Chapter 17

ELECTRICITY & LOCKOUT/TAGOUT

‘It takes little electrical current to kill. Just one second of contact at 110 volts can be deadly and as little as 60 volts has been reported fatal.’

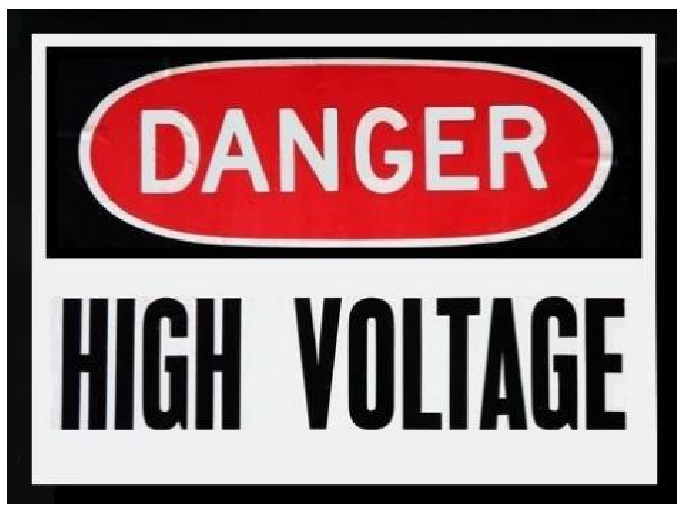
Introduction

Every year in the US alone, 300 to 500 workers are fatally electrocuted while working on the job. And surprisingly, many of those fatalities are people not directly employed in the electrical field. ‘Regular’ workers – persons working indirectly or near electrical hazards including construction workers, machine/equipment operators and even people in administrative roles can fall victim to electrical dangers. Electricity, as a raw source of power, presents as many hazards as it does benefits. Electrical shock can occur when electrical current passes through the body.

How It Acts: Electricity – The Basics

Here are a few electrical terms you should know:

- **Current** – the movement of electrical charge
- **Resistance** – opposition to current flow
- **Voltage** – a measure of electrical force
- **Conductors** – substances, such as metals, that have little resistance to electricity
- **Insulators** – substances (i.e. wood/rubber/glass) that have a high resistance to electricity
- **Grounding** – a conductive connection to the earth which acts as a protective measure



How Electricity Works - Understanding Ohm's Law

Think of electricity as a waterworks. Operating as electric switch is like turning on a water faucet. Behind the faucet there must be a source of water, a means of transport and a force to make it flow. In the case of water, the source is a reservoir of pumping station; the means of transport is a network of pipes; and the force to make it flow is provided by a pump.

In the case for actual electricity, the source is the power generating station. Current travels through electric conductors, wires for mast cases; and the force to make it flow which is voltage, measured in volts (it is provided by a generator). Resistance is a term that describes the forces that oppose the flow of electricity through a material. The way to measure resistance is in "Ohms," named after George Ohm, who discovered the relationship between current, voltage and resistance in 1827. **Ohm's Law** governs the three basic components of electricity:

- **Voltage (E)**
- **Current (I)**
- **Resistance (R)**

And using these (3) criteria, you can arrange the Ohm's Law equation to find any one of the three elements if you know the other two. Let's look at our first example: *E=IR*. In all our equations, 'E' equals Voltage; 'I' equals Current (in Amperes) and 'R' equals Resistance (in ohms). So, in our first equation, we can extend E=IR to: **(E) = Current (I) [Amps] X Resistance (R).** So let's plug in some values. If the current is 5 amps and the resistance is 20 ohms, what is the applied voltage? **E = 5 amps X 20 ohms** or **E = 100 Volts.**

Now let's change it around. If we know the voltage is 100 volts and the resistance is 25 ohms, what is the current in the circuit? We start off by setting up our equation like this: **I = E / R or (with values)** or **I = 100 / 25 which = 100/25 or 4 Amps.** And finally (and I think you can see how this works now), if the current is 2 AMPS and the applied voltage is 100, the resistance is **R=100/2 or R= 50 OHMS.**

Conductors and Insulators

Conductors are materials that permit electrons to flow freely from atom to atom and from molecule to molecule. Conductors are "electricity friendly" and include some of the elemental products you've come to associate with electrical work, like copper and aluminum. *Insulator*s are not electricity friendly. They impede the free flow of electrons and include materials such as rubber, porcelain and dry wood.

