Revised Edition

Electrical Safety

Safety and Health for Electrical Trades

Student Manual

DEPARTMENT OF HEALTH AND HUMAN SERVICES
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

CDC Workplace Safety and Health

NIOSH

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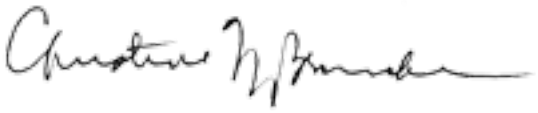
SAFER • HEALTHIER • PEOPLE™

Foreword

The National Institute for Occupational Safety and Health (NIOSH) estimates that 230,000 young workers under the age of 18 suffer work-related injuries in the United States each year. Young and new workers have a high risk for work-related injury compared with more experienced workers. Occupational safety and health training remains a fundamental element of hazard control in the workplace, and there is great potential to reduce these incidents through pre-employment training. Effective pre-employment training should include realistic environments and hands-on exercises. However, NIOSH recommends that actual employment in the electrical trades or any of the other construction trades be delayed until individuals reach the minimum age of 18.

This student manual is part of a safety and health curriculum for secondary and post-secondary electrical trades courses. The manual is designed to engage the learner in recognizing, evaluating, and controlling hazards associated with electrical work. It was developed through extensive research with vocational instructors, and we are grateful for their valuable contributions.



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Electrical Safety

Section 1
Electricity Is Dangerous

Whenever you work with power tools or on electrical circuits, there is a risk of electrical hazards, especially electrical shock. Anyone can be exposed to these hazards at home or at work. Workers are exposed to more hazards because job sites can be cluttered with tools and materials, fast-paced, and open to the weather. Risk is also higher at work because many jobs involve electric power tools.

Electrical trades workers must pay special attention to electrical hazards because they work on electrical circuits. Coming in contact with an electrical voltage can cause current to flow through the body, resulting in electrical shock and burns. Serious injury ***or even death*** may occur. As a source of energy, electricity is used without much thought about the hazards it can cause. Because electricity is a familiar part of our lives, it often is not treated with enough caution. As a result, an average of one worker is electrocuted on the job every day of every year!

According to the Bureau of Labor Statistics Census of Fatal Occupational Injuries Research File for 1992–2005, electrocution is the fifth leading cause of work-related deaths for 16- to 19-year-olds, after motor vehicle deaths, contact with objects and equipment, workplace homicide, and falls. Electrocution is the cause of 7% of all workplace deaths among young workers aged 16–19, causing an average of 10 deaths per year.[1]

***Note to the learner*—This manual describes the hazards of electrical work and basic approaches to working safely. You will learn skills to help you recognize, evaluate, and control electrical hazards. This information will prepare you for additional safety training such as hands-on exercises and more detailed reviews of regulations for electrical work.**

Your employer, co-workers, and community will depend on your expertise. Start your career off right by learning safe practices and developing good safety habits. Safety is a very important part of any job. Do it right from the start.

- ***Electrical shock may cause injury or death!***

Electrical work can be deadly if not done safely.

This manual will present many topics. There are four main types of electrical injuries: **electrocution (death due to electrical shock), electrical shock, burns, and falls**. The dangers of electricity, electrical shock, and the resulting injuries will be discussed. The various electrical hazards will be described. **You will learn about the safety model, an important tool for recognizing, evaluating, and controlling hazards**. Important definitions and notes are shown in the margins. Practices that will help keep you safe and free of injury are emphasized. To give you an idea of the hazards caused by electricity, case studies about real-life deaths will be described.

How Is an Electrical Shock Received?

- ***current*—**the movement of electrical charge
- ***voltage*—**a measure of electrical force
- ***circuit*—**a complete path for the flow of current
- ***You will receive a shock if you touch two wires at different voltages at the same time.***

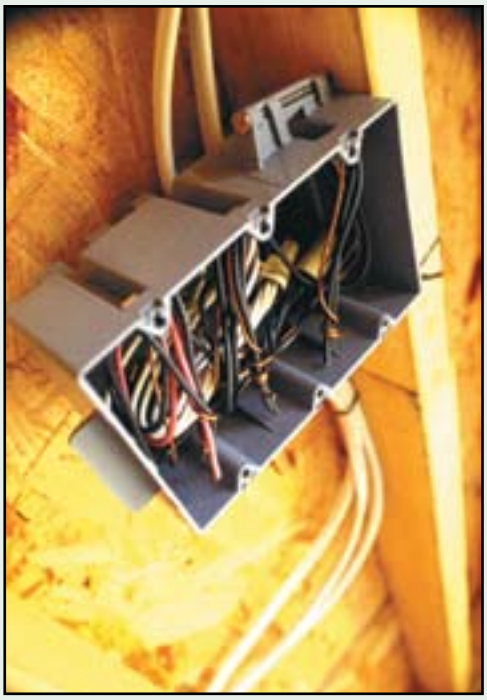
An electrical shock is received when electrical current passes through the body. Current will pass through the body in a variety of situations. Whenever two wires are at different voltages, current will pass between them if they are connected. Your body can connect the wires if you touch both of them at the same time. Current will pass through your body.

Wires carry current

- ***ground*—**a physical electrical connection to the earth
- ***energized (live, "hot")*—**similar terms meaning that a voltage is present that can cause a current, so there is a possibility of getting shocked

In most household wiring, the black wires and the red wires are at 120 volts. The white wires are at 0 volts because they are connected to ground. The connection to ground is often through a conducting ground rod driven into the earth. The connection can also be made through a buried metal water pipe. **If you come in contact with an**

energized black wire—and you are also in contact with the neutral white wire—current will pass through your body. You will receive an electrical shock.



Black and red wires are usually energized, and white wires are usually neutral.

- ***conductor—*** material in which an electrical current moves easily
- ***neutral—*** at ground potential (0 volts) because of a connection to ground

Metal electrical boxes should be grounded to prevent shocks.

If you are in contact with a live wire or any live component of an energized electrical device—and also in contact with any grounded object—you will receive a shock. Plumbing is often grounded. Metal electrical boxes and conduit are grounded.

Your risk of receiving a shock is greater if you stand in a puddle of water. But you don't even have to be standing in water to be at risk. Wet clothing, high humidity, and perspiration also increase your chances of being electrocuted. Of course, there is always a chance of electrocution, even in dry conditions.

- ***You will receive a shock if you touch a live wire and are grounded at the same time.***
- ***When a circuit, electrical component, or equipment is energized, a potential shock hazard is present.***

You can even receive a shock when you are not in contact with an electrical ground. Contact with both live wires of a 240-volt cable will deliver a shock. (This type of shock can occur because one live wire may be at +120 volts while the other is at -120 volts during an alternating current cycle—a difference of 240 volts.). You can also receive a shock from electrical components that are not grounded properly. Even contact with another person who is receiving an electrical shock may cause you to be shocked.

A 30-year-old male electrical technician was helping a company service representative test the voltage-regulating unit on a new rolling mill. While the electrical technician went to get the equipment service manual, the service representative opened the panel cover of the voltage regulator's control cabinet in preparation to trace the low-voltage wiring in question (the wiring was not color-coded). The service representative climbed onto a nearby cabinet in order to view the wires. The technician returned and began working inside the control cabinet, near exposed, energized electrical conductors. The technician tugged at the low-voltage wires while the service representative tried to identify them from above. Suddenly, the representative heard the victim making a gurgling sound and looked down to see the victim shaking as though he were being shocked. Cardiopulmonary resuscitation (CPR) was administered to the victim about 10 minutes later. He was pronounced dead almost 2 hours later as a result of his contact with an energized electrical conductor.

To prevent an incident like this, employers should take the following steps:

- *Establish proper rules and procedures on how to access electrical control cabinets without getting hurt.*
- *Make sure all employees know the importance of de-energizing (shutting off) electrical systems before performing repairs.*
- *Equip voltage-regulating equipment with color-coded wiring.*
- *Train workers in CPR.*

A maintenance man rode 12 feet above the floor on a motorized lift to work on a 277-volt light fixture. He did not turn off the power supply to the lights. He removed the line fuse from the black wire, which he thought was the "hot" wire. But, because of a mistake in installation, it turned out that the white wire was the "hot" wire, not the black one. The black wire was neutral. He began to strip the white wire using a wire stripper in his right hand. Electricity passed from the "hot" white wire to the stripper, then into his hand and through his body, and then to ground through his left index finger. A coworker heard a noise and saw the victim lying face-up on the lift. She immediately summoned another worker, who lowered the platform. CPR was performed, but the maintenance man could not be saved. He was pronounced dead at the scene.

You can prevent injuries and deaths by remembering the following points:

- *If you work on an electrical circuit, test to make sure that the circuit is de-energized (shut off)!*
- *Never attempt to handle any wires or conductors until you are absolutely positive that their electrical supply has been shut off.*
- *Be sure to lock out and tag out circuits so they cannot be re-energized.*
- *Always assume a conductor is dangerous.*

Always test a circuit to make sure it is de-energized before working on it.

Summary of Section 1

You will receive an electrical shock if a part of your body completes an electrical circuit by • • •

- touching a live wire and an electrical ground, or
- touching a live wire and another wire at a different voltage.

- ***ampere (amp)*—**the unit used to measure current
- ***milliampere (milliamp or mA)*—** 1/1,000 of an ampere
- ***shocking current*—**electrical current that passes through a part of the body
- ***You will be hurt more if you can't let go of a tool giving a shock.***
- ***The longer the shock, the greater the injury.***

Defibrillator in use.

Section 2
Dangers of Electrical Shock

The severity of injury from electrical shock depends on the amount of electrical current and the length of time the current passes through the body. For example, 1/10 of an ampere (amp) of electricity going through the body for just 2 seconds is enough to cause death. The amount of internal current a person can withstand and still be able to control the muscles of the arm and hand can be less than 10 milliamperes (milliamps or mA). Currents above 10 mA can paralyze or "freeze" muscles. When this "freezing" happens, a person is no longer able to release a tool, wire, or other object. In fact, the electrified object may be held even more tightly, resulting in longer exposure to the shocking current. For this reason, hand-held tools that give a shock can be very dangerous. If you can't let go of the tool, current continues through your body for a longer time, which can lead to respiratory paralysis (the muscles that control breathing cannot move). You stop breathing for a period of time. People have stopped breathing when shocked with currents from voltages as low as 49 volts. Usually, it takes about 30 mA of current to cause respiratory paralysis.

Currents greater than 75 mA cause ventricular fibrillation (very rapid, ineffective heartbeat). This condition will cause death within a few minutes unless a special device called a defibrillator is used to save the victim. Heart paralysis occurs at 4 amps, which means the heart does not pump at all. Tissue is burned with currents greater than 5 amps.[2]

The table shows what usually happens for a range of currents (lasting one second) at typical household voltages. Longer exposure times increase the danger to the shock victim. For example, a current of 100 mA applied for 3 seconds is as dangerous as a current of 900 mA applied for a fraction of a second (0.03 seconds). The muscle structure of the person also makes a difference. People with less muscle tissue are typically affected at lower current levels. Even low voltages can be extremely dangerous because the degree of injury depends not only on the amount of current but also on the length of time the body is in contact with the circuit.

LOW VOLTAGE DOES NOT MEAN LOW HAZARD!

Effects of Electrical Current in the Human Body[3,4]

Current	Reaction
Below 1 milliampere	Generally not perceptible.
1 milliampere	Faint tingle.
5 milliamperes	Slight shock felt; not painful but disturbing. Average individual can let go. Strong involuntary reactions can lead to other injuries.
6–25 milliamperes (women) **9–30 milliamperes** (men)	Painful shock, loss of muscular control. 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 (breathing stops), 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 and severe burns occur. Death is probable.
15,000 milliamperes	Lowest overcurrent at which a typical fuse or circuit breaker opens a circuit!

*If the extensor muscles are excited by the shock, the person may be thrown away from the power source. The lowest overcurrent at which a typical fuse or circuit breaker will open is 15,000 milliamps (15 amps).

Sometimes high voltages lead to additional injuries. High voltages can cause violent muscular contractions. You may lose your balance and fall, which can cause injury or even death if you fall into machinery that can crush you. High voltages can also cause severe burns (as seen on pages 9 and 10).

High voltages cause additional injuries!

At 600 volts, the current through the body may be as great as 4 amps, causing damage to internal organs such as the heart. High voltages also produce burns. In addition, internal blood vessels may clot. Nerves in the area of the contact point may be damaged. Muscle contractions may cause bone fractures from either the contractions themselves or from falls.

Higher voltages can cause larger currents and more severe shocks.

A severe shock can cause much more damage to the body than is visible. A person may suffer internal bleeding and destruction of tissues, nerves, and muscles. Sometimes the hidden injuries caused by electrical shock result in a delayed death. Shock is often only the beginning of a chain of events. Even if the electrical current is too small to cause injury, your reaction to the shock may cause you to fall, resulting in bruises, broken bones, or even death.

Some injuries from electrical shock cannot be seen.

The length of time of the shock greatly affects the amount of injury. If the shock is short in duration, it may only be painful. A longer

shock (lasting a few seconds) could be fatal if the level of current is high enough to cause the heart to go into ventricular fibrillation. This is not much current when you realize that a small power drill uses 30 times as much current as what will kill. At relatively high currents, death is certain if the shock is long enough. However, if the shock is short and the heart has not been damaged, a normal heartbeat may resume if contact with the electrical current is eliminated. (This type of recovery is rare.)

- ***The greater the current, the greater the shock!***

- ***Severity of shock depends on voltage, amperage, and resistance.***

The amount of current passing through the body also affects the severity of an electrical shock. Greater voltages produce greater currents. So, there is greater danger from higher voltages. Resistance hinders current. The lower the resistance (or impedance in AC circuits), the greater the current flow will be. Dry skin may have a resistance of 100,000 ohms or more. Wet skin may have a resistance of only 1,000 ohms. Wet working conditions or broken skin will drastically reduce resistance. The low resistance of wet skin allows current to pass into the body more easily and give a greater shock. When more force is applied to the contact point or when the contact area is larger, the resistance is lower, causing stronger shocks.

Power drills use 30 times as much current as what will kill.

- ***resistance*—**a material's ability to decrease or stop electrical current

- ***ohm*—**unit of measurement for electrical resistance

- ***Lower resistance causes greater currents.***

The path of the electrical current through the body affects the severity of the shock. Currents through the heart or nervous system are most dangerous. If you contact a live wire with your head, your nervous system may be damaged. Contacting a live electrical part with one hand—while you are grounded at the other side of your body—will cause electrical current to pass across your chest, possibly injuring your heart and lungs.

- ***Currents across the chest are very dangerous.***

A male service technician arrived at a customer's house to perform pre-winter maintenance on an oil furnace. The customer then left the house and returned 90 minutes later. She noticed the service truck was still in the driveway. After 2 more hours, the customer entered the crawl space with a flashlight to look for the technician but could not see him. She then called the owner of the company, who came to the house. He searched the crawl space and found the technician on his stomach, leaning on his elbows in front of the furnace. The assistant county coroner was called and pronounced the technician dead at the scene. The victim had electrical burns on his scalp and right elbow.

After the incident, an electrician inspected the site. A toggle switch that supposedly controlled electrical power to the furnace was in the "off" position. The electrician described the wiring as "haphazard and confusing."

Two weeks later, the county electrical inspector performed another inspection. He discovered that incorrect wiring of the toggle switch allowed power to flow to the furnace even when the switch was in the "off" position. The owner of the company stated that the victim was a very thorough worker. Perhaps the victim performed more maintenance on the furnace than previous technicians, exposing himself to the electrical hazard.

This death could have been prevented!

- *The victim should have tested the circuit to make sure it was de-energized.*
- *Employers should provide workers with appropriate equipment and training. Using safety equipment should be a requirement of the job. In this case, a simple circuit tester may have saved the victim's life.*
- *Residential wiring should satisfy the National Electrical Code (NEC). Although the NEC is not retroactive, all homeowners should make sure their systems are safe.*

Electrical burn on hand and arm.

