

## Controlling Electrical Hazards

### Why should you be concerned about electrical hazards?

Electricity has long been recognized as a serious workplace hazard, exposing employees to electric shock, electrocution, burns, fires, and explosions. In 1999, for example, 278 workers died from electrocutions at work, accounting for almost 5 percent of all on-the-job fatalities that year, according to the Bureau of Labor Statistics. What makes these statistics more tragic is that most of these fatalities could have been easily avoided.

### What OSHA standards address electrical safety?

OSHA's general industry electrical safety standards are published in *Title 29 Code of Federal Regulations (CFR)*, Part 1910.302 through 1910.308 and 1910.331 through 1910.335. OSHA's electrical safety standards for the construction industry are published in 29 CFR 1926, Subpart K.

OSHA's electrical standards are based on the National Fire Protection Association Standards NFPA 70, *National Electric Code*, and NFPA 70E, *Electrical Safety Requirements for Employee Workplaces*.

### How do OSHA's standards minimize electrical hazards?

OSHA standards focus on the design and use of electrical equipment and systems. The standards cover only the exposed or operating elements of an electrical installation such as lighting, equipment, motors, machines, appliances, switches, controls, and enclosures, requiring that they be constructed and installed to minimize workplace electrical dangers. Also, the standards require that certain approved testing organizations test and certify electrical equipment before use in the workplace to ensure it is safe.

## Electricity: The Basics

### What affects the flow of electricity?

Electricity flows more easily through some materials than others. Some substances such as metals generally offer very little resistance to the flow of electric current and are called "conductors." A common but perhaps overlooked conductor is the surface or subsurface of the earth. Glass, plastic, porcelain, clay, pottery, dry wood, and similar substances generally slow or stop the flow of electricity. They are called "insulators." Even air, normally an insulator, can become a conductor, as occurs during an arc or lightning stroke.

### How does water affect the flow of electricity?

Pure water is a poor conductor. But small amounts of impurities in water like salt, acid, solvents, or other materials can turn water itself and substances that generally act as insulators into conductors or better conductors. Dry wood, for example, generally slows or stops the flow of electricity. But when saturated with water, wood turns into a conductor. The same is true of human skin. Dry skin has a fairly high resistance to electric current. But when skin is moist or wet, it acts as a conductor. This means that anyone working with electricity in a damp or wet environment needs to exercise extra caution to prevent electrical hazards.

## What causes shocks?

Electricity travels in closed circuits, normally through a conductor. But sometimes a person's body -- an efficient conductor of electricity -- mistakenly becomes part of the electric circuit. This can cause an electrical shock. Shocks occur when a person's body completes the current path with:

- both wires of an electric circuit;
- one wire of an energized circuit and the ground;
- a metal part that accidentally becomes energized due, for example, to a break in its insulation; or
- another "conductor" that is carrying a current.

When a person receives a shock, electricity flows between parts of the body or through the body to a ground or the earth.

## What effect do shocks have on the body?

An electric shock can result in anything from a slight tingling sensation to immediate cardiac arrest. The severity depends on the following:

- the amount of current flowing through the body,
- the current's path through the body,
- the length of time the body remains in the circuit, and
- the current's frequency.

This table shows the general relationship between the amount of current received and the reaction when current flows from the hand to the foot for just 1 second.

### Effects of Electric Current in the Human Body

Current	Reaction
Below 1 milliamperere	Generally not perceptible
1 milliamperere	Faint tingle
5 milliampereres	Slight shock felt; not painful but disturbing. Average individual can let go. Strong involuntary reactions can lead to other injuries.
6–25 milliamperes (women)	Painful shock, loss of muscular control*
9–30 milliamperes (men)	The freezing current or "let-go" range.* Individual cannot let go, but can be thrown away from the circuit if extensor muscles are stimulated.
50–150 milliamperes	Extreme pain, respiratory arrest, severe muscular contractions. Death is possible.
1,000–4,300 milliamperes	Rhythmic pumping action of the heart ceases. Muscular contraction and nerve damage occur; death likely.
10,000 milliamperes	Cardiac arrest, severe burns; death probable

- If the extensor muscles are excited by the shock, the person may be thrown away from the power source.