What is Grounding?

Grounding can make the difference between life and death. *Anything* that is conductive – a copper wire, water, YOU – that touches an electrical current and the ground at the same time becomes "Grounded." The object providing the connection between the current and the ground is referred to as the "path to ground." If the power source being used is ungrounded, and someone comes in contact with the electrical current, they may provide what is called a "path to ground."

When someone provides a path to ground, the electrical current takes the shortest path through their body. This means that they – THE PERSON – becomes the conductor, allowing the electrical current to pass through their body. If a hot wire hits their hand it will pass from their hand through their body (more likely to affect the heart and other organs) then out through their feet. There is a greater chance of survival is the current if the current passes through their foot to the ground.

Grounding Types:

There are two kinds of electrical grounds: both are required by OSHA Standards:

1. ***System or Service Ground***: with this type of ground, a wire called the neutral conductor is grounded at the transformer, and again at the service entrance to the building. This is primarily designed to protect machines, tools, and insulation against damage.

2. ***Equipment Ground:*** This is intended to offer enhanced protection to the workers themselves. If a malfunction causes the metal frame on a tool to become energized, the equipment ground provides another path for the current to flow through the tool to the ground. (This is also known as secondary or backup protection in the event of a primary ground fault break or breach).

The danger is very real. Consider the following situations:

- What if there is a break in the grounding system that the user doesn't know about? Here's one example: suppose there is a 3-prong plug that is correctly attached to a 3 prong receptacle, but the receptacle is not correctly grounded to a lightning rod.

- Or (and this is far more common) what if the extension cord YOU'RE USING RIGHT NOW has a grounding break unknown to the user? A properly functioning grounded extension cord can accidently be cut with any sharp object while exposed to the day-to-day rigors of the jobsite.

- A wet user (you're working in the rain) connects two wet extension cords and provides a path to ground.

Faulty Grounding Paths

It was mentioned earlier that a good ground path is critical to maintaining the integrity of an electrical circuit. One of the more common violations found in the work place occurs when grounding prongs are either damaged or missing altogether. Why this is so common is apathy and laziness - pure and simple.

A Story:

Here's an (all-too-common) event: Tony starts to plug in a cord. He notices that the neutral prong has broken off the plug. In his haste, he goes ahead and uses the cord anyway because he knows th cord will typically still work when the ground is missing. It just won't work safely. But here's the thing: now, if there's a fault in the electrical system, Tony could be severely shocked while handling the cord. Tony could be risking his own life (and the lives of others) simply because he's being lazy. Instead, Tony should stop and take the time to replace the cord and plug with a good one (and dispose of the bad cord).

GFCI's – Ground Fault Circuit Interrupters

Anyone of the situations above could turn out to be deadly. So how does one protect themselves from such hazards? Well, on a GFCI is one answer. A GFCI - or *ground fault circuit interrupter* - works by comparing the amount of current returning from the device along the electrical conductors. If it senses something amiss, GFCIs can shut off electrical power in as little as 1/40 of a second, greatly increasing the likelihood of survival for the person who is attached to the other end. UL (Underwriters Laboratories) recommends testing GFCIs once a month or after severe thunderstorms to verify they are working properly.

