GFCIs FOR COMMERCIAL AND INDUSTRIAL APPLICATIONS

Prevention through Design with Special-Purpose GFCIs

TECHNICAL PAPER

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Introduction

With power, comes great responsibility. Companies must never take electrical shock lightly, or believe that safety training and PPE are enough on their own. Hundreds of workers are killed every year from electrical shock[1]. More than 90 % of electrical fatalities among US workers are due to electrical shock, and tens of thousands of electrical shock incidents over the years have resulted in injuries that require time away from work.

Ground-fault circuit protection is one of the most effective preventative measures against electrical shock because it actively reacts to irregular electrical conditions regardless of a person's qualifications or use of PPE. Where applicable, they are an out-of-sight-out-of-mind practice that require zero energy from the workers for it to guarantee their safety.

This paper will begin with a brief overview of the conditions that make an electrical shock hazard potentially lethal (which aims to help readers understand why lower voltages do not constitute safer conditions). Then, it will provide a discussion of how ground-fault circuit interrupters (GFCIs) are used to keep workers safe from electrical shock. Specifically, this paper will discuss:

- How electrical shock affects the human body
- How GFCIs work
- Different GFCI classes and their respective applications
- How GFCI protection is different than equipment ground fault protection
- NEC GFCI requirements and applications where GFCIs are not required by the NEC but are essential due to the electrical shock hazards these applications present

Acronyms

AC	alternating current
BLS	Bureau of Labor Statistics
DC	direct current
EGFPD	equipment ground-fault protection device
GFCI	ground-fault circuit interrupter
HRG	high-resistance grounding
PPE	personal protective equipment
SPGFCI	special-purpose ground-fault circuit interrupter

Electrical Shock Overview

What Makes Electrical Shock So Dangerous

An electric shock is a sudden violent response to electrical current flowing through any part of a person's body. Even minor shock injuries can result in life-altering and debilitating symptoms. Electrical shocks can cause long-term injuries with both neurological (such as loss of balance, poor coordination, and neuropathy), psychological (fatigue, irritability, and depression) and physical symptoms (such as muscle spasms, reduced range of motion, muscle aches, and joint stiffness) [1].

Potential long-term consequences of electrical injuries may include neurological (e.g., neuropathy, seizures, syncope, tinnitus, paresthesias, weakness, loss of balance, poor coordination, or gait ataxia), psychological (e.g., memory or attention difficulties, irritability, depression or post-traumatic stress), ocular (e.g., cataracts) or physical (e.g., pain, fatigue, contractures, muscle spasms, pruritus, headaches, fever or night sweats, and reduced range of motion or stiffness in the joints) disturbances.

When and Why More than 50 Volts Can Be Lethal

It is current, not voltage, that kills a person. Electrical current can travel through the human body in several ways, such as:

- from hand to foot (touching a live conductor, for example, while standing on a grounded surface);
- from hand to hand; or
- from foot to foot (the step potential, which is the difference in voltage between each foot and the electrode). A foot-to-foot path most commonly occurs in incidents where the victim was standing on a surface that became energized during a fault.

1 Between 2003 and 2019, an annual average of 183 fatalities were attributed to electrical shock, according to BLS CFOI. Because many worker fatality incidents that are initiated from electrical shock but ultimately are classified under a different cause of death, such as a worker who falls from a ladder after being electrically shocked, the number of workers who die each year from electrical shock is most likely significantly higher than the BLS data reflects.

Many factors affect the current's ability to pass through the body, and it only takes about 6 mA (for the average female) and 9 mA (for the average male) to reach the "let-go threshold," which when the current causes the muscles to uncontrollably contract and renders the victim unable to let go and break from the current on their own (see **Figure 1**).

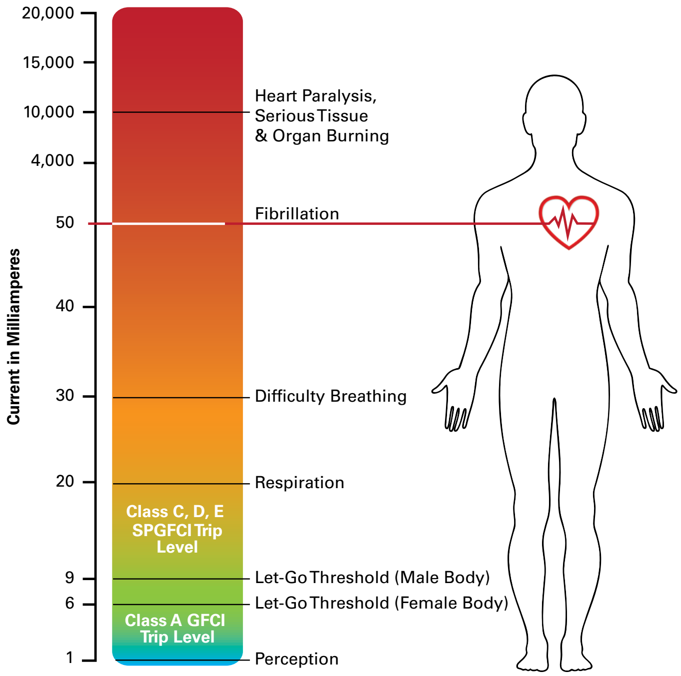

FIGURE 1. The effects of different ac levels flowing through the human body.

