the hazards these applications encompass. If the NEC were to require companies to use GFCIs in these applications, the electrical fatality rate may once again drop like it did when electrical codes were ramped up in the past. However, GFCIs save lives, so companies should continue to apply them wherever they are applicable regardless of whether they are mandated or not.

"OSHA currently requires GFCI protection through 120-volt, single-phase, 15- and 20-ampere temporary receptacle outlets used on construction sites (§ 1926.404(b)(1)). In the 28 years that this requirement has been in effect, the Agency estimates that between about 650 and 1,100 lives have been saved because of it" [8].

[7] questioned why this rate has not continued to decrease despite the time and energy companies have spent on human-based safety practices:

> Workers following safety-related work practice requirements, limiting the approach, learning the arc flash concept, and wearing proper personal protective equipment (PPE) has a significant effect on injury and death rates. But why haven't these practices continued to reduce the deaths and injuries? Making it the employer's duty to create an electrical safety program and making it an enforced practice within companies should have had a greater effect than waiting for an incident that called OSHA in to penalize the company.

Most companies' current electrical safety approach is not foolproof, particularly among those who rely on PPE and administrative controls such as safety training. While well intentioned, these methods are prone to human error.

Too many workers are injured or die each year due to electrical shock, and we must do better at preventing these incidents from happening. Developing an awareness of how and why these incidents occur is the first step, and designing out the hazards using engineering controls, such as GFCIs, is the best solution.

Littelfuse Survey Results

Of those included in the survey, the respondents were divided into two groups, which were given a separate set of questions based upon their occupation. One group consisted of safety professionals and consultants, while the other group included those whose work is directly involved with electricity, such as electrical engineers, electricians, and plant floor managers. In this paper, the group who works directly with electricity will be referred to as "electrical workers."

Electrical Workers

The electrical group surveyed work among a range of voltages: 41 % said they primarily work with 240 volts or less, 43 % said they work with more than 240 volts and up to 600 volts, and 16 % said they primarily work with more than 600 volts.

Working On Energized Equipment and Confusion Over Which Equipment is Exempt From 1910.333(A)

The survey's results found something very alarming—possibly the most alarming result Littelfuse has found in the three years this annual report has been conducted:

> 93 % of the electrical workers said they have witnessed someoneworking on or near energized equipment of more than 50 volts.

Among those who said they have witnessed someone working on or near energized equipment, slightly more than one third said the equipment "was not considered critical." The remaining two-thirds who said they considered the equipment critical worked in a range of industries. While we do not specifically know what type of equipment they use that they consider critical, some of the industries in this group included food and beverage, hospitality, process analyzers, material handling, and construction—all of which typically do not use equipment that is considered critical enough to be exempt from 29 CFR 1910.333(a).

Critical equipment, such as equipment used in hospitals, is equipment that must be worked on while energized because de-energizing it will put people's lives at risk. The term critical equipment is not used by OSHA codes to describe equipment that may be worked on while energized, but people within the industry commonly use the term in reference to equipment that is considered critical enough to be worked on while energized.

Some companies and facility managers mistakenly believe that if maintaining their equipment's power is critical to business operations, they are exempt from 29 CFR 1910.333(a)(1), which requires live electrical parts that operate at 50 volts or more to be de-energized prior to working on them. However, being critical to business operations—the bottom line—is not the same thing as being critical to keeping people safe and alive, and thus not exempt from being hit with steep OSHA fines. It does not matter if a company was misinformed or genuinely believed they were exempt from CFR 1910.333. Codes are black and white, and companies that violate them will be subject to OSHA fines.

OSHA requires live electrical parts that operate at 50 volts or more to be de-energized prior to working on them. Under 29 CFR 1910.333(a)(1), the equipment is exempt only if "the employer can demonstrate that de-energizing [the equipment] introduces additional or increased hazards or is infeasible due to equipment design or operational limitations."

