A Guide to

Electrical Safety

Bobby R. Davis
Series Editor

NCDOL
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N.C. Department of Labor
Division of Occupational Safety and Health
1101 Mail Service Center
Raleigh, NC 27699-1101

Cherie K. Berry
Commissioner of Labor

N.C. Department of Labor
Occupational Safety and Health Program

Cherie K. Berry
Commissioner of Labor
OSHA State Plan Designee

Allen McNelly
Deputy Commissioner for Safety and Health

Kevin Beauregard
Assistant Deputy Commissioner for Safety and Health

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This guide is intended to be consistent with all existing OSHA standards; therefore, if an area is considered by the reader to be inconsistent with a standard, then the OSHA standard should be followed.

To obtain additional copies of this book, or if you have questions about N.C. occupational safety and health standards or rules, please contact:

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Additional sources of information are listed on the inside back cover of this book.

The projected cost of the OSHNC program for federal fiscal year 2002–2003 is $13,130,589. Federal funding provides approximately 37 percent ($4,920,000) of this total.

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Foreword

Everyone from office clerks to farmers work around electricity on a daily basis. Our world is filled with overhead power lines, extension cords, electronic equipment, outlets and switches. Our access to electricity has become so common that we tend to take our safety for granted. We forget that one frayed power cord or a puddle of water on the floor can take us right into the electrical danger zone.

A Guide to Electrical Safety can help electricians, plant maintenance personnel and many others review safe procedures for electrical work. It also covers the main U.S. Occupational Safety and Health Administration standards concerning electrical safety on the job.

In North Carolina, state inspectors enforce the federal laws through a state plan approved by the U.S. Department of Labor. The N.C. Department of Labor is charged with this mission. NCDOL enforces all current OSHA standards. It offers many educational programs to the public and produces publications, including this guide, to help inform people about their rights and responsibilities.

When reading this guide, please remember the NCDOL mission is greater than enforcement of regulations. An equally important goal is to help citizens find ways to create safer workplaces. *A Guide to Electrical Safety* can help you make and keep your workplace free of dangerous electrical hazards.

Cherie K. Berry
Commissioner of Labor

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Introduction

Electricity is the modern version of the genie in Aladdin's lamp. When electricity is safely contained in an insulated conductor, we normally cannot see, smell, taste, feel or hear it. It powers an endless list of laborsaving appliances and life-enhancing and support systems that have become such an assumed part of our lives that we give little thought to its potential for causing harm. Many myths and misstatements about electrical action are accepted as fact by many people.

For a recent five-year period, the National Safety Council reported that workplace electrocutions accounted for 7 percent of all work-related fatalities. Work-related electrical fatalities are a recurring and very serious problem in North Carolina and throughout the United States.

The National Institute for Occupational Safety and Health (NIOSH) conducted a study of workplace electrocutions that revealed the following information about workers who were electrocuted:

- The average age was 32.
- 81 percent had a high school education.
- 56 percent were married.
- 40 percent had less than one year of experience on the job to which they were assigned at the time of the fatal accident.
- 96 percent of the victims had some type of safety training, according to their employers.

This information reminds us that more effective training and education must be provided to employees if we are to reduce workplace electrocution hazards. Employees should receive initial training then refresher electrical hazard recognition training on an annual basis.

In addition to the shock and electrocution hazards, electricity can also cause fires and explosions. According to the U.S. Consumer Product Safety Commission, an estimated 169,000 house fires of electrical origin occur each year, claiming 1,100 lives and injuring 5,600 persons. Property losses from fires begun by electricity are estimated at $1.1 billion each year. The safe use and maintenance of electrical equipment at work (and at home) will help prevent fire and physical injury.

The purpose of this guide is to provide a clear understanding of electrical action and its control in the workplace environment. This information will enable you to recognize electrical hazards in the workplace as well as provide information on their control and/or elimination. **The guide does not qualify a person to work on or near exposed energized parts. Training requirements for "qualified" persons (those permitted to work on or near exposed energized parts) are detailed in 29 CFR 1910.332(b)(3). The guide will, however, enhance your ability to find and report electrical deficiencies in need of a qualified person's attention.**

Dangers of Electricity

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 jobsites 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. Electrocution is the third leading cause of work-related deaths among 16- and 17-year-olds, after motor vehicle deaths and workplace homicide. Electrocution is the cause of 12 percent of all workplace deaths among young workers.[1]

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[1] Castillo D.N. [1995]. NIOSH Alert: Preventing Death and Injuries of Adolescent Workers. Cincinnati, Ohio: 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. 95-125.

Electrical work can be deadly if not done safely.

- **Electrical shock causes injury or death!**
- **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.**

This industry guide offers discussion on a variety of topics as pertained to electrical hazards. There are four main types of electrical injuries: **electrocution (death due to electrical shock), electrical shock, burns and falls**. The guide discusses the dangers of electricity, electrical shock and the resulting injuries. It describes the various electrical hazards. The guide includes a sample plan (Safety Model) or approach to address these hazards in a later section. (This sample model/approach is also useful with other hazards.) You will learn about the **Safety Model**, as an important tool for **recognizing, evaluating** and **controlling hazards**. The guide includes important definitions and notes are shown throughout. It emphasizes practices that will help keep you safe and free of injury. It also includes case studies about real-life deaths to give you an idea of the hazards caused by electricity.

How Is an Electrical Shock Received?

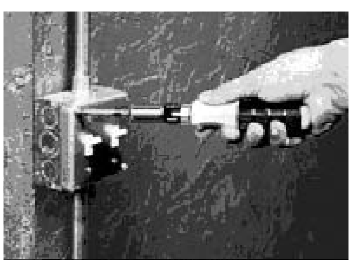
An electrical shock is received when electrical current passes through the body. Current will pass through the body in a variety of situations. Whenever two wires are at different voltages, current will pass between them if they are connected. Your body can connect the wires if you touch both of them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

- **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

Wires carry current.

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.

- **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.

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

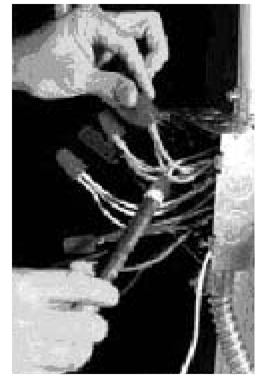
If you are in contact with a live wire or any live component of an energized electrical device-and also in contact with any grounded object-you will receive a shock. Plumbing is often grounded. Metal electrical boxes and conduit are grounded.

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 shocked. Of course, there is always a chance of shock, even in dry conditions. 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.

- **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.**

Summary

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.



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

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Fundamentals of Electricity

A review of the fundamentals of electricity is necessary to an understanding of some common myths and misstatements about electricity. First we must review Ohm's Law and understand the effects of current on the human body. Basic rules of electrical action will enhance your ability to analyze actual or potential electrical hazards quickly. This information will also enable you to understand other important safety concepts such as reverse polarity, equipment grounding, ground fault circuit interrupters, double insulated power tools, and testing of circuits and equipment.

Ohm's Law

There are three factors involved in electrical action. For electrons to be activated or caused to flow, those three factors must be present. A voltage (potential difference) must be applied to a resistance (load) to cause current to flow when there is a complete loop or circuit to and from the voltage source. Ohm's Law simply states that 1 volt will cause a current of 1 ampere to flow through a resistance of 1 ohm. As a formula this is stated as follows:

Voltage (E) = Current (I) X Resistance (R).

We will be concerned about the effects of current on the human body, so the formula relationship we will use most will be I = E/R. When you analyze reported shock hazards or electrical injuries, you should look for a voltage source and a resistance (high or low) ground loop. The human body is basically a resistor and its resistance can be measured in ohms. Figure 1 depicts a body resistance model. The resistive values are for a person doing moderate work. An increase in perspiration caused from working at a faster work pace would decrease the resistance and allow more current to flow.

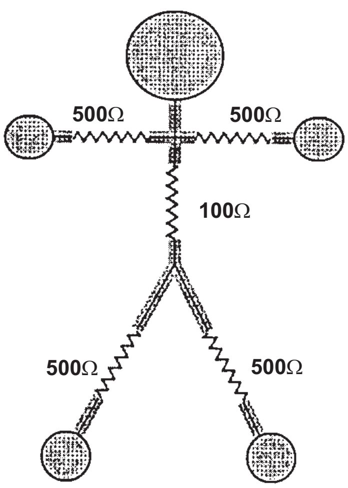


Figure 1

Human Body Resistance Model

As an example, let's use the hand to hand resistance of the body model, 500 + 500 = 1,000 ohms. Using I = E/R, I = 120/1,000 (assuming a 120 volt AC (alternating current) power source) or 0.120 amps. If we multiply 0.120 amps by 1,000 (this converts amps to milliamps), we get 120 milliamps (mA) which we will refer to in figure 2. If a person were working in a hot environment, and sweating, the body resistance could be lowered to a value of 500 ohms. Then the current that could flow through the body would equal I = 120/500 or 0.240 amps. Changing this to milliamps, 1,000 X 0.240 = 240 mA. This means that we have doubled the hazard to the body by just doing our job.

This can be explained by looking at figure 2. Figure 2 plots the current flowing through the chest area and the time it takes to cause the heart to go into ventricular fibrillation (arrhythmic heartbeat). Using the example of the body resistance at 1,000 ohms allowing 120 mA to flow (follow the dark line vertically from 120 mA to the shaded area, then left to the time of 0.8 seconds), you can see that it would only take 0.8 seconds to cause electrocution. When the body resistance is 500 ohms, at 240 mA it would only take 0.2 seconds to cause electrocution. Variable conditions can make common-use electricity (110 volts, 15 amps) fatal.

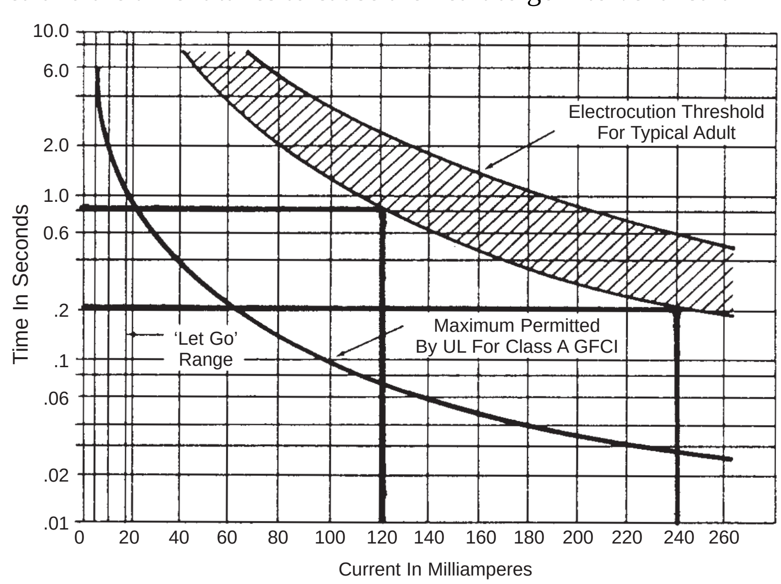


Figure 2

Electrical Current (AC) Versus the Time It Flows through the Body

Current and Its Effect on the Human Body

Based on the research of Professor Dalziel of the University of California, Berkeley, the effect of 60 Hz (cycles per second) of alternating current on the human body is generally accepted to be as follows:

- 1 milliamp (mA) or less—no sensation—not felt (1,000 milliamps equal 1 amp)
- 3 mA or more painful shock
- 5 mA or more—local muscle contractions—50 percent cannot let go
- 30 mA or more—breathing difficult—can cause unconsciousness
- 50–100 mA—possible heart ventricular fibrillation
- 100–200 mA—certain heart ventricular fibrillation
- 200 mA or more—severe burns and muscular contractions—heart more apt to stop than fibrillate
- Over a few amps—irreversible body damage

Thus, we can see that there are different types of injuries that electricity can cause. At the 20 to 30 mA range a form of anoxia (suffocation) can result. This could happen in a swimming pool where there is a ground loop present (the drain at the bottom of the pool) if a faulty light fixture or appliance is dropped into the water. Current would flow from the light fixture to the drain, using the water as the conducting medium. Any person swimming through the electrical field created by the fault current, would be bathed in potential difference and the internal current flow in the body could paralyze the breathing mechanism. This is why it is very important to keep all portable electrical appliances away from sinks, tubs and pools.

Ventricular fibrillation generally can occur in the range of 50 to 200 mA. Ventricular fibrillation is the repeated, rapid, uncoordinated contractions of the ventricles of the heart resulting in the loss of synchronization between the heartbeat and the pulse beat. Once ventricular fibrillation occurs, death can ensue in a few minutes. Properly applied CPR (cardiopulmonary resuscitation) techniques can save the victim until emergency rescue personnel with a defibrillator arrive at the scene. Workers in the construction trades and others working with electrical power tools should receive CPR training.

Above a few amperes, irreversible body damage can occur. This condition is more likely to occur at voltages above 600 volts AC. For example, if a person contacted 10,000 volts, I = 10,000/1,000 = 10 amps. This amount of current would create a great amount of body heat. Since the body consists of over 60 percent water, the water would turn to steam at a ratio of approximately 1 to 1,500. This would cause severe burns or exploding of body parts. These are the types of injuries that you would normally associate with electric power company workers. They can also occur, however, when people accidentally let a television or radio antenna contact an uninsulated power line. Accidents involving mobile vertical scaffolding or cranes booming up into power lines can cause these types of injuries or fatalities.

The route that the current takes through the body affects the degree of injury. If the current passes through the chest cavity (e.g., left hand to right hand), the person is more likely to receive severe injury or electrocution; however, there have been cases where an arm or leg was burned severely when the extremity came in contact with the voltage and the current flowed through a portion of the body without going through the chest area of the body. In these cases the person received a severe injury but was not electrocuted.