Unfortunately, this ability to let go (and thus break from the electrical current) will often make the difference between life and death. Alternating current (ac) repetitively stimulates nerves and muscles that cause sustained contraction onto the muscles, which will continue as long as there is contact with the object. When a person's muscles contract, their grip tightens, which renders them powerless to disconnect the electrical current from their body.

Once the current passes through the heart, ventricular fibrillation—which causes the heart's chambers to uselessly quiver instead of pump blood—is likely. Without a heartbeat, the person will die within three minutes if they do not receive an electrical countershock (a defibrillator) to correct their heart rhythm [2].

The heart fibrillation threshold is the highest acceptable level that the body can tolerate without causing significant risk of death. Blood does not travel to the brain during a ventricular fibrillation cardiac arrest. Therefore, even if the person receives defibrillation treatment in time and survives, but does not immediately receive CPR before the defibrillator becomes available, then they will likely become brain damaged with lifelong disabilities.

Most victims, however, do not survive. Due to factors that impede rapid access to emergency medical care, CPR and defibrillation, reported survival rates range from 3 % to 10 % [3].

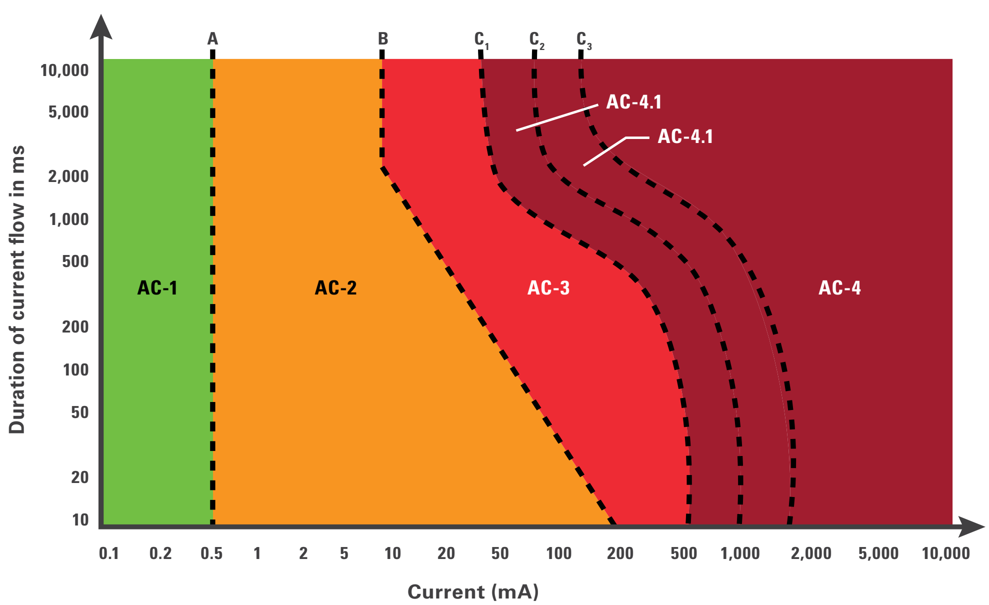

FIGURE 2. The effects of different ac levels flowing through the human body, according to IEC 60364-4-41.