***NEC*—National Electrical Code**—a comprehensive listing of practices to protect workers and equipment from electrical hazards such as fire and electrocution

There have been cases where an arm or leg is severely burned by high-voltage electrical current to the point of coming off, and the victim is not electrocuted. In these cases, the current passes through only a part of the limb before it goes out of the body and into another conductor. Therefore, the current does not go through the chest area and may not cause death, even though the victim is severely disfigured. If the current does go through the chest, the person will almost surely be electrocuted. A large number of serious electrical injuries involve current passing from the hands to the feet. Such a path involves both the heart and lungs. This type of shock is often fatal.

Arm with third degree burn from high-voltage line.

Summary of Section 2

The danger from electrical shock depends on • • •

the ***amount*** of the shocking current through the body,

the ***duration*** of the shocking current through the body, and

the ***path*** of the shocking current through the body.

Section 3

Burns Caused by Electricity

Electrical shocks cause burns.

The most common shock-related, nonfatal injury is a burn. Burns caused by electricity may be of three types: **electrical burns, arc burns, and thermal contact burns**. Electrical burns can result when a person touches electrical wiring or equipment that is used or maintained improperly. Typically, such burns occur on the hands. Electrical burns are one of the most serious injuries you can receive. They need to be given immediate attention. Additionally, clothing may catch fire and a thermal burn may result from the heat of the fire.

Contact electrical burns. The knee on the left was energized, and the knee on the right was grounded.

arc-blast—explosive release of molten material from equipment caused by high-amperage arcs

arcing—the luminous electrical discharge (bright, electrical sparking) through the air that occurs when high voltages exist across a gap between conductors

Arc Blasts

Arc-blasts occur when powerful, high-amperage currents arc through the air. Arcing is the luminous electrical discharge that occurs when high voltages exist across a gap between conductors and current travels through the air. This situation is often caused by equipment failure due to abuse or fatigue. Temperatures as high as 35,000°F have been reached in arc-blasts. A common example of arcing is the flash you sometimes see when you turn a light switch on or off. This is not dangerous because of the low voltage.

There are three primary hazards associated with an arc-blast.

(1) Arcing gives off thermal radiation (heat) and intense light, which can cause burns. Several factors affect the degree of injury, including skin color, area of skin exposed, and type of clothing worn. Proper clothing, work distances, and overcurrent protection can reduce the risk of such a burn.

(2) A high-voltage arc can produce a considerable pressure wave blast. A person 2 feet away from a 25,000-amp arc feels a force of about 480 pounds on the front of the body. In addition, such an explosion can cause serious ear damage and memory loss due to

concussion. Sometimes the pressure wave throws the victim away from the arc-blast. While this may reduce further exposure to the thermal energy, serious physical injury may result. The pressure wave can propel large objects over great distances. In some cases, the pressure wave has enough force to snap off the heads of steel bolts and knock over walls.

(3) A high-voltage arc can also cause many of the copper and aluminum components in electrical equipment to melt. These droplets of molten metal can be blasted great distances by the pressure wave. Although these droplets harden rapidly, they can still be hot enough to cause serious burns or cause ordinary clothing to catch fire, even if you are 10 feet or more away.

Five technicians were performing preventive maintenance on the electrical system of a railroad maintenance facility. One of the technicians was assigned to clean the lower compartment of an electrical cabinet using cleaning fluid in an aerosol can. But, he began to clean the upper compartment as well. The upper compartment was filled with live circuitry. When the cleaning spray contacted the live circuitry, a conductive path for the current was created. The current passed through the stream of fluid, into the technician's arm, and across his chest. The current caused a loud explosion. Co-workers found the victim with his clothes on fire. One worker put out the fire with an extinguisher, and another pulled the victim away from the compartment with a plastic vacuum cleaner hose. The paramedics responded in 5 minutes. Although the victim survived the shock, he died 24 hours later of burns.

This death could have been prevented if the following precautions had been taken:

- *Before doing any electrical work, de-energize all circuits and equipment, perform lock-out/tag-out, and test circuits and equipment to make sure they are de-energized.*
- *The company should have trained the workers to perform their jobs safely.*
- *Proper personal protective equipment (PPE) should always be used.*
- *Never use aerosol spray cans around high-voltage equipment.*

Thermal burns may result if an explosion occurs when electricity ignites an explosive mixture of material in the air. This ignition can result from the buildup of combustible vapors, gases, or dusts. Occupational Safety and Health Administration (OSHA) standards, National Fire Protection Association (NFPA) standards, and other safety standards give precise safety requirements for the operation of electrical systems and equipment in such dangerous areas. Ignition can also be caused by overheated conductors or equipment, or by normal arcing at switch contacts or in circuit breakers.

***OSHA*—Occupational Safety and Health Administration—the Federal agency in the U.S. Department of Labor that establishes and enforces workplace safety and health regulations**

Electrical Fires

Electricity is one of the most common causes of fires and thermal burns in homes and workplaces. Defective or misused electrical equipment is a major cause of electrical fires. If there is a small electrical fire, be sure to use only a Class C or multipurpose (ABC) fire extinguisher, or you might make the problem worse. All fire extinguishers are marked with letter(s) that tell you the kinds of fires they can put out. Some extinguishers contain symbols, too.

The letters and symbols are explained below (including suggestions on how to remember them).

A (think: **Ashes**) = paper, wood, etc.

B (think: **Barrel**) = flammable liquids

C (think: **Circuits**) = electrical fires

Here are a couple of fire extinguishers at a worksite. Can you tell what types of fires they will put out?

This extinguisher can only be used on Class B and Class C fires.

This extinguisher can only be used on Class A and Class C fires.

Learn how to use fire extinguishers at work.

However, do not try to put out fires unless you have received proper training. If you are not trained, the best thing you can do is evacuate.

Summary of Section 3

Burns are the most common injury caused by electricity. The three types of burns are . . .

- electrical burns,
- arc burns, and
- thermal contact burns.

All fire extinguishers are marked with a letter(s), which identifies the kinds of fires they put out. Sometimes the label is marked with both a letter and symbol. Be sure to read the label and use the appropriate extinguisher.

First Aid Fact Sheet

What Should I Do If a Co-Worker Is Shocked or Burned by Electricity?

Shut off the electrical current if the victim is still in contact with the energized circuit. While you do this, have someone else call for help. If you cannot get to the switchgear quickly, pry the victim from the circuit with something that does not conduct electricity such as dry wood. ***Do not touch the victim yourself if he or she is still in contact with an electrical circuit!*** You do not want to be a victim, too!

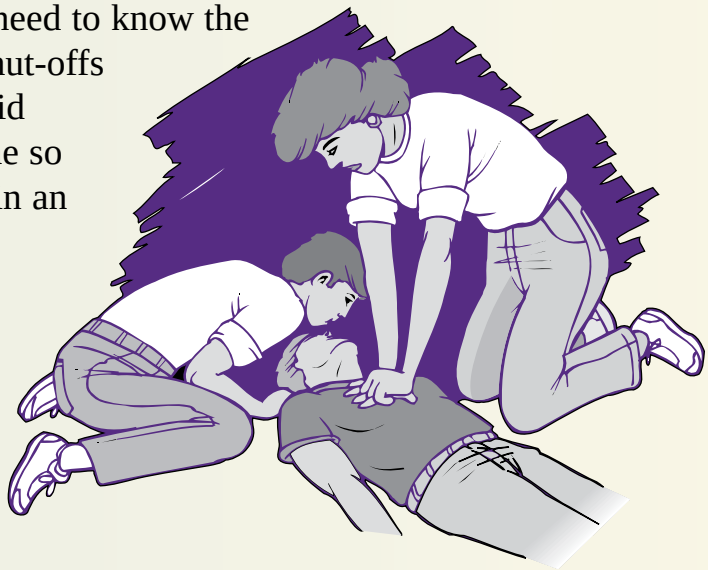
Do not leave the victim unless there is absolutely no other option. You should stay with the victim while emergency medical services (EMS) are contacted. The caller should come back to you afterwards to verify that the call was made. If the victim is not breathing, does not have a heartbeat, or is badly injured, quick response by a team of emergency medical technicians (EMTs) or paramedics gives the best chance for survival.

Learn first aid

Once you know that electrical current is no longer flowing through the victim, call out to the victim to see if he or she is conscious (awake). If the victim is conscious, ***tell the victim not to move.*** It is possible for a shock victim to be seriously injured but not realize it. Quickly examine the victim for signs of major bleeding. If there is a lot of bleeding, place a cloth (such as a handkerchief or bandanna) over the wound and apply pressure. If the wound is in an arm or leg and keeps bleeding a lot, gently elevate the injured area while keeping pressure on the wound. Keep the victim warm and talk to him or her until help arrives.

If the victim is unconscious, check for signs of breathing. While you do this, move the victim as little as possible. If the victim is not breathing, someone trained in CPR should begin artificial breathing, then check to see if the victim has a pulse. Quick action is essential! To be effective, CPR must be performed within 4 minutes of the shock.

If you are not trained in CPR or first aid, ***now*** is the time to get trained—***before*** you find yourself in this situation! Ask your instructor or supervisor how you can become certified in CPR. You also need to know the location of (1) electricity shut-offs ("kill switches"), (2) first-aid supplies, and (3) a telephone so you can find them quickly in an emergency.



and CPR now!

Section 4:
Overview of the Safety Model

What Must Be Done to Be Safe?

- *Use the safety model to recognize, evaluate, and control hazards.*

Use the three-stage ***safety model***: recognize, evaluate, and control hazards. To be safe, you must think about your job and plan for hazards. To avoid injury or death, you must understand and recognize hazards. You need to evaluate the situation you are in and assess your risks. You need to control hazards by creating a safe work environment, by using safe work practices, and by reporting hazards to a supervisor or teacher.

Report hazards to your supervisor or teacher.

If you do not recognize, evaluate, and control hazards, you may be injured or killed by the electricity itself, electrical fires, or falls. If you use the safety model to recognize, evaluate, and control hazards, you are much safer.

(1) Recognize hazards

- *Identify electrical hazards.*

The first part of the safety model is recognizing the hazards around you. Only then can you avoid or control the hazards. It is best to discuss and plan hazard recognition tasks with your co-workers. Sometimes we take risks ourselves, but when we are responsible for others, we are more careful. Sometimes others see hazards that we overlook. Of course, it is possible to be talked out of our concerns by someone who is reckless or dangerous. Don't take a chance. Careful planning of safety procedures reduces the risk of injury. Decisions to lock out and tag out circuits and equipment need to be made during this part of the safety model. Plans for action must be made now.

- *Don't listen to reckless, dangerous people.*

OSHA regulations, the NEC, NFPA 70E Standard for Electrical Safety in the Workplace, and the National Electrical Safety Code (NESC) provide a wide range of safety information. Although these sources may be difficult to read and understand at first, with practice they can become very useful tools to help you recognize unsafe conditions and practices. Knowledge of OSHA standards is an important part of training for electrical apprentices. See the Appendix for a list of relevant standards.

Always lock out and tag out circuits.

(2) Evaluate hazards

When evaluating hazards, it is best to identify all possible hazards first, then evaluate the risk of injury from each hazard. Do not assume the risk is low until you evaluate the hazard. It is dangerous to overlook hazards. Job sites are especially dangerous because they are always changing. Many people are working at different tasks. Job sites are frequently exposed to bad weather. A reasonable place to work on a bright, sunny day might be very hazardous in the rain. The risks in your work environment need to be evaluated all the time. Then, whatever hazards are present need to be controlled.

Evaluate your risk.

(3) Control hazards

Once electrical hazards have been recognized and evaluated, they must be controlled. You control electrical hazards in two main ways: (1) create a safe work environment and (2) use safe work practices. Controlling electrical hazards (as well as other hazards) reduces the risk of injury or death.

Take steps to control hazards:
Create a safe workplace.
Work safely.

One way to implement this safety model is to conduct a job hazard analysis (JHA). This involves development of a chart: 1) Column 1, breaking down the job into its separate task or steps; 2) Column 2, evaluating the hazard(s) of each task, and 3) Column 3, developing a control for each hazard. See the example below.

JHA: Changing a Wall Ground Fault Circuit Interrupter (GFCI)

Task analysis	Hazard analysis	Hazard abatement
Removing the cover	Electric shock from exposed live wires	De-energize by opening circuit breaker or removing fuse
Removing old GFCI	Possible other live wires in opening	Test wires with appropriate voltmeter to ensure all wires are de-energized
Installing new GFCI	Possible connecting wires incorrectly	Check wiring diagrams to ensure proper connections
Replace cover and re-energize	Possible defective GFCI	Test GFCI

Use the safety model to *recognize*, *evaluate*, and *control* workplace hazards like those in this picture.

Summary of Section 4

The three stages of the safety model are . . .

Stage 1— ***Recognize*** hazards

Stage 2— ***Evaluate*** hazards

Stage 3— ***Control*** hazards

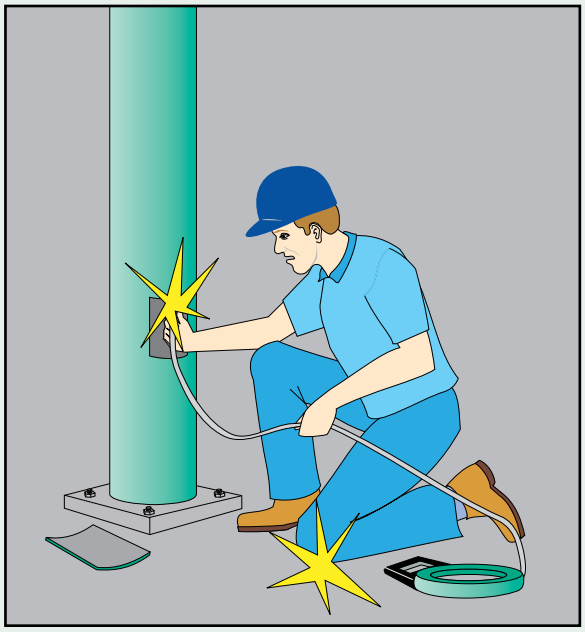
Section 5
Safety Model Stage 1—Recognizing Hazards

How Do You Recognize Hazards?

The first step toward protecting yourself is recognizing the many hazards you face on the job. To do this, you must know which situations can place you in danger. Knowing where to look helps you to recognize hazards.

- ❑ Inadequate wiring is dangerous.
- ❑ Exposed electrical parts are dangerous.
- ❑ Overhead powerlines are dangerous.
- ❑ Wires with bad insulation can give you a shock.
- ❑ Electrical systems and tools that are not grounded or double-insulated are dangerous.
- ❑ Overloaded circuits are dangerous.
- ❑ Damaged power tools and equipment are electrical hazards.
- ❑ Using the wrong PPE is dangerous.
- ❑ Using the wrong tool is dangerous.
- ❑ Some on-site chemicals are harmful.
- ❑ Defective or improperly set up ladders and scaffolding are dangerous.
- ❑ Ladders that conduct electricity are dangerous.
- ❑ Electrical hazards can be made worse if the worker, location, or equipment is wet.

Workers face many hazards on the job.

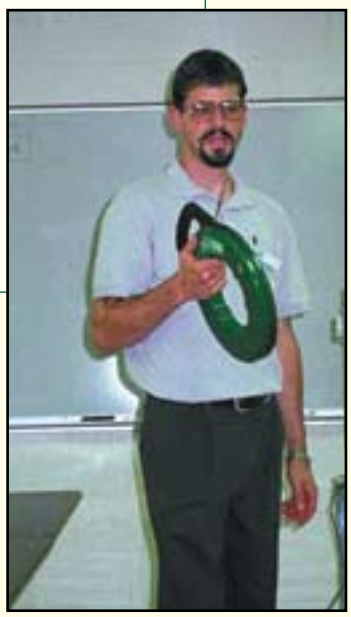


Worker was electrocuted while removing energized fish tape.

An electrician was removing a metal fish tape from a hole at the base of a metal light pole. (A fish tape is used to pull wire through a conduit run.) The fish tape became energized, electrocuting him. As a result of its inspection, OSHA issued a citation for three serious violations of the agency's construction standards.