Typical 120 Volt AC System

At some time in your life, you may have received an electrical shock. Figure 3 illustrates a typical 120 volt AC system. Somewhere near your home or workplace there is a transformer with wires going between the transformer and the service entrance panel (SEP). In small establishments and homes, the SEP may also contain circuit breakers or fuses to protect the circuits leaving the SEP. Typical overcurrent protection for these circuits would be 15 or 20 amps. This protection is designed

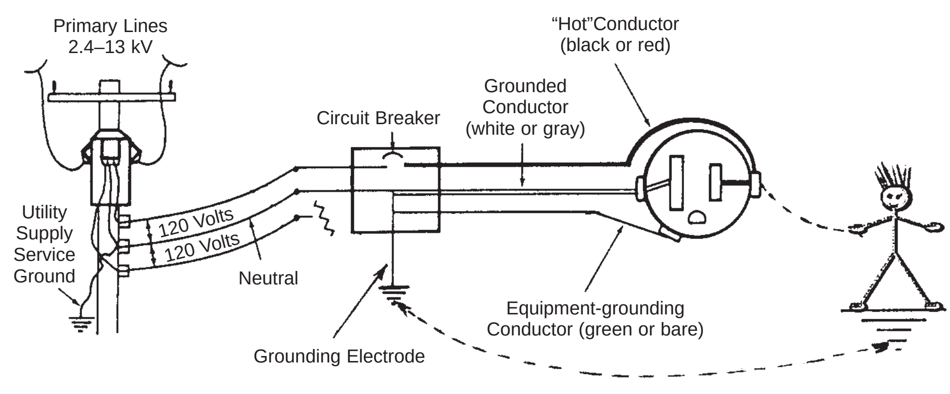


Figure 3

AC Systems—Contact with "Hot" Conductor

for line (hot) to line (grounded conductor) faults that would cause current greater than 15 or 20 amps to flow. If a person accidentally contacted the "hot" conductor while standing on the ground with wet feet (see figure 3), a severe shock could result. Current could flow through the body and return to the transformer byway of the "ground loop" path. Most electrical shocks result when the body gets into a ground loop and then contacts the "hot" or ungrounded conductor. If you analyze electrical shock incidents, look for these two factors: a ground loop and a voltage source.

We normally think of ground as the earth beneath our feet. From an electrical hazard standpoint, ground loops are all around us. A few ground loops that may not be under our feet include: metal water piping, metal door frames in newer building construction, ventilation ducts, metal sinks, metal T-bars holding ceiling acoustical panels, wet or damp concrete floors and walls, grounded light fixtures, and grounded power tools/appliances. When you are using or working around electrical equipment, be alert to these and other ground loops. The person shown in figure 3 could have isolated the ground loop by standing on insulated mats or dry plywood sheets. Wearing dry synthetic soled shoes would also have isolated the ground loop.

The utility supply ground and the grounding electrode conductor are system safety grounds. These grounds protect the users of electrical equipment in case of lightning storms and in instances where high voltage lines accidentally fall on lower voltage lines. These system safety grounds are not designed for individual safety. Actually, they are a hazard to the individual in that it is very easy to get into a ground loop, and once into a ground loop, you only need one fault path to the hot conductor before shock or injury can result.

Four Principles of Electrical Action

Knowing the basic principles of electrical action will help you understand and evaluate electrical shock hazards. These principles and an explanation for each are as follows:

1. Electricity does not "spring" into action until current flows.
2. Current will not flow until there is a loop (intentionally or accidentally) from the voltage source to a load and back to the source.
3. Electrical current always returns to the voltage source (transformer) that created it.
4. When current flows, energy (measured in watts) results.

Explanation for Principle 1

A person can contact voltage and not be shocked if there is high resistance in the loop. In figure 3, the person is standing on the ground and touching the 120 volt conductor. That would cause a shock and make your hair stand on end. If that same person were standing on insulated mats or wore shoes with insulated soles, the person would not be shocked even though there was 120 volts in his or her body. This explains why a person can be working outside with a defective power tool and not receive a shock when the ground is very dry or the person is isolated from a ground loop by plywood. That same person with the same power tool could change work locations to a wet area, then receive a shock when contacting a ground loop of low resistance. As previously stated, 3 mA or more can cause painful shock. Using Ohm's Law $I = E/R$, 120 volts and 3 mA, we can calculate how much resistance would allow 3 mA of current to flow. $R = E/I$ or $120/0.003$ or $R = 40{,}000$ ohms. Any ground loop resistance of less than 40,000 ohms would allow a shock that could be felt. This principle can also explain why birds sitting on a power line are not electrocuted. Their bodies would receive voltage, but current would not flow since another part of their body is not in contact with a ground loop.

Explanation for Principle 2

For current to flow, a complete loop must be established from the voltage source to the person and back to the voltage source. In figure 3, the loop is through the person's hand touching a 120 volt conductor, through the body to ground and then through the grounding electrode and back to the transformer secondary through the neutral conductor. Once that loop is established and becomes less than 40,000 ohms, a shock or serious injury can result. If the loop can be interrupted, as noted in Principle 1, then current will not flow. These two principles give you a common sense way to figure out how and why someone received a shock and the action that should be taken to prevent future shocks of the same type.

Explanation for Principle 3

Electric current always seeks to return to the transformer that created it. Current will also take all resistive paths to return to the transformer that created it. Since the voltage source has one wire already connected to ground (figure 3), contact with the “hot” wire provides a return path for current to use. Other ground loop paths in the workplace could include metal ducts, suspended ceiling T-bars, water pipes and other similar ground loops.

Explanation for Principle 4

This principle explains the shock and injury to the human body that current can do. The higher the voltage involved, the greater the potential heat damage to the body. As previously mentioned, high voltage can cause high current flow resulting in severe external and internal body damage. Remember that the flow of current causes death or injury; voltage determines how the injury or death is effected.

Some Misconceptions About Electrical Action

Americans use more electrical power per person than do individuals of any other country in the world, but that does not mean that we have a better understanding of electricity. Some common misconceptions about electrical actions are addressed and corrected in the following discussion.

“If an Appliance or Power Tool Falls Into Water, It Will Short Out”

When an appliance falls into a tub or container of water, it will not short out. In fact, if the appliance switch is “on,” the appliance will continue to operate. If the appliance has a motor in it, the air passage to keep the motor cool will be water cooled. Unfortunately, that same air passage, when wet, will allow electricity to flow outside the appliance if a current loop is present (such as a person touching the metal faucet and reaching into the water to retrieve a hair dryer). The current loop due to the water resistance will be in the 100 to 300 mA range, which is considerably less than the 20,000+ mA needed to trip a 20 amp circuit breaker. Since an appliance will not short out when dropped in a sink or tub, no one should ever reach into the water to retrieve an appliance accidentally dropped there. The water could be electrified, and a person touching a grounded object with some other part of the body could receive a serious shock depending on the path the current takes through the body. The most important thing to remember is that appliances do not short out when dropped or submerged in water.

“Electricity Wants to Go to the Ground”

Sometimes editors of motion films about electrical safety make the statement that “electricity wants to go to the ground.” There are even books published about electrical wiring that contain the same statement. As previously stated, electricity wants to return to the transformer that created it, and the two conductors that were designed to carry it safely are the preferred route it takes. Whenever current goes to ground or any other ground loop, it is the result of a fault in the appliance, cords, plugs or other source.

“It Takes High Voltage to Kill; 120 Volts AC Is Not Dangerous”

Current is the culprit that kills. Voltage determines the form of the injury. Under the right conditions, AC voltage as low as 60 volts can kill. At higher voltages the body can be severely burned yet the victim could live. Respect all AC voltages, high or low, as having the potential to kill.

“Double Insulated Power Tools Are Doubly Safe and Can Be Used in Wet and Damp Locations”

Read the manufacturer’s operating instructions carefully. Double insulated power tools are generally made with material that is nonconductive. This does give the user protection from electrical faults that occur within the insulated case of the appliance. However, double insulated power tools can be hazardous if dropped into water. Electrical current can flow out of the power tool case into the water. Remember that double insulated power tools are not to be used in areas where they can get wet. If conditions or situations require their use under adverse conditions, use GFCI (ground fault circuit interrupter) protection for the employee.

- **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.**

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]

Table 1 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.

Defibrillator in use.

LOW VOLTAGE DOES NOT MEAN LOW HAZARD!

Table 1

Effects of Electrical Current* on the Body[3]

Current	Reaction
1 milliamp	Just a faint tingle.
5 milliamps	Slight shock felt. Disturbing, but not painful. Most people can let go. However, strong involuntary movements can cause injuries.
6–25 milliamps (women)† **9–30 milliamps** (men)	Painful shock. Muscular control is lost. This is the range where "freezing currents" start. It may not be possible to let go.
5–150 milliamps	Extremely painful shock, respiratory arrest (breathing stops), severe muscle contractions. Flexor muscles may cause holding on; extensor muscles may cause intense pushing away. Death is possible.
1,000–4,300 milliamps (1–4.3 amps)	Ventricular fibrillation (heart pumping action not rhythmic) occurs. Muscles contract; nerve damage occurs. Death is likely.
10,000 milliamps (10 amps)	Cardiac arrest and severe burns occur. Death is probable.
15,000 milliamps (15 amps)	Lowest overcurrent at which a typical fuse or circuit breaker opens a circuit!

* Effects are for voltages less than about 600 volts. Higher voltages also cause severe burns.
† Differences in muscle and fat content affect the severity of shock.

[2] Lee R.L. [1973]. Electrical Safety in Industrial Plants. Am Soc Safety Eng J18(9):36-42.
[3] USDOL [1997]. Controlling Electrical Hazards. Washington, D.C.: U.S. Department of Labor, Occupational Safety and Health Administration.

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 photos later in this and other sections).

- **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.**
- **Resistance—**a material's ability to decrease or stop electrical current.
- **Ohm**—unit of measurement for electrical resistance.
- **Lower resistance causes greater currents.**
- **Currents across the chest are very dangerous.**

The amount of current passing through the body also affects the severity of an electrical shock. Greater voltages produce greater currents. There is greater danger from higher voltages. Resistance hinders current. The lower the resistance (or impedance in AC circuits), the greater the current 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.

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 will 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.

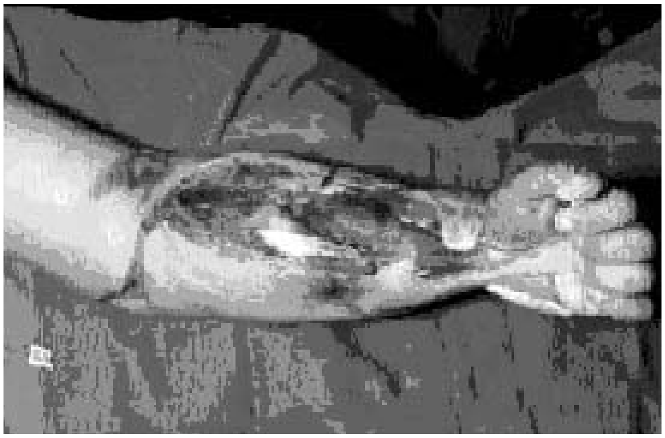
- **NEC**—National Electrical Code—a comprehensive listing of practices to protect workers and equipment from electrical hazards such as fire and electrocution

There have been cases where an arm or leg is severely burned by high-voltage electrical

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

Electrical burn on hand and arm.

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

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

3

Branch Circuit Wiring

Definitions

Discussion of wiring methods must be preceded by an understanding of terms used to define each specific conductor in a typical 120/240 volt AC system. Refer to figure 4 for an example of most of the following definitions. The National Electrical Code (NEC) is used as the reference source.

Ampacity. The current (in amps) that a conductor can carry continuously under the conditions of use without exceeding its temperature rating. When you find attachment plugs, cords or receptacle face plates that are hot to touch, this may be an indication that too much of a load (in amps) is being placed on that branch circuit. If the insulation on the conductors gets too hot, it can melt and cause arcing, which could start a fire.

Attachment Plug. Describes the device (plug) that when inserted into the receptacle establishes the electrical connection between the appliance and branch circuit.

Branch Circuit. The electrical conductors between the final overcurrent device (the service entrance panel (SEP) in figure 4) protecting the circuit and the receptacle. The wiring from the SEP to the pole mounted transformer is called the "service."

Circuit Breaker. Opens and closes a circuit by nonautomatic means as well as being designed to open automatically at a predetermined current without causing damage to itself. Be alert to hot spots in circuit breaker panels indicating that the circuit breaker is being overloaded or that there may be loose connections.

Equipment. A general term for material, fittings, devices, appliances, fixtures, apparatus and the like used as a part of, or in connection with, an electrical installation. In figure 4, the SEP and any associated conduit and junction boxes would be considered equipment.

Feeder. The term given to the circuit conductors between the SEP and the final branch circuit overcurrent device. In figure 4 there is no feeder since the SEP is also the final branch circuit overcurrent device.

Ground. A conducting connection (whether intentional or accidental) between an electrical circuit or equipment and the earth, or to some conducting body that serves in place of the earth. It is important to remember that a conducting body can be in the ceiling and that we must not think of ground as restricted to earth. This is why maintenance personnel may not realize that a ground loop exists in the space above a drop ceiling, due to the electrical conduit and other grounded equipment in that space.

Grounded Conductor. The conductor in the branch circuit wiring that is intentionally grounded in the SEP. This conductor is illustrated in figure 4. From the SEP to the transformer the same electrical path is referred to as the neutral. From the final overcurrent device to the receptacle the conductor is referred to as the grounded conductor.

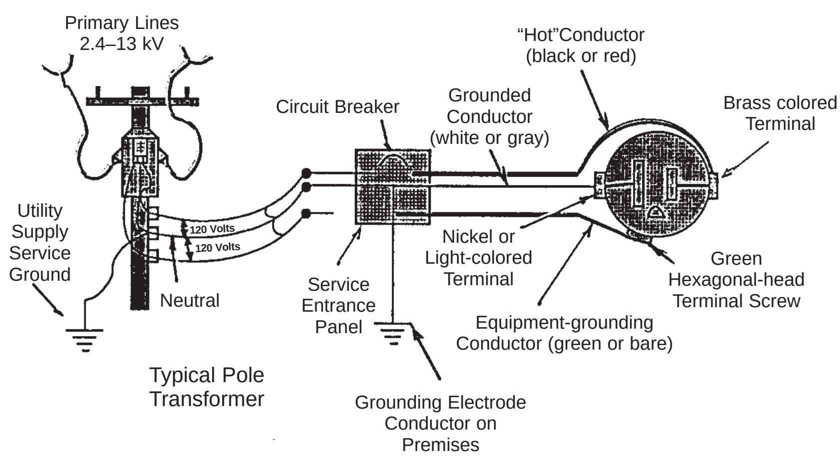


Figure 4

Branch Circuit Wiring

Grounding Conductor, Equipment. The conductor used to connect the noncurrent-carrying metal parts of equipment, raceways and other enclosures to the system grounded conductor at the SEP. The equipment grounding conductor path is allowed to be a separate conductor (insulated or noninsulated), or where metal conduit is used, the conduit can be used as the conductor. There are some exceptions to this such as in hospital operating and intensive care rooms. The equipment grounding conductor is the human safety conductor of the electrical system in that it bonds all noncurrent-carrying metal surfaces together and then connects them to ground. By doing this we can prevent a voltage potential difference between the metal cabinets and enclosures of equipment and machinery. This conductor also acts as a low impedance path (in the event of a voltage fault to the equipment case or housing) so that if high fault current is developed, the circuit breaker or fuse will be activated quickly.