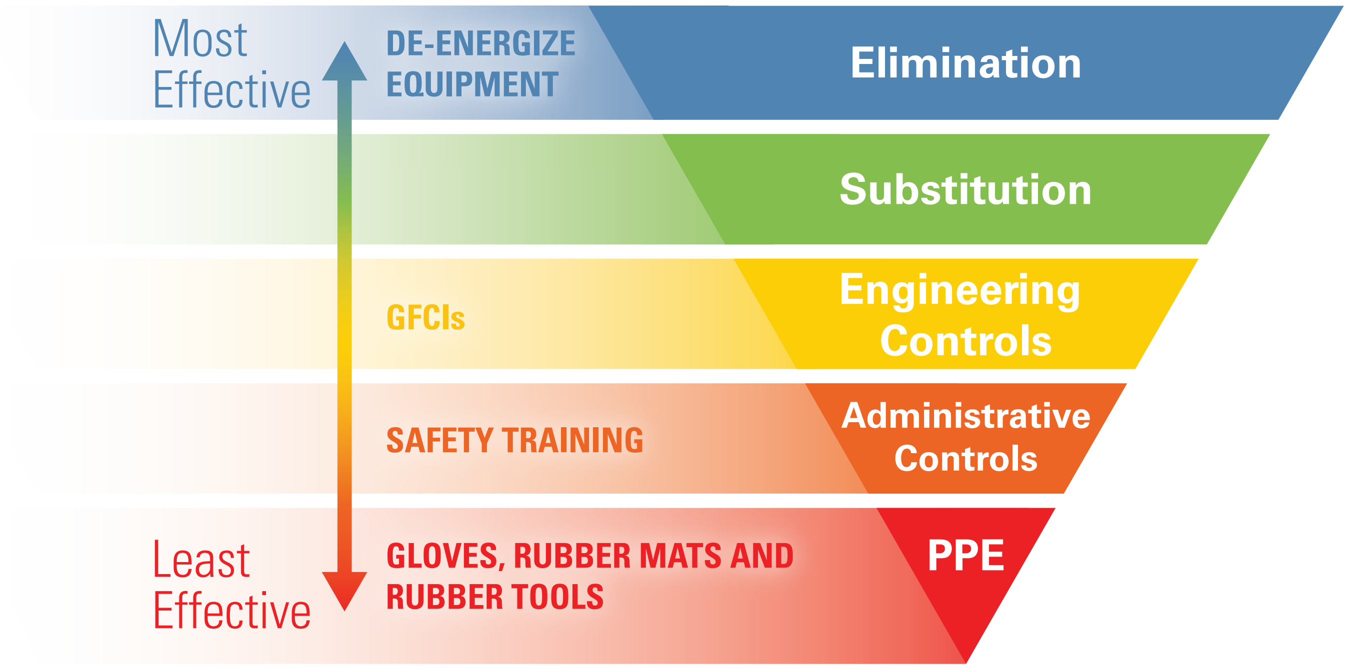

FIGURE 3. The Hierarchy of Controls.

The longer the current lasts, the greater the injury. A person who has passed the let-go threshold is physically incapable of breaking from the current on their own. At this point, the current will not stop traveling through their body until it is interrupted by a GFCI or similar device.

GFCIs limit the human body's exposure to shock by interrupting the circuit before the magnitude of current and its duration poses the risk of ventricular fibrillation. The area shown as AC-2 (see **Figure 2**), indicates where the threat of ventricular fibrillation is unlikely. GFCIs operate according to a curve that is faster, and more sensitive than the lagging edge of AC-2. If there is a 50-milliampere fault, then the GFCI will trip in 100 ms or less, keeping the person safe from heart fibrillation.

While duration is one of the most significant factors that determines the severity of an injury, it is not the only one. The amount of moisture in the body (resistance) is also an important contributor. Tissue density (ratio of fat to muscle), body mass, the presence of moisture in the environment, the victim's sex, and the type of current are all variables which can affect the severity of the shock injury.

For more information about the contributing factors of severe electrical shock incidents and their prevalence among U.S. workers, read the Littelfuse electrical shock survey report.

Prevention through Design: GFCI Electrical Shock Prevention

Prevention through Design is the best way to protect workers from serious injuries and death. While human-based safety measures (PPE and safety training) are important components of occupational safety, 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 3**).

Most industrial sites require employees to wear PPE. However, standard-issue PPE (such as general-purpose gloves, which often provide heat protection) does not protect from electric shock and electrical workers might be lax in properly wearing electrical PPE. Additionally, workers often complain electrical gloves make it difficult to get the job done because they are cumbersome or bulky. This often causes many workers to perform work without wearing their PPE when required.

PPE (such as rubber-insulating gloves) are considered the least effective safety method under NFPA 70E hierarchy of controls due to the high level of human error that must be overcome for them to effectively work. While absolutely important, electrical gloves are the last line of defense. Electrical gloves must maintain their dielectric properties, physical strength, flexibility and durability for them to remain effective. Whether the worker ultimately wears them is a different story.

To learn more about why PPE and safety training are dangerous mitigation methods to rely upon, read The State of Electrical Shock Safety survey report.

How GFCIs Work

GFCIs eliminate shock hazards by cutting off power when even the slightest amount of current flows where it should not. If a person touches a live GFCI-protected conductor, the GFCI will open the circuit before the shock incident becomes lethal.

A single-phase GFCI contains a zero-sequence current transformer in which the hot and neutral lines pass through. Its sense winding feeds a triggering circuit that is connected to an interrupting device.

If there is no leakage to ground (through either bad insulation, a person, or both), then the currents in the hot and neutral lines will be equal and cancel each other out in the current transformer. However, if there is leakage (if some of the current that is going out on the hot conductor does not return through the neutral), then the two currents will no longer sum to zero and the sense circuit will trip the contactor to shut off the power.

Special-Purpose GFCIs

GFCI Classes and Their Applications

UL divides GFCIs into Classes A, C, D and E[2]. A GFCI's trip threshold is determined by its class.

Class A GFCIs (Non-Residential)

Class A GFCIs, which are commonly used in residential and commercial settings, have a 6-milliampere trip level and are used in single- and three-phase systems with 150 V to ground (usually 120 V or 240 V for single-phase systems, and 208 V for three-phase systems). This includes both standard household GFCIs and commercial GFCIs that are used in restaurants, garages and other non-residential applications.

Class A GFCIs are governed by UL 943, which applies to Class A, single- and three-phase GFCIs in accordance with the NEC, the Canadian Electrical Code (CE Code), and ANSI/NFPA 70. Class A GFCIs provide let-go protection and do not require equipment ground conductor monitoring.