Hazards of Electricity

Electricity in and of itself can often seem harmless – familiarity can often lead to complacency - however no one should ever take it for granted. There are three (3) primary hazards posed by electricity: 1) s**hock, 2) arc-flash and 3) arc-blast. And** there are (4) main types of electrical injuries that may result:

1. **Electrocution** (death due to electrical shock)
2. **Electrical shock** (non-lethal)
3. **Burns** (which can range from mild to lethal)
4. **Falls** (think lineman at the top of a transformer tower. If the shock isn't deadly; the fall surely may be.)

The *severity* of the injury or shock depends on a variety of criteria including 1) the *path of current through the body*, 2) the *amount of current flowing through the body* and 3) the *length of time the body is in the circuit*.

Electrocution and Electrical Shock

Received when current passes through the body. The persons actually becomes part of the circuit. When an individual is in contact with the ground and then comes in contact with 1) both wires of an electrical circuit, 2) one wire of an electrical circuit or 3) any metallic part that has become energized through contact with an energized conductor, electrical shock including and up to electrocution can occur. The severity of an electrical shock varies according to:

- *The amount of current measured in amps*
- *The path through the body*
- *The length of time the body is part of the circuit*

Electrical Arc-Flash

Electric Arc-flash is a short circuit through the air when working on or near energized equipment, resulting in a phase-to-ground or a phase-to-phase fault. In order to provide a understanding of the intensity of an arc-flash, during an arc-flash, temperatures may exceed 35,000 degrees F (the sun surface is 9,000 degrees F). The air at this temperature can 1) ignite or melt clothing on skin causing severe burns, 2) damage vision, sometimes resulting in blindness or (if you're lucky) 3) knock you off your feet.

Make no mistake about it - lives can be changed in a flash. Arc-flashes may also generate fires and can even cause explosions when in close proximity to flammable gasses, vapors or combustible dust. The most common injuries resulting from arc-flash are (normally non-fatal) burns received when an individual touches faulty electrical wiring or equipment that has been improperly used or maintained. Typically the injuries occur on the hands

Electrical Arc-Blast

The third electrical hazard, arc-blast occurs as a secondary result of the arc-flash (think thunder after lightning). Arc-blast produces a sound, pressure wave (141.5 decibels and 2,160 pounds per square foot) that can be severe enough to rupture ear drums and collapse lungs. The blast can also be so violent as to create projectiles from formerly harmless, incidental surrounding materials. And a small piece of plastic traveling at 800 miles per hour CAN kill you.

What You Need to Know

There are standards when workers are required to work on potentially "live" electrical components, such as Trouble-shooting an electrical panel or maintaining a substation. Of course the FIRST rule of electricity is that ONLY workers who have been specifically and extensively trained in the use and dangers of electrical wiring and components should be allowed to work on or in close proximity with electrical trade work. But of course other trades will find themselves working in close quarters or within live electrical work at times so even these workers:

- Should have the ability to distinguish between exposed live parts and other parts for electrical equipment.
- Should have the skills and techniques necessary to determine the nominal voltage of exposed live parts.
- Should understand the risks involved when working on a specific energized component.
- Should be aware of the working clearances and approach boundaries as outlined by the National Fire Protection Association's (NFPA) 70E code. This is the governing document that determines how far away workers must be from potential arc-flash & arc-blast hazards. There are 3 approach boundaries:

1) **Limited**
2) **Restricted**
3) **Prohibited**

1) The *Limited Boundary* applies to unqualified personnel. This boundary is as close as unqualified workers are allowed to get to the live work. Even at this point, they must be accompanied by a qualified worker to ensure the

2) The *Restricted Boundary* should be crossed only by qualified persons properly outfitted with the necessary personnel protective equipment, or PPE.

3) The *Prohibited Boundary* is the closest boundary to the source. Only qualified personnel wearing PPE who have a documented plan justifying the need to perform this work may get this close. Many experts see no difference between crossing the prohibited boundary and actually contacting the exposed energized part.