Grounding Electrode Conductor. Used to connect the grounding electrode to the equipment grounding conductor and/or to the grounded conductor of the circuit at the service equipment or at the source of a separately derived system (see figure 4).

Overcurrent. Any current in excess of the rated current of equipment or the ampacity of a conductor is considered overcurrent. This condition may result from an overload, short circuit or a ground fault.

Wiring Methods

The NEC requires the design and installation of electrical wiring to be consistent throughout the facility. To accomplish this, it is necessary to follow NEC requirements. For 120 volt grounding-type receptacles, the following wiring connections are required (see figure 4).

- The ungrounded or “hot” conductor (usually with black or red insulation) is connected to the brass colored terminal screw. This terminal and the metal tension springs form the small slot receiver for any appliance attachment plug. An easy way to remember the color coding is to remember “black to brass” or the initials “B & B.”
- The “grounded conductor” insulation is generally colored white (or gray) and should be fastened to the silver or light colored terminal. This terminal and the metal tension springs form the large slot for a polarized attachment plug. An easy way to remember this connection is to think “white to light.”
- The equipment grounding conductor path can be a conductor, or where metal conduit is used, the conduit can be substituted for the conductor. If the latter is used, you must monitor the condition of the conduit system to ensure that it is not damaged or broken. Any “open” in the conduit system will eliminate the equipment grounding conductor path. Additionally, the condition of the receptacles must be monitored to ensure that they are securely fastened to the receptacle boxes. When a third wire is run to the receptacle either in a conduit or as a part of a nonmetallic sheathed cable assembly, the conductor must be connected to the green colored terminal on the receptacle.

These wiring methods must be used to ensure that the facility is correctly wired. Circuit testing methods will be discussed in part 4. In older homes, knob and tube or other two-wire systems may be present. The NEC requires that grounding type receptacles be used as replacements for existing nongrounding types and be connected to a grounding conductor. An exception is that where a grounding means does not exist in the enclosure, either a nongrounding or a GFCI-type receptacle must be used. A grounding conductor must not be connected from the GFCI receptacle to any outlet supplied from the GFCI receptacle. The exception further allows nongrounding type receptacles to be replaced with the grounding type where supplied through a GFCI receptacle.

Plug and Receptacle Configurations

Attachment plugs are devices that are fastened to the end of a cord so that electrical contact can be made between the conductor in the equipment cord and the conductors in the receptacle. The plugs and receptacles are designed for different voltages and currents, so that only matching plugs will fit into the correct receptacle. In this way, a piece of equipment rated for one voltage and/or current combination cannot be plugged into a power system that is of a different voltage or current capacity.

The polarized three-prong plug is designed with the equipment grounding prong slightly longer than the two parallel blades. This provides equipment grounding before the equipment is energized. Conversely, when the plug is removed from the receptacle, the equipment grounding prong is the last to leave, ensuring a grounded case until power is removed. The parallel line blades maybe the same width on some appliances since the three-prong plug can only be inserted in one way. A serious problem results whenever a person breaks or cuts off the grounding prong. This not only voids the safety of the equipment grounding conductor but allows the attachment plug to be plugged in with the correct polarity or with the wrong polarity.

Figure 5 illustrates some of the National Electrical Manufacturers Association (NEMA) standard plug and receptacle connector blade configurations. Each configuration has been developed to standardize the use of plugs and receptacles for different voltages, amperes, and phases from 115 through 600 volts and from 10 through 60 amps, and for single- and three-phase systems.

You should be alert to jury-rigged adaptors used to match, as an example, a 50 amp attachment plug to a 20 amp receptacle configuration. Using these adaptors poses the danger of mixing voltage and current ratings and causing fire and/or shock hazards to personnel using equipment. Equipment attachment plugs and receptacles should match in voltage and current ratings to provide safe power to meet the equipment ratings. Also the attachment plug cord clamps must be secured to the cord to prevent any strain or tension from being transmitted to the terminals and connections inside the plug.

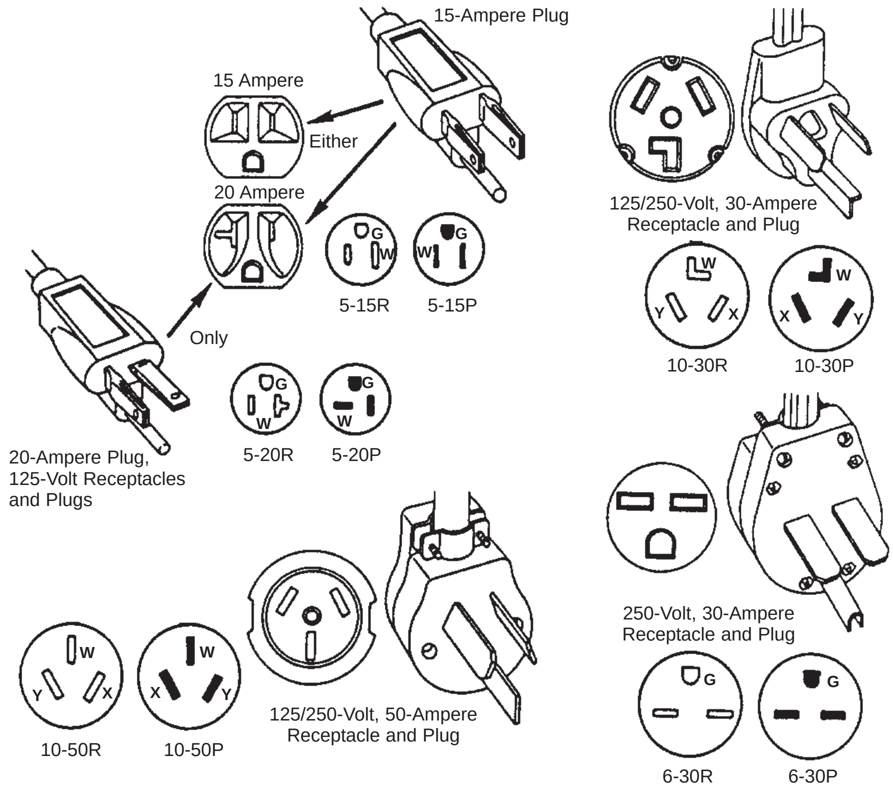


Figure 5

Plug and Receptacle Configurations

Understanding Reverse Polarity

The NEC recognizes the problem of reverse polarity. It states that no grounded conductor may be attached to any terminal or lead so as to reverse the designated polarity. Many individuals experienced with electrical wiring and appliances think that reverse polarity is not hazardous. A few example situations should heighten your awareness of the potential shock hazard from reverse polarity.

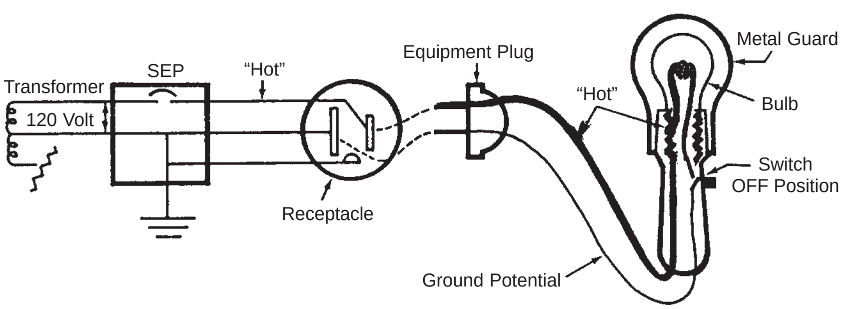


Figure 6

Hand Lamp—Reverse Polarity

An example of one hazardous situation would be an electric hand lamp. Figure 6 illustrates a hand lamp improperly wired and powered.

When the switch is turned off, the shell of the lamp socket is energized. If a person accidentally touched the shell (while changing a bulb) with one hand and encountered a ground loop back to the transformer, a shock could result. If the lamp had no switch and was plugged in as shown, the lamp shell would be energized when the plug was inserted into the receptacle. Many two-prong plugs have blades that are the same size, and the right or wrong polarity is just a matter of chance. If the plug is reversed (figure 7), the voltage is applied to the bulb center terminal

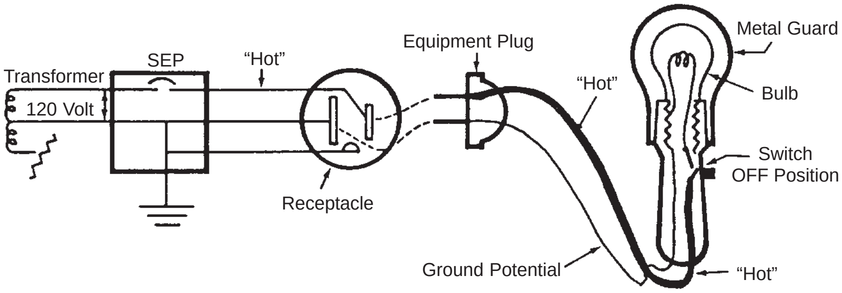


Figure 7

Hand Lamp—Correct Polarity

and the shell is at ground potential. Contact with the shell and ground would not create a shock hazard in this situation. In this example the hand lamp is wired correctly.

Another example is provided by electric hair dryers or other plastic-covered electrical appliances. Figure 8 illustrates a hair dryer properly plugged into a receptacle with the correct polarity.

You will notice that the switch is single pole-single throw (SPST). When the appliance is plugged in with the switch in the hot or 120 volt leg, the voltage stops at the switch when it is in the off position. If the hair dryer were accidentally dropped into water, current could flow out of the plastic housing, using the water as the conducting medium. The water does not short out the appliance since the exposed surface area of the hot wire connection to the switch terminal offers such a high resistance. This limits the current flow to less than 1 mA (correct polarity). The fault current is not sufficient to trip a 20-amp circuit breaker. To trip the circuit breaker, there would have to be a line-to-line short that would cause an excess of 20 amps (20,000 mA). Should a person try to retrieve the appliance from the water while it is still plugged into the outlet? In this configuration, the fault current would be extremely low (unless the switch were in the on position). Since you have no way to tell if the polarity is correct, don't take chances. NEVER REACH INTO WATER TO RETRIEVE AN APPLIANCE. Always unplug the appliance first, then retrieve the appliance and dry it out.

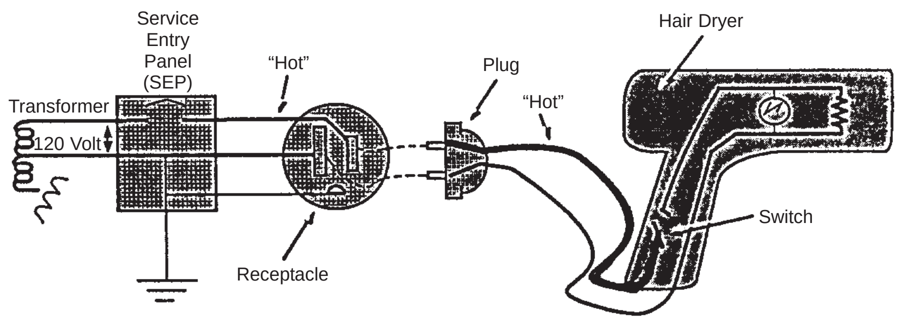


Figure 8

Hair Dryer—Correct Polarity

If the appliance is plugged in as shown in figure 9, when the switch is off, voltage will be present throughout all the internal wiring of the appliance. Now if it is dropped into water, the drastically increased "live" surface area will allow a drastic increase in the available electric current (I = E/R). A person who accidentally tries to retrieve the dryer would be in a hazardous position because the voltage in the water could cause current to flow through the body (if another part of the body contacts a ground loop). This illustrates the concept that reverse polarity is a problem whenever appliances are used with plastic housings in areas near sinks, or where the appliance is exposed to rain or water. Remember, most motorized appliances have air passages for cooling. Wherever air can go, so can moisture and water.

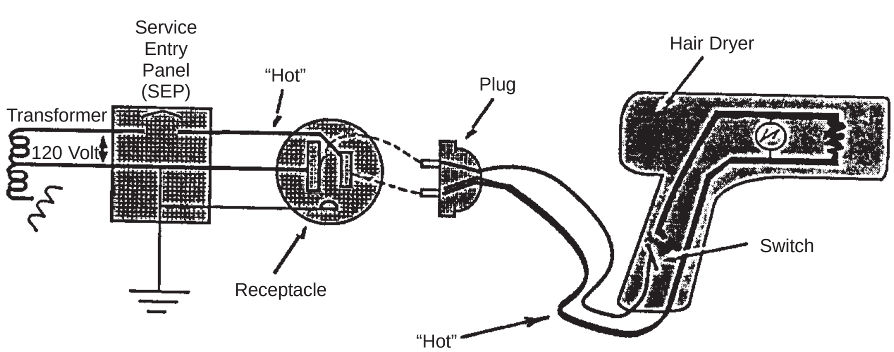


Figure 9

Hair Dryer—Reverse Polarity

If the appliance had a double pole-double throw switch (DPDT), it would make no difference how the plug was positioned in the outlet. The hazard would be minimized since the energized contact surface would be extremely small. If the appliance were dropped into water, a high resistance contact in the water and a resulting low available fault current ($I = E/R$) would result. Later, we will see how GFCIs can be used to protect against shock hazards when using appliances with nonconductive housings around water.

