1. ELECTRICAL HAZARD

When electrical tools are working properly a complete circuit is maintained between the tool and the energy source. However, if the tool is damaged the person may come in contact with the electricity and can become a path for the current. The person will be shocked!

The following is a list of common electrical hazards found on construction sites:

1. Improper grounding
2. Exposed electrical parts
3. Inadequate wiring
4. Damaged insulation
5. Overloaded circuits
6. Wet conditions
7. Damaged tools and equipment.
8. Overhead power lines

1. Improper grounding

Grounding is the process used to eliminate unwanted voltage. A ground is a physical electrical connection to the earth. Electrical equipment must be properly grounded. Grounding reduces the risk of being shocked or electrocuted. The ground pin safely returns leakage current to ground. Never remove the ground pin.

Removing the ground pin removes an important safety feature. You can get shocked!

2. Exposed electrical parts

Exposed wires or terminals are hazardous. Report these conditions to your supervisor. This electrical panel has missing circuit breakers. Never use a panel that has exposed wires. All openings must be closed. Outer insulation on electrical cords must be intact. On construction sites, temporary lighting must be properly guarded and protected to avoid contact with broken bulbs and avoid potential shocks.

3. Inadequate wiring

Use properly rated extension cords. Make sure your power tools are being used with a properly rated extension cord.

4. Damaged insulation

Defective or inadequate insulation is a hazard. Insulation prevents conductors from contacting each other or you. Never attempt to repair a damaged cord with tape. Never use tools or extension cords with damaged insulation. Never hang extension cords from nails or sharp objects. Do not run extension cords through doors or windows.

5. Overloaded circuits

Overloaded circuits can cause fires. Use proper circuit breakers. Never overload an outlet.

Do not use power strips or surge protectors on construction sites. Use a 3-way extension with a GFCI instead.

6. Wet conditions

Wet conditions are hazardous. Damaged insulation increases the hazard. Always avoid using tools in wet locations. Water increases the risk of electric shock.

7. Damaged tools and equipment.

Do not use electric tools that are damaged. You may receive a shock or be electrocuted.

Double insulated tools are labeled. It will be marked “Double Insulated”. It will have the following symbol:

8. Overhead power lines

Survey the site for overhead power lines. Never store materials or equipment under overhead power lines. Maintain a distance of at least 10’ between tools and equipment and overhead power lines. Shocks and electrocutions occur where physical barriers are not in place to prevent contact with the wires. Maintain safe distances between scaffolding and overhead power lines. Overhead power lines are very dangerous. Never attempt to contact an overhead power line.

9. Electrical Arc Blast

Another hazard to employees is the blast effect that can result from arcing. High energy arcs can damage equipment causing fragmented metal to fly in all directions. Low energy arc can cause violent explosions. Inhaling the hot vaporized metal from the arc blast will cause damage to respiratory system.

2. EFFECT OF ELELCTRIC CURRENT ON HUMAN BODY:

An electric shock can result in anything from a slight tingling sensation to immediate cardiac arrest.

- **SHOCK.** Electric shock occurs when the human body becomes part of a path through which electrons can flow. The resulting effect on the body can be either direct or indirect.
  - **a. Direct.** Injury or death can occur whenever electric current flows through the human body. Currents of less than 30 mA can result in death. A thorough coverage of the effects of electricity on the human body is contained in the section of this module entitled *Effects of Electricity on the Human Body*.
  - **b. Indirect.** Although the electric current through the human body may be well below the values required to cause noticeable injury, human reaction can result in falls from ladders or scaffolds, or movement into operating machinery. Such reaction can result in serious injury or death.
- **BURNS.** Burns can result when a person touches electrical wiring or equipment that is improperly used or maintained. Typically, such burn injuries occur on the hands. Also burns are the result of the electric current flowing in the tissues, and may be either skin deep or may affect deeper layers (such as muscles and bones) or both. Tissue damage is caused by the heat generated from the current flow; if the energy delivered by the electric shock is high, the body cannot dissipate the heat, and the tissue is burned. Typically, such electrical burns are slow to heal.