Class C, D, and E GFCIs (Special-Purpose GFCIs)

Class C, D, and E GFCIs are considered special-purpose GFCIs. Special-purpose GFCIs are used in industrial systems, typically those that have voltages of 480 or 600 V line-to-line potential.

Special-purpose GFCIs trip when the leakage current exceeds 20 mA, or when the equipment ground conductor for that circuit is compromised.

Ground monitoring is not required for the supply-side of permanently connected special-purpose GFCIs or when the load employs a system of double insulation.

Until 2009, GFCI protection was limited to single-phase ac circuits up to 240 V (150 V line-to-ground). However, because the hazards that GFCIs protect against extend beyond these applications, UL published UL 943C, which established three new classes of special-purpose GFCIs for systems up to 600 V.

Special-purpose GFCIs trip at 20 mA instead of Class A's residential trip-level of 6 mA. This higher trip level provides a greater flexibility for an industrial application, while still tripping fast enough to protect workers from a ventricular fibrillation event.

For instance, a 20-milliampere ground fault would require a special-purpose GFCI to trip in one second or less to stay below the ventricular fibrillation threshold. Likewise, a 200-milliampere ground fault would require the special-purpose GFCI to operate in 37 ms or less for the same reason. This can be seen in the AC-3 zone in **Figure 2**. This higher trip level provides a greater flexibility for an industrial application, while still tripping fast enough to protect workers and meet UL 943 requirements.

Classes C, D, and E are governed by UL 943C, Special Purpose Ground-Fault Circuit-Interrupters. UL 943C addresses two limitations of Class A GFCIs that prohibit their use in many industrial applications: the system voltage limitation to a maximum of 240 V and a maximum allowed leakage current of 6 mA.

Class C devices are rated for phase-to-ground voltages of 300 V and less (480-volt three-phase applications), while Class D and E cover applications greater than 300 V line-to-ground (600-volt three-phase applications).

2 There are also Class B GFCIs, but they are rare—if not obsolete—because they are only for use in pool light fixtures installed before 1965.

All special-purpose GFCIs must have a minimum trip rating of 15 to 20 mA, but Class C devices are permitted to have a trip threshold as low as 6 mA. In addition, UL 943C requires the GFCI to monitor the continuity of the ground wire and interrupt power to the load if ground integrity is lost.

- Class C GFCIs: for use in circuits with no conductor over 300 V to ground where reliable equipment grounding or double insulation is provided. Class C GFCIs interrupt the circuit when the ground-fault current is between 15 mA and 20 mA. They have trip thresholds between 6 mA and 20 mA, which provides limited let-go protection.
- Class D GFCIs: for use in circuits with one or more conductors over 300 V to ground, and with specially sized reliable grounding to provide a low impedance path so that the voltage across the body during a fault does not exceed 150 V. Class D GFCIs interrupt the circuit when the ground-fault current is between 15 mA and 20 mA.
- Class E GFCIs: for use in circuits with one or more conductors over 300 V to ground but with conventional equipment grounding provided for the protected equipment in the system or double insulation. Class E GFCIs interrupt the circuit when the ground-fault current is between 15 mA and 20 mA and require high speed tripping for fault currents 300 mA and above.

All special-purpose GFCIs are required to monitor the ground conductor unless the load employs a system of double insulation. Ground conductor monitoring is always required for Class D devices since they are not subject to the double insulation exemption.

Ground check is required for anyone using a Class C GFCI with a conventional ground conductor (as per NEC 250.110 and 250.114), and though highly recommended—is optional for Class A GFCIs. The Shock Block has a ground check feature integrated into the unit for both the Class A and C models, so anyone using the Shock Block has the feature available, regardless of whether ground check is required or not.

Special-purpose GFCIs, such as the Littelfuse Shock Block series, are specifically designed to protect people from electrical shock in industrial and commercial applications due to their higher trip levels. The Shock Block SB6100 is currently one of the few GFCIs that meets UL 943C and rated for use on various system voltages (up to 600 V line-to-line) and loads up to 100 A.

FIGURE 4. A cart-mounted GFCI provides portable shock protection.

The Shock Block SB6100 has built-in overcurrent protection that is provided by Class T fuses. The load can be single-phase (line-to-line) or three-phase (without a neutral). The Shock Block SB6100 can be used on either solidly-grounded or high-resistance grounded power systems, and used as a GFCI (with a fixed 20-milliampere trip level) or as an EGFPD (it can be adjusted as low as 6 mA, or from 10 mA to 100 mA in increments of 10).

The Shock Block SB6100 can be used with two different types of installations: a UL recognized open-chassis model for installation in existing electrical enclosures, and a UL Listed enclosed model in a NEMA-4X enclosure for stand-alone installations.

Littelfuse has a Shock Block cart, which is discussed in greater detail on page 11 of this document, that enables portable GFCI protection in temporary installations (see **Figure 4**).

Proactive GFCIs Detect Ground Faults and Protect Against Fatal Shocks with One Device

Ground check tremendously increases safety. Ground check monitors the continuity of the grounding circuit, causing the power conductors to be de-energized if ground continuity is lost.