Remember that any electric appliance dropped in water or accidentally exposed to moisture should be considered as energized. The electric power must be safely removed from the appliance before it is retrieved or picked up. You never know if the appliance is plugged in with the right polarity, without test equipment. **Do not take chances. Remove the power first.**

Grounding Concepts

Grounding falls into two safety categories. It is important to distinguish between "system grounding" and "equipment grounding." Figure 10 illustrates these two grounding components. The difference between these two terms is that system grounding actually connects one of the current carrying conductors from the supply transformer to ground. Equipment grounding connects or bonds all of the noncurrent-carrying metal surfaces together and then is connected to ground.

System grounding (figure 10) at the transformer provides a grounding point for the power company surge and lightning protection devices. In conjunction with the system grounding at the SEP, the voltage across system components is limited to a safe value should they be subjected to lightning or high voltage surges. The system grounding at the SEP also helps to limit high voltages from entering the electrical system beyond the SEP. It is important to check all of the connections both indoors and outdoors since many times they are exposed to moisture, chemicals and physical damage.

Equipment grounding does two things. First, it bonds all noncurrent-carrying metal surfaces together so that there will be no potential difference between them. Second, it provides a path for current to flow under ground fault conditions. The equipment grounding path must have low impedance to ensure rapid operation of the circuit overcurrent device should a "hot" to ground fault occur.

Figure 11 depicts some common equipment faults that can occur. A problem with the equipment grounding system is that under normal conditions it is not a current-carrying conductor and a fault would not be readily detected. Necessary visual inspection will not provide an operational verification. In figure 11 we can test the condition of the equipment grounding conductor using test procedures in this guide. To test the quality of the branch circuit equipment grounding system, a special tester called a ground loop impedance tester is needed. It is generally recommended that an impedance of 0.5 ohms be achieved in the equipment grounding conductor path. In case of a "hot" to ground fault, the fault current would quickly rise to a value ($I = E/R = 120/0.5 = 240$ amps) necessary to trip a 20 amp fuse or breaker.

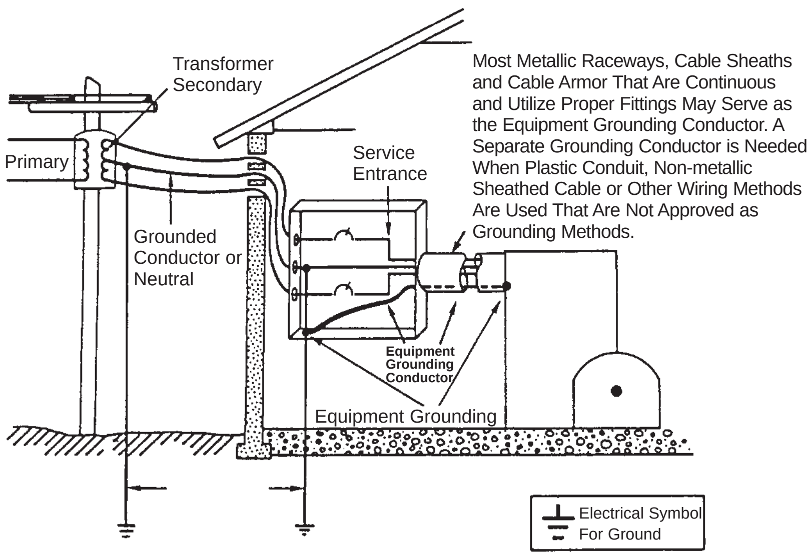


Figure 10

System and Equipment Grounding

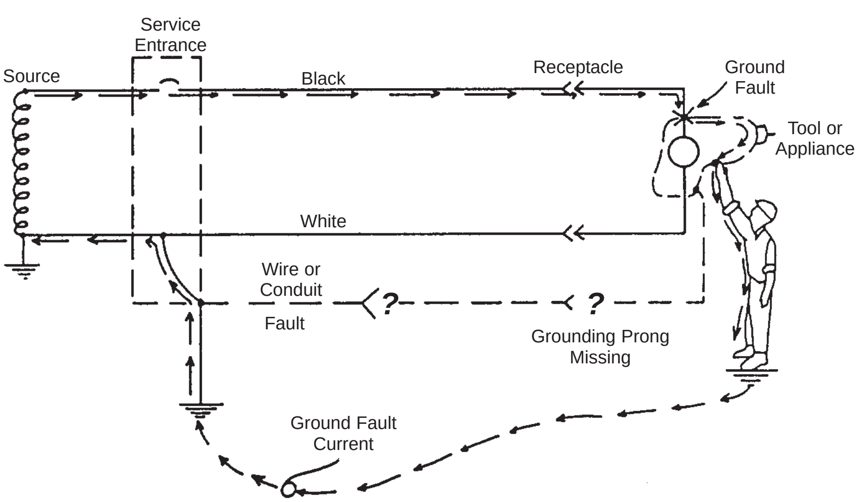


Figure 11

Equipment Grounding Faults

If there is an open or break in the conduit system, as shown in figure 11, a fault in a power tool with a good grounding prong would allow the voltage to be placed directly on the ungrounded conduit. This would create a serious shock hazard to anyone touching the conduit with one hand while touching a ground loop with the other. The missing ground prong (with a good conduit or equipment grounding path) would create a serious shock hazard to the person if the ground loop through the feet was low resistance (e.g., wet earth or concrete and wet shoes). It is important to emphasize the need for low impedance on the equipment grounding loop. If the ground fault current loop in figure 11 were 25 ohms and the body resistance of the person were 850 ohms, then the 25 ohm ground loop resistance would be too high to cause enough circuit breaker current to trip it open. In this case, the person would then receive multiples of current considered deadly (141 mA in this case) through the body, causing death in most instances. Remember that standard circuit breakers are for equipment and fire protection, not people protection. However, ground fault circuit interrupter (GFCI) circuit breakers are specifically designed for people protection.

Burns Caused by Electricity

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.

- **Electrical shocks cause burns.**

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.

- **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

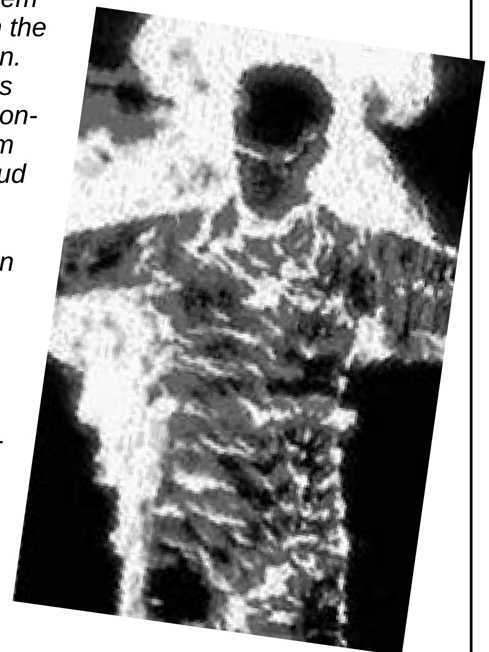
There are three primary hazards associated with an arc-blast.

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. 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 lockout/tagout, 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.*



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 multi-purpose (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.

Note: *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 the area and call for help.*

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. OSHA standards, the NEC 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.

Summary

Burns are the most common injury caused by electricity. The three types of burns are electrical burns, arc burns and thermal contact burns.

4

Branch Circuit and Equipment Testing

Testing Branch Circuit Wiring

Branch circuit receptacles should be tested periodically. The frequency of testing should be established on the basis of outlet usage. In shop areas, quarterly testing may be necessary. Office areas may only need annual testing. A preventive maintenance program should be established. It is not unusual to find outlets as old as the facility. For some reason, a popular belief exists that outlets never wear out. This is false. For example, outlets take severe abuse from employees disconnecting the plug from the outlet by yanking on the cord. This can put severe strain on the contacts inside the outlet as well as on the plastic face.

The electrical receptacle is a critical electrical system component. It must provide a secure mechanical connection for the appliance plug so that there is a continuous electrical circuit for each of the prongs. Receptacles must be wired correctly, or serious injuries can result from their use. For this reason, the following two-step testing procedure is recommended.

Receptacle Testing

Step 1

Plug in a three-prong receptacle circuit tester and note the combination of the indicator lights (see figure 12). The tester checks the receptacle for the proper connection of the grounding conductor, wiring polarity and other combinations of wiring errors. If the tester checks the receptacle as OK, proceed to the next step. If the tester indicates a wiring problem, have it corrected as soon as possible. Retest after the problem is corrected.

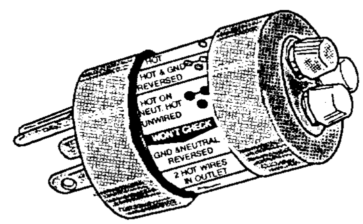


Figure 12

Receptacle Tester

Step 2

After the outlet has been found to be wired (electrically) correct, the receptacle contact tension test must be made. A typical tension tester is shown in figure 13. The tension should be 8 ounces or more. If it is less than 8 ounces, have it replaced. The first receptacle function that loses its contact tension is usually the grounding contact circuit. The plug grounding prong is the last part to leave the receptacle. Because of the leverage (due to its length) it wears out the tension of the receptacle contacts quicker than the parallel blade contacts. Since this is the human safety portion of the grounding system, it is very important that this contact tension be proper. In determining the frequency of testing, the interval must be based on receptacle usage. All electrical maintenance personnel should be equipped with receptacle circuit and tension testers. Other maintenance employees could also be equipped with testers and taught how to use them. In this manner, the receptacles can be tested before maintenance workers use them. Home receptacles should also be tested.

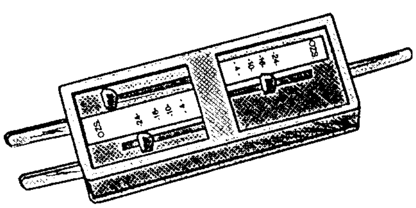


Figure 13

Receptacle Tension Tester

Testing Extension Cords

New extension cords should be tested before being put into service. Many inspectors have found that new extension cords have open ground or reverse polarity. Do not assume that a new extension cord is correct. Test it.

Extension cord testing and maintenance are extremely important. The extension cord takes the electrical energy from a fixed outlet or source and provides this energy at a remote location. The extension cord must be wired correctly, or it can become the critical fault path.

Testing of extension cords new and used should use the same two steps as used in electrical outlet testing. These two steps are:

Step 1

Plug the extension cord into an electrical outlet that has successfully passed the outlet testing procedure. Plug in any three-prong receptacle circuit tester into the extension receptacle and note the combination of indicator lights. If the tester checks the extension cord as OK, proceed to the next step. If the tester indicates a faulty condition, repair or replace the cord. Once the extension cord is correctly repaired and passes the three-prong circuit tester test, proceed to step 2.

Step 2

Plug a reliable tension tester into the receptacle end. The parallel receptacle contact tension and the grounding contact tension should check out at 8 ounces or more. If the tension is less than 8 ounces, the receptacle end of the extension cord must be repaired. As with fixed electrical outlets, the receptacle end of an extension cord loses its grounding contact tension first. This path is the critical human protection path and must be both electrically and mechanically in good condition.

Testing Plug- and Cord-Connected Equipment

The last element of the systems test is the testing of plug- and cord-connected equipment. The electrical inspector should be on the alert for jury-rigged repairs made on power tools and appliances. Many times a visual inspection will disclose three-prong plugs with the grounding prong broken or cut off. In such instances, the grounding path to the equipment case has been destroyed. (The plug can now also be plugged into the outlet in the reverse polarity configuration.)

Double insulated equipment generally has a nonconductive case and will not be tested using the procedures discussed below. Some manufacturers that have listed double insulation ratings may also provide the three-prong plug to ground any exposed noncurrent-carrying metal parts. In these cases, the grounding path continuity can be tested.

A common error from a maintenance standpoint is the installation of a three-prong plug on a two-conductor cord to the appliance. Obviously, there will be no grounding path if there are only two conductors in the cord. Some hospital grade plugs have transparent bases that allow visual inspection of the electrical connection to each prong. Even in that situation, you should still perform an electrical continuity test.

Maintenance shops may have commercial power tool testing equipment. Many power tool testers require the availability of electric power. The ohmmeter can be used in the field and in locations where electric power is not available or is not easily obtained. Plug- and cord-connected equipment tests are made on de-energized equipment. Testing of de-energized equipment in wet and damp locations can also be done safely.

The plug- and cord-connected equipment test using a self-contained battery-powered ohmmeter is simple and straightforward. The two-step testing sequence that can be performed on three-prong plug grounded equipment follows:

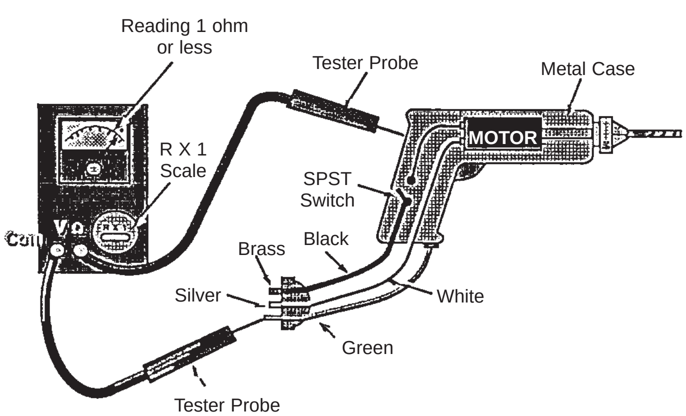


Figure 14

Continuity Test

Step 1—Continuity Test—Ground Pin to Case Test

Set the ohmmeter selector switch to the lowest scale (such as R X 1). Zero the meter by touching the two test probes together and adjusting the meter indicator to zero. Place one test lead (tester probe) on the grounding pin of the de-energized equipment as shown in figure 14. While holding that test lead steady, take the other test lead and make contact with an unpainted surface on the metal case of the appliance. You should get a reading of less than 1 ohm. If the grounding path is open, the meter will indicate infinity. If there is no continuity, then the appliance must be tagged out and removed from service. If the appliance grounding path is OK, proceed to step 2.

Step 2—Leakage Test—Appliance Leakage Test

Place the ohmmeter selector switch on the highest ohm test position (such as R X 1,000). Set the meter at zero. Place one test lead on an unpainted surface of the appliance case (see figure 15), then place the other test lead on one of the plug's parallel blades.

Observe the reading. The ideal is close to infinity. (If a reading of less than 1 meg-ohm is noted, return the appliance to maintenance for further testing.) With one test lead still on the case, place the other test lead on the remaining parallel blade and note the ohmmeter reading. A reading approaching infinity is required. (Again, anything less than 1 meg-ohm should be checked by a maintenance shop.)