- **ARC-BLAST.** Arc-blasts occur from high-amperage currents arcing through air. This abnormal current flow (arc-blast) is initiated by contact between two energized points. This contact can be caused by persons who have an accident while working on energized components, or by equipment failure due to fatigue or abuse. Temperatures as high as 35,000F have been recorded in arc-blast research.

Effects of arc flash

Severe burns, broken bones, Vision damage, Hearing loss, Brain/internal injuries, Punctures and lacerations, Death

The three primary hazards associated with an arc-blast are:

a. **Thermal Radiation.** In most cases, the radiated thermal energy is only part of the total energy available from the arc. Numerous factors, including skin color, area of skin exposed, type of clothing have an effect on the degree of injury. Proper clothing, work distances and over current protection can improve the chances of curable burns.
b. **Pressure Wave.** A high-energy arcing fault can produce a considerable pressure wave. Research has shown that a person 2 feet away from a 25 Ka arc would experience a force of approximately 480 pounds on the front of their body. In addition, such a pressure wave can cause serious ear damage and memory loss due to mild concussions. In some instances, the pressure wave may propel the victim away from the arc-blast, reducing the exposure to the thermal energy. However, such rapid movement could also cause serious physical injury.
c. **Projectiles.** The pressure wave can propel relatively large objects over a considerable distance. In some cases, the pressure wave has sufficient force to snap the heads of 3/8 inch steel bolts and knock over ordinary construction walls. The high-energy arc also causes many of the copper and aluminum components in the electrical equipment to become molten. These "droplets" of molten metal can be propelled great distances by the pressure wave. Although these droplets cool rapidly, they can still be above temperatures capable of causing serious burns or igniting ordinary clothing at distances of 10 feet or more. In many cases, the burning effect is much worse than the injury from shrapnel effects of the droplets.

- **EXPLOSIONS.** Explosions occur when electricity provides a source of ignition for an explosive mixture in the atmosphere. Ignition can be due to overheated conductors or equipment, or normal arcing (sparking) at switch contacts. OSHA standards, the National Electrical Code and related safety standards have precise requirements for electrical systems and equipment when applied in such areas.

- **FIRES.** Electricity is one of the most common causes of fire both in the home and workplace. Defective or misused electrical equipment is a major cause, with high resistance connections being one of the primary sources of ignition. High resistance connections occur where wires are improperly spliced or connected to other components such as receptacle outlets and switches. This was the primary cause of fires associated with the use of aluminum wire in buildings during the 1960s and 1970s.

Heat is developed in an electrical conductor by the flow of current at the rate I2R. The heat thus released elevates the temperature of the conductor material. A typical use of this formula illustrates a common electrical hazard. If there is a bad connection at a receptacle, resulting in a resistance of 2 ohms, and a current of 10 amperes flows through that resistance, the rate of heat produced (W) would be: If you have ever touched an energized 200 watt light bulb, you will realize that this is a lot of heat to be concentrated in the confined space of a receptacle. Situations similar to this can contribute to electrical fires.

3. EFFECTS OF ELECTRICITY ON THE HUMAN BODY

The effects of electric shock on the human body depend on several factors. The major factors are:

1. Current and Voltage
2. Resistance
3. Path through body
4. Duration of shock

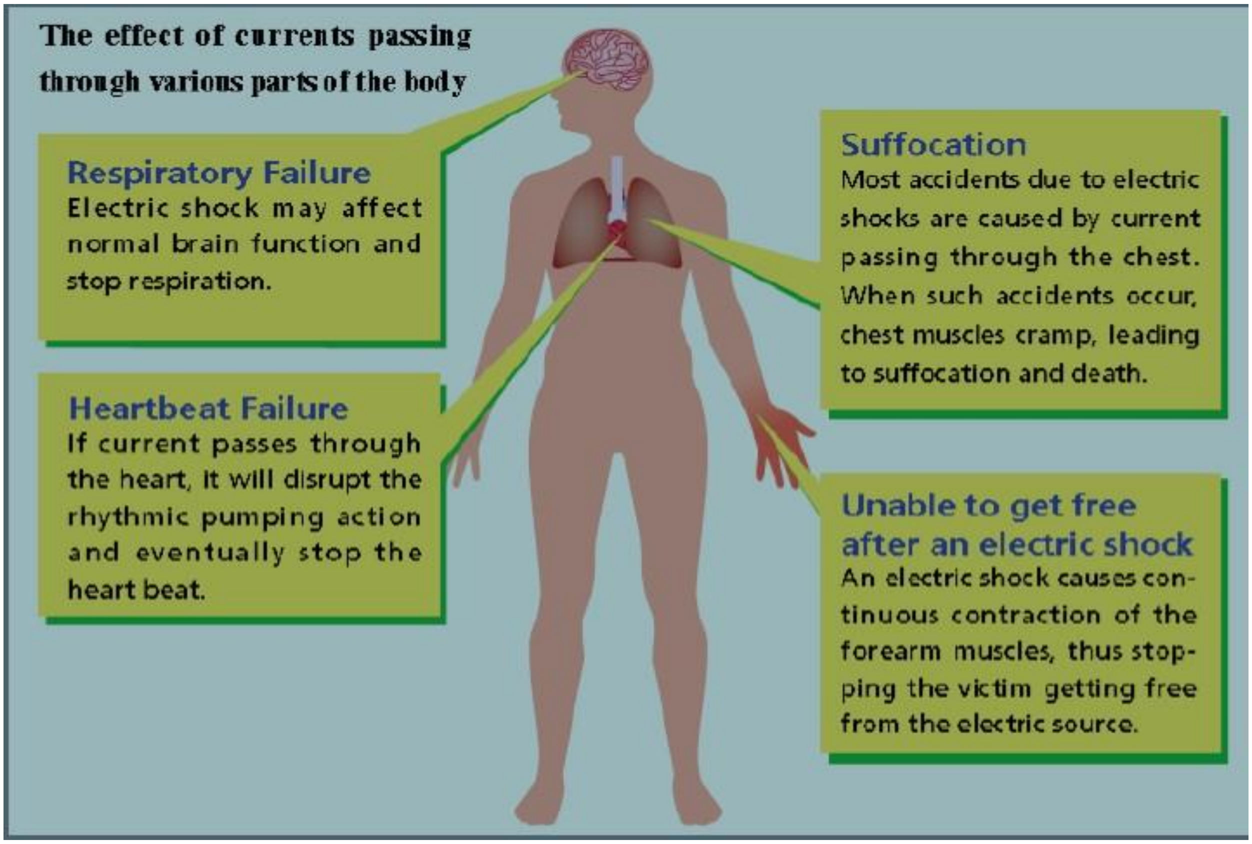
The muscular structure of the body is also a factor in that people having less musculature and more fat typically show similar effects at lesser current values.

CURRENT AND VOLTAGE:

Although high voltage often produces massive destruction of tissue at contact locations, it is generally believed that the detrimental effects of electric shock are due to the *current* actually flowing through the body. Even though Ohm's law (I=E/R) applies, it is often difficult to correlate voltage with damage to the body because of the large variations in contact resistance usually present in accidents. Any electrical device used on a house wiring circuit can, under certain conditions, transmit a fatal current. Although currents greater than 10 mA are capable of producing painful to severe shock, currents between 100 and 200 mA can be lethal. With increasing alternating current, the sensations of tingling give way to contractions of the muscles. The muscular contractions and accompanying sensations of heat increase as the current is increased. Sensations of pain develop, and voluntary control of the muscles that lie in the current pathway becomes increasingly difficult. As current approaches 15 mA, the victim cannot let go of the conductive surface being grasped. At this point, the individual is said to "freeze" to the circuit. This is frequently referred to as the "let-go" threshold. As current approaches 100 mA, ventricular fibrillation of the heart occurs.

Ventricular fibrillation is defined as "very rapid uncoordinated contractions of the ventricles of the heart resulting in loss of synchronization between heartbeat and pulse beat." Once ventricular fibrillation occurs, it will continue and death will ensue within a few minutes. Use of a special device called a de-fibrillator is required to save the victim. Heavy current flow can result in severe burns and heart paralysis. If shock is of short duration, the heart stops during current passage and usually re-starts normally on current interruption, improving the victim's chances for survival.