Electrical Accidents

Electrical accidents are most commonly the result of one of these three factors:

- Unsafe equipment and or installation
- Work places made unsafe by environmental factors, such as dampness
- Unsafe work practices

Preventing Electrical Accidents

Here are some common ways to protect yourself against potential electrical accidents:

- Insulation – always ensure that there are no exposed wires. If you come across exposed or bare live wiring, notify the electrician at once to have the situation repaired.
- Guarding – electrical live parts of 50 volts or more must be guarded against accidental contact – generally with some type of non-conductive cover or shield. Installations over 600 volts must be controlled by a metal enclosure that has been appropriately constructed, NEMA-rated and marked with caution signs.

- Grounding – ensure that the item you are working on has a low-resistance path to the earth intentionally created and in place. The ground *does not guarantee* that there will be no shock, injuries or fatalities, but it greatly reduces the possibilities.
- Become familiar with and check for these common installed electrical safe guards:
  - GFCI (ground fault circuit interrupter; see above) switches and circuit protection devices. GFCI's are is designed to shut off electric power within as little as 1/40 of a second, by comparing the amount of current returning from the device along the circuit conductors.
  - Switches - always shut down equipment with the switch.
  - Circuit protection devises (i.e. circuit breakers) are designed to automatically limit or shut off the flow of electricity. In the event of a ground fault, overload or short circuit in the wiring system. In older constructions, these can be fuses in lieu of circuit breakers.
  - Arc Fault Circuit Interrupter (AFCI) is designed to reduce the likelihood of fire caused by electrical arcing faults; required in bedroom receptacles.

Safe Work Practices

And here is a comprehensive (and common sense) list of safe work practices and methods to be employed when working on or near potentially live electrical components:

- Whenever possible, de-energize all lines, no matter how low the voltage, before any work is done. This de• energizing work and subsequent installation or repairs must be done by a qualified craftsman.
- When working in or on energized substations, transmission lines, power plants, etc., follow the accident prevention rules, procedures and regulations of the client or energy provider.
- Electricians must wear approved (e.g., CSA) electrical hard hats (no aluminum, metal-fiber, etc.) when working around energized lines or equipment in hard hat areas.
- Use the correct equipment and clothing. Use insulated tools to avoid the shock hazard and to prevent accidental short-circuits. Wear gloves and safety glasses or goggles to reduce injury in case a fault does occur.
- Remove metal rings, bracelets and wristwatch bands to avoid accidental short-circuit where small work clearances are involved.
- Never make repairs to electrical equipment unless you are qualified and trained to do so.
- Do not carry material on your shoulders while working around energized equipment, lines or buses.
- To ensure your personal safety, handle all wires as though they are energized.
- Do not do electrical work 'hot' when it can be done 'cold'.
- Do not use metal ladders for electrical work or where they might make contact with electrical conductors.
- Know and understand related permit requirements.
- Do not string cords and plug-ends in water.
- Use G.F.I. plugs in all electrical panels.
- Where functional GFCI (Ground Fault Circuit Interruption) protection does not exist, implement and use an assured grounding program to ensure all equipment is grounded properly.
- Color-code extension cords and power tools to verify continuity and polarity testing.
- Ensure compliance with Regulations governing your place of work.

- Turn off, unplug and, if appropriate, lock out systems.
- Always use properly functioning tools and ONLY use tools that have been properly inspected, maintained and (as applicable) UL approved.
- When in doubt, and if possible, ALWAYS have the line de-energized when performing maintenance. Ensure that the line remains de-energized by using a formal lockout/tag-out procedure described in this chapter.
- Always keep a safe distance from energized lines.
- Always use protective equipment.
- Use required PPE. The equipment should always be appropriate electrical protection for the level of potential electrical danger you may encounter.
- It's best to assume that EVERY workplace has electrical violations or lapses. Most of the time, it's not a matter of 'if' but 'when'. And that's why it's important to recognize them early, address any deficiencies, and always let the workers around you know about sub-par or suspect situations.
- If you do come across and deficiency, address it with urgency and immediately. Do not assume the 'other guy' will take care of it.
- Inadequate Wiring (size): be sure you don't use just any extension cord for all equipment. Extensions cords, like building wiring, must be sized correctly. All users must first consider whether the size of the extension cord's wire is too small to handle the current that the tool or machine will draw from the power source. The tool may draw more current than the cord can handle, causing overheating and a potential fire before tripping the circuit breaker. Also, the breaker may not be rated for a smaller-wire extension cord.
- Overload: sometimes there may be more plugs than outlets (this one is VERY common).
- Plan ahead to determine how many power sources will typically be needed in each work week area and make sure there are ample electrical outlets for those sources.