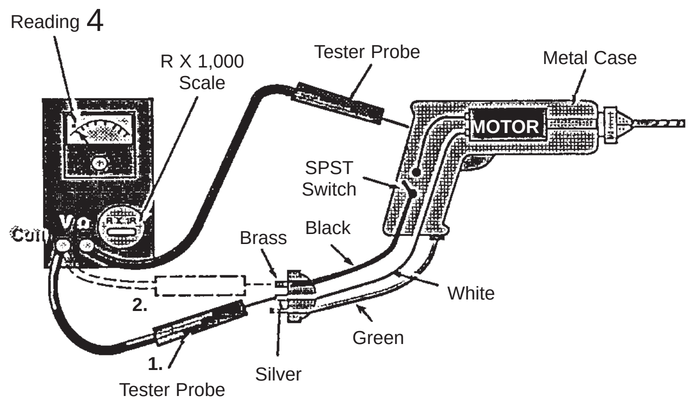


Figure 15

Leakage Test

5

Voltage Detector Testing

Operation

When you are conducting an electrical inspection, a voltage detector should be used in conjunction with the circuit tester, ohmmeter and tension tester. Several types of these devices are inexpensive and commercially available.

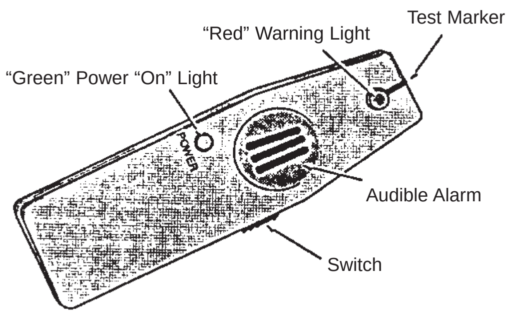


Figure 16

Voltage Detector

These testers are battery powered and are constructed of nonconducting plastic. Lightweight and self-contained, these testers make an ideal inspection tool.

The voltage detector works like a radio receiver in that it can receive or detect the 60 hertz electromagnetic signal from the voltage waveform surrounding an ungrounded ("hot") conductor. Figure 17 illustrates the detector being used to detect the "hot" conductor in a cord connected to a portable hand lamp. When the front of the detector is placed near an energized "hot" or ungrounded conductor, the tester will provide an audible as well as a visual warning. In figure 17 if the plug were disconnected from the receptacle, the detector would not sound an alarm since there would not be any voltage waveform present.

Typical Voltage Detector Uses

The detector can also be used to test for properly grounded equipment. When the tester is positioned on a properly grounded power tool (e.g., the electric drill in figure 18), the tester will not sound a warning. The reason is that the electromagnetic field is shielded from the detector so that no signal is picked up. If the grounding prong had been removed and the drill were not grounded, the electromagnetic waveform would radiate from the drill and the detector would receive the signal and give off an alarm.

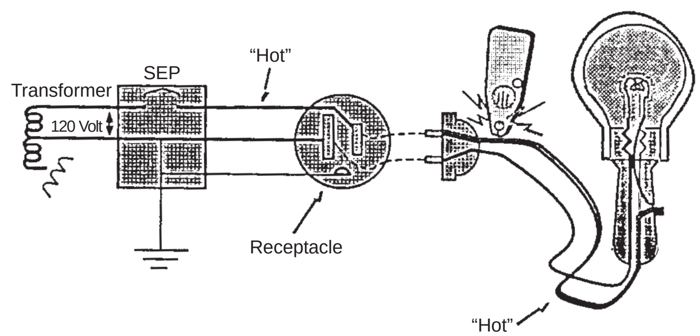


Figure 17

Testing for "Hot" Conductor

As illustrated in figure 18, the detector can be used to test for many things during an inspection. Receptacles can be checked for proper AC polarity. Circuit breakers can be checked to determine if they are on or off. All fixed equipment can be checked for proper grounding. If the detector gives a warning indication on any equipment enclosed by metal, perform further testing with a volt-ohmmeter. Ungrounded equipment can be ungrounded or, in addition, there may be a fault to the enclosure making it "hot" with respect to ground. An experienced inspector should use the voltmeter to determine if there is voltage on the enclosure. The voltage detector should be used as an indicating tester and qualitative testing should be accomplished with other testing devices such as a volt-ohmmeter. The use of the detector can speed up the inspection process by allowing you to check equipment grounding quickly and safely.

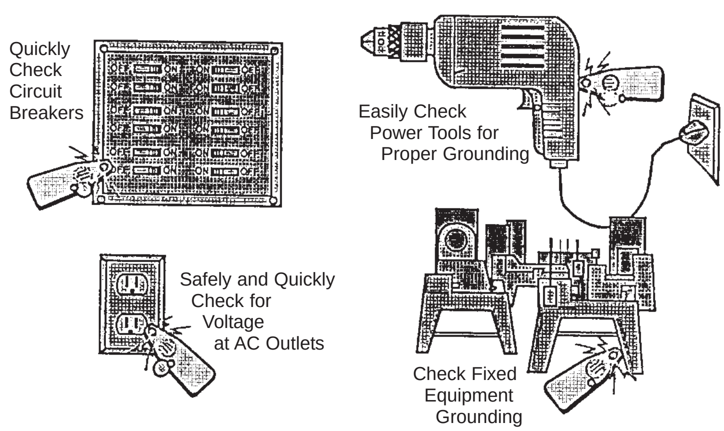


Figure 18

Typical Voltage Detector Uses

Voltage Versus Detection Distance

Another unique feature of the voltage detector shown in figure 18 is that it is voltage sensitive. Figure 19 lists distances versus voltage at which the detector “red” light will turn on. As an example, a conductor energized with 120 volts AC can be expected to be detected from 0 to 1 inch from the conductor.

To Determine Approximate Voltage:

Slowly approach the circuitry being tested with the front sensor of the unit and observe the distance at which the red LED light glows along with the “beep” sound. Use the chart below to determine the approximate voltage in the circuitry.

VOLTAGE (V)	100	200	600	1K	5K	9K
DISTANCE (inch)	0–1	1–2	3–5	15	5 ft	6–7 ft up

These figures may vary due to conditions governing the testing, i.e., static created by your standing on grounded material, carpets, etc.

Figure 19

Voltage vs. Detection Distance

The transformer secondary wiring on a furnace automatic ignition system rated at 10,000 volts can be expected to be detected from 6 to 7 feet away. You can use this feature to assist in making judgments regarding the degree of hazard and urgency for obtaining corrective action.

When you are using the voltage detector, you must understand how it operates to interpret its warning light properly. If you apply the tester to an energized power tool listed as double insulated, you will see the red warning light turn on. In this situation, the voltage waveform is detected because there is no metal enclosure to shield the waveform. The same would occur if you were to test in any of the typewriters used in offices. This does not mean that the plastic or nonmetallic enclosed equipment is unsafe, only that it is energized and not a grounding type piece of equipment. The examples and explanation of the operational features should be understood fully. Using the detector provides the opportunity for finding many electrical hazards that others may have overlooked.

6

Ground Fault Circuit Interrupters

Operational Theory

The ground fault circuit interrupter (GFCI) is a fast-acting device that monitors the current flow to a protected load. The GFCI can sense any leakage of current when current returns to the supply transformer by any electrical loop other than through the white (grounded conductor) and the black (hot) conductors. When any "leakage current" of 5 mA or more is sensed, the GFCI, in a fraction of a second, shuts off the current on both the "hot" and grounded conductors, thereby interrupting the fault current to the appliance and the fault loop.

This is illustrated in figure 20. As long as I_1 is equal to I_2 (normal appliance operation with no ground fault leakage), the GFCI switching system remains closed. If a fault occurs between the metal case of an appliance and the "hot" conductor, fault current I_3 will cause an imbalance (5 mA or greater for human protection) allowing the GFCI switching system to open (as illustrated) and the removal of power from both the white and the "hot" conductors.

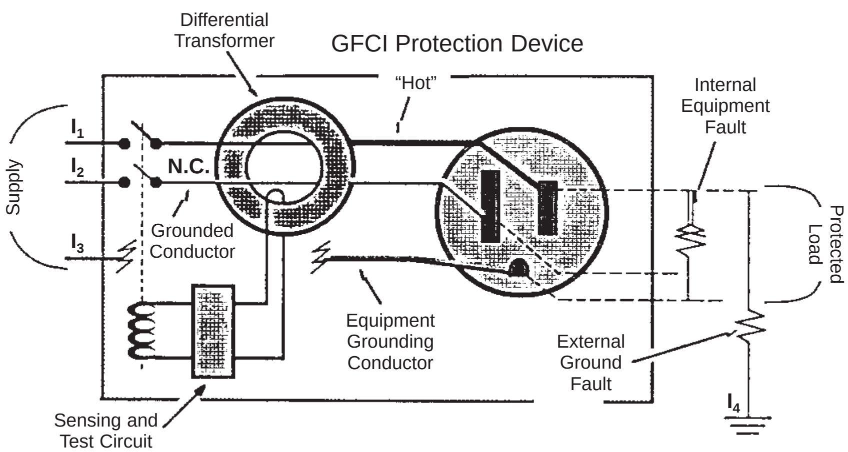


Figure 20

Circuit Diagram for a GFCI

Another type of ground fault can occur when a person comes in contact with a "hot" conductor directly or touches an appliance with no (or a faulty) equipment grounding conductor. In this case I_4 represents the fault current loop back to the transformer. This type of ground fault is generally the type that individuals are exposed to.

The GFCI is intended to protect people. It de-energizes a circuit, or portion thereof, in approximately $^1/_{40}$ of a second when the ground fault current exceeds 5 mA. The GFCI should not be confused with ground fault protection (GFP) devices that protect equipment from damaging line-to-ground fault currents. Protection provided by GFCIs is independent of the condition of the equipment grounding conductor. The GFCI can protect personnel even when the equipment grounding conductor is accidentally damaged and rendered inoperative.

The NEC requires that grounding type receptacles be used as replacements for existing nongrounding types. Where a grounding means does not exist in the receptacle enclosure, the NEC allows either a nongrounding or GFCI receptacle. Nongrounding type receptacles are permitted to be replaced with grounding type receptacles when powered through a GFCI.

Remember that a fuse or circuit breaker cannot provide "hot" to ground loop protection at the 5 mA level. The fuse or circuit breaker is designed to trip or open the circuit if a line to line or line to ground fault occurs that exceeds the circuit protection device rating. For a 15 amp circuit breaker, a short in excess of 15 amps or 15,000 mA would be required. The GFCI will trip if 0.005 amps or 5 mA start to flow through a ground fault in a circuit it is protecting. This small amount (5 mA), flowing for the extremely short time required to trip the GFCI, will not electrocute a person but will shock the person in the magnitude previously noted.

Typical Types of GFCIs

GFCIs are available in several different types. Figure 21 illustrates three of the types available (portable, circuit breaker and receptacle).

Circuit breakers can be purchased with the GFCI protection built in. These combination types have the advantage of being secured in the circuit breaker panel to prevent unauthorized persons from having access to the GFCI. The receptacle type GFCI is the most convenient in that it can be tested and/or reset at the location where it is used. It can also be installed so that if it is closest to the circuit breaker panel, it will provide GFCI protection to all receptacles on the load side of the GFCI. The portable type can be carried in a maintenance person's tool box for instant use at a work location where the available AC power is not GFCI protected. Other versions of GFCIs are available including multiple outlet boxes for use by several power tools and for outdoor applications. A new type is available that can be fastened to a person's belt and carried to the job location.

The difference between a regular electrical receptacle and a GFCI receptacle is the presence of the TEST and RESET buttons. The user should follow the manufacturer's instructions regarding the testing of the GFCI. Some instructions recommend pushing the TEST button and resetting it monthly. Defective units should be replaced immediately.

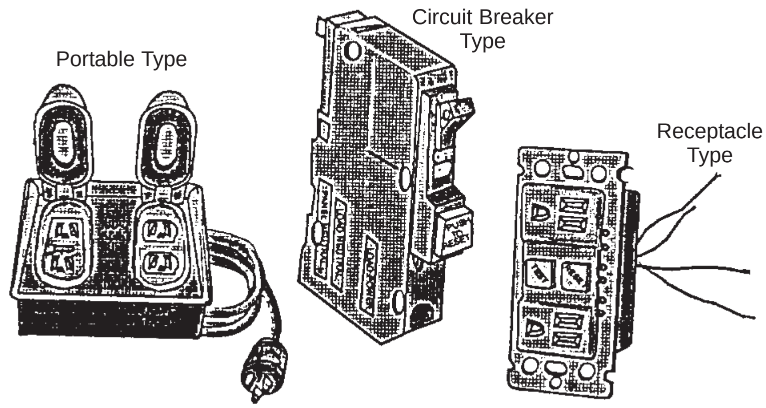


Figure 21

Typical Types of GFCIs

Be aware that a GFCI will not protect the user from line (hot) to line (grounded conductor) electrical contact. If a person were standing on a surface insulated from ground (e.g., a dry, insulated floor mat) while holding a faulty appliance with a "hot" case in one hand, then reached with the other hand to unplug an appliance plug that had an exposed grounded (white) conductor, a line to line contact would occur. The GFCI would not protect the person (since there is no ground loop). To prevent this type of accident from occurring, it is very important to have an ensured equipment grounding conductor inspection program in addition to a GFCI program. **GFCIs do not replace an ongoing electrical equipment inspection program.** GFCIs should be considered as additional protection against the most common form of electrical shock and electrocution: the line ("hot") to ground fault.

GFCI Uses

GFCIs should be used in dairies, breweries, canneries, steam plants, construction sites, and inside metal tanks and boilers. They should be used where workers are exposed to humid or wet conditions and may come in contact with ground or grounded equipment. They should be used in any work environment that is or can become wet and in other areas that are highly grounded.

Nuisance GFCI Tripping

When GFCIs are used in construction activities, the GFCI should be located as close as possible to the electrical equipment it protects. Excessive lengths of electrical temporary wiring or long extension cords can cause ground fault leakage current to flow by capacitive and inductive coupling. The combined leakage current can exceed 5 mA causing the GFCI to trip—"nuisance tripping." GFCIs are now available that can be fastened to your belt. You can plug the extension cord into the GFCI and use the protected duplex to power lighting and power tools. This is the ideal GFCI for construction and maintenance workers. It also allows the GFCI to be near the user location, thereby reducing nuisance trips.