If the following OSHA requirements had been followed, this death could have been prevented.

- *De-energize all circuits before beginning work.*
- *Always lock out and tag out de-energized equipment.*
- *Companies must train workers to recognize and avoid unsafe conditions associated with their work.*



Fish tape.

Inadequate wiring hazards

- ***wire gauge***—wire size or diameter (technically, the cross-sectional area)
- ***ampacity***—the maximum amount of current a wire can carry safely without overheating
- ***Overloaded wires get hot!***

An electrical hazard exists when the wire is too small a gauge for the current it will carry. Normally, the circuit breaker in a circuit is matched to the wire size. However, in older wiring, branch lines to permanent ceiling light fixtures could be wired with a smaller gauge than the supply cable. Let's say a light fixture is replaced with another device that uses more current. The current capacity (ampacity) of the branch wire could be exceeded. When a wire is too small for the current it is supposed to carry, the wire will heat up. The heated wire could cause a fire.

When you use an extension cord, the size of the wire you are placing into the circuit may be too small for the equipment. The circuit breaker could be the right size for the circuit but not right for the smaller-gauge extension cord. A tool plugged into the extension cord may use more current than the cord can handle without tripping the circuit breaker. The wire will overheat and could cause a fire.

The kind of metal used as a conductor can cause an electrical hazard. Special care needs to be taken with aluminum wire. Since it is more brittle than copper, aluminum wire can crack and break more easily. Connections with aluminum wire can become loose and oxidize if not made properly, creating heat or arcing. ***You need to recognize that inadequate wiring is a hazard***.

- ***Incorrect wiring practices can cause fires!***

Exposed electrical parts hazards

Electrical hazards exist when wires or other electrical parts are exposed. Wires and parts can be exposed if a cover is removed from a wiring or breaker box. The overhead wires coming into a home may be exposed. Electrical

This hand-held sander has exposed wires and should not be used.

- ***If you touch live electrical parts, you will be shocked.***

terminals in motors, appliances, and electronic equipment may be exposed. Older equipment may have exposed electrical parts. If you contact exposed live electrical parts, you will be shocked. ***You need to recognize that an exposed electrical component is a hazard*.**

Approach boundaries

The risk from exposed live parts depends on your distance from the parts. Three "boundaries" are key to protecting yourself from electric shock and one to protect you from arc flashes or blasts. These boundaries are set by the National Fire Protection Association (NFPA 70E).

The **limited approach boundary** is the closest an unqualified person can approach, unless a qualified person accompanies you. A qualified person is someone who has received mandated training on the hazards and on the construction and operation of equipment involved in a task.

The **restricted approach boundary** is the closest to exposed live parts that a qualified person can go without proper PPE (such as, flame-resistant clothing) and insulated tools. When you're this close, if you move the wrong way, you or your tools could touch live parts. Same for the next boundary:

The **prohibited approach boundary**—the most serious—is the distance you must stay from exposed live parts to prevent flashover or arcing in air. Get any closer and it's like direct contact with a live part.

Electric Shock Boundaries To Live Parts for 300–600 Volts

Prohibited Approach Boundary	Restricted Approach Boundary	Limited Approach Boundary
1 inch	1 ft.	3 ft. 6 in.

Power source ➔

APPROACH BOUNDARIES

To protect against burns, there's one more boundary: The **flash protection boundary** is where you need PPE to prevent incurable burns, if there's an arc flash.

Flash Protection Boundary For Live Parts For 300–600 Volts

Flash Protection Boundary
4 ft.

Power source ➔

Overhead powerlines kill many workers!

Keep outside the flash protection boundary

Photo from Fluke Corporation "Electrical Safety Video" by Franny Olshefski (reprinted in IBEW Local 26 Newsletter May 2005)

Overhead powerline hazards

Most people do not realize that overhead powerlines are usually not insulated. More than half of all electrocutions are caused by direct worker contact with energized powerlines. Powerline workers must be especially aware of the dangers of overhead lines. In the past, 80% of all lineman deaths were caused by contacting a live wire with a bare hand. Due to such incidents, all linemen now wear special rubber gloves that protect them up to 36,000 volts. Today, most electrocutions involving overhead powerlines are caused by failure to maintain proper work distances.

Watch out for exposed electrical wires around electronic equipment.

Electrical line workers need special training and equipment to work safely.

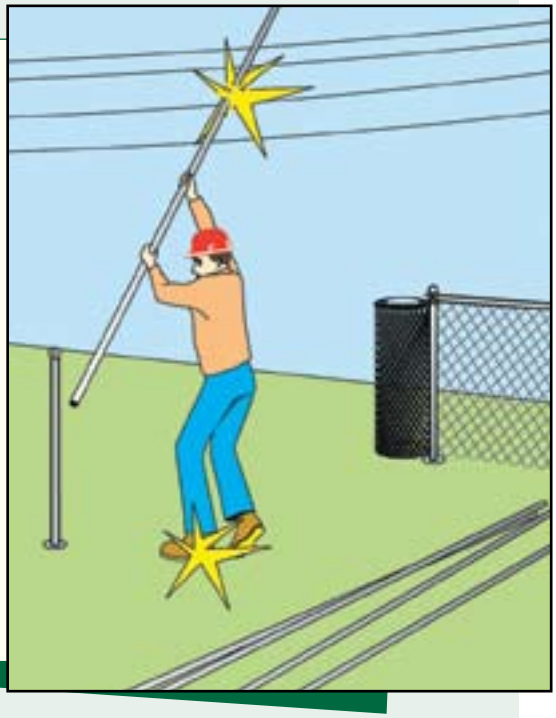
Operating a crane near overhead wires is very hazardous.

Shocks and electrocutions occur where physical barriers are not in place to prevent contact with the wires. When dump trucks, cranes, work platforms, or other conductive materials (such as pipes and ladders) contact overhead wires, the equipment operator or other workers can be killed. If you do not maintain required clearance distances from powerlines, you can be shocked and killed. (The minimum distance for voltages up to 50kV is 10 feet. For voltages over 50kV, the minimum distance is 10 feet plus 4 inches for every 10 kV over 50kV.) Never store materials and equipment under or near overhead powerlines. ***You need to recognize that overhead powerlines are a hazard***.

Five workers were constructing a chain-link fence in front of a house, directly below a 7,200-volt energized powerline. As they prepared to install 21-foot sections of metal top rail on the fence, one of the workers picked up a section of rail and held it up vertically. The rail contacted the 7,200-volt line, and the worker was electrocuted. Following inspection, OSHA determined that the employee who was killed had never received any safety training from his employer and no specific instruction on how to avoid the hazards associated with overhead powerlines.

In this case, the company failed to obey these regulations:

- *Employers must train their workers to recognize and avoid unsafe conditions on the job.*
- *Employers must not allow their workers to work near any part of an electrical circuit **UNLESS** the circuit is de-energized (shut off) and grounded, or guarded in such a way that it cannot be contacted.*
- *Ground-fault protection must be provided at construction sites to guard against electrical shock.*



Defective insulation hazards

Insulation that is defective or inadequate is an electrical hazard. Usually, a plastic or rubber covering insulates wires. Insulation prevents conductors from coming in contact with each other. Insulation also prevents conductors from coming in contact with people.

insulation—material that does not conduct electricity easily

Extension cords may have damaged insulation. Sometimes the insulation inside an electrical tool or appliance is damaged. When insulation is damaged, exposed metal parts may become energized if a live wire inside touches them. Electric hand tools that are old, damaged, or misused may have damaged insulation inside. If you touch damaged power tools or other equipment, you will receive a shock. You are more likely to receive a shock if the tool is not grounded or double-insulated. (Double-insulated tools have two insulation barriers and no exposed metal parts.) ***You need to recognize that defective insulation is a hazard***.

This extension cord is damaged and should not be used.

A damaged live power tool that is not grounded or double-insulated is very dangerous! If you touch a damaged live power tool, you will be shocked!

Improper grounding hazards

When an electrical system is not grounded properly, a hazard exists. The most common OSHA electrical violation is improper grounding of equipment and circuitry. The metal parts of an electrical wiring system that we touch (switch plates, ceiling light fixtures, conduit, etc.) should be grounded and at 0 volts. If the system is not grounded properly, these parts may become energized. Metal parts of motors, appliances, or electronics that are plugged into improperly grounded circuits may be energized. When a circuit is not grounded properly, a hazard exists because unwanted voltage cannot be safely eliminated. If there is no safe path to ground for fault currents, exposed metal parts in damaged appliances can become energized.

Extension cords may not provide a continuous path to ground if there is a broken ground wire or plug. If you contact a defective electrical

***fault current*—**any current that is not in its intended path

***ground potential*—**the voltage a grounded part should have; 0 volts relative to ground

device that is not grounded (or grounded improperly), you will be shocked. ***You need to recognize that an improperly grounded electrical system is a hazard***.

- ***If you touch a defective live component that is not grounded, you will be shocked.***

Electrical systems are often grounded to metal water pipes that serve as a continuous path to ground. If plumbing is used as a path to ground for fault current, all pipes must be made of conductive material (a type of metal). Many electrocutions and fires occur because (during renovation or repair) parts of metal plumbing are replaced with plastic pipe, which does not conduct electricity. In these cases, the path to ground is interrupted by nonconductive material.

A ground fault circuit interrupter, or GFCI, is an inexpensive lifesaver. GFCIs detect any difference in current between the two circuit wires (the black wires and white wires). This difference in current could happen when electrical equipment is not working correctly, causing leakage current. If leakage current (a ground fault) is detected in a GFCI-protected circuit, the GFCI switches off the current in the circuit, protecting you from a dangerous shock. GFCIs are set at about 5 mA and are designed to protect workers from electrocution. GFCIs are able to detect the loss of current resulting from leakage through a person who is beginning to be shocked. If this situation occurs, the GFCI switches off the current in the circuit. GFCIs are different from circuit breakers because they detect leakage currents rather than overloads.

GFCI receptacle.

- ***GFCI*—ground fault circuit interrupter—a device that detects current leakage from a circuit to ground and shuts the current off**
- ***leakage current*—current that does not return through the intended path but instead "leaks" to ground**
- ***ground fault*—a loss of current from a circuit to a ground connection**

Circuits with missing, damaged, or improperly wired GFCIs may allow you to be shocked. ***You need to recognize that a circuit improperly protected by a GFCI is a hazard***.

Overload hazards

Overloads in an electrical system are hazardous because they can produce heat or arcing. Wires and other components in an electrical system or circuit have a maximum amount of current they can carry safely. If too many devices are plugged into a circuit, the electrical current will heat the wires to a very high temperature. If any one tool uses too much current, the wires will heat up.

Overloads are a major cause of fires.

- ***overload*—too much current in a circuit**
- ***An overload can lead to a fire or electrical shock.***

The temperature of the wires can be high enough to cause a fire. If their insulation melts, arcing may occur. Arcing can cause a fire in the area where the overload exists, even inside a wall.

In order to prevent too much current in a circuit, a circuit breaker or fuse is placed in the circuit. If there is too much current in the circuit, the breaker "trips" and opens like a switch. If an overloaded circuit is equipped with a fuse, an internal part of the fuse melts, opening the circuit. Both breakers and fuses do the same thing: open the circuit to shut off the electrical current.

If the breakers or fuses are too big for the wires they are supposed to protect, an overload in the circuit will not be detected and the current will not be shut off. Overloading leads to overheating of circuit components (including wires) and may cause a fire. ***You need to recognize that a circuit with improper overcurrent protection devices—or one with no overcurrent protection devices at all—is a hazard***.

- ***circuit breaker—*** an overcurrent protection device that automatically shuts off the current in a circuit if an overload occurs
- ***trip—*** the automatic opening (turning off) of a circuit by a GFCI or circuit breaker
- ***fuse—*** an overcurrent protection device that has an internal part that melts and shuts off the current in a circuit if there is an overload
- ***Circuit breakers and fuses that are too big for the circuit are dangerous (e.g., using a 30 amp fuse in a 20 amp circuit).***
- ***Circuits without circuit breakers or fuses are dangerous.***

Overcurrent protection devices are built into the wiring of some electric motors, tools, and electronic devices. For example, if a tool draws too much current or if it overheats, the current will be shut off from within the device itself. Damaged tools can overheat and cause a fire. ***You need to recognize that a damaged tool is a hazard***.

- ***Damaged power tools can cause overloads.***

Damaged equipment can overheat and cause a fire.

Wet conditions hazards

Working in wet conditions is hazardous because you may become an easy path for electrical current. If you touch a live wire or other electrical component—and you are standing in even a small puddle of water—you will receive a shock. Damaged insulation, equipment,

- ***Wet conditions are dangerous.***

or tools can expose you to live electrical parts. A damaged tool may not be grounded properly, so the housing of the tool may be energized, causing you to receive a shock. Improperly grounded metal switch plates and ceiling lights are especially hazardous in wet conditions. If you touch a live electrical component with an uninsulated hand tool, you are more likely to receive a shock when standing in water.

But remember: you don't have to be standing in water to be electrocuted. Wet clothing, high humidity, and perspiration reduce resistance and increase your chances of being electrocuted. ***You need to recognize that all wet conditions are hazards***.

An electrical circuit in a damp place without a GFCI is dangerous! A GFCI reduces the danger.

Additional hazards

In addition to electrical hazards, other types of hazards are present at job sites. Remember that all of these hazards can be controlled.

There are non-electrical hazards at job sites, too.

- There may be chemical hazards. Solvents and other substances may be poisonous or cause disease.
- Frequent overhead work can cause tendinitis (inflammation) in your shoulders.

Overhead work can cause long-term shoulder pain.

- Intensive use of hand tools that involve force or twisting can cause tendinitis of the hands, wrists, or elbows. Use of hand tools can also cause carpal tunnel syndrome, which results when nerves in the wrist are damaged by swelling tendons or contracting muscles.

Frequent use of some hand tools can cause wrist problems such as carpal tunnel syndrome.

A 22-year-old carpenter's apprentice was killed when he was struck in the head by a nail fired from a powder-actuated nail gun (a device that uses a gun powder cartridge to drive nails into concrete or steel). The nail gun operator fired the gun while attempting to anchor a plywood concrete form, causing the nail to pass through the hollow form. The nail traveled 27 feet before striking the victim. The nail gun operator had never received training on how to use the tool, and none of the employees in the area was wearing PPE.

In another situation, two workers were building a wall while remodeling a house. One of the workers was killed when he was struck by a nail fired from a powder-actuated nail gun. The tool operator who fired the nail was trying to attach a piece of plywood to a wooden stud. But the nail shot though the plywood and stud, striking the victim.

Below are some OSHA regulations that should have been followed.

- *Employees using powder- or pressure-actuated tools must be trained to use them safely.*
- *Employees who operate powder- or pressure-actuated tools must be trained to avoid firing into easily penetrated materials (like plywood).*
- *In areas where workers could be exposed to flying nails, appropriate PPE must be used.*

***PPE*—personal protective equipment** (eye protection, hard hat, special clothing, etc.)

Lift with your legs, not your back!

- Low back pain can result from lifting objects the wrong way or carrying heavy loads of wire or other material. Back pain can also occur as a result of injury from poor working surfaces such as wet or slippery floors. Back pain is common, but it can be disabling and can affect young individuals.
- Chips and particles flying from tools can injure your eyes. Wear eye protection.
- Falling objects can hit you. Wear a hard hat.
- Sharp tools and power equipment can cause cuts and other injuries. If you receive a shock, you may react and be hurt by a tool.
- You can be injured or killed by falling from a ladder or scaffolding. If you receive a shock—even a mild one—you may lose your balance and fall. Even without being shocked, you could fall from a ladder or scaffolding.
- You expose yourself to hazards when you do not wear PPE.

All of these situations need to be recognized as hazards.

You need to be especially careful when working on scaffolding or ladders.