Current level (milliamperes)	Probable Effect on Human Body
1 mA	Perception level. Slight tingling sensation.
5 mA	Slight shock felt; not painful but disturbing. Average individual can let go.
6 – 16 mA	Painful shock. Loss of muscular control. Commonly referred to as the freezing current or "let-go" range.
17 – 99 mA	Extreme pain, respiratory arrest, severe muscular contractions. Individual cannot let go the source in contact with. Can cause ventricular fibrillation.
100 – 2000 mA	Ventricular fibrillation (uneven pumping of the heart.) Muscular contraction and nerve damage begins to occur. Death likely.
> 2,000 mA	Cardiac arrest, internal organ damage, and severe burns. Death probable.



4. CAUSES OF ELECTRICAL ACCIDENT

Electrical accidents commonly occur whilst equipment is being maintained. This may be electrical equipment such as switchgear or equipment that uses electrical power. Most accidents happen because workers have not been adequately trained, are being poorly supervised, or because the risks of the work have not been properly assessed. The incidents are real.

Unsafe system of work

- An employee was killed by 86 Volts when changing a welding electrode whilst working in a metal silo.
- An apprentice electrician was severely injured from contact with live equipment in a substation.
- An employee received an electric shock that broke both shoulders.
- An employee was trying to apply insulating tape to a live electrical cable but received an electric shock.

Inadequate information: An employee received a fatal electric shock whilst examining a faulty air conditioning unit.

No training: A worker was injured when working in a live electrical panel. He had not been trained.

Inadequate isolation: An electrician received a severe electric shock because he had not properly isolated the supply.

Live working: An employee suffered brain damage following an electric shock he received whilst live working.

Unsuitable test equipment: An employee was killed when setting up equipment to test printed circuit boards.

Poor maintenance: A worker received a 240 Volt electric shock whilst using a pressure washer.

Failure to manage work: A contractor's employee received an electric shock after confusion over isolation.

Person not competent: Person received a severe electric shock after he incorrectly wired a machine.

Uninsulated electrical wiring: A worker was killed whilst attempting to clear a blockage in a wrapping machine.

Let's take a closer look at five of those causes:

1. No Training. The worker in question has inadequate training to perform the tasks at hand.

Example: In one case, an untrained worker was ordered to work on an electrical control panel. Because the worker had never been trained, he attempted to work while the panel was still live, resulting in an electrical short. The worker sustained severe burns to his face and arms, while the employer was both prosecuted and fined. With adequate training, this worker would have known to isolate the circuit before beginning work, avoiding the accident altogether.

2. **Person not competent. Despite some training, the worker in question does not have enough knowledge to adequately perform the tasks at hand.**

Example: Though a worker had received some training, the employer did not realize that he was still not knowledgeable enough to perform the task he was given. He wired a machine incorrectly, and received a severe electrical shock in the process. Although competent people were available to perform the task, the employee was assigned and expected to complete the job, resulting in serious bodily injuries.

All employees should be proven competent at their jobs, for their own safety and the safety of others. The Memorandum of Guidance on the Electricity at Work Regulations articulates the minimum standard of worker competency for electrical personnel.

3. Inadequately Isolating Circuits. Worker does not properly isolate electrical circuits, resulting in electrical injuries.

Example: An electrician received a severe electrical shock when working on building refurbishments. The electrical supply had not been properly isolated and locked out, causing the accident. Moreover, no management system was in place to monitor the isolation of said supply. As a result, the company was prosecuted and fined.

Businesses need to have safety systems in place to monitor the isolation of electrical circuits. In addition, workers should have enough training and experience to know how to isolate, lockout and test for no voltage potential on circuits before beginning work.

4. Unsafe Rules and Training. Workers are unsure of the safety regulations and procedures in their work environment.
Example: One worker received a shock of 33,000 volts when he climbed a live apparatus in a substation. The company did not have adequate demarcations of safe / unsafe working zones, leading the worker to believe the apparatus was dead and therefore safe to climb. Furthermore, the training of the staff concerning safety zones was negligible. The shock resulted in the amputation of both the worker's arms and the company receiving a fine of about $90,000.
Employers should ensure that working methods, materials, and worker training meet the minimum safety standards. Otherwise, workers move in and out of unsafe environments all day without knowing the difference. For the minimum safety standards, view the free HSE leaflet "Controlling the Risks in the Workplace."