Other nuisance tripping may be caused by:

- Outdoor GFCIs not protected from rain or water
- Bad electrical equipment with case to hot conductor fault
- Too many power tools on one GFCI branch
- Resistive heaters
- Coiled extension cords (long lengths)
- Poorly installed GFCI

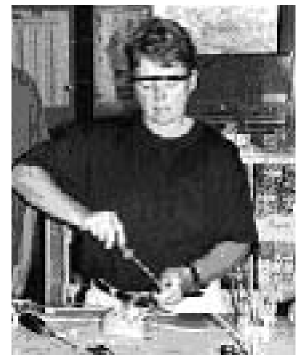
- Electromagnetic induced current near high voltage lines
- Portable GFCI plugged into a GFCI protected branch circuit

Remember that a GFCI does not prevent shock. It limits the duration of the shock so that the heart does not go into ventricular fibrillation. The shock lasts about $^1/_{40}$ of a second and can be intense enough to knock a person off a ladder or otherwise cause an accidental injury. Also, remember that the GFCI does not protect against line-to-line shock. Be sure to check insulation and connections on power tools each time before use.

Overview of the Safety Model

What Must Be Done to Be Safe?

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, trainer or appropriate person(s).



Report hazards to your supervisor, trainer or other personnel as appropriate.

- **Use the safety model to recognize, evaluate and control hazards.**
- **Identify electrical hazards.**
- **Don't listen to reckless, dangerous people.**

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.

Stage 1: Recognize 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.

OSHA regulations, the NEC 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.

Stage 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.**

Stage 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.**

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

Safety Model Stage 1—Recognizing Hazards

How Do You Recognize Hazards?

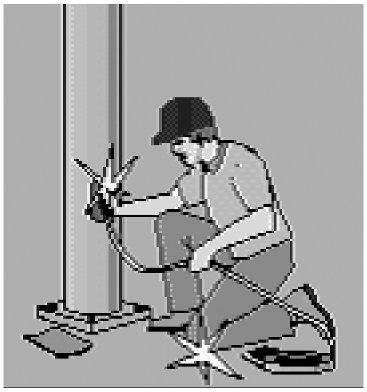
The first step toward protecting yourself is recognizing the many hazards you face on the job. To do this, you must know which situations can place you in danger. Knowing where to look helps you to recognize hazards.

Workers face many hazards on the job:

- 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 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.

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.



Worker was electrocuted while removing energized fish tape.

Fish tape.

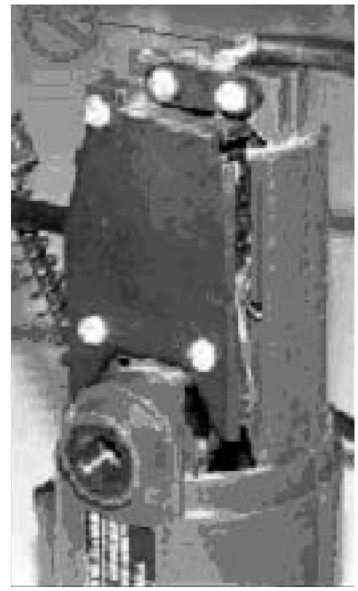
Inadequate Wiring Hazards

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. Again, keep in mind and consider the following wiring hazards to ensure proper safety:

- **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.**

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



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

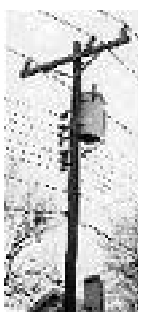
Electrical hazards exist when wires or other electrical parts are exposed. Wires and parts can be exposed if a cover is removed from a wiring or breaker box. The overhead wires coming into a home may be exposed. Electrical terminals in motors, appliances and electronic equipment may be exposed. Older 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.***

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

Overhead Powerline Hazards

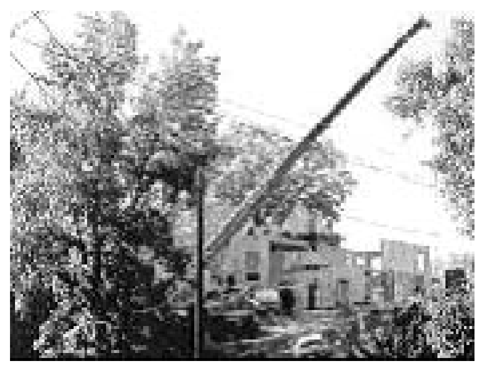
Most people do not realize that overhead powerlines are usually not insulated. More than half of all electrocutions are caused by direct worker contact with energized powerlines. Powerline workers must be especially aware of the dangers of overhead lines. In the past, 80 percent of all lineman deaths 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 34,500 volts. Today, most electrocutions involving overhead powerlines are caused by failure to maintain proper work distances.

- **Overhead powerlines kill many workers!**



Watch out for exposed electrical wires around electronic equipment.

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

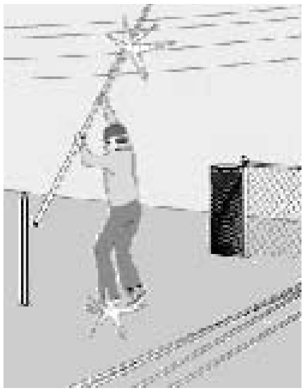


Operating a crane near overhead wires is very hazardous.

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 50 kV is 10 feet. For voltages over 5 kV, the minimum distance is 10 feet plus 4 inches for every 10 kV over 50 kV.) Never store materials and equipment under or near over-head powerlines. ***You need to recognize that overhead powerlines are a hazard.***

Example of overhead powerlines hazard

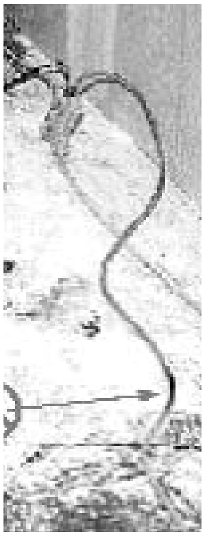
Five workers were constructing a chain-link fence in front of a house, directly below a 7,200-volt energized powerline. As they prepared to install 21-foot sections of metal top rail on the fence, one of the workers picked up a section of rail and held it up vertically. The rail contacted the 7,200-volt 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



This extension cord is damaged and should not be used.

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.***

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

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 because of a broken ground wire or plug. If you contact a defective electrical 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.***

- **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.
- **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 life-saver. GFCI's 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. GFCI's are set at about 5 mA and are designed to protect workers from electrocution. GFCI's 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. GFCI's are different from circuit breakers because they detect leakage currents rather than overloads. Circuits with missing, damaged, or improperly wired GFCI's may allow you to be shocked. You need to recognize that a circuit improperly protected by a GFCI is a hazard.

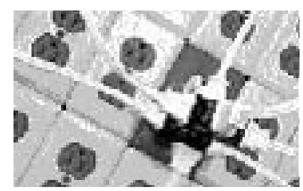
- **GFCI—**ground fault circuit interrupter-a device that detects current leakage from a circuit to ground and shuts the current off.
- **Leakage current**—current that does not return through the intended path but instead "leaks" to ground.
- **Ground fault**—a loss of current from a circuit to a ground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

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.

- **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.***



Overloads are a major cause of fires.

- **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.**
- **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.**

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 well-grounded because you are standing in even a small puddle of water—you will receive a shock.

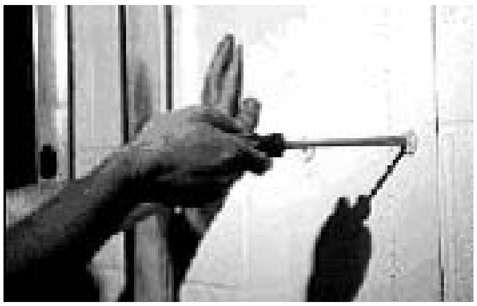
- **Wet conditions are dangerous.**

Damaged insulation, equipment 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 also 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.



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

- 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.
- 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.

Overhead work can cause long-term shoulder pain.

Examples of Additional Hazards (Non-electrical)

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.

Lift with your legs, not your back!

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

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

Safety Model Stage 2—Evaluating Hazards

How Do You Evaluate Your Risk?

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.

- **Risk**—the chance that injury or death will occur.

- **Make the right decisions.**

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 continuing 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.

Combinations of hazards increase risk.

- **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. 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. 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. You must decide when 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.

Summary

- 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.

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 NEC 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.

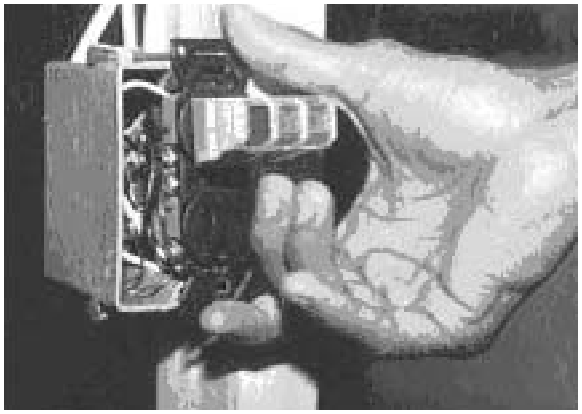
How Do You Create a Safe Work Environment?

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.
- 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.

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.

Lockout/tagout saves lives.

Lockout/Tagout Checklist

Lockout/tagout is an essential safety procedure that protects workers from injury while working on or near electrical circuits and equipment. Lockout 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, lockout/tagout prevents contact with operating equipment parts: blades, gears, shafts, presses, etc. When performing lockout/tagout on circuits and equipment, you can use the checklist items below as a guide.

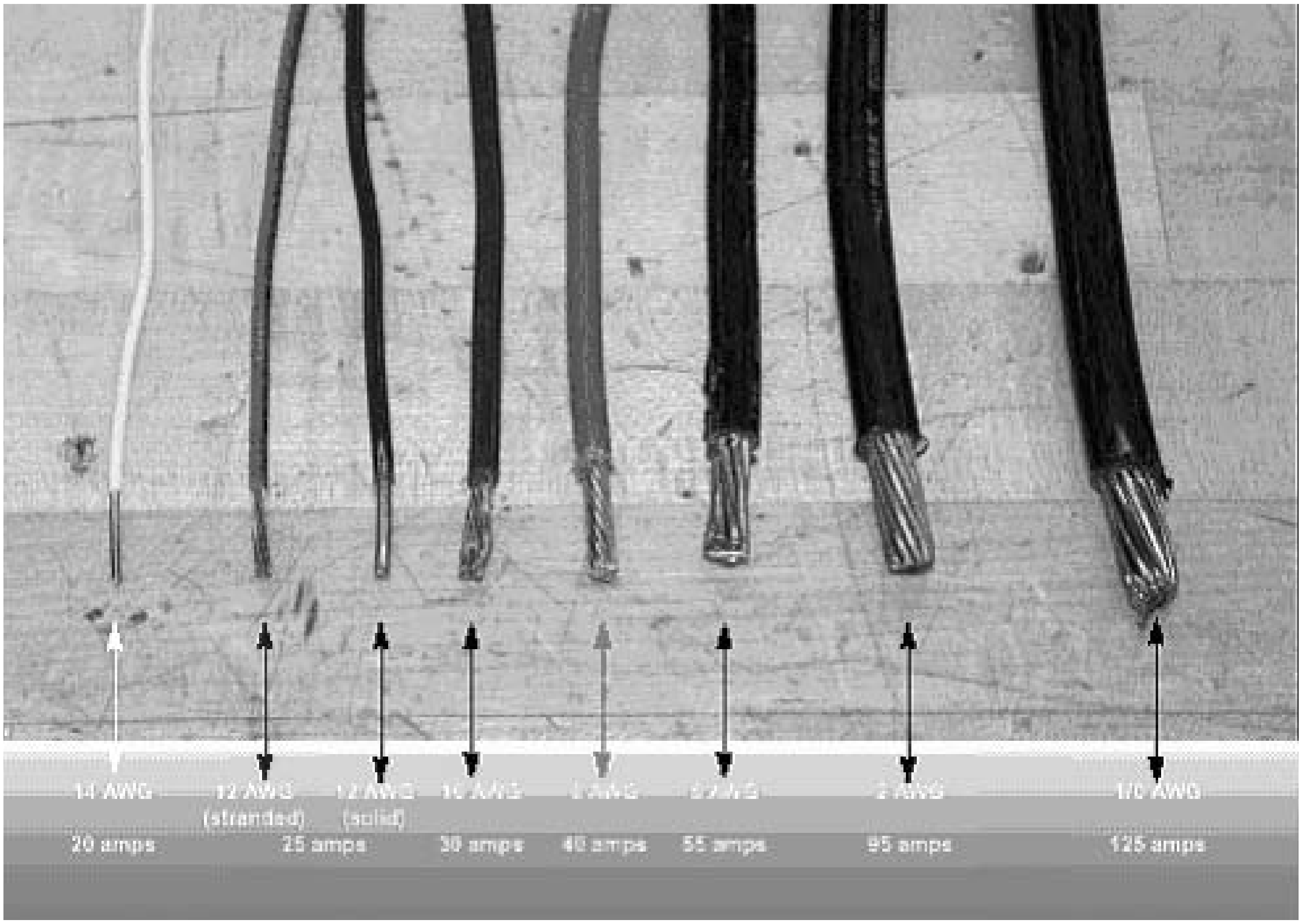
- Identify all sources of electrical energy for the equipment or circuits in question.
- Disable backup energy sources such as generators and batteries.
- Identify all shutoffs for each energy source.
- Notify all personnel that equipment and circuitry must be shut off, locked out and tagged out. (Simply 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 an authorized person. (An “authorized” person is defined as someone who has received required training on the hazards and on the construction and operation of equipment involved in a task.) (See 1910.147(b) as applicable.)
- Deplete stored energy 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 an authorized person may determine when it is safe to re-energize circuits.

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 size and type of wire.**

- **AWG**—American Wire Gauge—a measure of wire size.



Wires come in different sizes. The maximum current each size 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 extreme

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.

- **Fixed wiring**—the permanent wiring installed in homes and other buildings.

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.

Nonmetallic sheathing helps protect wires from damage.