## **What kind of burns can a shock cause?**

Burns are the most common shock-related injury. An electrical accident can result in an electrical burn, arc burn, thermal contact burn, or a combination of burns.

*Electrical burns* are among the most serious burns and require immediate medical attention. They occur when electric current flows through tissues or bone, generating heat that causes tissue damage.

*Arc or flash burns* result from high temperatures caused by an electric arc or explosion near the body. These burns should be treated promptly.

*Thermal contact burns* are caused when the skin touches hot surfaces of overheated electric conductors, conduits, or other energized equipment. Thermal burns also can be caused when clothing catches on fire, as may occur when an electric arc is produced.

In addition to shock and burn hazards, electricity poses other dangers. For example, arcs that result from short circuits can cause injury or start a fire. Extremely high-energy arcs can damage equipment, causing fragmented metal to fly in all directions. Even low-energy arcs can cause violent explosions in atmospheres that contain flammable gases, vapors, or combustible dusts.

## **Why do people sometimes "freeze" when they are shocked?**

When a person receives an electrical shock, sometimes the electrical stimulation causes the muscles to contract. This "freezing" effect makes the person unable to pull free of the circuit. It is extremely dangerous because it increases the length of exposure to electricity and because the current causes blisters, which reduce the body's resistance and increases the current. The longer the exposure, the greater the risk of serious injury. Longer exposures at even relatively low voltages can be just as dangerous as short exposures at higher voltages. Low voltage does not imply low hazard.

In addition to muscle contractions that cause "freezing," electrical shocks also can cause involuntary muscle reactions. These reactions can result in a wide range of other injuries from collisions or falls, including bruises, bone fractures, and even death.

## **What should you do if someone "freezes" to a live electrical contact?**

If a person is "frozen" to a live electrical contact, shut off the current immediately. If this is not possible, use boards, poles, or sticks made of wood or any other nonconducting materials and safely push or pull the person away from the contact. It's important to act quickly, but remember to protect yourself as well from electrocution or shock.

## **How can you tell if a shock is serious?**

A severe shock can cause considerably more damage than meets the eye. A victim may suffer internal hemorrhages and destruction of tissues, nerves, and muscles that aren't readily visible. Renal damage also can occur. If you or a coworker receives a shock, seek emergency medical help immediately.

## **What is the danger of static electricity?**

Static electricity also can cause a shock, though in a different way and generally not as potentially severe as the type of shock described previously. Static electricity can build up on the surface of an object and, under the right conditions, can discharge to a person, causing a shock. The most familiar example of this is when a person reaches for a door knob or other metal object on a cold, relatively dry day and receives a shock.

However, static electricity also can cause shocks or can just discharge to an object with much more serious consequences, as when friction causes a high level of static electricity to build up at a specific spot on an object. This can happen simply through handling plastic pipes and materials or during normal operation of rubberized drive or machine belts found in many worksites. In these cases, for example, static electricity can potentially discharge when sufficient amounts of flammable or combustible substances are located nearby and cause an explosion. Grounding or other measures may be necessary to prevent this static electricity buildup and the results.

## **Protection Against Electrical Hazards**

### **What is the best way to protect yourself against electrical hazards?**

Most electrical accidents result from one of the following three factors:

- unsafe equipment or installation,
- unsafe environment, or
- unsafe work practices.

Some ways to prevent these accidents are through the use of insulation, guarding, grounding, electrical protective devices, and safe work practices.

### **What protection does insulation provide?**

Insulators such as glass, mica, rubber, or plastic used to coat metals and other conductors help stop or reduce the flow of electrical current. This helps prevent shock, fires, and short circuits. To be effective, the insulation must be suitable for the voltage used and conditions such as temperature and other environmental factors like moisture, oil, gasoline, corrosive fumes, or other substances that could cause the insulator to fail.

### **How do you identify different types of insulation?**

Insulation on conductors is often color coded. Insulated equipment grounding conductors usually are either solid green or green with yellow stripes. Insulation covering grounded conductors is generally white or gray. Ungrounded conductors, or "hot wires," often are black or red, although they may be any color other than green, white, or gray.