For new electrical system designs, companies should consider any life safety circuits and design with redundancy in mind. This way, at the very least, a piece of equipment can be deenergized without a need to de-energize everything. This diminishes the need to put people's lives in jeopardy whenever maintenance must be performed. Whether it be during the initial design stage, or updating older equipment, a forward-thinking company will always look to mitigate electrical hazards through a design lens.

Working On Energized Equipment When The Worker Believes They Know Better

Only 25 % of the electrical workers we surveyed said they "never" work on or near energized equipment of 50 or more volts. Additionally, 36 % said they do not always wear the recommended level of PPE while working on or near energized equipment of more than 50 volts.

The "other" responses included the following:

- "Lack of easy-to-access equipment to borrow when task[s] suddenly change,"
- "Familiarity with equipment and tasks may lead to complacency regarding PPE."
- "I never considered it."
- "Amount of experience, history with safe handling of live conductors."
- "When I work with it, it is in a testing lab. I know the risks."
- "I learned too late, no enforcement or education when I was working."
- "Quick question at testing requires me to help and point out issues as I'm walking by. I know... My bad."

Many respondents said they do not know what the recommended level of PPE is [for their application] and others said their company does not even provide electrical

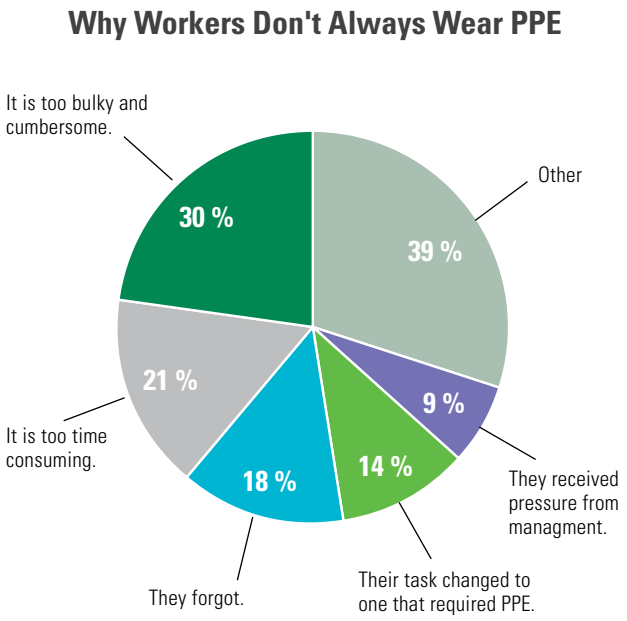


FIGURE 3. Electrical workers' reasons for why they do not always wear PPE when required.

PPE. Some respondents said they do not wear PPE because they are troubleshooting. However, PPE should always be worn when troubleshooting energized equipment.

One respondent said they don't wear PPE because "installing batteries requires handling small hardware." It's true that PPE is bulky and makes handling small hardware difficult, but the nature of the task does not make a condition any less hazardous. It's also worth noting that as of February 2021, there are still no known manufacturers that make electrical gloves for female hand proportions. While male workers often choose not to wear electrical gloves due to their bulkiness, electrical gloves handicap female workers' dexterity even more so.

Another respondent said, "the situations where I am exposed to a live cabinet are extremely rare." This is a great example why PPE should never be relied upon. It only takes one time to be electrically shocked. When a person is rarely exposed to a live cabinet, you would think they would take the time to put on their PPE, but this is not necessarily the case. **Figure 3** shows the overall reasons respondents gave for why they do not wear PPE when required.

It was difficult not to feel disheartened when we asked the electrical workers what action they took when they witnessed someone working on energized equipment, and the answers were interesting. Among the responses:

- "Unfortunately for some [of] us working so unsafe is a frequent thing, for some it's even part of fault finding."
- "I was the dumb apprentice that was taught this was accepted."
- "Permitted to do so."
- "They were a 'seasoned' and 'trained' electrician."
- "They were [a] trained electrical technician. I have had close calls especially when I was training."
- "Engineer with skills and warned about risks."