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. 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.

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:

- 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.
- Hidden in conduit or other raceways.

Use the Right Extension Cord

The size 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 percent 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 size that can handle the total current.

- **Power**—the amount of energy used in a second, measured in watts.
- **1 horsepower = 746 watts.**

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.

The length of the extension cord also needs to be considered when selecting the wire size. 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 size of the wire, the longer a cord can be without causing a voltage drop that could damage tools and equipment.

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

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

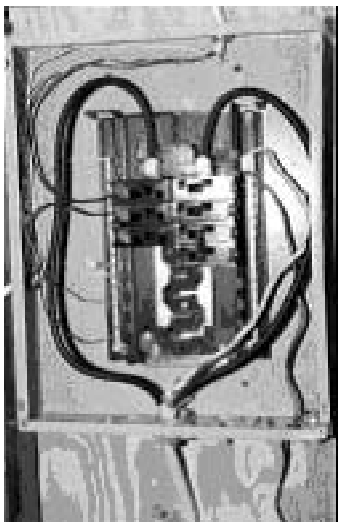
- A third wire in the cord, called a ground wire.
- A three-prong plug with a grounding prong on one end of the cord.
- A three-wire, grounding-type receptacle at the other end of the cord.
- A properly grounded outlet.

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.**



Use covers to prevent accidental contact with electrical circuits.

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

Outlets must be grounded properly.

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.

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.

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. If you don’t have a way to make this measurement, follow the steps below to determine if the ladder is positioned at a safe angle.
   a. Put your feet at the base of the ladder and extend your arms straight out.
   b. If you can touch the closest part of the ladder without bending your arms, the ladder is probably at the correct angle.
   c. If you have to bend your arms to touch the closest part of the ladder or if you can't reach the ladder at all, the ladder is not positioned at a safe angle.
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 or above 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.

Wear Correct PPE

OSHA requires that you be provided with personal protective equipment. 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 laws 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 and maintain PPE.**
- **Wear safety glasses**—Wear safety glasses to avoid eye injury.

Don't wear hard hats backwards.

- **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 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.

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

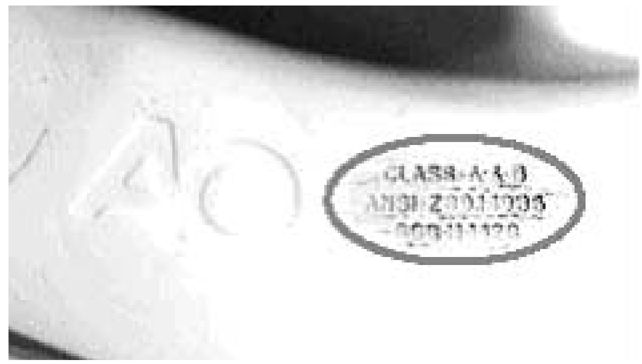
Head Protection

OSHA standards require 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.

Class E, Type 1 hard hat.



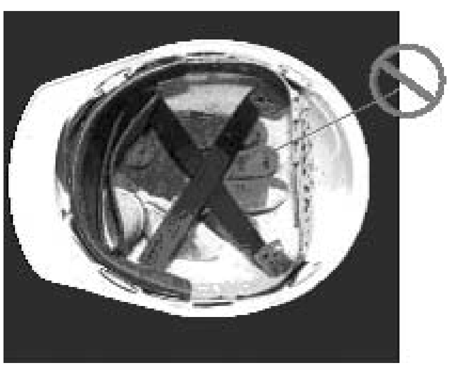
Class B hard hat.

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.

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!

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.

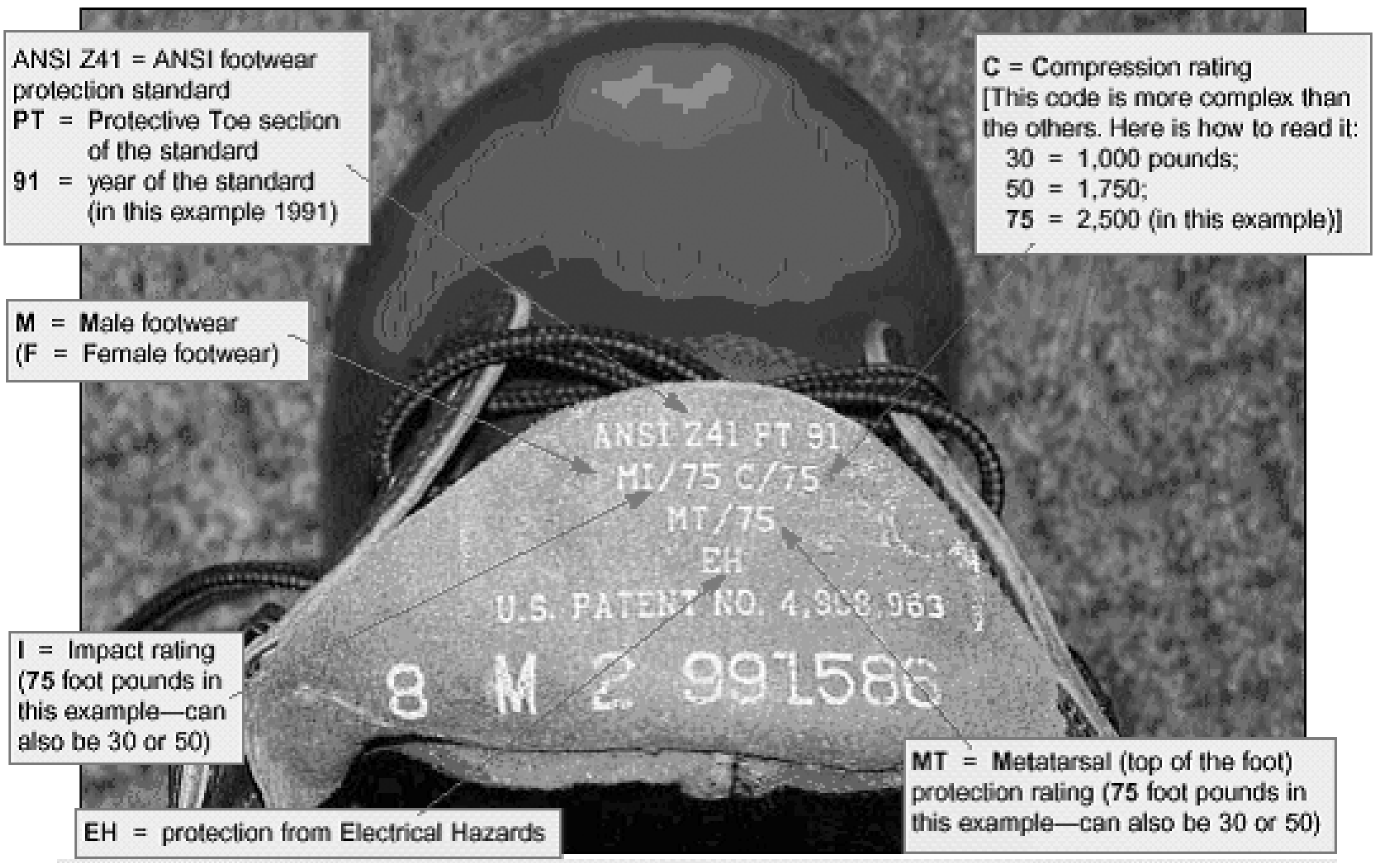
How do I choose the right footwear?

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.



7

Common Electrical Deficiencies

Table A offers a list of frequently violated standards regarding electricity. Items in table A should become a part of any electrical inspection checklist. Table A cross-references the National Electrical Code (1996 edition) and OSHA standards.

Table A

Frequently Violated Electrical Standards

NEC 70-1996 Reference	Subject	OSHA 29 CFR 1910 Standard	OSHA 29 CFR 1926 Standard
110-3	Suitability for safe installation	.303(b)(1)(i)	.403(b)(1)(i)
110-12(a)	Unused openings—cabinets/ boxes	.305(b)(1)	.405(b)(1)
110-13(a)	Secure mounting of equipment	.303(b)(1)(ii)	.403(b)(1)(ii)
110-14(a)	Electrical terminal connections	.303(b)(1)(i)	.403(b)(1)(i)
110-14(b)	Electrical splices	.303(c)	.403(e)
110-16	Working space about equipment	.303(g)(1)	.403(i)(1)
110-17	Guarding live parts	.303(g)(2)	.403(i)(2)
110-22	Disconnect and circuit identification	.303(f)	.403(h)
200-11	Reverse polarity	.304(a)(2)	.404(a)(2)
210-7	Receptacles, cords, and plugs	.305(j)(2)(i)	.405(j)(2)(i)
210-8	Ground fault circuit interrupters	.303(b)(1)(vii)	.404(b)(1)(ii)
210-63	Maintenance worker receptacles	.303(b)(1)(vii)	
250-42	Grounding fixed equipment	.304(f)(5)(iv)	.404(f)(7)(iii)
250-45	Grounding cord and plug equipment	.304(f)(5)(v)	.404(f)(7)(iv)
250-51	Effective grounding	.304(f)(4)	.404(f)(6)
250-59	Grounding cord-connected equipment		
400-7	Flexible cord and cable uses	.305(g)(1)(i)	.405(g)(1)(i)
400-8	Flexible cord and cable not permitted	.305(g)(1)(iii)	.405(g)(1)(iii)
400-9	Flexible cord and cable splices	.305(g)(2)(iii)	.405(g)(2)(iii)
400-10	Pull at joints and terminals	.305(g)(2)(iii)	.405(g)(2)(iv)
410-57	Receptacles—damp/wet locations	.305(i)(2)(ii)	.405(j)(2)(ii)
430-101	Motor disconnect means	.305(j)(4)(ii)	.405(j)(4)(ii)

NEC 110-3—29 CFR 1910.303(b)(1)—Examination, Identification, Installation and Use of Equipment. Operational characteristics to provide practical employee and facility safeguarding are provided. Suitability, mechanical strength of enclosures, connection space, insulation, heating and wiring effects, proper use of listed or labeled equipment, and any other factor that would provide personnel safeguarding should be evaluated. Fabricating and using extension cords with junction box receptacle ends would be a violation of this standard.

NEC 110-12(a)—29 CFR 1910.305(b)(1)—Unused Openings. This reference requires that electrical equipment be installed in a neat and professional manner. All openings in junction boxes and electrical equipment must be effectively closed to prevent metal objects from entering the enclosure and causing arcing or shorting of the supply conductors. Protection for personnel is also provided by preventing contact with electrically live parts.

NEC 110-13(a)—Secure Mounting of Equipment. Affixed electrical equipment must be firmly secured to the surface on which it is mounted. You may have noticed a conduit that is hanging loose or equipment boxes that are not secured to the wall. These are examples of violations of this standard.

NEC 110-14(a)—Electrical Terminal Connections. Loose or improperly tightened terminal connections have been determined as the cause of many electrical fires and equipment burnouts. Be alert to this problem when intermittent equipment operation or flickering lights are observed.

NEC 110-14(b)—29 CFR 1910.303(c)—Splices. Splices are required to be joined by suitable splicing devices or methods. The three elements of a proper splice are (1) mechanical strength, (2) electrical conductivity and (3) insulation quality. These factors must be at least equivalent to the conductors being spliced.

NEC 110-16—29 CFR 1910.303(g)(1)—Working Space About Electrical Equipment (600 volts, nominal, or less). This paragraph requires that sufficient access and working space be provided and maintained about all electric equipment. The electrical equipment clearance space must not become storage space. It maybe necessary to make the clearance space obvious by using floor stripes or other methods.

NEC 110-17—29 CFR 1910.303(g)(2)—Guarding of Live Parts (600 volts, nominal, or less). This reference requires that the live parts of electric equipment operating at 50 volts or more be guarded against accidental contact. Approved enclosures are recommended. When the alternative of location (e.g., 8-foot elevation above the floor) is used, employee safeguarding should be carefully evaluated.

NEC 110-22—29 CFR 1910.303(f)—Identification of Disconnecting Means. This reference requires that the disconnecting means for motors and appliances, and each service, feeder or branch circuit at the point where it originates, be legibly marked to indicate its purpose unless located and arranged so the purpose is evident. Many times a contractor will install new wiring and leave circuit breaker panels with blank circuit identification cards. Whenever electrical modifications are completed, the circuit identification cards should be updated.

NEC 200-11—29 CFR 1910.304(a)(2)—Polarity of Connections. No grounded conductor shall be attached to any terminal or lead so as to reverse designated polarity. This can usually be determined by using the three-prong circuit tester. Be sure to test not only wall receptacles but extension cord receptacles as well.

NEC 210-7 & 410-58—29 CFR 1910.305(j)(2)(i)—Grounding Type Receptacles, Cord Connectors and Attachment Plugs. These references require that receptacles installed on 15 and 20 ampere branch circuits be of the grounding type. Grounding type attachment plugs and mating cord connectors must also be used on electrical equipment where grounding type receptacles are provided. An exception would be the use of listed double insulated tools or appliances.

NEC 210-8—Ground Fault Circuit Interrupter Protection (GFCI) for Personnel. Whereas this section applies to dwelling units, hotels and motels, be reminded that GFCI protection may be provided for other circuits, locations and occupancies where personnel can be protected against line to ground shock hazards. GFCI protection requirements for other specific applications are NEC: 305-6—construction sites; 427-26—fixed heating for pipelines; 426-31—fixed outdoor deicing equipment; 511-10—commercial garages; 551-41(c)—recreational vehicles; and 680—swimming pools, tubs and fountains. The various codes and regulations are minimal requirements and in many cases are not retroactive. From an accident prevention standpoint, you should look for areas where potential line to ground shock hazards could occur and recommend GFCI protection regardless of the lack of retroactive need.

NEC 210-63—Heating, Air-Conditioning and Refrigeration Equipment Outlet. It is now a NEC requirement that a 125 volt, single phase, 15 or 20 ampere receptacle be installed at an accessible location and on the same level as equipment located on roof tops, in crawl spaces and in attic spaces, for use by maintenance personnel for servicing equipment. These receptacles must be on the same level and within 25 feet of the equipment. Provide GFCI protected receptacles if the maintenance work must be accomplished in wet conditions or in bathrooms or on roof tops.