Ground conductor monitoring enhances the standard protection of a GFCI by taking proactive measures. A ground check feature provides this by not allowing energization to a load with improper grounding, and de-energizing any circuit where the grounding becomes compromised under load. By decreasing these hazardous situations, the probability of a person becoming part of the ground conductor circuit is far less likely.

A GFCI that can detect ground faults is not only incredibly beneficial due to the time it saves in replacing the burden of an assured grounding program, but in its ability to provide shock protection as well.

Where a 20-milliampere Trip Level is Appropriate for Protection

The trip curve published by UL for GFCIs was developed to interrupt faster than the time it would take any magnitude of current to initiate ventricular fibrillation in the human heart. The time it takes for the GFCI to operate depends on the amount of leakage current: the higher the current, the faster the GFCI trip time. **Figure 2** shows the inverse-time response curve, which is set by UL 943 and defined by the equation:

$$T = \left(\frac{20}{I}\right)^{1.43}$$

where *T* is in seconds and *I* is in mA. For currents greater than 300 mA, the delay is fixed to 20 ms.

FOR INDUSTRIAL PERSONNEL PROTECTION, LOOK FOR THE UL 943C LISTED MARK OR THE CSA C22.2 NO. 144-M91 GROUND-FAULT CIRCUIT INTERRUPTERS, CLASS 1451-01 MARK.

A GFCI that is capable of an inverse time decision process provides a lot of value for industrial applications as unwanted trips will be avoided.

Many people associate 6 mA as the set GFCI trip level due to the prevalence of Class A GFCIs. The 6-milliampere trip level roots back to when UL set the trip level for Class A GFCIs below the let-go threshold, which was then adopted within North America.

Not all Products Marketed as ‘GFCIs’ are Actually GFCIs

Most people associate the acronym “GFCI” with a device that is designed to keep people safe from electrical shock. However, use of the acronym GFCI is not regulated, so anyone can call anything a “GFCI” regardless of whether the device meets the applicable GFCI standards for shock protection.

Some of the devices sold as “GFCIs” did not pass the necessary tests for providing electrical shock protection. Despite failing these tests, some of these products reference the applicable GFCI standards in their marketing materials, implying that the device meets or exceeds the requirements even though it does not.

For industrial personnel protection, look for the UL or CSA approval on the product nameplate or manufacturer's documentation.

However, ventricular fibrillation is very unlikely to occur below 20-milliampere currents. The human adult can survive extended shock incidents without sustaining severe injury so long as the contact does not exceed 2 seconds (see **Figure 2**). Class A GFCIs must safeguard against these lower currents to protect small children.

Equipment Ground-Fault Protection Devices and Nuisance Tripping

For some applications, 20 mA can be too sensitive (particularly if there are variable frequency drives present). Littelfuse equipment ground-fault protection devices (EGFPDs) are similar to special-purpose GFCIs and operate on the same inverse time curve as other GFCIs listed to UL 943 and UL 943C. Whereas GFCIs protect people, EGFPDs are designed to protect equipment. EGFPDs are oftentimes the best option when the normal ground leakage exceeds the industrial GFCI’s 20-milliampere trip level.

A good EGFPD will have an adjustable sensitivity, which is usually between 6 mA and 100 mA. This enables the sensitivity to be adjusted to the lowest sensitivity level that is above the base leakage current. Doing so creates the safest possible conditions for workers in environments where worker protection at 20 mA is not possible. Littelfuse EGFPDs can also monitor the ground conductor, which—though not required by UL 943C—provides an additional layer of protection.

EGFPDs are not covered by UL 943C (nor UL Listed as GFCIs) because the standard does not allow adjustable trip levels for GFCIs. Therefore, EGFPDs are considered for equipment protection only. Littelfuse EGFPDs will still provide protection against ventricular fibrillation (and other severe shock injuries) for any leakage currents greater than the user-selected setting.

How to Apply Industrial GFCIs

Industrial GFCIs can be used on equipment subject to wash-down cleaning, process equipment that handles wet material, such as large pumps, mixers, wet saws; equipment that comes into frequent contact with workers, such as arc-welding stations; and portable electric equipment used outdoors, where long power cords and less robust temporary connections may be exposed to rain and moisture.

Industrial GFCIs may be integrated by the original equipment manufacturer or the panel builder, or they may be installed in an electrical cabinet such as a motor control center. They are also available with their own enclosures, for mounting to the side of a machine or a wall.

The wiring is simple: attach source power on one side and the load circuit on the other side. In addition, there may be signal wiring for optional alarm communication.

Some models are equipped with built-in overcurrent protection (usually a fuse), which allows for a high interrupting rating (50 kA in some cases). This protects the internal contactor from damage and does not require the user to install a current limiting device upstream of the industrial GFCI. Some models also offer undervoltage and chatter detection.

Mitigation Methods Commonly Confused with Shock Protection Devices

Ground-Fault Relays

Ground-fault relays are not to be confused with GFCIs. Whereas ground fault relays protect equipment, GFCIs protect human life. Furthermore, ground-fault relays are not specifically designed to provide complete protection against electrical shock. Ground-fault relays do not open the affected circuit themselves. Instead, they send a signal upstream to a breaker.