Summary of Section 5

You need to be able to recognize that electrical shocks, fires, or falls result from these hazards:

- Inadequate wiring
- Exposed electrical parts
- Overhead powerlines
- Defective insulation
- Improper grounding
- Overloaded circuits
- Wet conditions
- Damaged tools and equipment
- Improper PPE

Section 6
Safety Model Stage 2—Evaluating Hazards

How Do You Evaluate Your Risk?

- ***risk***—the chance that injury or death will occur

After you recognize a hazard, your next step is to evaluate your risk from the hazard. Obviously, exposed wires should be recognized as a hazard. If the exposed wires are 15 feet off the ground, your risk is low. However, if you are going to be working on a roof near those same wires, your risk is high. The risk of shock is greater if you will be carrying metal conduit that could touch the exposed wires. You must constantly evaluate your risk.

- ***Make the right decisions.***

Combinations of hazards increase risk.

Combinations of hazards increase your risk. Improper grounding and a damaged tool greatly increase your risk. Wet conditions combined with other hazards also increase your risk. You will need to make decisions about the nature of hazards in order to evaluate your risk and do the right thing to remain safe.

There are "clues" that electrical hazards exist. For example, if a GFCI keeps tripping while you are using a power tool, there is a problem. Don't keep resetting the GFCI and continue to work. You must evaluate the "clue" and decide what action should be taken to control the hazard. There are a number of other conditions that indicate a hazard.

- ***short***—a low-resistance path between a live wire and the ground, or between wires at different voltages (called a fault if the current is unintended)

- ❑ Tripped circuit breakers and blown fuses show that too much current is flowing in a circuit or that a fault exists. This condition could be due to several factors, such as malfunctioning equipment or a short between conductors. You need to determine the cause in order to control the hazard.
- ❑ An electrical tool, appliance, wire, or connection that feels warm may indicate too much current in the circuit or equipment or that a fault exists. You need to evaluate the situation and determine your risk.
- ❑ An extension cord that feels warm may indicate too much current for the wire size of the cord or that a fault exists. You must decide what action needs to be taken.

- ❑ A cable, fuse box, or junction box that feels warm may indicate too much current in the circuits.
- ❑ A burning odor may indicate overheated insulation.
- ❑ Worn, frayed, or damaged insulation around any wire or other conductor is an electrical hazard because the conductors could be exposed. Contact with an exposed wire could cause a shock. Damaged insulation could cause a short, leading to arcing or a fire. Inspect all insulation for scrapes and breaks. You need to evaluate the seriousness of any damage you find and decide how to deal with the hazard.
- ❑ A GFCI that trips indicates there is current leakage from the circuit. First, you must decide the probable cause of the leakage by recognizing any contributing hazards. Then, you must decide what action needs to be taken.

*Any of these conditions, or "**clues**," tells you something important: there is a risk of fire and electrical shock. The equipment or tools involved must be taken out of service. You will frequently be caught in situations where you need to decide if these clues are present. A maintenance electrician, supervisor, or instructor needs to be called if there are signs of overload and you are not sure of the degree of risk. Ask for help whenever you are not sure what to do. By asking for help, you will protect yourself and others.*

Summary of Section 6

Look for "clues" that hazards are present.

Evaluate the seriousness of hazards.

Decide if you need to take action.

Don't ignore signs of trouble.

An 18-year-old male worker, with 15 months of experience at a fast food restaurant, was plugging a toaster into a floor outlet when he received a shock. Since the restaurant was closed for the night, the floor had been mopped about 10 minutes before the incident. The restaurant manager and another employee heard the victim scream and investigated. The victim was found with one hand on the plug and the other hand grasping the metal receptacle box. His face was pressed against the top of the outlet. An employee tried to take the victim's pulse but was shocked. The manager could not locate the correct breaker for the circuit. He then called the emergency squad, returned to the breaker box, and found the correct breaker. By the time the circuit was opened (turned off), the victim had been exposed to the current for 3 to 8 minutes. The employee checked the victim's pulse again and found that it was very rapid.

The manager and the employee left the victim to unlock the front door and place another call for help. Another employee arrived at the restaurant and found that the victim no longer had a pulse. The employee began administering CPR, which was continued by the rescue squad for 90 minutes. The victim was dead on arrival at a local hospital.

Later, two electricians evaluated the circuit and found no serious problems. An investigation showed that the victim's hand slipped forward when he was plugging in the toaster. His index finger made contact with an energized prong in the plug. His other hand was on the metal receptacle box, which was grounded. Current entered his body through his index finger, flowed across his chest, and exited through the other hand, which was in contact with the grounded receptacle.

To prevent death or injury, you must recognize hazards and take the right action.

- *If the circuit had been equipped with a GFCI, the current would have been shut off before injury occurred.*
- *The recent mopping increased the risk of electrocution. Never work in wet or damp areas!*
- *Know the location of circuit breakers for your work area.*

Section 7
Safety Model Stage 3—Controlling Hazards: Safe Work Environment

How Do You Control Hazards?

In order to control hazards, you must first create a safe work environment, then work in a safe manner. Generally, it is best to remove the hazards altogether and create an environment that is truly safe. When OSHA regulations and the NFPA 70E are followed, safe work environments are created.

But, you never know when materials or equipment might fail. Prepare yourself for the unexpected by using safe work practices. Use as many safeguards as possible. If one fails, another may protect you from injury or death.

How Do You Create a Safe Work Environment?

Guard against contact with electrical voltages and control electrical currents to create a safe work environment.

A safe work environment is created by controlling contact with electrical voltages and the currents they can cause. Electrical currents need to be controlled so they do not pass through the body. In addition to preventing shocks, a safe work environment reduces the chance of fires, burns, and falls.

You need to guard against contact with electrical voltages and control electrical currents in order to create a safe work environment. Make your environment safer by doing the following:

- ❑ Treat all conductors—even “de-energized” ones—as if they are energized until they are locked out and tagged.
- ❑ Verify circuits are de-energized before starting work.
- ❑ Lock out and tag out circuits and machines.
- ❑ Prevent overloaded wiring by using the right size and type of wire.
- ❑ Prevent exposure to live electrical parts by isolating them.
- ❑ Prevent exposure to live wires and parts by using insulation.
- ❑ Prevent shocking currents from electrical systems and tools by grounding them.
- ❑ Prevent shocking currents by using GFCIs.
- ❑ Prevent too much current in circuits by using overcurrent protection devices.

At about 1:45 a.m., two journeyman electricians began replacing bulbs and making repairs on light fixtures in a spray paint booth at an automobile assembly plant. The job required the two electricians to climb on top of the booth and work from above. The top of the booth was filled with pipes and ducts that restricted visibility and movement. Flashlights were required.

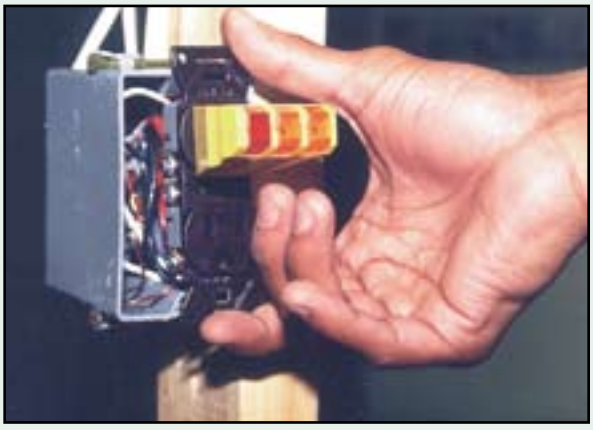
The electricians started at opposite ends of the booth. One electrician saw a flash of light, but continued to work for about 5 minutes, then climbed down for some wire. While cutting the wire, he smelled a burning odor and called to the other electrician. When no one answered, he climbed back on top of the booth. He found his co-worker in contact with a single-strand wire from one of the lights. Needle-nose wire strippers were stuck in the left side of the victim's chest. Apparently, he had been stripping insulation from an improperly grounded 530-volt, single-strand wire when he contacted it with the stripper. In this case, the electricians knew they were working on energized circuits. The breakers in the booth's control panel were not labeled and the lock used for lock-out/tag-out was broken. The surviving electrician stated that locating the means to de-energize a circuit often takes more time than the actual job.

The electrician would be alive today if the following rules had been observed.

- *Always shut off circuits—then test to confirm that they are de-energized—before starting a job.*
- *Switchgear that shuts off a circuit must be clearly labeled and easy to access.*
- *Lock-out/tag-out materials must always be provided, and lock-out/tag-out procedures must always be followed.*
- *Always label circuit breakers.*

Lock out and tag out circuits and equipment

Create a safe work environment by locking out and tagging out circuits and machines. Before working on a circuit, you must turn off the power supply. Once the circuit has been shut off and de-energized, lock out the switchgear to the circuit so the power cannot be turned back on inadvertently. Then, tag out the circuit with an easy-to-see sign or label that lets everyone know that you are working on the circuit. If you are working on or near machinery, you must lock out and tag out the machinery to prevent startup. Before you begin work, you must test the circuit to make sure it is de-energized.



Always test a circuit to make sure it is de-energized before working on it.

Lock-out/tag-out saves lives.

Lock-Out/Tag-Out Checklist

Lock-out/tag-out is an essential safety procedure that protects workers from injury while working on or near electrical circuits and equipment. Lock-out involves applying a physical lock to the power source(s) of circuits and equipment after they have been shut off and de-energized. The source is then tagged out with an easy-to-read tag that alerts other workers in the area that a lock has been applied.

In addition to protecting workers from electrical hazards, lock-out/tag-out prevents contact with operating equipment parts: blades, gears, shafts, presses, etc.

A worker was replacing a V-belt on a dust collector blower. Before beginning work, he shut down the unit at the local switch. However, an operator in the control room restarted the unit using a remote switch. The worker's hand was caught between the pulley and belts of the blower, resulting in cuts and a fractured finger.

When performing lock-out/tag-out on machinery, you must always lock out and tag out ALL energy sources leading to the machinery.

Also, lock-out/tag-out prevents the unexpected release of hazardous gases, fluids, or solid matter in areas where workers are present.

An employee was cutting into a metal pipe using a blowtorch. Diesel fuel was mistakenly discharged into the line and was ignited by his torch. The worker burned to death at the scene.

All valves along the line should have been locked out, blanked out, and tagged out to prevent the release of fuel. Blanking is the process of inserting a metal disk into the space between two pipe flanges. The disk, or blank, is then bolted in place to prevent passage of liquids or gases through the pipe.

When performing lock-out/tag-out on circuits and equipment, you can use the checklist below.

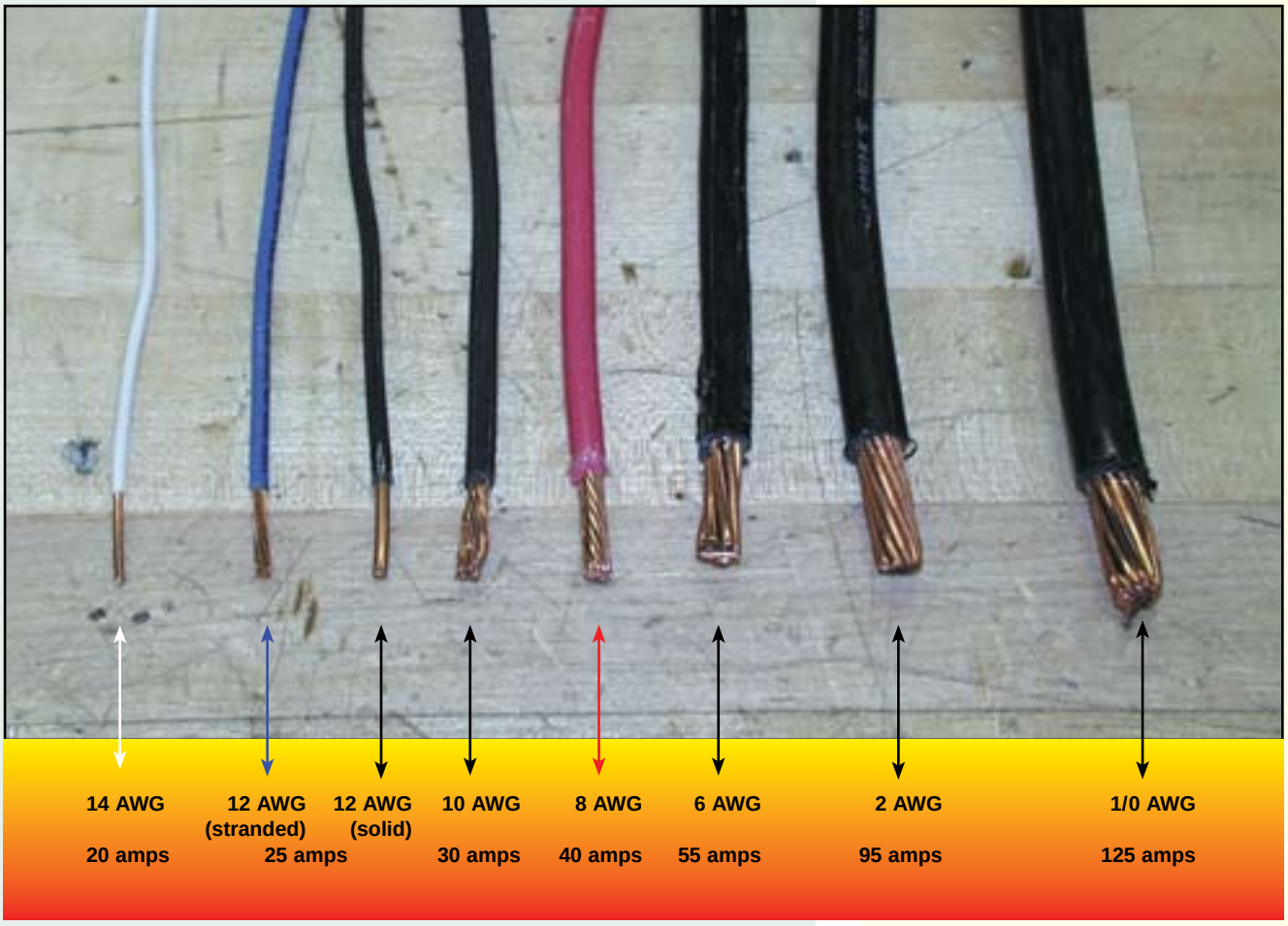
- ✔ Identify all sources of electrical energy for the equipment or circuits in question.
- ✔ Disable backup energy sources such as generators and batteries.
- ✔ Identify all shut-offs for each energy source.
- ✔ Notify all personnel that equipment and circuitry must be shut off, locked out, and tagged out. (Simply turning a switch off is NOT enough.)
- ✔ Shut off energy sources and lock switchgear in the **OFF** position. Each worker should apply his or her individual lock. Do not give your key to anyone.
- ✔ Test equipment and circuitry to make sure they are de-energized. This must be done by a qualified person.*
- ✔ Deplete stored energy (for example, in capacitors) by bleeding, blocking, grounding, etc.
- ✔ Apply a tag to alert other workers that an energy source or piece of equipment has been locked out.
- ✔ Make sure everyone is safe and accounted for before equipment and circuits are unlocked and turned back on. Note that only a qualified person may determine when it is safe to re-energize circuits.

*OSHA defines a "qualified person" as someone who has received mandated training on the hazards and on the construction and operation of equipment involved in a task.

Control inadequate wiring hazards

Electrical hazards result from using the wrong size or type of wire. You must control such hazards to create a safe work environment. You must choose the right size wire for the amount of current expected in a circuit. The wire must be able to handle the current safely. The wire's insulation must be appropriate for the voltage and tough enough for the environment. Connections need to be reliable and protected.

- ***Use the right gauge and type of wire.***
- ***AWG*—American Wire Gauge—a measure of wire size**



Wires come in different gauges. The maximum current each gauge can conduct safely is shown.

