Electrical Hazards (2)

Control hazards of exposure to live electrical wires: use proper insulation–Corresponds to NEC Articles 200-285

Insulation is made of material that does not conduct electricity (usually plastic, rubber, or fiber). Insulation covers wires and prevents conductors from coming in contact with each other or any other conductor. If conductors are allowed to make contact, a short circuit is created. In a short circuit, current passes through the shorting material without passing through a load in the circuit, and the wire becomes overheated. Insulation keeps wires and other conductors from touching, which prevents electrical short circuits. Insulation prevents live wires from touching people and animals, thus protecting them from electrical shock.

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

Special insulation is used on wires and cables that are used in harsh environments. Wires and cables that are buried in soil must have an outer covering of insulation that is flame-retardant and resistant to moisture, fungus, and corrosion. In all situations, you must be careful not to damage insulation while installing it. Do not allow staples or other supports to damage the insulation. Bends in a cable must have an inside radius of at least 5 times the diameter of the cable so that insulation at a bend is not damaged. Extension cords come with insulation in a variety of types and colors. The insulation of extension cords is especially important. Since extension cords often receive rough handling, the insulation can be damaged. Extension cords might be used in wet places, so adequate insulation is necessary to prevent shocks. Because extension cords are often used near combustible materials (such as wood shavings and sawdust) a short in an extension cord could easily cause arcing and a fire.

Insulation on individual wires is often color-coded. In general, insulated wires used as equipment grounding conductors are either continuous green or green with yellow stripes. The grounded conductors that complete a circuit are generally covered with continuous white or gray insulation. The ungrounded conductors, or “hot” wires, may be any color other than green, white, or gray. They are usually black or red. Conductors and cables must be marked by the manufacturer to show the following:

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

Control hazards of shocking currents

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

A 29-year-old male maintenance worker was found at 3:45 a.m. lying on his back and convulsing. Beside him were an overturned cart and an electric welding machine, both lying in a pool of water on the concrete floor. Arcing was visible between the welding machine and the floor. The worker was transported to the closest hospital, where he was pronounced dead. An examination of the welding machine showed that there were exposed conductors in the machine's cables. There were numerous cuts and scrapes in the cables' insulation. On other parts of the machine, insulation was damaged or missing. Also, the machine did not have a ground connection. Investigators concluded that the maintenance worker was electrocuted when he tried to turn off the welding machine, which was sitting on the cart. The metal frame of the machine had become energized due to the damaged insulation. When he touched the energized frame, he completed the conducting path to ground. The current traveled through his body to ground. Since he was probably standing in water, the risk of a ground fault was even greater. You must take steps to decrease such hazards in your workplace:

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

energized. The metal housings of equipment plugged into an outlet need to be grounded through the plug. Grounding is connecting an electrical system to the earth with a wire. Excess or stray current travels through this wire to a grounding device (commonly called a "ground") deep in the earth. Grounding prevents unwanted voltage on electrical components. Metal plumbing is often used as a ground. When plumbing is used as a grounding conductor, it must also be connected to a grounding device such as a conductive rod. (Rods used for grounding must be driven at least 8 feet into the earth.) Sometimes an electrical system will receive a higher voltage than it is designed to handle. These high voltages may come from a lightning strike, line surge, or contact with a higher-voltage line. Sometimes a defect occurs in a device that allows exposed metal parts to become energized. Grounding will help protect the person working on a system, the system itself, and others using tools or operating equipment connected to the system. The extra current produced by the excess voltage travels relatively safely to the earth. Grounding creates a path for currents produced by unintended voltages on exposed parts. These currents follow the grounding path, rather than passing through the body of someone who touches the energized equipment. However, if a grounding rod takes a direct hit from a lightning strike and is buried in sandy soil, the rod should be examined to make sure it will still function properly. The heat from a lightning strike can cause the sand to turn into glass, which is an insulator. A grounding rod must be in contact with damp soil to be effective.

Leakage current occurs when an electrical current escapes from its intended path. Leakages are sometimes low-current faults that can occur in all electrical equipment because of dirt, wear, damage, or moisture. A good grounding system should be able to carry off this leakage current. A ground fault occurs when current passes through the housing of an electrical device to ground. Proper grounding protects against ground faults. Ground faults are usually caused by misuse of a tool or damage to its insulation. This damage allows a bare conductor to touch metal parts or the tool housing. When you ground a tool or electrical system, you create a low-resistance path to the earth (known as a ground connection). When done properly, this path has sufficient current-carrying capacity to eliminate voltages that may cause a dangerous shock. Grounding does not guarantee that you will not be shocked, injured, or killed from defective equipment. However, it greatly reduces the possibility. Equipment needs to be grounded under any of these circumstances:

- The equipment is within 8 feet vertically and 5 feet horizontally of the floor or walking surface.
- The equipment is within 8 feet vertically and 5 feet horizontally of grounded metal objects you could touch.
- The equipment is located in a wet or damp area and is not isolated.