Defective Electric Tools

Another potential for electrical injuries arises from using defective or damaged electrical tools. Here are some precautions to keep in mind:

- Always inspect tools before each use. Ensure that the plug housing isn't cracked and test any interlocking safety switches.
- Monitor the condition of the cord (current as small a 10 milliamps can paralyze, or "freeze" muscles). Ordinary power drills use 30 times more current than the amount necessary for a fatal shock.
- Check for improper guarding of live parts. OSHA REG: Guard live parts of electrical equipment operation at 50 volts or higher against accidental contact by following some of these steps:
  - Use approved cabinets and enclosures
  - Make the equipment accessible to only qualified people,
  - Elevate live parts eight or more feet above the floor or working surface.
- Always marks entrances to guarded locations with conspicuous OSHA approved signs.
- When wiring or live electrical components are located in an area that might sustain damage perhaps due to a process flow or forklift traffic, they are to be protected against possible damage.

Substandard Cabinets, Boxes and Fittings

- Junction boxes, pull boxes and fittings must have approved NEMA covers.
- Unused openings in cabinets, boxes and fittings must be closed.

Blocked Electrical Panels

- An often overlooked violation centers on and around the electrical panels and disconnects switches. Ample clearance is to be maintained in order to provide access, at least 30 inches.
- For the same reason emergency exits should never by blocked, electrical panels and disconnect switches should remain accessible. If an electrical fire broke out or an employee was shocked, every second would count.
- It is vital that the panels and switches be easily reached in order to turn he power off

Inadequate Strain Relief on Cords and Conductors.

- The primary function of wiring is NOT to support the weight of the components.
- The primary function or wiring is NOT to be use as a place to pull when unplugging from a receptacle.
- It is necessary to keep rigid junctions and cord insulation intact.
- When violations like these are found, address them as soon as possible. In the meantime, do not use any equipment found in violation.

Improper Marking or Electrical Equipment

- Electrical equipment is manufactured for a very specific purpose: to safely house and direct electricity.
- Electrical equipment may not be used unless the manufacturer's name, trademark or other descriptive information is listed on the equipment itself.
- Additional markings such as voltage, current or other ratings should be listed as necessary.
- Markings are to be durable enough to withstand the anticipated workplace environmental conditions.
- The reason marking so important is that if two pieces of equipment rated for different voltage are connected, they will attempt to perform their intended functions, but the smaller of the two will eventually overheat and fail. Occurrences such as this can cause burns to employees and spark fires.
- Failure to mark disconnecting means and circuits: it is also required that equipment be clearly matched to its corresponding disconnect switch and circuit. Each service, feeder and branch circuit, as its disconnecting means or overcurrent device, needs to be legible marked to indicate its purpose. A *disconnecting means* is a switch that is used to disconnect the conductors for a circuit from the source of electrical current. If each switch is clearly identified with regards to what equipment that it controls, workers are better protected.

Flexible ('flex') Cords: Proper & Improper Applications

Flexible cords are handy, but have definite limitations. Here are some things to look out for when handling/installing flexible electrical cords & connectors:

- Proper uses of a flexible cord include:
  - Connecting a permanent appliance or pendant lighting.
  - To power portable lamps, tools and appliances.
  - To power appliances whose fastening means and mechanical connections are designed to permit removal for maintenance and repair
- In general, always seek a permanent wiring solution first; a flexible cord is by its very nature more vulnerable to damage.