Control hazards of fixed wiring

The wiring methods and size of conductors used in a system depend on several factors:

- Intended use of the circuit system
- Building materials
- Size and distribution of electrical load
- Location of equipment (such as underground burial)
- Environmental conditions (such as dampness)
- Presence of corrosives
- Temperature extremes

Fixed, permanent wiring is better than extension cords, which can be misused and damaged more easily. NEC requirements for fixed wiring should always be followed. A variety of materials can be used in wiring applications, including nonmetallic sheathed cable (Romex®), armored cable, and metal and plastic conduit. The choice of wiring material depends on the wiring environment and the need to support and protect wires.

Aluminum wire and connections should be handled with special care. Connections made with aluminum wire can loosen due to heat expansion and oxidize if they are not made properly. Loose or oxidized connections can create heat or arcing. Special clamps and terminals are necessary to make proper connections using aluminum wire. Antioxidant paste can be applied to connections to prevent oxidation.

Control hazards of flexible wiring

Use flexible wiring properly

Electrical cords supplement fixed wiring by providing the flexibility required for maintenance, portability, isolation from vibration, and emergency and temporary power needs.

fixed wiring—the permanent wiring installed in homes and other buildings

Nonmetallic sheathing helps protect wires from damage.

Flexible wiring can be used for extension cords or power supply cords. Power supply cords can be removable or permanently attached to the appliance.

***flexible wiring*—**cables with insulated and stranded wire that bends easily

A 29-year-old male welder was assigned to work on an outdoor concrete platform attached to the main factory building. He wheeled a portable arc welder onto the platform. Since there was not an electrical outlet nearby, he used an extension cord to plug in the welder. The male end of the cord had four prongs, and the female end was spring-loaded. The worker plugged the male end of the cord into the outlet. He then plugged the portable welder's power cord into the female end of the extension cord. At that instant, the metal case around the power cord plug became energized, electrocuting the worker.

An investigation showed that the female end of the extension cord was broken. The spring, cover plate, and part of the casing were missing from the face of the female connector. Also, the grounding prong on the welder's power cord plug was so severely bent that it slipped outside of the connection. Therefore, the arc welder was not grounded. Normally, it would have been impossible to insert the plug incorrectly. But, since the cord's female end was damaged, the "bad" connection was able to occur.

Do not let this happen to you. Use these safe practices:

- *Thoroughly inspect all electrical equipment before beginning work.*
- *Do not use extension cords as a substitute for fixed wiring. In this case, a weatherproof receptacle should have been installed on the platform.*
- *Use connectors that are designed to stand up to the abuse of the job. Connectors designed for light-duty use should not be used in an industrial environment.*

DO NOT use flexible wiring in situations where frequent inspection would be difficult, where damage would be likely, or where long-term electrical supply is needed. Flexible cords cannot be used as a substitute for the fixed wiring of a structure. Flexible cords must not be . . .

Don't use flexible wiring where it may get damaged.

- ❑ run through holes in walls, ceilings, or floors;
- ❑ run through doorways, windows, or similar openings (unless physically protected);
- ❑ attached to building surfaces (except with a tension take-up device within 6 feet of the supply end);
- ❑ hidden in walls, ceilings, or floors; or
- ❑ hidden in conduit or other raceways.

- ***power***—the amount of energy used in a second, measured in watts

- ***1 horsepower = 746 watts.***

Use the right extension cord

The gauge of wire in an extension cord must be compatible with the amount of current the cord will be expected to carry. The amount of current depends on the equipment plugged into the extension cord. Current ratings (how much current a device needs to operate) are often printed on the nameplate. If a power rating is given, it is necessary to divide the power rating in watts by the voltage to find the current rating. For example, a 1,000-watt heater plugged into a 120-volt circuit will need almost 10 amps of current. Let's look at another example: A 1-horsepower electric motor uses electrical energy at the rate of almost 750 watts, so it will need a minimum of about 7 amps of current on a 120-volt circuit. But, electric motors need additional current as they startup or if they stall, requiring up to 200% of the nameplate current rating. Therefore, the motor would need 14 amps.

Add to find the total current needed to operate all the appliances supplied by the cord. Choose a wire gauge that can handle the total current.

American Wire Gauge (AWG)

Wire size	Handles up to
#10 AWG	30 amps
#12 AWG	25 amps
#14 AWG	18 amps
#16 AWG	13 amps

Remember: The ***larger*** the gauge number, the ***smaller*** the wire!

- ***Do not use extension cords that are too long for the size of wire.***

The length of the extension cord also needs to be considered when selecting the wire gauge. Voltage drops over the length of a cord. If a cord is too long, the voltage drop can be enough to damage equipment. Many electric motors only operate safely in a narrow range of voltages and will not work properly at voltages different than the voltage listed on the nameplate. Even though light bulbs operate (somewhat dimmer) at lowered voltages, do not assume electric motors will work correctly at less-than-required voltages. Also, when electric motors start or operate under load, they require more current. The larger the gauge of the wire, the longer a cord can be without causing a voltage drop that could damage tools and equipment.

The grounding path for extension cords must be kept intact to keep you safe. A typical extension cord grounding system has four components:

- a third wire in the cord, called a ground wire;
- a three-prong plug with a grounding prong on one end of the cord;
- a three-wire, grounding-type receptacle at the other end of the cord; and
- a properly grounded outlet.

Control hazards of exposed live electrical parts: isolate energized components

Electrical hazards exist when wires or other electrical parts are exposed. These hazards need to be controlled to create a safe work environment. Isolation of energized electrical parts makes them inaccessible unless tools and special effort are used. Isolation can be accomplished by placing the energized parts at least 8 feet high and out of reach, or by guarding. Guarding is a type of isolation that uses various structures—like cabinets, boxes, screens, barriers, covers, and partitions—to close-off live electrical parts.

This exposed electrical equipment is guarded by an 8-foot fence.

Make sure the path to ground is continuous.

Outlets must be grounded properly.

***guarding*—a covering or barrier that separates you from live electrical parts**

Use covers to prevent accidental contact with electrical circuits.

A 20-year-old male laborer was carrying a 20-foot piece of iron from a welding shop to an outside storage rack. As he was turning a corner near a bank of electrical transformers, the top end of the piece of iron struck an uninsulated supply wire at the top of a transformer. Although the transformers were surrounded by a 6-foot fence, they were about 3 feet taller than the fence enclosure. Each transformer carried 4,160 volts.

When the iron hit the supply wire, the laborer was electrocuted. A forklift operator heard the iron drop to the ground at about 8:46 a.m. and found the victim 5 minutes later. He was pronounced dead on arrival at a local hospital.

- *According to OSHA, the enclosure around the transformers was too low. The fence should have been at least 8 feet tall.*
- *The company in this case did not offer any formal safety training to its workers. All employers should develop safety and health training programs so their employees know how to recognize and avoid life-threatening hazards.*

Take the following precautions to prevent injuries from contact with live parts:

- ❑ Immediately report exposed live parts to a supervisor or teacher. As a student, you should never attempt to correct the condition yourself without supervision.
- ❑ Provide guards or barriers if live parts cannot be enclosed completely.
- ❑ Use covers, screens, or partitions for guarding that require tools to remove them.
- ❑ Replace covers that have been removed from panels, motors, or fuse boxes.
- ❑ Even when live parts are elevated to the required height (8 feet), care should be taken when using objects (like metal rods or pipes) that can contact these parts.
- ❑ Close unused conduit openings in boxes so that foreign objects (pencils, metal chips, conductive debris, etc.) cannot get inside and damage the circuit.

This cover cannot be removed without special tools.

Control hazards of exposure to live electrical wires: use proper insulation

Insulation is made of material that does not conduct electricity (usually plastic, rubber, or fiber). Insulation covers wires and prevents

conductors from coming in contact with each other or any other conductor. If conductors are allowed to make contact, a short circuit is created. In a short circuit, current passes through the shorting material without passing through a load in the circuit, and the wire becomes overheated. Insulation keeps wires and other conductors from touching, which prevents electrical short circuits. Insulation prevents live wires from touching people and animals, thus protecting them from electrical shock.

A 29-year-old male maintenance worker was found at 3:45 a.m. lying on his back and convulsing. Beside him were an overturned cart and an electric welding machine, both lying in a pool of water on the concrete floor. Arcing was visible between the welding machine and the floor. The worker was transported to the closest hospital, where he was pronounced dead.

An examination of the welding machine showed that there were exposed conductors in the machine's cables. There were numerous cuts and scrapes in the cables' insulation. On other parts of the machine, insulation was damaged or missing. Also, the machine did not have a ground connection.

Investigators concluded that the maintenance worker was electrocuted when he tried to turn off the welding machine, which was sitting on the cart. The metal frame of the machine had become energized due to the damaged insulation. When he touched the energized frame, he completed the conducting path to ground. The current traveled through his body to ground. Since he was probably standing in water, the risk of a ground fault was even greater.

You must take steps to decrease such hazards in your workplace:

- *Ground circuits and equipment.*
- *Keep all equipment in good operating condition with a preventive maintenance program.*
- *Never use electrical equipment or work on circuits in wet areas. If you find water or dampness, notify your supervisor immediately.*

Insulation helps protect wires from physical damage and conditions in the environment. Insulation is used on almost all wires, except some ground wires and high-voltage power lines. Insulation is used internally in tools, switches, plugs, and other electrical and electronic devices.

Special insulation is used on wires and cables that are used in harsh environments. Wires and cables that are buried in soil must have an outer covering of insulation that is flame-retardant and resistant to moisture, fungus, and corrosion.

In all situations, you must be careful not to damage insulation while installing it. Do not allow staples or other supports to damage the insulation. Bends in a cable must have an inside radius of at least

Make sure insulation is the right type and in good condition.

Arc-fault circuit breaker.

5 times the diameter of the cable so that insulation at a bend is not damaged. Extension cords come with insulation in a variety of types and colors. The insulation of extension cords is especially important. Since extension cords often receive rough handling, the insulation can be damaged. Extension cords might be used in wet places, so adequate insulation is necessary to prevent shocks. Because extension cords are often used near combustible materials (such as wood shavings and sawdust), a short in an extension cord could easily cause arcing and a fire.

Insulation on individual wires is often color-coded. In general, insulated wires used as equipment grounding conductors are either continuous green or green with yellow stripes. The grounded conductors that complete a circuit are generally covered with continuous white or gray insulation. The ungrounded conductors, or "hot" wires, may be any color other than green, white, or gray. They are usually black or red.

Conductors and cables must be marked by the manufacturer to show the following:

- maximum voltage capacity,
- AWG size,
- insulation-type letter, and
- the manufacturer's name or trademark.

Control hazards of shocking currents

Ground circuits and equipment

Ground electrical devices.

When an electrical system is not grounded properly, a hazard exists. This is because the parts of an electrical wiring system that a person normally touches may be energized, or live, relative to ground. Parts like switch plates, wiring boxes, conduit, cabinets, and lights need to be at 0 volts relative to ground. If the system is grounded improperly, these parts may be energized. The metal housings of equipment plugged into an outlet need to be grounded through the plug.

Grounding is connecting an electrical system to the earth with a wire. Excess or stray current travels through this wire to a grounding device (commonly called a “ground”) deep in the earth. Grounding prevents unwanted voltage on electrical components. Metal plumbing is often used as a ground. When plumbing is used as a grounding conductor, it must also be connected to a grounding device such as a conductive rod. (Rods used for grounding must be driven at least 8 feet into the earth.) Sometimes an electrical system will receive a higher voltage than it is designed to handle. These high voltages may come from a lightning strike, line surge, or contact with a higher-voltage line. Sometimes a defect occurs in a device that allows exposed metal parts to become energized. Grounding will help protect the person working on a system, the system itself, and others using tools or operating equipment connected to the system. The extra current produced by the excess voltage travels relatively safely to the earth.

Grounding creates a path for currents produced by unintended voltages on exposed parts. These currents follow the grounding path, rather than passing through the body of someone who touches the energized equipment. However, if a grounding rod takes a direct hit from a lightning strike and is buried in sandy soil, the rod should be examined to make sure it will still function properly. The heat from a lightning strike can cause the sand to turn into glass, which is an insulator. A grounding rod must be in contact with damp soil to be effective.

Leakage current occurs when an electrical current escapes from its intended path. Leakages are sometimes low-current faults that can occur in all electrical equipment because of dirt, wear, damage, or moisture. A good grounding system should be able to carry off this leakage current. A ground fault occurs when current passes through the housing of an electrical device to ground. Proper grounding protects against ground faults. Ground faults are usually caused by misuse of a tool or damage to its insulation. This damage allows a bare conductor to touch metal parts or the tool housing.

When you ground a tool or electrical system, you create a low-resistance path to the earth (known as a ground connection). When done properly, this path has sufficient current-carrying capacity to eliminate voltages that may cause a dangerous shock.

Grounding does not guarantee you will not receive a shock, be injured, or killed from defective equipment. However, it greatly reduces the possibility.

Grounding rod in the earth.

Grounding-type receptacle.

Portable GFCI.

GFCIs have their limitations.

Equipment needs to be grounded under any of these circumstances:

- The equipment is within 8 feet vertically and 5 feet horizontally of the floor or walking surface.
- The equipment is within 8 feet vertically and 5 feet horizontally of grounded metal objects you could touch.
- The equipment is located in a wet or damp area and is not isolated.
- The equipment is connected to a power supply by cord and plug and is not double-insulated.

Use GFCIs

The use of GFCIs has lowered the number of electrocutions dramatically. A GFCI is a fast-acting switch that detects any difference in current between two circuit conductors. If either conductor comes in contact—either directly or through part of your body—with a ground (a situation known as a ground fault), the GFCI opens the circuit in a fraction of a second. If a current as small as 4 to 6 mA does not pass through both wires properly, but instead leaks to the ground, the GFCI is tripped. The current is shut off.

There is a more sensitive kind of GFCI called an isolation GFCI. If a circuit has an isolation GFCI, the ground fault current passes through an electronic sensing circuit in the GFCI. The electronic sensing circuit has enough resistance to limit current to as little as 2 mA, which is too low to cause a dangerous shock.

GFCIs are usually in the form of a duplex receptacle. They are also available in portable and plug-in designs and as circuit breakers that protect an entire branch circuit. GFCIs can operate on both two- and three-wire ground systems. For a GFCI to work properly, the neutral conductor (white wire) must (1) be continuous, (2) have low resistance, and (3) have sufficient current-carrying capacity.

GFCIs help protect you from electrical shock by continuously monitoring the circuit. However, a GFCI does not protect a person from line-to-line hazards such as touching two “hot” wires (240 volts) at the same time or touching a “hot” and neutral wire at the same time. Also be aware that instantaneous currents can be high when a GFCI is tripped. A shock may still be felt. Your reaction to the shock could cause injury, perhaps from falling.

Test GFCIs regularly by pressing the “test” button. If the circuit does not turn off, the GFCI is faulty and must be replaced.

A female assistant manager of a swim club was instructed to add a certain chemical to the pool. She went down into the pump room, barefoot. The room was below ground level, and the floor was covered with water. She filled a plastic drum with 35-40 gallons of water, then plugged a mixing motor into a 120-volt wall outlet and turned on the motor. The motor would be used to mix the water and the chemical, then the solution would be added to the pool. While adding the chemical to the water in the drum, she contacted the mixing motor with her left hand. Apparently, the motor had developed a ground fault. Because of the ground fault, the motor was energized, and she was electrocuted. A co-worker found the victim slumped over the drum with her face submerged in water. The co-worker tried to move the victim but was shocked. The assistant manager was dead on arrival at a local hospital.

An investigation showed that the mixing motor was in poor condition. The grounding pin had been removed from the male end of the power cord, resulting in a faulty ground. The circuit was equipped with a GFCI, but it was not installed properly. A properly wired and functioning GFCI could have sensed the ground fault in the motor and de-energized the circuit.

Take a look at what could have been done to prevent this death.