Collectively, these open-ended answers provided us with a lesson many of us may already know, but nonetheless often need to be reminded of repeatedly. As time passes, people tend to push aside safety bumpers until eventually, they are recklessly driving without any safeguards in place, and with the confidence of someone who believes nothing bad will happen as a result. Like the statistic that finds car accidents to be more than twice as likely to take place within one mile from home compared to 20 miles from home, the most unsafe situations tend to be those where we feel the safest. The amount of experience a person has or their history with handling live conductors does not determine whether PPE is necessary—and not just by Code, but by logic. The more familiarity a person has in doing something, the more likely they are to go into auto-pilot.

Unfortunately, however, preventing this is easier said than done. It can be preached in safety courses repeatedly, but whether people engage in these practices is a different story.

Companies often use rubber mats to provide an additional layer of shock protection for workers. However, similar to all forms of PPE, rubber mats do not eliminate the potential for injury and fatality incidents. Workers do not always use the mats due to the hassle of extra work they create when breakers or contactors are racked in or out. Rubber mats are also rendered ineffective when wet, which also causes workers to not use the mats [6].

The NEC requires GFCI protection in some specific applications, but there are many more areas with electrical shock hazards that GFCIs can be applied.

Oftentimes quick fixes that occur while a worker is troubleshooting a piece of equipment can change the nature of the work. For example, a worker might notice loose connections while troubleshooting a low-voltage control circuit and decide to tighten them while the cabinet is open. However, this changes the nature of the task, which may require an energized electrical work permit, arc-flash and shock hazard analysis, and so forth [9]. Troubleshooting energized equipment usually takes longer than if the equipment were not energized, and it can also cause the qualified technician to focus on more than one hazard at a time. Instances like these open the door to human error.

Other examples of places where GFCIs are essential to safety but may not be mandated by electrical codes include:

- Permanently connected equipment in wet or damp areas
- Plug and cord connected equipment in dry but extreme or harsh indoor environments (such as industrial, manufacturing where there is a high level of heat, dirt, and dust)

- Temporary power receptacles other than single-phase 125 volts, 30 amperes and below
- Any similar permanently connected or plug-and-cord application that is greater than 208 volts (Class C and D SPGFCI applications)

When an electrical designer knows they must put a control panel in a wet environment, they should consider installing a GFCI to protect the main or a portion of the circuits in that control panel. GFCIs can greatly impact safety when used in control panels where people perform work, along with other places that often require frequent troubleshooting.

Safety Professionals and Consultants

Forty percent of safety professionals and consultants said they face money or budget constraint obstacles when trying to gain approval for an electrical safety improvement project at their company. About the same number said it is difficult to show the return on investment when proposing electrical safety improvement projects. Almost one third said they are not aware of obstacles faced when presenting an improvement project. Other obstacles— a lack of available data to quantify the problem, the time required to build a case to secure approval, and a lack of time or people to implement electrical safety projects—were each reported by a similar amount of safety professionals and consultants ~15 %.

Roughly 15 % of the safety professionals and consultants cited not seeing a need for electrical safety improvement projects because their company has never had an incident.

This result was somewhat similar to a separate survey, which asked safety professionals which challenges they face when implementing electrical safety policies, 24 % of which said, "electrical hazards are considered infrequent and low priority." The survey asked people who are involved with electrical safety at their organization to select each challenge they face when implementing electrical safety policies. Those who were involved with electrical safety at their organization were divided into three groups: 1) safety professionals; 2) environmental health and safety (EHS) managers and directors; and 3) other. Of the 13 challenges they could select (excluding "other'), 32% of the overall respondents said the "safety culture [is] resistant to change." The study said a "lack of understanding of electrical standards and compliance requirements were particularly challenging for safety professionals," who were about 40 % more likely to select this than other respondents [2].

"Safety professionals are significantly less likely to be comfortable identifying electrical hazards independently, yet they are often the ones responsible for training employees on electrical safety processes. Only about one in three safety professionals report that they are "definitely" comfortable compared to about half of the remaining respondents" [2].