- The equipment is connected to a power supply by cord and plug and is not double-insulated.

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

There is a more sensitive kind of GFCI called an isolation GFCI. If a circuit has an isolation GFCI, the ground fault current passes through an electronic sensing circuit in the GFCI. The electronic sensing circuit has enough resistance to limit current to as little as 2 mA, which is too low to cause a dangerous shock. GFCI's are usually in the form of a duplex receptacle. They are also available in portable and plug-in designs and as circuit breakers that protect an entire branch circuit. GFCI's can operate on both two- and three-wire ground systems. For a GFCI to work properly, the neutral conductor (white wire) must (1) be continuous, (2) have low resistance, and (3) have sufficient current-carrying capacity.

GFCI's help protect you from electrical shock by continuously monitoring the circuit. However, a GFCI does not protect a person from line-to-line hazards such as touching two "hot" wires (240 volts) at the same time or touching a "hot" and neutral wire at the same time.

Also be aware that instantaneous currents can be high when a GFCI is tripped. A shock may still be felt. Your reaction to the shock could cause injury, perhaps from falling. Test GFCI's regularly by pressing the "test" button. If the circuit does not turn off, the GFCI is faulty and must be replaced.

The NEC requires that GFCI's be used in these high-risk situations:

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

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

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

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

Specifically, GFCI’s must be installed in bathrooms, garages, out-door areas, crawl spaces, unfinished basements, kitchens, and near wet bars. In order to assure a continuous, reliable electrical path to ground, a bonding jumper wire is used to make sure electrical parts are connected. Some physical connections, like metal conduit coming into a box, might not make a good electrical connection because of paint or possible corrosion. To make a good electrical connection, a bonding jumper needs to be installed.

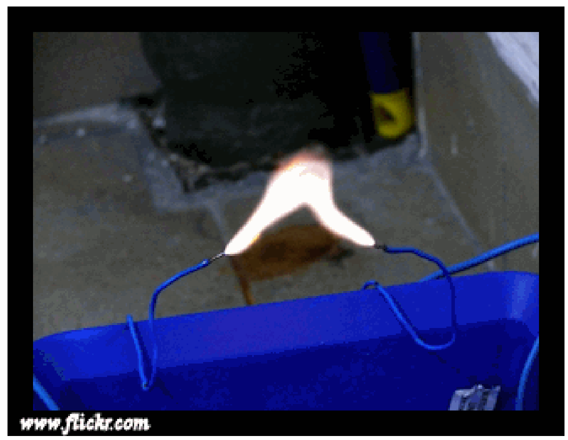
A metal cold water pipe that is part of a path to ground may need bonding jumpers around plastic anti-vibration devices, plastic water meters, or sections of plastic pipe. A bonding jumper is made of conductive material and is tightly connected to metal pipes with screws or clamps to bypass the plastic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

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

Control overload current hazards– Corresponds to NEC Articles 100, 430, 460, 610, 620

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

Overcurrent protection devices are designed to protect equipment and structures from fire. **They do not protect you from electrical shock!** Overcurrent protection devices stop the flow of current in a circuit when the amperage is too high for the circuit. A circuit breaker or fuse will not stop the relatively small amount of current that can cause injury or death. Death can result from 20 mA (.020 amps) through the chest (see Section 2). A typical residential circuit breaker or fuse will not shut off the circuit until a current of more than 20 amps is reached! But overcurrent protection devices are not allowed in areas where they could be exposed to physical damage or in hazardous environments. Overcurrent protection devices can heat up and occasionally arc or spark, which could cause a fire or an explosion in certain areas. Hazardous environments are places that contain flammable or explosive materials such as flammable gasses or vapors (Class I Hazardous Environments), finely pulverized flammable dusts (Class II Hazardous Environments), or fibers or metal filings that can catch fire easily (Class III Hazardous Environments). Hazardous environments may be found in aircraft hangars, gas stations, and storage plants for flammable liquids, grain silos, and mills where cotton fibers may be suspended in the air. Special electrical systems are required in hazardous environments.



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

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

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

Safety Model Stage 3—Controlling Hazards: Safe Work Practices

How Do You Work Safely?

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

He prepared the wires to be connected. While handling the wires, one of the energized wires caught the cuff of his left glove and pulled the cuff down. The conductor contacted the victim’s forearm near the wrist. He was electrocuted and fell backwards. He was wearing a climbing belt, which left him hanging upside down from the pole. Paramedics arrived 5 minutes after the contact. The power company lowered his dead body 30 minutes later. Several factors may have contributed to this incident. Below are some ways to eliminate these risk factors.

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

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

- What could go wrong?
- Do I have the knowledge, tools, and experience to do this work safely? All workers should be very familiar with the safety procedures for their jobs. You must know how to use specific controls that help keep you safe. You must also use good judgment and common sense. Control electrical hazards through safe work practices.
- Plan your work and plan for safety.
- Avoid wet working conditions and other dangers.
- Avoid overhead powerlines.
- Use proper wiring and connectors.
- Use and maintain tools properly.
- Wear correct PPE.