5. Employees, knowingly or unknowingly, working on live electrical equipment.
Example: After receiving a shock, an employee's heart actually stopped beating while working live on electrical equipment. The equipment should have been isolated and locked out before the work began but, due to the worker's under-training and incompetency, the equipment was left live. Although his heart was resuscitated, the worker suffered severe brain damage from the accident.
Personnel must be trained sufficiently on how to isolate, lockout and test for no voltage potential before beginning work in order to eliminate risks. If even one worker cannot tell the difference between a live and dead circuit, every worker is in danger.

5.PREVENTION OF ELECTRICAL ACCIDENTS

1. **Have only licensed electricians install, repair and dismantle jobsite wiring:** That way, everything will be completed according to electrical safety codes, ensuring greater protection for the workers who will be using the wiring to power tools and equipment. Bringing in a professional electrician also prevents the injuries that result when less-qualified individuals attempt electrical jobs that they aren't properly trained to do.
2. **Always plug into a GFCI:** Ground Fault Circuit Interrupter protection is required at every plug-in point associated with your jobsite's temporary electrical

supply - right down to extension cords. Make sure that only GFCI receptacles are installed, and that portable GFCIs are kept on hand in case additional grounding needs arise.

3. **Check each extension cord before use:** Ensure that insulation is completely intact (free from cracks, tears, or abrasion) and that power extension cables haven't been knotted, which can cause conductor damage and increase the risko fire
4. **Do a thorough check for electrical wiring before cutting through any wall, floor or ceiling:** Any time that a tool inadvertently makes contact with an unseen electrical line, the person holding that tool is likely to be shocked or electrocuted. Always size up the situation before you get started to reduce your risk of injury.
5. **Inspect power tools on a regular basis:** Look over the tools' power cords and plugs for any sign of damage to the insulation, blades, or grounding pin. If you find signs of excessive wear and tear, take tools out of commission until they've been properly repaired. Maintain awareness during electrical tool use as well; if a tool starts to overheat, smoke, give off a burning smell, or shock you on contact, discontinue use immediately.
6. **Check insulated tools for damage before each use:** Once the insulation layer of an insulated hand tool becomes nicked, cracked or cut, the tool is no longer effectively insulated - it actually becomes more of an electrical conductor, and can increase your risk of injury. If a tool has damaged insulation, it is no longer safe to use - destroy and replace it right away.
7. **Never modify electrical plugs:** Under no circumstances should you ever file down the blades, remove the ground pin, or otherwise modify an electrical plug so that it will fit into a socket - doing so only increases the likelihood of shock, electrocution, and fire. Either have a certified electrician change the device's plug, or replace outdated two-prong receptacles with grounded outlets that can accommodate a ground pin.
8. **Keep extension cords in a safe place where they won't be stepped on or driven over:** The force of a vehicle - or even repeated treading by pedestrians - can cause an extension cord's conductor to become misshapen or break, a problems that can lead to electrical fires. Because it occurs in the core of the cable, conductor damage isn't always obvious to the eye, so play

it safe from the start by guarding jobsite extension cords with heavy-duty cord covers.

9. **Ensure that all electrical components stay dry:** It's one of the cardinal rules of electrical safety: don't mix electricity and water. Store power tools and cables above water level when not in use, cover outdoor receptacles, and never use electrically powered tools in a wet environment.
10. **Use the right extension cord for the job:** Before you plug in, make sure that the wattage rating of the extension cord you're using is greater than the pull (or power requirement) of the equipment it's powering. Using an extension cord to supply more wattage than it's rated for can cause conductor strain, overheating, and possibly even fire.

6. PERSONAL PROTECTIVE EQUIPMENT

The best way to keep people safe from electrical hazards in the workplace is by implementing policies and procedures that reduce or eliminate various risks. Unfortunately, it is impossible to take steps that can be 100% effective, and if there is even one incident it can be deadly. With this in mind, it is important that anyone working with or around dangerous electrical equipment use personal protection equipment to keep them safe in the event of an accident. The following are among the most frequently used types of PPE, and how they can keep your workplace safer.