- Aging has a direct affect to a flexible cord. Many cords have a date stamped on them and should be checked before using.
- A flex cord is vulnerable to abrasions for a variety of sources so always be sure to check them over before use.
- Uses of a Flexible Cord that is an Electrical Violation
- A flexible cord should never be used as a substitute for fixed wiring where it hasn't been specifically called out and spec'd.
- A flexible cord cannot be run through walls, ceilings, floors and windows.
- A flexible cord cannot be concealed behind or attached to building surfaces, if this was done, any abrasions, frays or damage would not be detected.

Common Clues that Electrical Hazards Exist

Be aware of these common tell-tale signs that an electrical issue may exist:

- Tripped circuit breakers or blown fuses.
- Warm tools, wires, cords, connections, or junction boxes.
- GFCI that shuts off a circuit.
- Worn or frayed insulation around wire or connection.

Lockout/Tagout Procedures

Written lockout procedures must be made available to all workers who are required to work on machinery or equipment that can be energized. These lockout procedures must ensure all equipment/machinery in the system is secured in a Zero Energy state. When circumstances require lockout, control devices must be secured in the inoperative position by using locks. Such locks must be marked or tagged (brassing) to identify the person applying them.

All equipment must be locked/tagged or isolated according to Hight Policies and Procedures and the Occupational Health and Safety Regulations of the province, territory or state in which the work is being performed.

- All equipment or machinery installed with dual supply capability must be permanently labeled as to its "dual supply" nature. Lockout both energy sources before commencing work.
- Safe Work permits may be required.
- Any hydraulic machinery, or machinery/equipment with moveable parts, must be blocked or lowered until no further movement is possible. It is possible for components to drop, slide, rotate or move unexpectedly (gravity or trapped pressure) even when locked-out.
- Lockout measures include: locks, scissors, chains, blocks, blanking or off-setting.
- Where lockout requires locks, each worker must use a personal lock and key. Locks must be durable, made of case-hardened steel and key-operated only. The lock must be used with a tag identifying:
  - **Worker**
  - **Employer**
  - **Date/Time**

- **Location of work area**

- On each power source, every worker involved in the job must use a lock. A lockout bar or scissors can be used to accommodate several locks. Other locks are added by placing another bar or scissors in the last hole of the previous one.
- Never lend anyone else the key to your lock(s).
- Scissors should be made of case-hardened steel and be used when more than one worker is involved in the lockout.
- Chains or covers are used when equipment such as valves and control boxes cannot be locked. Locks are then applied to the chains or covers.
- Blocks are made of wood or metal in various shapes to prevent machine/equipment parts from moving.
- In-plant lockout procedures specified by the owner or client take precedence over the procedures outlined here, providing there is no contravention of existing codes or statutes.

- Electrical systems must be de-energized and temporarily grounded.
- A record must be kept of all locked-out switches, power sources, controls, interlocks, pneumatics, hydraulics, computer-controlled sources, robotics or other such devices opened, locked off or otherwise rendered inoperable so they can be re-activated once work is complete.
- Workers testing electrical systems must:
  - Remove all watches, rings, neck chains or other current-conducti ng jewelry, wear electric shock resistant footwear, wear safety glasses with side shields.
  - Always remove locks in exactly the reverse order of installation.

Overhead Power Line Hazards

Most people don't realize that overhead power lines are usually not insulated. Power line workers need special training and personal protective equipment (PPE) to work safely. Common sense is key here. One must always be aware of working off of scaffolding, staging or ladders when in the vicinity of power lines and – when working on or near the lines themselves – never, ever use metal ladders. Fiberglass or other type of non-conductive composite material should be used instead.