While the ground-fault relay reacts from 8 to 10 ms, the upstream circuit breaker may take 30 to 50 ms to open—which is enough time for an electrical shock to stop a human heart. A GFCI or an EGFPD contains its own interrupting device (a relay, contactor, or circuit breaker) to interrupt power, and it interrupts power much more quickly. Per UL 943C, a GFCI must open the circuit to interrupt power in less than 20 ms for higher currents. This time is fast enough to prevent shock injury.

High-Resistance Grounding Systems

High-resistance grounding (HRG) systems do not reduce electrical shock hazards. In HRG systems, which are no more than 10 A, the neutral point of the three-phase electrical supply is not directly connected to ground, but instead through a high-value resistor. When one of the phase conductors shorts to ground, the system continues to operate with the fault current limited to a low value by the grounding resistor.

Although HRG systems can dramatically reduce the risk of an arc flash and maintain an electrical system's operations in the event of a ground fault, they do nothing for shock hazards. The system's grounding resistor will still permit the flow of more than enough current to kill a person, so touching a live conductor can still be fatal.

Industry-Specific Challenges and Solutions

Locations Where GFCIs are Required by NEC 210.8(B) (Nonresidential)

GFCI requirements for nonresidential applications are outlined in NEC 210.8(B):

> All 125-volt through 250-volt receptacles supplied by single-phase branch circuits rated 150 V or less to ground, 50 A or less, and all receptacles supplied by three-phase branch circuits rated 150 V or less to ground, 100 A or less, installed in the locations specified in 210.8(B)(1) through (B)(12) shall have ground-fault circuit-interrupter protection for personnel.

This update applies to most receptacles in the locations listed below, which includes receptacles on 240-volt circuits and three-phase receptacles on 208Y/120-volt three-phase circuits.

The non-residential locations that NEC 210.8(B) requires GFCI protection include:

- Bathrooms
- Kitchens or areas with a sink and permanent provisions for either food preparation or cooking
- Rooftops
- Outdoors
- Sinks—where receptacles are installed within 1.8 m (6 ft) from the top inside edge of the bowl of the sink
- Indoor damp and wet locations
- Locker rooms with associated showering facilities
- Garages, accessory buildings, service bays, and similar areas other than vehicle exhibition halls and showrooms
- Crawl spaces at or below grade level
- Unfinished areas of basements
- Laundry areas
- Bathtubs and shower stalls—where receptacles are installed within 1.8 m (6 ft) of the outside edge of the bathtub or shower stall

It is important to note that any equipment connected to receptacles that have higher voltages and current ratings present the same shock hazards as those with lower voltage and current ratings.

Commercial Kitchens and Restaurants

GFCIs are required in all single-phase and three-phase receptacles in commercial kitchens and food preparation areas that have a sink, regardless of whether the receptacle serves a countertop area. According to NEC, electrical incident data finds that there are many electrical hazards in non-dwelling kitchens, including poorly maintained electrical equipment, damaged cords, and wet floors. The installation of GFCIs in these locations protects personnel who might be exposed to electrical shock.

The requirements under NEC 210.8(B)(2) apply to all kitchens (or areas with a sink and permanent provisions for food preparation or cooking) found in restaurants, hotels, schools, churches, dining halls, and similar facilities.

In 2017, the NEC began to require GFCI protection for circuits up to 100 A. For commercial kitchens, this posed a challenge because large appliances, such as a 60-ampere 208-volt fryer, require GFCIs that are rated for at least 60 A. Traditional GFCIs, however, were unavailable in this range.

RESIDUAL-CURRENT CIRCUIT BREAKERS AND GROUND-FAULT RELAYS ARE NOT APPROVED TO PROTECT PEOPLE FROM ELECTRICAL SHOCK, AND THUS MUST NEVER BE USED IN LIEU OF A GFCI.

According to the NEC, a GFCI is required for cord-connected equipment. While hard-wiring equipment means the equipment is not required to be connected to a GFCI, doing so makes it difficult to meet health and sanitation codes. Doing so requires the large appliance to be hard-wired to the wall, which makes it difficult to clean the surrounding area. When these appliances are not portable, workers usually cannot efficiently (if at all) access those areas which are required to be kept clean per health and sanitation codes.

It is important for designers and companies to understand that residual-current devices and ground-fault relays are not the same as GFCIs. In North American codes and standards the term GFCI is synonymous with personnel level protection from electric shock, and since those other devices are not listed to UL943 or UL943C (the standards for GFCIs and SPGFCIs), they should only be considered for equipment level protection.

The Littelfuse Shock Block SB6100-02X-3 is a Class-A GFCI that can handle up to 100-ampere circuits, and the SB5060-021-0 Class-A GFCI is for circuits up to 60 A (see **Figure 5**). This GFCI enables kitchens to meet NEC's requirement while also meeting health and sanitation codes with ease.