Before connecting electrical equipment to a power source, it's a good idea to check the insulation for any exposed wires for possible defects. Insulation covering flexible cords such as extension cords is particularly vulnerable to damage.

The insulation that covers conductors in non-construction applications is regulated by Subpart S of 29 CFR 1910.302 through 1910.308, *Wiring Design and Protection*. Subpart S generally requires insulation on circuit conductors. It also specifies that the insulation used should be suitable for the voltage and conditions. Conductors used in construction applications are regulated by Subpart K of 29 CFR 1926.402 through 1926.408.

### **What is guarding and what protection does it offer?**

Guarding involves locating or enclosing electric equipment to make sure people don't accidentally come into contact with its live parts. Effective guarding requires equipment with exposed parts operating at 50 volts or more to be placed where it is accessible only to authorized people qualified to work with it. Recommended locations are a room, vault, or similar enclosure; a balcony, gallery, or elevated platform; or a site elevated 8 feet or more above the floor. Sturdy, permanent screens also can serve as effective guards.

Conspicuous signs must be posted at the entrances to electrical rooms and similarly guarded locations to alert people to the electrical hazard and to forbid entry to unauthorized people. Signs may contain the word "Danger," "Warning," or "Caution," and beneath that, appropriate concise wording that alerts people to the hazard or gives an instruction, such as "Danger/High Voltage/Keep Out."

## **What is grounding and what protection does it offer?**

" Grounding" a tool or electrical system means intentionally creating a low-resistance path that connects to the earth. This prevents the buildup of voltages that could cause an electrical accident.

Grounding is normally a secondary protective measure to protect against electric shock. It does not guarantee that you won't get a shock or be injured or killed by an electrical current. It will, however, substantially reduce the risk, especially when used in combination with other safety measures discussed in this fact sheet.

A *service* or *system ground* is designed primarily to protect machines, tools, and insulation against damage. One wire, called the " neutral" or " grounded" conductor, is grounded. In an ordinary low-voltage circuit, the white or gray wire is grounded at the generator or transformer and at the building's service entrance.

An *equipment ground* helps protect the equipment operator. It furnishes a second path for the current to pass through from the tool or machine to the ground. This additional ground safeguards the operator if a malfunction causes the tool's metal frame to become energized. The resulting flow of current may activate the circuit protection devices.

## **What are circuit protection devices and how do they work?**

Circuit protection devices limit or stop the flow of current automatically in the event of a ground fault, overload, or short circuit in the wiring system. Well-known examples of these devices are fuses, circuit breakers, ground-fault circuit interrupters, and arc-fault circuit interrupters.

*Fuses* and *circuit breakers* open or break the circuit automatically when too much current flows through them. When that happens, fuses melt and circuit breakers trip the circuit open. Fuses and circuit breakers are designed to protect conductors and equipment. They prevent wires and other components from overheating and open the circuit when there is a risk of a ground fault.

*Ground-fault circuit interrupters*, or GFCIs, are used in wet locations, construction sites, and other high-risk areas. These devices interrupt the flow of electricity within as little as 1/40 of a second to prevent electrocution. GFCIs compare the amount of current going into electric equipment with the amount of current returning from it along the circuit conductors. If the difference exceeds 5 milliamperes, the device automatically shuts off the electric power.

*Arc-fault devices* provide protection from the effects of arc-faults by recognizing characteristics unique to arcing and by functioning to deenergize the circuit when an arc-fault is detected.

## **What work practices help protect you against electrical hazards?**

Electrical accidents are largely preventable through safe work practices. Examples of these practices include the following:

- deenergizing electric equipment before inspection or repair,
- keeping electric tools properly maintained,
- exercising caution when working near energized lines, and
- using appropriate protective equipment.

Electrical safety-related work practice requirements for general industry are detailed in Subpart S of 29 CFR Part 1910, in Sections 1910.331–1910.335. For construction applications, electrical safety-related work practice requirements are detailed in Subpart K of 29 CFR Part 1926.416 to 1926.417.