- *The employer should have kept the motor in better condition. Power cords should be inspected regularly, and any missing ground prongs should be replaced.*
- *All pool-area electrical circuits should be installed by qualified electricians.*
- *The victim should have worn insulating boots or shoes since she was handling electrical equipment.*
- *The employer should have followed the law. The NEC requires that all pool-associated motors have a permanent grounding system. In this case, this regulation was not followed. Also, electrical equipment is not permitted in areas without proper drainage.*
- *OSHA requires employers to provide a work environment free of safety and health hazards.*

The NEC and NFPA 70E require that GFCIs be used in these high-risk situations:

- ❑ Electricity is used near water.
- ❑ The user of electrical equipment is grounded (by touching grounded material).
- ❑ Circuits are providing power to portable tools or outdoor receptacles.
- ❑ Temporary wiring or extension cords are used.

Specifically, GFCIs must be installed in bathrooms, garages, outdoor areas, crawl spaces, unfinished basements, kitchens, and near wet bars.

Bond components to assure grounding path

In order to assure a continuous, reliable electrical path to ground, a bonding jumper wire is used to make sure electrical parts are connected. Some physical connections, like metal conduit coming into a

Install bonding jumpers around nonconductive material.

- ***Use GFCIs to help protect people in damp areas.***

- ***bonding***—joining electrical parts to assure a conductive path

bonding jumper—the conductor used to connect parts to be bonded

box, might not make a good electrical connection because of paint or possible corrosion. To make a good electrical connection, a bonding jumper needs to be installed.

A metal cold water pipe that is part of a path to ground may need bonding jumpers around plastic antivibration devices, plastic water meters, or sections of plastic pipe. A bonding jumper is made of conductive material and is tightly connected to metal pipes with screws or clamps to bypass the plastic and assure a continuous grounding path. Bonding jumpers are necessary because plastic does not conduct electricity and would interrupt the path to ground.

Additionally, interior metal plumbing must be bonded to the ground for electrical service equipment in order to keep all grounds at the same potential (0 volts). Even metal air ducts should be bonded to electrical service equipment.

Control overload current hazards

When a current exceeds the current rating of equipment or wiring, a hazard exists. The wiring in the circuit, equipment, or tool cannot handle the current without heating up or even melting. Not only will the wiring or tool be damaged, but the high temperature of the conductor can also cause a fire. To prevent this from happening, an overcurrent protection device (circuit breaker or fuse) is used in a circuit. These devices open a circuit automatically if they detect current in excess of the current rating of equipment or wiring. This excess current can be caused by an overload, short circuit, or high-level ground fault.

Use overcurrent protection devices (circuit breakers or fuses) in circuits.

Overcurrent protection devices are designed to protect equipment and structures from fire. **They do not protect you from electrical shock!** Overcurrent protection devices stop the flow of current in a circuit when the amperage is too high for the circuit. A circuit breaker or fuse will not stop the relatively small amount of current that can cause injury or death. Death can result from 20 mA (.020 amps) through the chest (see Section 2). A typical residential circuit breaker or fuse will not shut off the circuit until a current of more than 20 amps is reached!

But overcurrent protection devices are not allowed in areas where they could be exposed to physical damage or in hazardous environments. Overcurrent protection devices can heat up and occasionally arc or spark, which could cause a fire or an explosion in certain areas. Hazardous environments are places that contain flammable or explosive materials such as flammable gases or vapors (Class I Hazardous Environments), finely pulverized flammable dusts (Class II Hazardous Environments), or fibers or metal filings that can catch fire easily (Class III Hazardous Environments). Hazardous environments may be found in aircraft hangars, gas stations, storage plants for flammable liquids, grain silos, and mills where cotton fibers may be suspended in the air. Special electrical systems are required in hazardous environments.

If an overcurrent protection device opens a circuit, there may be a problem along the circuit. (In the case of circuit breakers, frequent tripping may also indicate that the breaker is defective.) ***When a circuit breaker trips or a fuse blows, the cause must be found.***

A circuit breaker is one kind of overcurrent protection device. It is a type of automatic switch located in a circuit. A circuit breaker trips when too much current passes through it. A circuit breaker should not be used regularly to turn power on or off in a circuit, unless the breaker is designed for this purpose and marked “SWD” (stands for “switching device”).

A fuse is another type of overcurrent protection device. A fuse contains a metal conductor that has a relatively low melting point. When too much current passes through the metal in the fuse, it heats up within a fraction of a second and melts, opening the circuit. After an overload is found and corrected, a blown fuse must be replaced with a new one of appropriate amperage.

Find the cause of an overload.

Only circuit breakers marked “SWD” should be used as switches.

When You Must Work on or Near Live Circuits

Working on live circuits means actually touching energized parts. Working near live circuits means working close enough to energized parts to put you at risk even though you may be working on de-energized parts. Common tasks where you need to work on or near live circuits include:

- taking voltage and current measurements,
- opening and closing disconnects and circuit breakers,
- racking circuit breakers on and off the bus,
- removing panels and dead fronts, and
- opening electric equipment doors for inspection.

There should be standard written procedures and training for these common tasks. For instance, when opening and closing disconnects, use the left-hand rule when possible (stand to the right side of equipment with a disconnect on the right, and operate the disconnect with your left hand). For other situations where you might need to work on or near live circuits, your employer should institute a written live-work permit system, which must be authorized by a qualified supervisor.

Live-work permit system

A live-work permit should, at least, contain this information:

- a description of the circuit and equipment to be worked on and the location,
- explanation why the work must be done “live”,
- date and time covered by the permit,
- a description of the safe work practices to be used,
- results of shock hazard analysis and determination of shock protection boundaries,
- results of flash hazard analysis and determination of the flash protection boundary,
- PPE needed to safely perform the job,
- who will do the work and how unqualified persons will be kept away, and
- evidence of completion of job briefing, including discussion of job-specific hazards.

- ❑ Energized-work approval signatures (authorizing or approving management, safety officer, owner, etc.).

To work on or near live parts, you must do the following:

- ❑ Have a written live-work permit for the work to be done.
- ❑ Wear the right PPE to protect against electric shock and arc flash. Never wear clothing made from synthetic materials, such as acetate, nylon, polyester, polypropylene, or rayon – alone or combined with cotton. Such clothing is dangerous because it can burn and melt into your skin.

  The PPE that's needed depends on the type of electric work being done. The **minimum** PPE required would be an untreated natural fiber long-sleeve shirt and long pants plus safety glasses with side shields. Depending on the voltage and the electric task to be done, different types of PPE are required. Fire-resistant protective clothing can include multi-layer flash suit jacket and pants, wraparound face shield, double-layer switching hood, voltage-rated gloves with leather protectors, electrically rated hard hats, and so forth. [(See Table 130.7(C)(9)(a) Hazard/Risk Category Classifications and Table 130.7(C)(10)) (NFPA 70E, 2004 Edition).
- ❑ Use the proper type of protective equipment, such as insulated tools and/or handling equipment that is rated for the voltage. These can include insulated fuse or fuse holding equipment, nonconductive ropes and handlines, fiberglass-reinforced plastic rods, nonconductive portable ladders (such as, fiberglass), protective shields, rubber insulating equipment, voltage-rated plastic guards, and so forth.

A lineman (the victim) was killed after contacting a 17,400-volt charged switch.The victim was part of a three-man crew replacing cables under a switch cabinet. At the time of the accident, the crew was feeding a new cable under the concrete foundation pad below the cabinet. As one worker pushed the cable under the foundation, the victim looped the cable inside the foundation under the cabinet. The victim was using a hot stick to loop the cable but was not wearing his hardhat when his head came either in close proximity to or contacted the charged switch. Crewmembers saw a flash and came around the switch cabinet to where the victim was located. He was found slumped partially in the cabinet. A crewmember used a hot stick to move the victim away from the cabinet and then began CPR. Emergency Medical Services transported the victim to a nearby hospital where he was declared dead from injuries associated with high-voltage electrocution.Based on the findings of the investigation, to prevent similar occurrences, employers should:

- *Ensure workers use personal protective equipment and enforce its use;*
- *Ensure workers are capable of recognizing and avoiding hazardous situations;*
- *Emphasize de-energizing, isolating, or cover energized work areas whenever personnel need to work within high voltage danger zones.*

NIOSH FACE Program: Alaska Case Report 00AK011 | CDC/NIOSHFACE 00-AK-011

Summary of Section 7

Control contact with electrical voltages and control electrical currents to create a safe work environment.

Lock out and tag out circuits and machines.

Prevent overloaded wiring by using the right size and type of wire.

Prevent exposure to live electrical parts by isolating them.

Prevent exposure to live wires and parts by using insulation.

Prevent shocking currents from electrical systems and tools by grounding them.

Prevent shocking currents by using GFCIs.

Prevent too much current in circuits by using overcurrent protection devices.

Prevent against electric shock or arc blast when working live by using proper PPE and protective tools.

Section 8
Safety Model Stage 3—Controlling Hazards: Safe Work Practices

How Do You Work Safely?

A safe work environment is not enough to control all electrical hazards. You must also work safely. Safe work practices help you control your risk of injury or death from workplace hazards. If you are working on electrical circuits or with electrical tools and equipment, you need to use safe work practices.

Before you begin a task, ask yourself:

- ❑ What could go wrong?
- ❑ Do I have the knowledge, tools, and experience to do this work safely?

All workers should be very familiar with the safety procedures for their jobs. You must know how to use specific controls that help keep you safe. You must also use good judgment and common sense.

Control electrical hazards through safe work practices.

- ❑ Plan your work and plan for safety.
- ❑ Avoid wet working conditions and other dangers.
- ❑ Avoid overhead powerlines.
- ❑ Use proper wiring and connectors.
- ❑ Use and maintain tools properly.
- ❑ Wear correct PPE.

Plan your work and plan for safety

Take time to plan your work, by yourself and with others. Safety planning is an important part of any task. It takes effort to recognize, evaluate, and control hazards. If you are thinking about your work tasks or about what others think of you, it is hard to take the time to plan for safety. But, **YOU MUST PLAN**.

Plan to be safe.

A 40-year-old male meter technician had just completed a 7-week basic lineman training course. He worked as a meter technician during normal working hours and as a lineman during unplanned outages. One evening, he was called to repair a residential power outage. By the time he arrived at the site of the outage, he had already worked 2 hours of overtime and worked 14 straight hours the day before. At the site, a tree limb had fallen across an overhead powerline. The neutral wire in the line was severed, and the two energized 120-volt wires were disconnected. The worker removed the tree limb and climbed up a power pole to reconnect the three wires. He was wearing insulated gloves, a hard hat, and safety glasses.

He prepared the wires to be connected. While handling the wires, one of the energized wires caught the cuff of his left glove and pulled the cuff down. The conductor contacted the victim's forearm near the wrist. He was electrocuted and fell backwards. He was wearing a climbing belt, which left him hanging upside down from the pole. Paramedics arrived 5 minutes after the contact. The power company lowered his dead body 30 minutes later.

Several factors may have contributed to this incident. Below are some ways to eliminate these risk factors.

- *Ask for assistance when you are assigned tasks that cannot be safely completed alone. The task assigned to the victim could not have been done safely by only one person.*
- *Do not work overtime performing hazardous tasks that are not part of your normal assignments.*
- *Employees should only be given tasks that they are qualified to perform. All employees below the journeyman level should be supervised.*

Don't work alone.

Planning with others is especially helpful. It allows you to coordinate your work and take advantage of what others know about identifying and controlling hazards. The following is a list of some things to think about as you plan.

- ❑ **Work with a "buddy"**—Do not work alone. Both of you should be trained in CPR. Both of you must know what to do in an emergency.

- ❑ **Know how to shut off and de-energize circuits**—You must find where circuit breakers, fuses, and switches are located. Then, the circuits that you will be working on (even low-voltage circuits) **MUST BE TURNED OFF!** Test the circuits before beginning work to make sure they are completely de-energized.

Test circuits to make sure they are de-energized.

This worker is applying a group lock-out device. The equipment cannot be re-started until all workers remove their locks.

- **Plan to lock out and tag out circuits and equipment**—Make certain all energy sources are locked out and tagged out before performing any work on an electrical circuit or electrical device. Working on energized ("hot") circuits is one of the most dangerous things any worker could do. If someone turns on a circuit without warning, you can be shocked, burned, or electrocuted. The unexpected starting of electrical equipment can cause severe injury or death.

  Before **ANY** work is done on a circuit, shut off the circuit, lock out and tag out the circuit at the distribution panel, then test the circuit to make sure it is de-energized.

  Before **ANY** equipment inspections or repairs—even on so-called low-voltage circuits—the current must be turned off at the switch box, and the switch must be padlocked in the OFF position. At the same time, the equipment must be securely tagged to warn everyone that work is being performed. Again, test circuits and equipment to ensure they are de-energized.

  No two locks should be alike. Each key should fit only one lock, and only one key should be issued to each worker. If more than one worker is working on a circuit or repairing a piece of equipment, each worker should lock out the switch with his or her own lock and never permit anyone else to remove it. At all times, you must be certain that you are not exposing other workers to danger. Workers who perform lock-out/tag-out must be trained and authorized to repair and maintain electrical equipment. A locked-out switch or feeder panel prevents others from turning on a circuit. The tag informs other workers of your action.

- **Remove jewelry and metal objects**—Remove jewelry and other metal objects or apparel from your body before beginning work. These things can cause burns if worn near high currents and can get caught as you work.

- **Plan to avoid falls**—Injuries can result from falling off scaffolding or ladders. Other workers may also be injured from equipment and debris falling from scaffolding and ladders.

A worker was attempting to correct an electrical problem involving two non-operational lamps. He examined the circuit in the area where he thought the problem was located. He had not shut off the power at the circuit breaker panel and did not test the wires to see if they were live. He was electrocuted when he grabbed the two live wires with his left hand. He collapsed to the floor and was found dead.

- *Employers should not allow work to be done on electrical circuits unless an effective lock-out/tag-out program is in place.*
- *No work should be done on energized electrical circuits. Circuits must be shut off, locked out, and tagged out. Even then, you must test the circuit before beginning work to confirm that it is de-energized ("dead").*

Ladder Safety Fact Sheet

To prevent injury when climbing, follow these procedures:

1. Position the ladder at a safe angle to prevent slipping. The horizontal distance from the base of the ladder to the structure should be one-quarter the length of the ladder to its resting position.

2. Make sure the base of the ladder has firm support and the ground or floor is level. Be very careful when placing a ladder on wet, icy, or otherwise slippery surfaces. Special blocking may be needed to prevent slipping in these cases.

3. Follow the manufacturer's recommendations for proper use.

4. Check the condition of the ladder before using it. Joints must be tight to prevent wobbling or leaning.

5. When using a stepladder, make sure it is level and fully open. Always lock the hinges. Do not stand on the top step.

6. When using scaffolding, use a ladder to access the tiers. Never climb the cross braces.

7. Do not use metal ladders. Instead, use ladders made of fiberglass. (Although wooden ladders are permitted, wood can soak up water and become conductive.)

8. Beware of overhead powerlines when you work with ladders and scaffolding.

Learn how to use ladders and scaffolding properly.

A crew of 7 workers was painting a 33-foot sign at a shopping mall. The crew used tubular welded frame scaffolding that was 31 feet tall and made up of several tiers. The sign was partially painted when the crew was instructed to move the scaffolding so that concrete could be poured for an access road. The crew moved the scaffolding 30 feet without disassembling it. An overhead powerline was located about 10 feet away from the scaffolding. After the concrete hardened, the workers lifted the scaffolding to move it back to the sign. The top tier came loose, fell, and contacted the powerline. All seven workers were knocked away from the scaffolding. Two died; five were hospitalized.

You must take certain precautions when working with scaffolding.

- *Scaffolding should not be moved until all potential safety hazards are identified and controlled. In this case, the scaffolding should have been taken apart before it was moved.*
- *Locking pins must be used to secure tiers to one another.*
- *Always make sure you have enough time to complete your assignment safely. If you are rushed, you may be more likely to take deadly short-cuts (such as failing to dismantle scaffolding before moving it).*
- *Employers must have a written safety program that includes safe work procedures and hazard recognition.*

❑ **Do not do any tasks that you are not trained to do or that you do not feel comfortable doing!**

A company was contracted to install wiring and fixtures in a new office complex. The third floor was being prepared in a hurry for a new tenant, and daily changes to the electrical system blueprints were arriving by fax. The light fixtures in the office were mounted in a metal grid that was fastened to the ceiling and properly grounded.