The survey [2] found that only 34 % of safety professionals believe they are "definitely" comfortable identifying electrical hazards without help from electrical workers or engineers [2]. Among the rest of the safety professionals surveyed, 31 % said they are "probably" comfortable, 17 % said they are "possibly" comfortable, 11 % said they are "probably not" comfortable, and 6 % said "no," they are not comfortable independently identifying electrical hazards without support from electrical workers or engineers [2].

While the vast majority of surveyed safety professionals either said they are "extremely familiar" or "very familiar" with lockout/tagout, OSHA, and hierarchy of controls topics, a full 41 % of surveyed safety professionals either said they are "somewhat familiar" or "not very familiar" with NFPA 70E. Thankfully, there were no safety professionals who said they were "not at all familiar" with NFPA 70E [2]. Additionally, the majority of the surveyed safety professionals reported a lack of familiarity with the National Electrical Code (NEC): 47 % said they are "somewhat familiar" with the NEC, 8 % said they are "not very familiar", and 1 % said they are not at all familiar with the Code. On the theory of Prevention Through Design[1], 44 % either said they were "somewhat familiar" (29 %), not very familiar (14 %), or "not at all familiar" (1%) [10].

Meanwhile, a significant majority (67 %) said EHS or safety managers are responsible for conducting electrical safety training, which was followed by maintenance (36 %), safety consultants (26 %), and third-party organizations (25 %) [2]. Safety professionals' training in risk assessment and safety management make their contribution to electrical safety programs immense. However, few safety professionals have backgrounds in electrical applications, and thus their ability to teach electrical safety training is limited [2].

1 Both the terms safety by design and Prevention through Design, both of which are commonly used throughout industrial- and safety-related industries, refer to the same concept. Though Prevention through Design is usually called safety by design in Europe, and the safety professionals surveyed were North American-based, safety by design is used enough throughout North America that it is possible that some of those who indicated a lack of familiarity with Prevention through Design may know the concept as safety by design.

Collectively, these surveys found that the majority of safety managers—most of whom are responsible for conducting electrical safety training—not only do not have a strong comfort level in identifying electrical hazards themselves, but also lack a necessary familiarity with those safety measures that extend beyond administrative controls. The majority reported being extremely or very familiar with lockout/tagout administrative controls, but when it came to NFPA 70E and the NEC, where the implementation of Prevention Through Design methods are embodied, less than half said they are "extremely" or "very" familiar.

These studies were not the first bodies of research to discuss the pitfalls of electrical safety training. To learn about other challenges and misinformation found to be taught in electrical safety training, read The State of Electrical Shock Safety. It is important to note that even the best safety training is not the best method to keep workers safe.

When the safety professionals and consultants in the Littelfuse survey were asked which response would best describe their company's mindset if the existing power distribution equipment at their facility were to no longer meet present day electrical safety codes and technologies, one-third of the respondents said their company would upgrade the equipment as soon as possible to conform with the latest safety technology and standards, while 40 % said they would upgrade their equipment within a reasonable amount of time if they considered the code to be important to their company. Unfortunately, a full 27 % reported that their company would continue to use the outdated equipment until the end of its lifecycle—new Code requirements usually only apply to new installations, so doing so is legal because it is grandfathered in.

Though the majority (80 %) of safety professionals and consultants said their facility uses the hierarchy of controls and strives to implement controls closest to the top of the pyramid, many of the respondents (20 %) said their facility does not follow the hierarchy of controls.

Safety professionals and consultants were given an open-answer field when asked, "What does your facility do to enhance safety?" Only one response involved action, which was "gradual changing [of] equipment" and the rest of the responses were all efforts that involve talking about safety but lacked action, or as one respondent said, "we talk about [electrical safety] a lot but we are slow to change."

When the safety professionals and consultants were asked how important electrical safety is [in their company's] safety culture, not one respondent said electrical safety is "not so important" or "not at all important" (56 % said "extremely important," 36 % said "very important," and 8 % said "somewhat important"). It is worth noting, however, that these responses come from people whose company employs safety professionals or consultants, and thus does not reflect companies that do not employ safety professionals and consultants.