## **How can you protect yourself against metal parts that become energized?**

A break in an electric tool's or machine's insulation can cause its metal parts to become "hot" or energized, meaning that they conduct electricity. Touching these energized parts can result in an electrical shock, burn, or electrocution. The best way to protect yourself when using electrical tools or machines is to establish a low-resistance path from the device's metallic case to the ground. This requires an equipment grounding conductor, a low-resistance wire that directs unwanted current directly to the ground. A properly installed grounding conductor has a low resistance to ground and greatly reduces the amount of current that passes through your body. Cord and plug equipment with a three-prong plug is a common example of equipment incorporating this ground conductor.

Another form of protection is to use listed or labeled portable tools and appliances protected by an approved system of double insulation or its equivalent. Where such a system is employed, it must be marked distinctively to indicate that the tool or appliance uses an approved double insulation system.

## **How can you prevent an accidental or unexpected equipment startup?**

Proper lockout/tagout procedures protect you from the dangers of the accidental or unexpected startup of electrical equipment and are required for general industry by OSHA Standard 1910.333, *Selection and Use of Work Practices*. Requirements for construction applications are in 29 CFR 1926.417, *Lockout and Tagging of Circuits*. These procedures ensure that electrical equipment is deenergized before it is repaired or inspected and protects you against electrocution or shock.

The first step before beginning any inspection or repair job is to turn the current off at the switch box and padlock the switch in the OFF position. This applies even on so-called low-voltage circuits. Securely tagging the switch or controls of the machine or equipment being locked out of service clarifies to everyone in the area which equipment or circuits are being inspected or repaired.

Only qualified electricians who have been trained in safe lockout procedures should maintain electrical equipment. No two of the locks used should match, and each key should fit just one lock. In addition, one individual lock and key should be issued to each maintenance worker authorized to lock out and tag the equipment. All employees who repair a given piece of equipment should lock out its switch with an individual lock. Only authorized workers should be permitted to remove it.

## **How can you protect yourself from overhead power lines?**

Before working under or near overhead power lines, ensure that you maintain a safe distance to the lines and, for very high-voltage lines, ground any equipment such as cranes that can become energized. If working on power lines, ensure that the lines have been deenergized and grounded by the owner or operator of the lines. Other protective measures like guarding or insulating the lines help prevent accidental contact.

Employees unqualified to work with electricity, as well as mechanical equipment, should remain at least 10 feet away from overhead power lines. If the voltage is more than 50,000 volts, the clearance increases by 4 inches for each additional 10,000 volts.

When mechanical equipment is operated near overhead lines, employees standing on the ground should avoid contact with the equipment unless it is located outside the danger zone. When factoring the safe standoff distance, be sure to consider the equipment's maximum reach.

## **What protection does personal equipment offer?**

Employees who work directly with electricity should use the personal protective equipment required for the jobs they perform. This equipment may include rubber insulating gloves, hoods, sleeves, matting, blankets, line hose, and industrial protective helmets designed to reduce electric shock hazard. All help reduce the risk of electrical accidents.

## **What role do tools play?**

Appropriate and properly maintained tools help protect workers against electric hazards. It's important to maintain tools regularly because it prevents them from deteriorating and becoming dangerous. Check each tool before using it. If you find a defect, immediately remove it from service and tag it so no one will use it until it has been repaired or replaced.

When using a tool to handle energized conductors, check to make sure it is designed and constructed to withstand the voltages and stresses to which it has been exposed.

## **What special training do employees need?**

All employees should be trained to be thoroughly familiar with the safety procedures for their particular jobs. Moreover, good judgment and common sense are integral to preventing electrical accidents. When working on electrical equipment, for example, some basic procedures to follow are to:

- deenergize the equipment,
- use lockout and tag procedures to ensure that the equipment remains deenergized,
- use insulating protective equipment, and
- maintain a safe distance from energized parts.

## **What's the value of a safety and health program in controlling electrical hazards?**

Every good safety and health program provides measures to control electrical hazards. The measures suggested in this booklet should be helpful in establishing such a program. The responsibility for this program should be delegated to someone with a complete knowledge of electricity, electrical work practices, and the appropriate OSHA standards for installation and performance.

Everyone has the right to work in a safe environment. Safety and health add value to your business and your workplace. Through cooperative efforts, employers and employees can learn to identify and eliminate or control electrical hazards.