Ground Check One Two: GFCIs for the Entertainment Industry and Temporary Installations

The primary reason the entertainment industry traditionally struggles to protect its workers from electrical shock is not only due to worn cable insulation, which can cause ground faults, and wet conditions frequently found on site, but because its installations are usually temporary. Wet conditions are a recipe for electrical shock incidents, and temporary installations historically made the installation of GFCI protection difficult due to many factors such as:

1 Drop-Down Receptacles for Prep 2 Meat Grinder 3 Electric Oven/Pizza Oven 4 Dishwasher 5 Electric Range 6 Deep Fryer

FIGURE 5. The SB5000, a Class A GFCI, allows restaurants to meet new NEC requirements without making it difficult to also meet health and sanitation codes.

- A lack of proper ground conductors
- Improperly protected conductors (i.e., lack of conduit)
- Worn conductors on portable and mobile equipment
- Multiple trades on site using various equipment and trying to get their task done as quickly as possible
- Complex switching of circuits to support a load

GFCIs Designed for the Entertainment Industry and Temporary Installations

There are three different types of rental shock blocks that are designed to provide protection in temporary installations:

1. Shock Block Lunchbox LB100 (people protection)
2. Shock Block SB100B (people and equipment protection)
3. Shock Block SB3000 (equipment protection)

The rental Class A Littelfuse Shock Block is a GFCI designed to protect workers in the entertainment industry, who often encounter wet conditions and cables with worn insulation.

The entertainment industry and Hollywood sets often use portable GFCIs (such as the Shock Block GFCI) that have these specific features critical for onset usage such as:

- A rugged outer cage
- Connectors that fit pre-existing equipment (like Bates connectors) for Hollywood on-set equipment
- Compatibility with three-phase 4-wire systems
- Meets UL requirements for portable applications and ANSI E1.19 - 2015 - Recommended Practice for the Use of Class A Ground-Fault Circuit Interrupters (GFCIs) Intended for Personnel Protection in the Entertainment Industry

> *"A third-party engineering firm independently evaluated the performance of three special-purpose GFCIs. The Littelfuse Shock Block SB6100 performed well and was the only product that met all our test criteria."*
>
> EHS ENGINEERING MANAGER

These GFCIs provide ground-fault protection for equipment that is subject to wet conditions, moisture, and worn cable insulation.

The SB3000 monitors leakage current to eliminate potential electrical hazards caused by wet equipment.

Because the SB3000 does not provide GFCI shock protection, it should be used in conjunction with either the SB100B, SB250B or the LB100 Shock Blocks.

The SB3000 is used on the main higher amperage connection to the generator. The SB100 or SB250B are used on the branch circuits that go to individual loads, which is where the GFCI protection will be.

The Lunchbox has hospital-grade duplex receptacles with recessed circuit breakers and indicator lights to provide GFCI protection for single-phase 120 volt equipment.

Case Studies

Special-Purpose GFCI with 480 V Ac and 600 V Ac in Outdoor Locations and Confined Spaces

A major Canadian power company that generates about half of Ontario's electric power, wanted electrical shock protection for their personnel working in outdoor locations, wet environments, and confined spaces.

The company's Environmental Health and Safety (EHS) department mandates that all its portable equipment (such as arc welders, pumps, and concrete saws) is connected to a GFCI, which is typically connected with extension cords. Aside from posing a trip and fall hazard to workers, extension cords can quickly deteriorate, which is a serious electrical shock and fire hazard.

The company uses portable equipment that operates at 480 volts ac and 600 volts ac, which requires Class C and D special-purpose GFCIs, respectively. The engineers, however, did not have a GFCI appropriate for these environments that was specified and approved for use with both of these voltages.

The company wanted to make the safest conditions for their workers, and contacted Littelfuse to help them achieve this within the specific conditions of their system.

To determine the appropriate special-purpose GFCI that would comply with the UL 943C, their environmental health and safety department hired an independent consultant to identify a suitable product. The consultant selected products from three manufacturers for evaluation. One of the products selected for testing was the Littelfuse Shock Block SB6100 special-purpose GFCI, Class C and Class D. The evaluation consisted of three tests:

1. Trip level at a sustained current level
2. Inverse time trip characteristic for high currents
3. Cable imbalance test for a nuisance tripping condition

The inverse time curve is important as it requires the GFCI device to trip quickly on high fault currents but allows a longer time to trip on low level currents creating a safe system with reduced nuisance trips.

The Littelfuse Shock Block SB6100 was the only device that passed all three tests. According to the consultant's tests, the Littelfuse Shock Block SB6100 was the only one of the three manufacturers' devices that they found to be capable of working in their system while still providing true GFCI personnel protection trip levels. Additionally, the Shock Block SB61000 was the only one of the three devices that was actually UL Listed and therefore the only device that could be considered a true GFCI.

The company says they are planning to replace all of their 600 volt GFCIs made by other manufacturers with the Littelfuse Shock Block SB6100 Class D GFCI. The EHS department is planning to install SB6100 systems in all of the company's facilities throughout Ontario, Canada.

Heavy-Industry Manufacturing

A brick manufacturing plant in the western United States processes clay into bricks and other building materials for residential and commercial projects. The process involves wet saws that operate at 480 volts.

In this type of application, there will always be some amount of leakage current. Therefore, the company installed the Shock Block SB6100 EGFPD, which allowed them to adjust the trip level to be above the nominal leakage current.