Safety professionals are oftentimes at the forefront of a company's safety approach, and yet do not have electrical backgrounds. Consequently, this can have two subsequent effects on the company's electrical safety. Firstly, It shifts the facility's primary approach to focus on safety training and PPE rather than Prevention through Design methods. Additionally, the training tends to exclusively focus on subject areas such as lockout/tagout, rather than electrical hazards in wet environments or in areas that may have long, worn cables.

Regardless of whether the training covers the most essential electrical topics or not, as our survey found, these methods are a poor choice to exclusively rely upon. Instead, electrical workers should work with safety professionals to ensure a company prioritizes Prevention Through Design in every aspect of their safety strategy.

Safety professionals and electrical workers must come together to ensure the best safety methods are utilized within a facility. To companies and safety professionals, the importance of electrical safety comes without shock. However, there seems to be a lack of tangible steps among each group to ensure their electrical shock approach actually works.

> People's ability to identify electrical hazards is poor—and this is among those who have actually been provided with training. Untrained workers—especially those who work in wet conditions or places where flexible cables are used—are even more at risk. Safety training has demonstrated in many studies and surveys to have a tendency toward being inadequate. Even when the issues within safety training are explained as inevitable, and the importance of Prevention Through Design is stressed to a company or a group, all too often people respond with "so how can safety training be improved?"

Why Prevention Through Design, GFCIs, Are More Surefire Than Human-Based Methods

The Hierarchy of Controls

Safety by design is the best way to protect workers from serious injuries and death. NFPA 70E Standard for Electrical Safety in the Workplace, which is the long-time OSHA recognized standard for electrical safety, is not meant to create a standard for workers who do not interact with energized electrical equipment as their regular job tasks, nor available in languages other than English [11]. An examination of 897 OSHA Fatality and Catastrophe Investigation Summaries of fatal electrical injuries that occurred between Jan. 1, 2011 and Dec. 31, 2018 said 64 % of all workplace electrical fatalities occurred in occupations outside the electrical field [11]. Many of these fatalities occurred in the "laborers, except construction," "construction laborers," and "tree trimming occupations" [11].

The hierarchy of controls starts with the most effective and moves down to the least effective safety measure (see **Figure 4**). Not all hazards can be eliminated, but the idea is that the closer you get to the top, the safer workers will be.

The hierarchy of control's methods are:

- Elimination: Physically remove the hazard
- Substitution: Replace the hazard
- Engineering controls: Isolate people from the hazard
- Awareness: Inform people of possible hazards
- Administrative controls: Change the way people work
- Personal protective equipment: Protect the worker with PPE

NFPA 70E follows the model of the hierarchy of controls. The standard establishes the de-energization of energy sources as the preferred approach to working on or around electrical hazards, and emphasizes that PPE should solely be relied upon as a last resort (or an extra layer of protection). PPE is not the first line of defense, it is the last.

The hierarchy of controls is incredibly important for this reason. While safety training and PPE do not guarantee incidents won't happen to any worker group, given that a

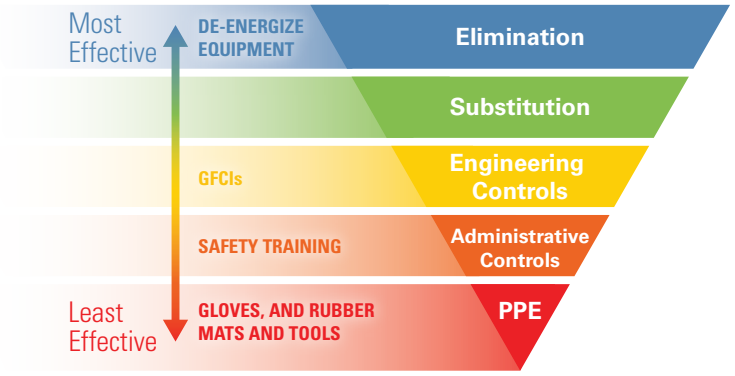


FIGURE 4. The hierarchy of controls pyramid.

majority of occupational electrical fatalities occur to workers outside of the electrical field, it is essential to build in safety by design rather than rely on human-based safety methods.