- **Insulated Gloves** – Insulated gloves will prevent electricity from traveling into your hands should there be an exposed wire, short circuit, or other issue.

- **Insulated Matting** – Insulated matting will put a protective layer between the employee and the floor. This is helpful when working at switchboards, transformers, and other high-voltage areas. It can help prevent electricity from traveling up from the floor into the person's body, as well as eliminating a path for electricity to travel through the body and out to the floor.

- **Insulated Ladders** – Insulated ladders won't transmit electricity into the person who is using it. If a normal metal ladder accidentally touches a live electrical wire, it can be devastating. With the insulated ladder, this isn't an electrical concern.

- **Rescue Rods** – In the event that someone is being electrocuted, people will be tempted to rush in to save them. Unfortunately, this will only lead to them becoming electrocuted as well. Having a rescue rod present will allow those in the areas to pull the victim to safety, or push the source of the electricity away.
- **Voltage Detectors** – Even after a power source has been removed, there can still be electricity in a system because of capacitors. A voltage detector will show the level of electricity in a given system at the current time, so employees won't mistakenly begin working on a system until all power has been eliminated

ELECTRIC SHOCK

Electric shock refers to the electricity passing through the human body, affecting the normal function of the heart, lungs and nervous system. Ventricular fibrillation caused by electricity is the main reason for death from electric shocks. Electric shocks may indirectly lead to accidents, e.g. falling from heights and bruising due to body trauma etc.

Electric shock occurs when the body becomes part of an electrical circuit. Shocks can happen in three ways.

- A person may come in contact with both conductors in a circuit.
- A person may provide a path between an ungrounded conductor and the ground.
- A person may provide a path between the ground and a conducting material that is in contact with an ungrounded conductor.

EFFECT OF AC AND DC

No matter what, if either AC or DC comes in contact with the human body, it can be hazardous. The actual effect varies, though, as it depends upon several different factors, including the amount of current administered, duration of which it was in contact with the body, pathway of the current, voltage applied, and impedance of the body itself. All of that being said, if it comes down to one or the other, AC can generally be viewed as the more dangerous of the two currents — here's why:

1) To start off, in order for both currents to have the same effect on the human body, the magnitude of DC flow of constant strength needs to be two to four times great than AC; that is, more DC current is needed to induce the same amount of physical damage as AC current. This is because the effect of the currents on the

body is a direct result of the excitatory actions of its magnitude — specifically, the actual making and breaking of the current itself. Such excitatory actions include nerve / muscle stimulation, induction of cardiac atrial or ventricular fibrillation, and more. For DC to produce the same effect as AC on the human body, its flow of constant strength must be two to four times that being administered by the AC.

2) When death by electric shock occurs, it's typically due to ventricular fibrillation, and the likelihood of a human suffering this sort of life-ending injury is much higher when coming in contact with an AC than a DC due to the fact that the human body's threshold of DC-caused ventricular fibrillation is several times higher than for AC.

3) Generally speaking, the human body's impedance is higher for DC, and it only decreases when the frequency increase. As such, the severity of electric shock is less when in contact with DC than it is with AC.

4) It's easier to let go / remove contact with "live" parts in the case of DC than AC. This runs counter to the popular belief that because the alternating cycles of an AC current pass through zero, the individual is afforded enough time to pull their limb / body away from the part itself, whereas with the constant flow of the DC current, there is no frequency oscillations that afford the brief moment for the person to pull their body away. The basis for this argument can be sourced in the "let-go" experiment, which was reported in the same aforementioned IEC publication 60479. In it, the lowest level of current that could safely pass through a human body was administered through an electrode held in a test person's hand; it was enough current to make the person unable to open his hand and drop the electrode.

Without getting into all of the details of the actual experiment, the conclusion was that the test subjects found it easier to release the electrode when DC was administered rather than AC. Now, while it can be surmised that AC is more dangerous than DC, the safest solution is to avoid contact with any and all high-voltage electrical conductors, no matter the type of electrical current