NEC 250-42—29 CFR 1910.304(f)(5)(iv)—Grounding Fixed Equipment—General. This paragraph requires exposed noncurrent-carrying metal parts of fixed equipment to be grounded. By using the noncontact voltage detector, you can quickly determine whether the equipment metal housing is properly grounded.

NEC 250-45—29 CFR 1910-304(f)(5)(iv)—Grounding of Cord- and Plug-Connected Equipment. This paragraph requires that exposed noncurrent-carrying metal parts of cord- and plug-connected equipment be grounded. Exceptions to this requirement are tools and appliances that are listed as double insulated or that are supplied through an isolating transformer with an ungrounded secondary of not over 50 volts.

NEC 250-51—Effective Grounding Path. The path to ground from circuits, equipment and conductor enclosure shall: (1) be permanent and continuous, (2) have capacity to conduct safely any fault current likely to be imposed on it, and (3) have sufficiently low impedance to limit the voltage to ground and to facilitate the operation of the circuit protective devices. If a portable power tool had the equipment grounding prong broken off, the NEC 250-51(1) requirement would not be met since the grounding path would not be continuous. Extension cords being used with defects in the equipment grounding conductor path would also not meet this requirement. If the grounding path test result was more than 10 ohms, NEC 250-51(3) would not be met. It is recommended that the equipment grounding conductor loop impedance be less than 0.5 ohm, and this can only be determined by use of a ground loop impedance tester.

NEC 250-59—Cord- and Plug-Connected Equipment. This section describes three methods that can be used to ground equipment effectively. One method is the use of the metal enclosure of the conductors supplying such equipment when used with approved connectors and receptacles. The second method is by means of the equipment grounding connector run with the power supply conductors in a cable assembly or flexible cord. The third method is by means of a separate flexible wire or cable. The main purpose of alternative methods is to ensure that all metal enclosures and frames are bonded together at the same ground potential.

NEC 400-7—29 CFR 1910.305(g)(1)(i)—Flexible Cord and Cable Uses Permitted. Specific applications where flexible cords and cables are permitted include pendants, wiring of fixtures, portable lamps, appliances, and stationary equipment that may have to be moved frequently for maintenance or other purposes. Another important use is the prevention of the transmission of noise and vibration. Special attention should be given to the proper installation and protection of flexible cords and cables.

NEC 400-8—29 CFR 1910.305(g)(1)(iii)—Flexible Cord and Cable Uses Not Permitted. Flexible cords must not be used as a substitute for fixed wiring. Additionally, they must not be run through holes in walls, ceilings or floors, or doorways or windows.

NEC 400-9—29 CFR 1910.305(g)(2)(ii)—Splices. This section prohibits the use of flexible cords that have been spliced or tapped. The repair by splicing of hard service cord No. 14 or larger is permitted if done in accordance with NEC 110-14(b).

NEC 400-10—29 CFR 1910.305(g)(2)(iii)—Pull at Joints and Terminals. This reference requires that flexible cords be connected to devices and fittings so that tension will not be transmitted to joints or terminals. This requirement is applicable to the connection of the cord to the appliance as well as the attachment plug.

NEC 410-57—29 CFR 1910.305(j)(2)(ii)—Receptacles in Damp and Wet Locations. A receptacle installed outdoors in a location where it is protected from the weather, such as under a roof, is required to be in an enclosure that is weatherproof only when an attachment plug is not plugged in. In areas where the receptacle is exposed to outdoor weather (unprotected) or other wet locations (e.g., an equipment water washing or steam cleaning area) the receptacle and attachment plug must be a weatherproof combination except in instances where the receptacle is used for portable tools and equipment normally connected to the receptacle only when attended.

NEC 430-101—29 CFR 1910.305(j)(4)(ii)—Motor Disconnecting Means. This section requires that electrical motor-driven equipment have a disconnecting means capable of disconnecting motors and controllers from the circuit. For motor branch circuits under 600 volts, the disconnecting means must be located in sight from the controller location. Consideration must also be given to using disconnects that are designed to accept a lockout device.

The above list is not comprehensive. It identifies some of the most common electrical safety problem areas. Testing methods in part 4 of this guide will help you document many electrical hazards.

Appendix

OSHA Standards

OSHA occupational safety and health standards for General Industry are located in the 29 CFR 1910. Standards for Construction are located in 29 CFR 1926. The full text of these standards is available on OSHA's Web site: www.osha.gov. In addition, state specific requirements and other publication materials by NCDOL can be found at: www.nclabor.com.

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

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

8

Inspection Guidelines/Checklist

Before you conduct an electrical inspection, check your test equipment to be sure it is in proper working order. You should have a circuit tester, a GFCI tester (there are combination circuit/GFCI testers available), a contact tension tester and a volt-ohmmeter. Remove jewelry, watches and other metal objects. Footwear should have synthetic soles (do not wear leather soles). A clipboard, writing material, and the checklist in table B should also be included. A camera is optional, but if used, before-and-after photos/slides will make valuable visual training aids. Table B provides general guidelines that will assist you in checking for electrical hazards from the service entrance panel(s) to the equipment using the power.

Table B

Inspection Guidelines

1. **Service Entrance Panel—**Circuit I.D., Secure Mounting, Knockouts, Connectors, Clearances, Live Parts, Ratings
2. **System Grounding—**Secure Connections, Corrosion, Access, Protection, Wire Size
3. **Wiring—**Temporary, Splices, Protected, Box Covers, Openings, Insulation, Fittings, Workmanship
4. **Electrical Equipment/Machinery—**Grounding, Wire Size, Overcurrent and Disconnects, Installation, Protection
5. **Small Power Tools—**Attachment Plugs, Cords, Clamps, Leakage, Grounding, Splices
6. **Receptacles—**Polarity, Adequate Number, Mounting, Covers, Grounding, Tension, Connections, Protection
7. **Lighting—**Grounding, Connections, Plugs and Cords, Cord Clamps, Live Parts
8. **GFCI Protection—**Bathrooms, Crawl Spaces, Basements, Wet Locations, Outdoors, Garages, Pools/Tubs, Testing

Inspector____

Date ____

Further explanation of these guidelines is as follows:

1. **Service Entrance Panel—**Check the branch circuit identification. It should be up to date and posted on the panel door. Be sure the panel and cable or conduit connectors are secure. There should be no storage within 3 feet of the panel. No flammable materials of any kind should be stored in the same area or room. Look for corrosion and water in or around the area. Missing knockouts, covers or openings must be covered properly to eliminate exposure to live parts.
2. **System Grounding—**Check connection of the grounding electrode conductor to the metal cold water pipe and to any driven ground rod. Also check any bonding jumper connections and any supplemental grounding electrode fittings. These items should not be exposed to corrosion and should be accessible for maintenance and visual inspection.
3. **Wiring (General)—**Temporary wiring that is being used on a permanent basis should be replaced with fixed wiring. Conduit and/or cable systems must be protected from damage by vehicles or other mobile equipment. All fittings and connections to junction boxes and other equipment must be secure. No exposed wiring can be allowed. Check for missing knockouts and cover plates. Jury-rigged splices on flexible cords and cables should be correctly repaired. Electrical equipment should be installed in a neat and professional manner. Check for damaged insulation on flexible cord and pendant drop cords.
4. **Electrical Equipment/Machinery—**Test for proper grounding. All electrical equipment and machinery must be grounded effectively so that there is no potential difference between the metal enclosures. Use the voltage detector to find discrepancies and other test equipment to determine the corrective action required. Disconnects should be easily identified with the specific machinery they shut off. Disconnects should also be accessible near the machinery for use in an emergency. The disconnects should be activated periodically to be sure they are operable. All electrical connections to the equipment must be secure so that no cord or cable tension will be transmitted to the electrical terminals within the equipment. The wiring installation should be such that it is protected from damage at all times.

5. **Small Power Tools—**Attachment plugs should be checked for defective cord clamps and broken or missing blades. Connection of the cord to the power tool should be secure. Use your ohmmeter to check for leakage and for an effective equipment grounding conductor.

6. **Receptacles—**The receptacles should be tested for proper wiring configuration. There should be enough receptacles installed to eliminate, as much as possible, the use of extension cords. Covers should be in place and not broken. Multiple outlet adapters on a single outlet should be discouraged to prevent overloading. Surface mounted receptacle boxes should be protected from damage by mobile or motorized equipment.

7. **Lighting—**Cord- and plug-connected metal lamps and fixtures should be tested for grounding. Check all cord clamps for secure connections. Frayed or old cords should be replaced.

8. **GFCI Protection—**Generally, GFCI protection is not required by the NEC on a retroactive basis. Where there is an employee exposure to potential line to ground shock hazards, GFCI protection should be provided. This is especially important in work areas where portable electrical equipment is being used in wet or damp areas in contact with earth or grounded conductive surfaces. Use your GFCI tester to be sure that the GFCI is operable. After years of service, GFCIs can become defective and need to be replaced. Receptacles receiving GFCI protection should be labeled to inform of that fact.

9

Safety Program Policy and Procedures

Policy

Each facility should have an electrical safety program policy. The policy should cover the responsibilities of all employees including supervisors, employees and the specialists who inspect, install and maintain the electrical systems and equipment. The policy should stress management's concern and support. Individuals who are responsible for applying and enforcing the electrical policy should have standards of performance that include periodic assessment of their electrical safety performance.

In addition to policy and implementation procedures, the electrical safety program should include four basic areas of concern: training and education; hazardous condition reporting; work practices; and housekeeping.

The professionals responsible for installing, repairing and maintaining electrical equipment and systems should be familiar with NFPA 70E, Electrical Safety Requirements for Employee Workplaces. Management should support an effective preventive maintenance program. Use NFPA 70B, Electrical Equipment Maintenance, as a guide to implement or refine this type of program. Suggestions for improving any electrical safety program should include the items in this section. All employees must be responsible for being aware of and reporting unsafe electrical equipment. Discussion in the next section offers suggestions for ensuring that these responsibilities are carried out effectively.

Policy and the Safety-Related Work Practices Standard

Policy regarding training must encompass all applicable features of the OSHA Safety-Related Work Practices Standard—29 CFR 1910.331–335. That standard:

- 1910.332—requires training for both "qualified" and "unqualified" persons (defined by the standard) who work on, near or with electrical hazards (defined by the standard).
- 1910.332—lists typical occupational categories of employees for which training is required.
- 1910.332—includes additional training requirements for qualified persons.
- 1910.333—provides lockout/tagout requirements for electrical conductors and equipment in electrical utilization installations and thus extends protections of the lockout/tagout standard (29 CFR 1910.147) to electrical workers.
- 1910.333—includes acceptable practices for performing specific types of work as a qualified and unqualified person (requirements address, among other things: energized equipment; overhead lines; illumination; confined or enclosed work spaces; conductive materials and equipment; portable ladders; conductive apparel; housekeeping duties; and interlocks).
- 1910.334—addresses portable electric equipment including, among other things, requirements for: handling practices; visual inspection; conductive work locations; attachment plugs and circuits (and circuit testing, which only qualified persons may perform).
- 1910.335—personal protective equipment.

Supervisory Responsibilities

Training and Education

Supervisors should be trained to assist in discharging the electrical safety program responsibilities for their specific areas. If employees under their supervision use, install, repair or modify electrical equipment and/or appliances, the supervisor must ensure that they have received the proper training. The supervisor should also monitor employees and assess their performance against the established facility safety program policy.

Hazardous Condition Reporting

A written procedure promoting the observation and reporting of electrical hazards should be implemented. An employee recognition program should also be included in conjunction with the hazard reporting program. That will recognize employees who help locate electrical hazards and help ensure that hazards are eliminated in a timely manner.

Work Practices

The supervisor must ensure that employees follow safe work practices. A sample of suggested work practices is included in this section under Employee Responsibilities. Employees should be rated on their performance in following safe work practices. The supervisor should also be familiar with OSHA and OSHANC (Occupational Safety and Health Act of North Carolina) standards as they apply to the workplace under his or her responsibility.

Housekeeping

Floor area problems always present challenges to the supervisor. Areas around electrical equipment, such as circuit breaker panels, disconnects and fixed power tools, should be kept free from stored items, debris, and any liquids or material that would create slippery floors or obstruct access to the equipment for maintenance or emergencies. When hazards of this nature are reported to the supervisor, they should be recorded and necessary work orders should be issued for corrective action.

Employee Responsibilities

Training and Education

Employees should be trained in electrical safety work practices and equipment operation. Any changes in job duties will require additional safety training. Many accidents are caused when employees lack knowledge of the equipment or its operation. Sometimes employees are blamed for accidents when, in reality, specific training was not provided for the employees.

Hazardous Condition Reporting

Employees should always report unsafe equipment, conditions or procedures. Repairing equipment should receive top priority, even if that means rescheduling a process or project. Under no condition should defective electrical equipment causing electrical shock be used. The electrical safety policy should be followed, and deviations should be reported immediately.

Work Practices

Employees are responsible for following their employer's safe work practices, procedures and policy. Each employee should also be familiar with OSHA regulations as they apply to workplace safety.

Housekeeping

In the process of performing their work, employees should remain observant and report conditions that could cause any type of accident. Good housekeeping requires all employees to observe activities that could cause electrical shock hazards. Using electrical equipment that is not properly grounded in areas that have water on the floor can create shock hazards. Storing tools or other materials around electrical panels or equipment disconnects can create hazards for others, as well as prevent immediate access to electrical equipment for disconnection in an emergency. Cleaning tools and electrical equipment with solvents can create health and physical safety problems. Discarding rags containing solvents into trash receptacles can create fire hazards as well.

Electrical Safety Policy

Supervisors must know all facets of their employer's electrical safety policy and ensure that their employees also know and follow these policies. As a minimum, the following items should be included in the electrical safety policy:

- Power equipment should be plugged into wall receptacles with power switches in the off position.
- Electrical equipment should be unplugged by grasping the plug and pulling. Never pull or jerk the cord to unplug the equipment.
- Frayed, cracked or exposed wiring on equipment cords must be corrected. Also check for defective cord clamps at locations where the power cord enters the equipment or the attachment plug.
- "Cheater plugs," extension cords with junction box receptacle ends or other jury-rigged equipment should not be used.

- Temporary or permanent storage of materials must not be allowed within 3 feet of an electrical panel or electrical equipment.
- Any electrical equipment causing shocks or which has high leakage potential must be tagged with a DANGER—DO NOT USE label or equivalent.