A 23-year-old male apprentice electrician was working on a light fixture when he contacted an energized conductor. He came down from the fiberglass ladder and collapsed. Apparently, he had contacted the "hot" conductor while also in contact with the metal grid. Current passed through his body and into the grounded grid. Current always takes a path to ground. In this case, the worker was part of that path.

He was dead on arrival at a nearby hospital. Later, an investigation showed that the victim had cross-wired the conductors in the fixture by mistake. This incorrect wiring allowed electricity to flow from a live circuit on the completed section of the building to the circuit on which the victim was working.

Below are some safety procedures that should have been followed in this case. Because they were ignored, the job ended in death.

- *Before work begins, all circuits in the immediate work area must be shut off, locked out, and tagged out—then tested to confirm that they are de-energized.*
- *Wiring done by apprentice electricians should be checked by a journeyman.*
- *A supervisor should always review changes to an original blueprint in order to identify any new hazards that the changes might create.*

Avoid wet working conditions and other dangers

Remember that any hazard becomes much more dangerous in damp or wet conditions. To be on the safe side, assume there is dampness in any work location, even if you do not see water. Even sweat can create a damp condition!

- **Do not work wet**—Do not work on circuits or use electrical equipment in damp or wet areas. If necessary, clear the area of loose material or hanging objects. Cover wet floors with wooden planking that can be kept dry. Wear insulating rubber boots or shoes. Your hands must be dry when plugging and unplugging power cords and extension cords. Do not get cleaning solutions on energized equipment.

- **Use a GFCI**—Always use a GFCI when using portable tools and extension cords.

Avoid overhead powerlines

Be very careful not to contact overhead powerlines or other exposed wires. More than half of all electrocutions are caused by contact with overhead lines. When working in an elevated position near overhead lines, avoid locations where you (and any conductive object you hold) could contact an unguarded or uninsulated line. You should be at least 10 feet away from high-voltage transmission lines.

Vehicle operators should also pay attention to overhead wiring. Dump trucks, front-end loaders, and cranes can lift and make contact with overhead lines. If you contact equipment that is touching live wires, you will be shocked and may be killed. If you are in the vehicle, stay inside. Always be aware of what is going on around you.

Use proper wiring and connectors

- **Avoid overloads**—Do not overload circuits.

- **Test GFCIs**—Test GFCIs monthly using the "test" button.

Avoid wet conditions! Even avoid damp conditions!

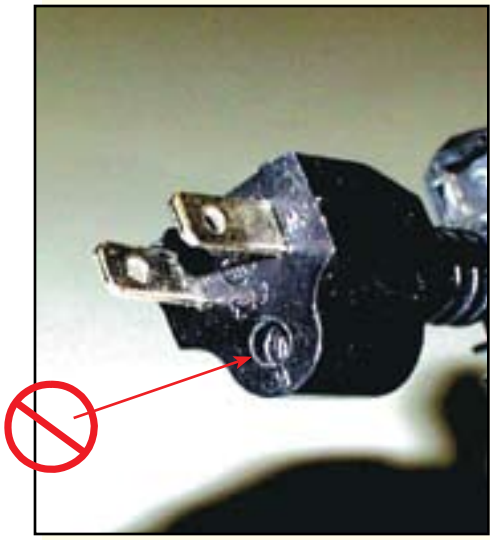
Portable GFCI.

A worker from an electrical service company was changing bulbs in pole-mounted light fixtures in a shopping center parking lot. The procedure for installing the bulbs was as follows: The worker would park the truck near the first light pole. The truck was equipped with a roof-mounted ladder. The worker would extend the ladder high enough to change the bulb, then drive to the next pole without lowering the ladder.

After the worker replaced the first bulb, he got back in the truck and drove toward the next light pole. As the truck moved along, a steel cable attached to the top of the ladder contacted an overhead powerline. The worker realized something was wrong, stopped the truck, and stepped onto the pavement while still holding onto the door of the truck. By doing this, he completed the path to ground for the current in the truck. Because the ladder was still in contact with the powerline, the entire truck was now energized. He was engulfed in flames as the truck caught fire. Fire, police, and paramedic units arrived within 5 minutes. Utility workers arrived in about 10 minutes and de-energized (shut off) the powerline. The victim burned to death at the scene.

Below are some ways to prevent contact with overhead powerlines.

- *A safe distance must be maintained between ladders (and other equipment) and overhead lines. OSHA requires that a clearance of at least 10 feet be maintained between aerial ladders and overhead powerlines of up to 50,000 volts.*
- *Moving a truck with the ladder extended is a dangerous practice. One way to control this hazard is to install an engine lock that prevents a truck's engine from starting unless the ladder is fully retracted.*
- *If there are overhead powerlines in the immediate area, lighting systems that can be serviced from ground level are recommended for safety.*
- *If the worker had been trained properly, he may have known to stay inside the truck.*
- *Job hazard analysis should always be performed to identify and control hazards. In this case, a survey would have identified the powerlines as a possible hazard, and appropriate hazard control measures (such as lowering the ladder between installations) could have been taken.*



Never use a three-prong grounding plug with the ground prong broken off.

- **Check switches and insulation**—Tools and other equipment must operate properly. Make sure that switches and insulating parts are in good condition.
- **Use three-prong plugs**—Never use a three-prong grounding plug with the ground prong broken-off. When using tools that require a third-wire ground, use only three-wire extension cords with three-prong grounding plugs and three-hole electrical outlets. Never remove the grounding prong from a plug! You could be shocked or expose someone else to a hazard. If you see a cord without a grounding prong in the plug, remove the cord from service immediately.
- **Use extension cords properly**—If an extension cord must be used, choose one with sufficient ampacity for the tool being used. An undersized cord can overheat and cause a drop in voltage and tool power. Check the tool manufacturer's recommendations for the required wire gauge and cord length. Make sure the insulation is intact. To reduce the risk of damage to a cord's insulation, use cords with insulation marked "S" (hard

service) rather than cords marked “SJ” (junior hard service). Make sure the grounding prong is intact. In damp locations, make sure wires and connectors are waterproof and approved for such locations. Do not create a tripping hazard.

- **Check power cords and extensions**—Electrical cords should be inspected regularly using the following procedure:

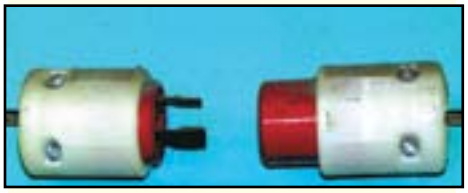
  1. Remove the cord from the electrical power source before inspecting.
  2. Make sure the grounding prong is present in the plug.
  3. Make sure the plug and receptacle are not damaged.
  4. Wipe the cord clean with a diluted detergent and examine for cuts, breaks, abrasions, and defects in the insulation.
  5. Coil or hang the cord for storage. Do not use any other methods. Coiling or hanging is the best way to avoid tight kinks, cuts, and scrapes that can damage insulation or conductors.

You should also test electrical cords regularly for ground continuity using a continuity tester as follows:

1. Connect one lead of the tester to the ground prong at one end of the cord.
2. Connect the second lead to the ground wire hole at the other end of the cord.
3. If the tester lights up or beeps (depending on design), the cord’s ground wire is okay. If not, the cord is damaged and should not be used.

- **Do not pull on cords**—Always disconnect a cord by the plug.

- **Use correct connectors**—Use electrical plugs and receptacles that are right for your current and voltage needs. Connectors are designed for specific currents and voltages so that only matching plugs and receptacles will fit together. This safeguard prevents a piece of equipment, a cord, and a power source with different voltage and current requirements from being plugged together. Standard configurations for plugs and receptacles have been established by the National Electric Manufacturers Association (NEMA).



Locking-type attachment plug.

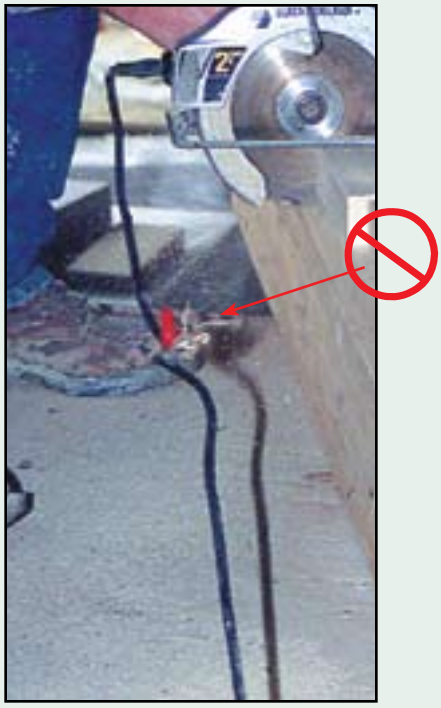
- *Maintain tools and equipment.*
- *Inspect your equipment before you use it.*

❑ **Use locking connectors**—Use locking-type attachment plugs, receptacles, and other connectors to prevent them from becoming unplugged.

Use and maintain tools properly

Your tools are at the heart of your craft. Tools help you do your job with a high degree of quality. Tools can do something else, too. They can cause injury or even death! You must use the right tools for the job. Proper maintenance of tools and other equipment is very important. Inadequate maintenance can cause equipment to deteriorate, creating dangerous conditions. You must take care of your tools so they can help you and not hurt you.

❑ **Inspect tools before using them**—Check for cracked casings, dents, missing or broken parts, and contamination (oil, moisture, dirt, corrosion). Damaged tools must be removed from service and properly tagged. These tools should not be used until they are repaired and tested.

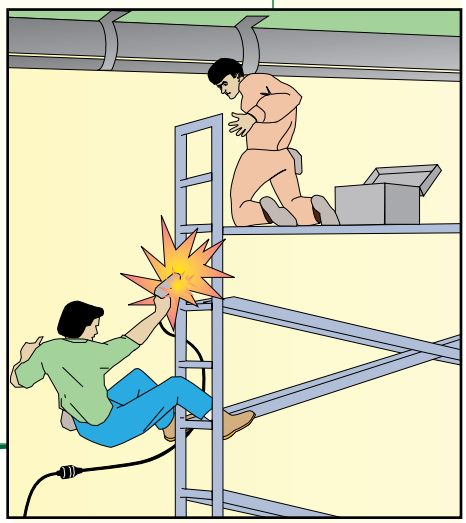


This cord has been spliced using a wire nut. Spliced cords are very dangerous!

An employee was climbing a metal ladder to hand an electric drill to the journeyman installer on a scaffold about 5 feet above him. When the victim reached the third rung of the ladder, he received an electrical shock that killed him. An investigation showed that the grounding prong was missing from the extension cord attached to the drill. Also, the cord's green grounding wire was, at times, contacting the energized black wire. Because of this contact with the "hot" wire, the entire length of the grounding wire and the drill's frame became energized. The drill was not double-insulated.

To avoid deadly incidents like this one, take these precautions:

- *Make certain that approved GFCIs or equipment grounding systems are used at construction sites.*
- *Use equipment that provides a permanent and continuous path to ground. Any fault current will be safely diverted along this path.*
- *Inspect electrical tools and equipment daily and remove damaged or defective equipment from use right away.*



- **Use the right tool correctly**—Use tools correctly and for their intended purposes. Follow the safety instructions and operating procedures recommended by the manufacturer. When working on a circuit, use approved tools with insulated handles. However, **DO NOT USE THESE TOOLS TO WORK ON ENERGIZED CIRCUITS. ALWAYS SHUT OFF AND DE-ENERGIZE CIRCUITS BEFORE BEGINNING WORK ON THEM**.

- **Protect your tools**—Keep tools and cords away from heat, oil, and sharp objects. These hazards can damage insulation. If a tool or cord heats up, stop using it! Report the condition to a supervisor or instructor immediately. If equipment has been repaired, make sure that it has been tested and certified as safe before using it. Never carry a tool by the cord. Disconnect cords by pulling the plug—not the cord!

- **Use double-insulated tools**—Portable electrical tools are classified by the number of insulation barriers between the electrical conductors in the tool and the worker. The NEC permits the use of portable tools only if they have been approved by Underwriter's Laboratories (UL Listed). Equipment that has two insulation barriers and no exposed metal parts is called double-insulated. When used properly, double-insulated tools provide reliable shock protection without the need for a third ground.

- ***Use the right tools and equipment.***
- ***Do not work on energized circuits.***

Don't work on energized circuits like this one! Always follow correct lock-out/tag-out procedures.

A 22-year-old male carpenter was building the wooden framework of a laundry building. He was using portable power tools. Electricity was supplied to the tools by a temporary service pole 50 feet away. The service pole had not been inspected and was not in compliance. It was also not grounded. The carpenter plugged a "homemade" cord into the service pole and then plugged a UL-approved cord into the homemade cord. His power saw was plugged into the UL-approved cord.

The site was wet. Humidity was high and the carpenter was sweating. Reportedly, he was mildly shocked throughout the morning and replaced the extension cord he was using in an effort to stop the shocks. At one point, as he was climbing down a makeshift ladder constructed from a floor truss, he shifted the power saw from his right hand to his left hand and was shocked. He fell from the ladder into a puddle of water, still holding the saw. The current had caused his hand to contract, and he was "locked" to the saw. A co-worker disconnected the power cord to the saw. CPR was given, but the shock was fatal.

Attention to these general safety principles could have prevented this death.

- *Any and all electrical equipment involved in a malfunction should be taken out of service immediately. The carpenter should have taken the saw out of service, not just the extension cord. (As it turns out, the saw was the source of the shocks, not the cord.)*
- *Although the homemade extension cord does not seem to have contributed to this incident, it should not have been used.*
- *The floor truss should not have been used as a ladder. For climbing, use only approved ladders or other equipment designed specifically for climbing.*
- *Do not work in wet areas. The water should have been removed from the floor as soon as it was found. Humidity and perspiration can also be hazards. Try to stay as dry as possible, be alert, and take action to protect yourself when needed.*
- *OSHA requires that all receptacles at construction sites that are not part of the permanent wiring have GFCIs.*
- *Be aware that shocks can cause you to lose your balance and fall, often resulting in more severe injury.*

wire. Power tools with metal housings or only one layer of effective insulation must have a third ground wire and three-prong plug.

❑ **Use multiple safe practices**—Remember: A circuit may not be wired correctly. Wires may contact other "hot" circuits. Someone else may do something to place you in danger. Take all possible precautions.

Wear and maintain PPE.

Wear correct PPE

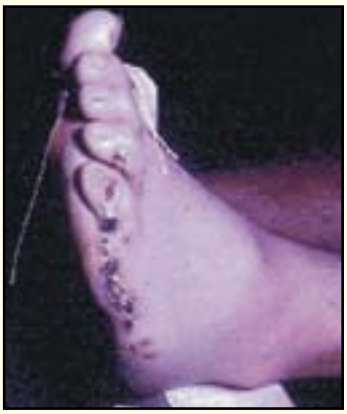
OSHA requires that you be provided with personal protective equipment (PPE). This equipment must meet OSHA requirements and be appropriate for the parts of the body that need protection and the work performed. There are many types of PPE: rubber gloves, insulating shoes and boots, face shields, safety glasses, hard hats, etc. Even if regulations did not exist requiring the use of PPE, there would still be every reason to use this equipment. PPE helps keep you safe. It is the last line of defense between you and the hazard.

- **Wear safety glasses**—Wear safety glasses with side shields or goggles to avoid eye injury. They should have a Z87 stamped on them to show they are certified by the American National Standards Institute Z87 Standard for eye and face protection.

Wear safety glasses to avoid eye injury.