Since the Littelfuse EGFPDs follow the UL 943 trip curve, personnel level protection was still provided for any leakage currents higher than the customer's selected trip threshold.

The plant set the adjustable trip on their SB6100 to 30-milliampere which enabled it to operate at the lowest leakage current that would not cause unnecessary tripping. In applications like this one, companies sometimes consider the use of a standard ground-fault relay in combination with an interrupting device. However, these field-installed combinations are rarely–if ever–proven to work when tested together under the UL 943 protection limits.

Since they installed the SB6100, the company has not experienced any shock incidents.

Mine Extends GFCI Protection to 480-Volt Portable Equipment

A coal mine in the southern United States operates a machine repair shop, where workers use portable 480-volt stud-gun welders. The maintenance manager installed the Littelfuse Shock Block SB6100 GFCI so that they could improve worker safety while keeping their process running.

However, they needed the GFCI to be moved around so that it could be used with various receptacle locations around the shop or in the field when needed. To accommodate this requirement, the shop manager used the two-wheeled Shock Block cart with the Shock Block SB6100 GFCI. They then added a six-foot power cord that terminates in a standard plug (see **Figure 4**). On the load side, they added 200 feet of electrical cable connected to the portable welder. The cables included a ground wire and pilot wire used for ground continuity verification.

The maintenance manager's workers said it was lightweight, and easy to use and test. Moreover, the maintenance manager is happy knowing that their workers are protected.

Submersible Pump Applications

A large municipal water utility company needed to protect their workers who clean water tanks from electrical shock while the submersible pumps are in operation. Because many dewatering applications are temporary, this was difficult to do without a GFCI that was capable of being moved from one installation to the next.

The utility company used the Littelfuse GFCI cart with the SB61000 Shock Block EGFPD, which enabled their workers to safely work in temporary installations without putting their lives at risk.

Conclusion

GFCIs are an integral component to electrical safety. Technological advancements have enabled their protection to be expanded into areas beyond a 120-volt level. Electrical systems should always be designed with safety in mind, and use engineering controls (such as GFCIs) whenever possible, regardless of whether the Code requires them in that given application or not.

Technological advancements have also enabled GFCIs to be easily implemented in applications where they traditionally might have caused unwanted tripping. To learn about how GFCIs or special-purpose GFCIs can protect the personnel in your specific application, contact one of our Littelfuse experts.

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Definitions

Ampacity: The maximum current, in amperes, that a conductor can carry continuously under the conditions of use without exceeding its temperature rating.

Direct Contact: Occurs when a person comes into contact with a part that is live under normal circumstances.

Energized: Electrically connected to, or is, a source of voltage.

Fault Current: The current that flows when a phase conductor is faulted to another phase or ground.

Ground: The earth.

Grounded (Grounding): Connected (connecting) to ground or to a conductive body that extends the ground connection.

Grounded, Solidly: Connected to ground without inserting any resistor or impedance device.

Ground Fault: Unintentional contact between a phase conductor and ground or equipment frame. The words "ground" and "earth" are used interchangeably when it comes to electrical applications.

Ground-Fault Current Path: An electrically conductive path from the point of a ground fault on a wiring system through normally non–current-carrying conductors, equipment, or the earth to the electrical supply source.

Ground-Fault Circuit Interrupter (GFCI): A device intended for the protection of personnel that functions to de-energize a circuit or portion thereof within an established period of time when a current to ground exceeds the values established for a Class A device.

Ground-Fault Protection of Equipment: A system intended to provide protection of equipment from damaging line-to ground fault currents by causing a disconnecting means to open all ungrounded conductors of the faulted circuit. This protection is provided at current levels less than those required to protect conductors from damage through the operation of a supply circuit overcurrent device.

Indirect Contact: When a person comes into contact with any part of an electric circuit that is not normally live, but has accidentally become live.

Ungrounded: Not connected to ground or to a conductive body that extends the ground connection.

Voltage: The greatest root-mean-square (rms) difference of potential between any two conductors of the circuit concerned.

Additional Resources

Shock Safety Education

Shock: Electrical's Deadliest Act **survey report**

Misconceptions about Shock Safety **webcast**

Safety by Design **webcast**

Electrical Shock: Deadly and Prevalent **survey report**

Electrical Shock Prevention Needs a Jolt of Change **webcast**

Industrial Safety **resource center**

Shock Block Resources

Shock Block GFCI and EGFPDs

Shock Block SB6100 **product information**

Shock Block SB6100 **case studies**

Shock Block SB6100 **manual**

Shock Block SB6100 **datasheet**

Shock Block SB6100 **brochure**

Shock Block SB6100 **FAQ**

Shock Block SB6100 **video**

Shock Block Rental Series for the Entertainment Industry

Shock Block portable rental series **product information**

Shock Block LB100 GFCI Lunchbox **datasheet**

Shock Block SB100B, SB250B and SB300A **datasheet**

For technical support, sales inquiries, or to simply talk shop about shock, contact one of our experts directly.

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Application and Field Support

Our experienced product and application engineers will work with you from design to installation to determine the best solution for your specific needs.

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