Human-based safety measures (PPE and safety training) are important components of occupational safety, but these methods are prone to error and are unreliable on their own, which is why NFPA 70E, Standard for Electrical Safety in the Workplace, stresses that they must never be used as the sole safety method unless the company has no other choice (see **Figure 4**).

Ground-Fault Circuit Interrupters

It is easy to understand why safety methods that rely on human involvement are less effective than Prevention Through Design methods, which operate independently of people. And yet, companies continue to fixate on these methods, treating them as their go-to safety measures—which, though important, are supposed to be used as either a last-resort or as an extra layer of protection.

NEC does not require ground-fault circuit interrupters (GFCIs) for all areas where shock hazards exist that can injure or kill a person. PPE, however, is always required whenever a shock hazard exists that can cause injury or death. And yet, according to the hierarchy of controls, PPE is the least effective preventative measure and responsible for many injuries and fatalities due to its human-based practices [12].

For example, the reason that electrocution incidents began to decline after the 1970s can be attributed to the implementation of US safety legislation and of the regulations of the Industrial Safety and Health Act and the Industrial Safety and Health Regulations that were

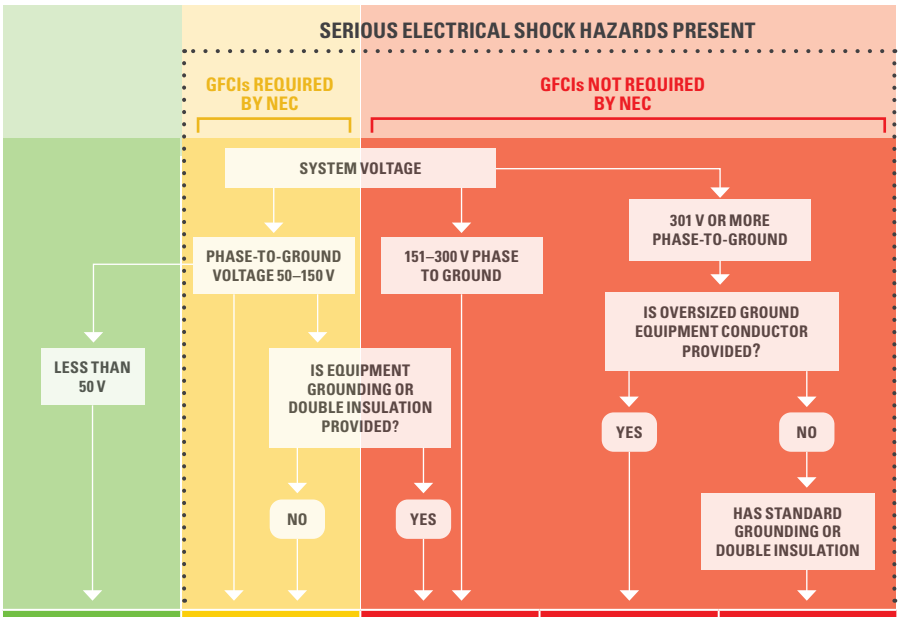
established in 1972. In 1969, the installation of ground-leakage current circuit breakers became a requirement for certain applications.

GFCI protection is a much more effective preventative measure as it does not require human involvement for it to work. It's an out-of-sight-out-of-mind practice that requires zero energy from the workers for it to guarantee their safety.

Figure 5 shows which class of GFCI to use in given applications. Applications in the red and yellow areas contain serious electrical shock hazards. The NEC only mandates the use of GFCIs for applications in the yellow section.

Systems that have higher maintenance requirements are less forgiving of human error and more prone to failure. Again, the most cited rationale provided by the survey respondents for working on energized equipment was maintenance and troubleshooting. Implementing GFCIs and other Prevention Through Design components will not only save costs but save lives as well.

Human life is priceless, and the cost of an incident exceeds far beyond even the steepest of OSHA fines. Companies sometimes focus solely on the cost of compliance, but estimating costs should be framed in a way to consider the benefit of lives and dollars saved in the prevention of deaths, injuries, and property loss.