- **Wear proper clothing**—Wear clothing that is neither floppy nor too tight. Loose clothing will catch on corners and rough surfaces. Clothing that binds is uncomfortable and distracting.
- **Contain and secure loose hair**—Wear your hair in such a way that it does not interfere with your work or safety.
- **Wear proper foot protection**—Wear shoes or boots that have been approved for electrical work. (Tennis shoes will not protect you from electrical hazards.) If there are non-electrical hazards present (nails on the floor, heavy objects, etc.), use footwear that is approved to protect against these hazards as well.
- **Wear a hard hat**—Wear a hard hat to protect your head from bumps and falling objects. Hard hats must be worn with the bill forward to protect you properly.
- **Wear hearing protectors**—Wear hearing protectors in noisy areas to prevent hearing loss.
- **Follow directions**—Follow the manufacturer's directions for cleaning and maintaining PPE.
- **Make an effort**—Search out and use any and all equipment that will protect you from shocks and other injuries.

Don't wear hard hats backwards!



Arcing electrical burns through the victim's shoe and around the rubber sole.

- ***Think about what you are doing.***
- ***PPE is only effective when used correctly.***

PPE Fact Sheet—The Right Equipment—Head to Toe

PPE is the last line of defense against workplace hazards. OSHA defines PPE as "equipment for the eyes, face, head, and extremities, protective clothing, respiratory devices, protective shields and barriers." Many OSHA regulations state that PPE must meet criteria set by the American National Standards Institute (ANSI).

HEAD PROTECTION

Head Protection

OSHA requires that head protection (hard hats) be worn if there is a risk of head injury from electrical burns or falling/flying objects.

Aren't all hard hats the same?

No. You must wear the right hat for the job. All hard hats approved for electrical work made since 1997 are marked "Class E." Hard hats made before 1997 are marked "Class B." These markings will be on a label inside the helmet or stamped into the helmet itself. Newer hats may also be marked "***Type 1***" or "***Type 2***." Type 1 hard hats protect you from impacts on the top of your head. Type 2 hard hats protect you from impacts on the top and sides of your head.

How do I wear and care for my hard hat?

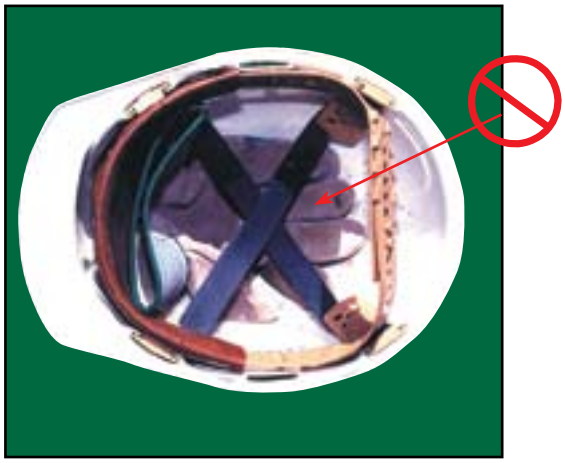
Always wear your hat with the bill forward. (Hats are tested in this position.) If you wear a hat differently, you may not be fully protected. The hat should fit snugly without being too tight. You should clean and inspect your hard hat regularly according to the manufacturer's instructions. Check the hat for cracks, dents, frayed straps, and dulling of the finish. These conditions can reduce protection. Use only mild soap and water for cleaning. Heavy-duty cleaners and other chemicals can damage the hat.

Don't wear another hat under your hard hat!

Class E, Type 1 hard hat.

Class B hard hat.

Do not "store" anything (gloves, wallet, etc.) in the top of your hard hat while you are wearing it. The space between the inside harness and the top of the hard hat must remain open to protect you. Do not put stickers on your hat (the glue can weaken the helmet) and keep it out of direct sunlight. If you want to express your personality, hard hats come in many colors and can be imprinted with custom designs by the manufacturer. Some hats are available in a cowboy hat design or with sports logos.



Never "store" anything in the top of your hard hat while you are wearing it.

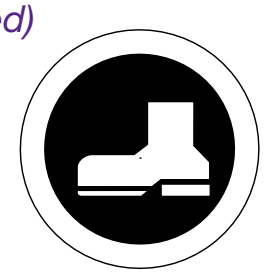
Class B hard hat in a cowboy hat design.

Keep your hard hat out of direct sunlight when you are not wearing it!

Use your head and protect your head!

PPE Fact Sheet *(continued)*

Foot Protection


FOOT PROTECTION

Workers must wear protective footwear when there is a risk of foot injury from sharp items or falling/rolling objects—or when electrical hazards are present. As with hard hats, always follow the manufacturer's instructions for cleaning and maintenance of footwear. Remember that cuts, holes, worn soles, and other damage can reduce protection.

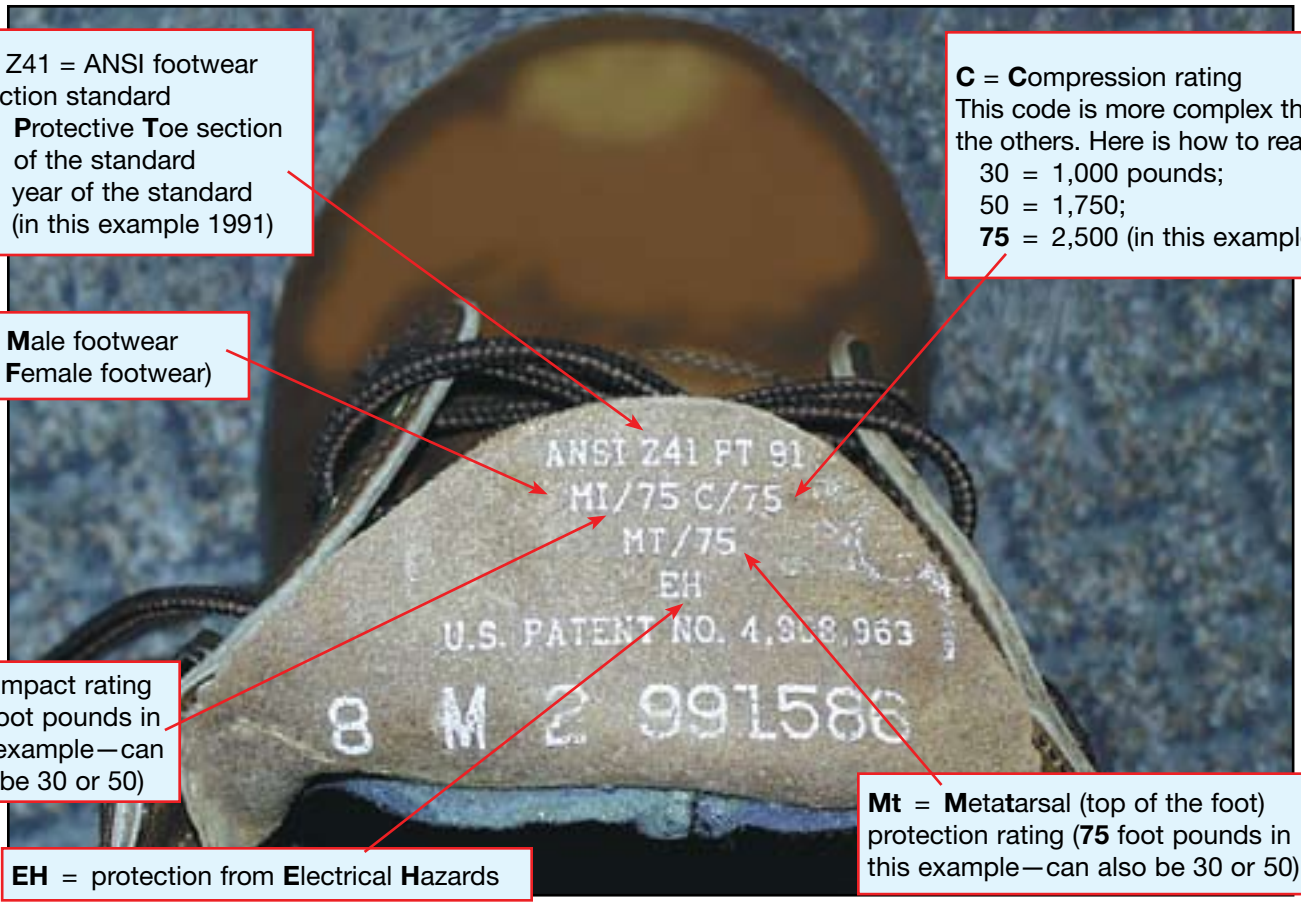
How do I choose the right footwear?

The footwear must be ANSI approved. ANSI approval codes are usually printed inside the tongue of the boot or shoe. Footwear will be marked "***EH***" if it is approved for electrical work. (The ANSI approval stamp alone does not necessarily mean the footwear offers protection from electrical hazards.) Note that footwear made of leather must be kept dry to protect you from electrical hazards, even if it is marked "***EH***."

What about non-electrical hazards?

All ANSI approved footwear has a protective toe and offers impact and compression protection. But the type and amount of protection is not always the same. Different footwear protects you in different ways. Check the product's labeling or consult the manufacturer to make sure the footwear will protect you from the hazards you face.

Don't take risks because you are wearing PPE.
PPE is the last line of defense against injury!



Summary of Section 8

Control hazards through safe work practices.

- Plan your work and plan for safety.
- Avoid wet working conditions and other dangers.
- Avoid overhead powerlines.
- Use proper wiring and connectors.
- Use and maintain tools properly.
- Wear correct PPE.

Glossary of Terms

ampacity
maximum amount of current a wire can carry safely without overheating

amperage
strength of an electrical current, measured in amperes

ampere (amp)
unit used to measure current

arc-blast
explosive release of molten material from equipment caused by high-amperage arcs

arcing
luminous electrical discharge (bright, electrical sparking) through the air that occurs when high voltages exist across a gap between conductors

AWG
American **W**ire **G**auge—measure of wire size

bonding
joining electrical parts to assure a conductive path

bonding jumper
conductor used to connect parts to be bonded

circuit
complete path for the flow of current

circuit breaker
overcurrent protection device that automatically shuts off the current in a circuit if an overload occurs

conductor
material in which an electrical current moves easily

CPR
cardio**p**ulmonary **r**esuscitation—emergency procedure that involves giving artificial breathing and heart massage to someone who is not breathing or does not have a pulse (requires special training)

current
movement of electrical charge

de-energize
shutting off the energy sources to circuits and equipment and depleting any stored energy

double-insulated
equipment with two insulation barriers and no exposed metal parts

energized (live, “hot”)
similar terms meaning that a voltage is present that can cause a current, so there is a possibility of getting shocked

fault current
any current that is not in its intended path

Glossary of Terms *(continued)*

fixed wiring
permanent wiring installed in homes and other buildings

flexible wiring
cables with insulated and stranded wire that bends easily

fuse
overcurrent protection device that has an internal part that melts and shuts off the current in a circuit if there is an overload

GFCI
ground **f**ault **c**ircuit **i**nterrupter—a device that detects current leakage from a circuit to ground and shuts the current off

ground
physical electrical connection to the earth

ground fault
loss of current from a circuit to a ground connection

ground potential
voltage a grounded part should have; 0 volts relative to ground

guarding
covering or barrier that separates you from live electrical parts

insulation
material that does not conduct electricity easily

leakage current
current that does not return through the intended path, but instead "leaks" to ground

lock-out
applying a physical lock to the energy sources of circuits and equipment after they have been shut off and de-energized

milliampere (milliamp or mA)
1/1,000 of an ampere

NEC
National **E**lectrical **C**ode—comprehensive listing of practices to protect workers and equipment from electrical hazards such as fire and electrocution

neutral
at ground potential (0 volts) because of a connection to ground

NFPA 70E Standard for Electrical Safety in the Workplace
This standard addresses those electrical safety requirements for employee workplaces that are necessary for the practical safeguarding of employees. It covers the installation of electrical conductors, electrical equipment, signaling and communications conductors and equipment, and raceways, excluding generating plants, substations, and control centers.

ohm
unit of measurement for electrical resistance

Glossary of Terms *(continued)*

OSHA
Occupational **S**afety and **H**ealth **A**dministration—Federal agency in the U.S. Department of Labor that establishes and enforces workplace safety and health regulations

overcurrent protection device
device that shuts off the current in a circuit when it reaches a certain level

overload
too much current in a circuit

power
amount of energy used each second, measured in watts

PPE
personal **p**rotective **e**quipment (eye protection, hard hat, special clothing, etc.)

qualified person
someone who has received mandated training on the hazards and on the construction and operation of equipment involved in a task

resistance
material's ability to decrease or stop electrical current

risk
chance that injury or death will occur

shocking current
electrical current that passes through a part of the body

short
low-resistance path between a live wire and the ground, or between wires at different voltages (called a fault if the current is unintended)

tag-out
applying a tag that alerts workers that circuits and equipment have been locked out

trip
automatic opening (turning off) of a circuit by a GFCI or circuit breaker

voltage
measure of electrical force

wire gauge
wire size or diameter (technically, the cross-sectional area)

References

1. NIOSH [2003]. NIOSH alert: preventing deaths, injuries, and illnesses of young workers. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2003–128.
2. Mccann M [2007]. Unpublished data.
3. Lee RL [1973]. Electrical safety in industrial plants. Am Soc Safety Eng J *18*(9):36–42.
4. Kouwenhoven WB [1968]. Human Safety and Electrical Shock. Electrical Safety Practices, Monograph 112, Instrument Society of America, P. 93.

Appendix

OSHA Standards

OSHA occupational safety and health standards for General Industry are located in the *Code of Federal Regulations* (CFR), Title 29, Part 1910 (abbreviated as 29 CFR 1910). Standards for Construction are located in Part 1926 (abbreviated as 29 CFR 1926). The full text of these standards is available on OSHA's Web site: www.osha.gov.

OSHA standards related to electrical safety for General Industry are listed below:

Subpart S—Electrical

GENERAL

1910.301 - Introduction

DESIGN SAFETY STANDARDS FOR ELECTRICAL SYSTEMS

1910.302 – Electric utilization systems
1910.303 – General requirements
1910.304 – Wiring design and protection
1910.305 – Wiring methods, components, and equipment for general use
1910.306 – Specific purpose equipment and installations
1910.307 – Hazardous (classified) locations
1910.308 – Special systems

SAFETY-RELATED WORK PRACTICES

1910.331 – Scope
1910.332 – Training
1910.333 – Selection and use of work practices
1910.334 – Use of equipment
1910.335 – Safeguards for personnel protection
1910.399 – Definitions applicable to this subpart
1910 Subpart S App A – Reference Documents
1910 Subpart S App B – Explanatory Data
1910 Subpart S App C – Tables, Notes, and Charts

Subpart J—General Environment Controls

1910.147 – The control of hazardous energy (lock-out/tag-out)
1910.147 – Appendix A—Typical minimal lock-out procedures

Subpart R—Special Industries

1910.268 – Telecommunications
1910.269 – Electric power generation, transmission, and distribution

OSHA standards related to electrical safety for Construction are listed below:

Subpart K—Electrical

GENERAL

1926.400 – Introduction

INSTALLATION SAFETY REQUIREMENTS

1926.402 – Applicability
1926.403 – General requirements
1926.404 – Wiring design and protection
1926.405 – Wiring methods, components, and equipment for general use
1926.406 – Specific purpose equipment and installations
1926.407 – Hazardous (classified) locations
1926.408 – Special systems

SAFETY-RELATED WORK PRACTICES

1926.416 – General requirements
1926.417 – Lock-out and tagging circuits

SAFETY-RELATED MAINTENANCE AND ENVIRONMENTAL CONSIDERATIONS

1926.431 – Maintenance of equipment
1926.432 – Environmental deterioration of equipment

SAFETY REQUIREMENTS FOR SPECIAL EQUIPMENT

1926.441 – Batteries and battery charging

DEFINITIONS

1926.449 – Definitions applicable to this subpart

Subpart V—Power Transmission and Distribution

1926.950 – General requirements
1926.951 – Tools and protective equipment
1926.952 – Mechanical equipment
1926.953 – Material handling
1926.954 – Grounding for protection of employees
1926.955 – Overhead lines
1926.956 – Underground lines
1926.957 – Construction in energized substations
1926.958 – External load helicopters
1926.959 – Lineman's body belts, safety straps, and lanyards
1926.960 – Definitions applicable to this subpart

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