Plan your work and plan for safety

Take time to plan your work, by yourself and with others. Safety planning is an important part of any task. It takes effort to recognize, evaluate, and control hazards. If you are thinking about your work tasks or about what others think of you, it is hard to take the time to plan for safety. But, **YOU MUST PLAN**. Planning with others is especially helpful. It allows you to coordinate your work and take advantage of what others know about identifying and controlling hazards. The following is a list of some things to think about as you plan.

- **Work with a "buddy"—**Do not work alone. Both of you should be trained in CPR. Both of you must know what to do in an emergency.
- **Know how to shut off and de-energize circuits—**You must find where circuit breakers, fuses, and switches are located. Then, the circuits that you will be working on (even low-voltage circuits) **MUST BE TURNED OFF!** Test the circuits before beginning work to make sure they are completely de-energized.
- **Plan to lock out and tag out circuits and equipment—**Make certain all energy sources are locked out and tagged out before performing any work on an electrical circuit or electrical device. Working on energized ("hot") circuits is one of the most dangerous things any worker could do. If someone turns on a circuit without warning, you can be shocked, burned, or electrocuted. The unexpected starting of electrical equipment can cause severe injury or death.

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

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

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

Before **ANY** equipment inspections or repairs—even on so-called low-voltage circuits—the current must be turned off at the switch box, and the switch must be padlocked in the OFF position. At the same time, the equipment must be securely tagged to warn everyone that work is being performed. Again, test circuits and equipment to ensure they are de-energized. No two locks should be alike. Each key should fit only one lock, and only one key should be issued to each worker. If more than one worker is working on a circuit or repairing a piece of equipment, each worker should lock out the switch with his or her own lock and never permit anyone else to remove it. At all times, you must be certain that you are not exposing other workers to danger. Workers who perform lock-out/tag-out must be trained and authorized to repair and maintain electrical equipment. A locked-out switch or feeder panel prevents others from turning on a circuit. The tag informs other workers of your action.

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

- **Plan to avoid falls**—Injuries can result from falling off scaffolding or ladders. Other workers may also be injured from equipment and debris falling from scaffolding and ladders. To prevent injury when climbing, follow these procedures:

- 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.

  - Put your feet at the base of the ladder and extend your arms straight out.
  - If you can touch the closest part of the ladder without bending your arms, the ladder is probably at the correct angle.
  - 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.

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

Avoid wet working conditions and other dangers

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

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

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

Avoid overhead power lines

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

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

Use proper wiring and connectors

- **Avoid overloads—**Do not overload circuits.
- **Test GFCI's—**Test GFCI's monthly using the "test" button.

- **Check switches and insulation—**Tools and other equipment must operate properly. Make sure that switches and insulating parts are in good condition.
- **Use three-prong plugs—**Never use a three-prong grounding plug with the third prong broken-off. When using tools that require a third-wire ground, use only three-wire extension cords with three-prong grounding plugs and three-hole electrical outlets. Never remove the grounding prong from a plug! You could be shocked or expose someone else to a hazard. If you see a cord without a grounding prong in the plug, remove the cord from service immediately.
- **Use extension cords properly—**If an extension cord must be used, choose one with sufficient ampacity for the tool being used. An undersized cord can overheat and cause a drop in voltage and tool power. Check the tool manufacturer's recommendations for the required wire gauge and cord length. Make sure the insulation is intact. To reduce the risk of damage to a cord's insulation, use cords with insulation marked "S" (hard service) rather than cords marked "SJ" (junior hard service). Make sure the grounding prong is intact. In damp locations, make sure wires and connectors are waterproof and approved for such locations. Do not create a tripping hazard.

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

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

> An employee was climbing a metal ladder to hand an electric drill to the journeyman installer on a scaffold about 5 feet above him. When the victim reached the third rung of the ladder, he received an electrical shock that killed him. An investigation showed that the grounding prong was missing from the extension cord attached to the drill. Also, the cord’s green grounding wire was, at times, contacting the energized black wire. Because of this contact with the "hot" wire, the entire length of the grounding wire and the drill’s frame became energized. The drill was not double-insulated. To avoid deadly incidents like this one, take these precautions:
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> - Make certain that approved GFCI’s or equipment grounding systems are used at construction sites.
> - Use equipment that provides a permanent and continuous path to ground. Any fault current will be safely diverted along this path.
> - Inspect electrical tools and equipment daily and remove damaged or defective equipment from use right away.

- **Do not pull on cords—**Always disconnect a cord by the plug.
- **Use correct connectors—**Use electrical plugs and receptacles that are right for your current and voltage needs. Connectors are designed for specific currents and voltages so that only matching plugs and receptacles will fit together. This safeguard prevents a piece of equipment, a cord, and a power source with different voltage and current requirements

from being plugged together. Standard configurations for plugs and receptacles have been established by the National Electric Manufacturers Association (NEMA).

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