	GFCI NOT NECESSARY	CLASS A GFCI[1]	CLASS C GFCI	CLASS D GFCI	CLASS E GFCI
REQUIRED BY NEC	N/A	✓	✗	✗	✗
WORKERS ARE SAFE IF GFCIs ARE USED	N/A	✓	✓	✓	✓

[1] Required by NEC under certain settings.

FIGURE 5. Diagram to determine which GFCI class to use with portable equipment. NEC does not require GFCI protection for all applications with less than 1000 volts—regardless of whether serious electrical shock hazards are present or not.

Despite safety training, our survey of people who work directly with electricity found that workers often believe they are safe to use equipment under conditions where electrical shock hazards are present, even though they oftentimes are not. Electrical shock hazards exist for both qualified and unqualified workers. If qualified workers do not consistently work in a manner reflective of their safety training, we can assume unqualified workers—who use portable equipment and work in other conditions where electrical shock hazards are present, are even more so at risk. Using GFCIs can protect every worker—both qualified or unqualified—from innocent work practices becoming deadly.

Conclusion

The honest responses to the Littelfuse survey provide a better understanding of the reasons electrical workers often take unsafe actions, and the challenges safety professionals and consultants experience when trying to keep these workers safe.

Electrical workers often become complacent and take unsafe actions for a variety of reasons. Sometimes it is because they think they know better, while other times it is due to the nature of the task. Electrical safety can easily be missed among workers who are using portable equipment since they are often not provided with adequate safety training, or because the equipment was not protected with a GFCI. Fortunately, Littelfuse has a solution for hazardous situations like these—including environments that require a certain degree of mobility.

Safety professionals are tasked with keeping workers safe while having little experience identifying the hazards the workers face. Oftentimes, companies' safety methods primarily focus on providing workers with PPE and safety training and unfortunately, these companies usually believe it to be the best, most responsible course of action for protecting their workers. PPE is considered the last line of defense on the hierarchy of controls, with safety training (which is an "administrative control") falling next in line. A last line of defense is a last resort, and thus for companies to devote their resources to last-resort protection methods, the disproportionate rate of worker fatalities that occur from electrical shock each year comes as no surprise.

Too many people's gut reaction when discussing the electrical fatality rate is to ask how safety training can be improved. However, safety training is not the problem. A decrease in the electrical fatality rate requires companies to not be so laser-focused on safety training that they disregard opportunities to use GFCIs or other Prevention Through Design engineering methods.

Code requirements are only the bare minimum. GFCIs' ability to protect human life has proven reliable since their introduction—not only in applications where they were required, but also where they were not mandated by Code.

Oftentimes, the most difficult part of widespread issues is in recognizing that you are among the group who can do better. Embracing the Prevention Through Design philosophy will dramatically improve a company's safety culture and the more advocates we have for this mindset, the more lives we can save.

When 'Critical' Equipment Isn't 'Critical': What Data Centers Can Teach Other Industrial Applications

As discussed, many of our survey's respondents said they work on or near energized equipment, which they consider to be critical. However, based on the industries these particular respondents work in, it is highly unlikely that the equipment they use is considered critical enough by laws and codes to be worked on while energized.

Data center applications are a great case study for other industries to understand where bias and convenience can easily misconstrue important—but not critical—equipment as essential. Data center operators have long held that they meet CFR 1910.33's industrial process exemption [13], [14] and may thus perform work on energized equipment because of the uninterruptible nature of 24-hours-a-day, 365-days-a-year data center operations [13], [14]. If the nature of data centers' 24-7 operations does not make them exempt from CFR 1910.33's requirement to de-energize equipment before working on or near it, what led so many people in the industry to believe otherwise?

Many people argue that some of today's data center operations approach the status of being "essential" because they comprise of so much of the underlying infrastructure that runs society [15]. These centers support the functioning of power grids and utilities, air traffic control operations, communication networks, and the information processing that support vital activities ranging from daily commerce to national security [14]. It would make sense for their equipment to be considered essential since these systems require uninterruptible operations.

However, OSHA does not see it this way. If de-energizing the equipment does not create more or worse hazards than the hazard of working on energized components, or if de-energizing the equipment is infeasible (such as maintenance and testing operations that can only be done on energized circuits), then OSHA requires the equipment to be shut down—no matter how time consuming it is, no matter the cost, no matter what.

No matter the application, there will always be certain situations or pieces of equipment that naturally seem critical to remain energized while maintenance is performed. However, OSHA's interpretation for which equipment is exempt from CFR 1910.33 is fairly black and white, and it is easy for an industry's demanding nature of operations or self-important biases to blur their interpretation to grey.

Most data centers add redundancy to their electrical system. This allows them to de-energize a piece of equipment before working on it without shutting down their entire process, which is thus powered by one or two other redundant systems in parallel. This is an improved safety approach because it at least takes a Prevention Through Design approach. However, given that about a third of people in the data center say their company does not require them to de-energize equipment before performing maintenance, the approach still relies on humans for it to work, and therefore, its ability to prevent incidents is not guaranteed.

References

[1] Census of Fatal Occupational Injuries (CFOI), US Department of Labor, Bureau of Labor Statistics, 2019. [Online] Available: https://www.bls.gov/iif/oshcfoi1.htm

[2] R. 10 and H. L. Floyd, "Best Practices for Engaging Safety Professionals on Electrical Topics.

[3] Chicago Electrical Trauma Rehabilitation Institute. "Understanding the Connection Between Electrical Shock and Subsequent Neuromuscular Disorders." Current Research. https://cetri.org/research

[4] M. S. Morse, "A report on the current state and understanding of human response to electrical contacts," presented at the IEEE Industry Applications Society Electrical Safety Workshop, Dallas, TX, USA, Mar. 11–15, 2013, Paper ESW2013-05.

[5] M. R. Zemaitis, L. A. Foris, R. A. Lopez, et al,"Electrical Injuries," StatPearls Treasure Island (FL): StatPearls Publishing; 2020 Jan. Available from: https://www.ncbi.nlm.nih.gov/books/NBK448087

[6] B. 11, J.C. Cawley and D. Majano, "Electrically Hazardous Jobs in the US," IEEE Transactions on Industry Applications, to be published. DOI 10.1109/TIA.2020.2980221.

[7] R. 7. "Flatlining: The Decline in Electrical Fatalities Has Nearly Leveled." Electrical Contractor. https://www.ecmag.com/section/safety/flatlining-decline-electrical-fatalities-has-nearly-leveled accessed (Mar. 13, 2020).

[8] Department of Labor, 8, 29 CFR Part 1910, Subpart S. Available from: https://www.osha.gov/sites/default/files/laws-regs/federalregister/2007-02-14.pdf

[9] T. 9 and S. Jamil, "The Disconnect Between Electrical Safety and Accident Prevention," IEEE Industry Applications Magazine," to be published.

[10] R. 10, "Applying Prevention Through Design to Voltage Testing," IEEE Industry Applications Magazine, pp 12–23, May/June, 2017.

[11] B. 11 and D. Majano "Expanding workplace electrical safety to non-electrical occupations" Proc. IEEE IAS Elect. Saf. Workshop pp. 1–5 Mar. 2020.

[12] Occupational Health and Safety Management Systems, ANSI/ASSP Z10.0, 2019.

[13] "Uptime Institute Data Center Industry Survey," Uptime Institute. https://UPTIME 1institute.com/UPTIME 1_assets/08200c5b92224d561ba5ff84523e5fdefeec6b58cbf64c19da7338e185a9c828-survey15.pdf

[14] "Balancing Life Safety, Infrastructure Investment, and Downtime," Uptime Institute. https://uptimeinstitute.com/balancing-life-safety-infrastructure-investment-and-downtime

[15] "Data Center Energized Electrical Work," Mission Critical. https://www.missioncriticalmagazine.com/articles/88786-data-center-energized-electrical-work

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