Appendix B
PCC Electrical Safety Training

ELECTRICAL SAFETY TRAINING OBJECTIVES

OSHA regulations have been adopted on electrical safety-related work practices for general industry. These new standards include requirements for work performed on or near exposed energized and de-energized parts of electrical equipment; and the safe use of electrical equipment. The purpose of the regulations is to reduce the number of electrical accidents resulting from unsafe work practices by employees. The objective of this training program is to provide the required information regarding the new safety standards.

TRAINING AGENDA

This training program is to supplement the safety procedures and provide information about the OSHA Electrical Safe-Work Practices. The first part of the training is basic information and the second section provides basic information for qualified employees working on or near electrically installations.

1. **Basic Electrical Hazards and Safety Guards**
   - Basic Definitions – see Appendix A: Definitions
   - What is Electricity?
   - Hazard for Electrical Shock
   - Common Usage of Portable Tools and Electrical Hazards
   - Basic Prevention: Review of Part A of this Chapter

2. **Qualified Employee Electrical Safety Training**
   - Review of the OSHA Electrical Safety Rules
   - How to Distinguish Exposed Live Parts and Nominal Voltage
   - De-Energizing and Re-Energizing Procedures
   - Working Space - Clearance Distances
   - Capacitors
   - Confined or Enclosed Work Space
   - Conductive Materials and Locations
   - Test Equipment
   - Protective Devices and Tools
   - Flammable or Ignitable Materials
     - Altering Techniques

INTRODUCTION - WHAT IS ELECTRICITY?

Basically, an electric current is the movement of electrons in a wire called a **conductor**. The force or pressure that moves these electrons is called an electromotive force or **VOLTAGE**, which is measured in volts. The rate at which these electrons move is called the **current**, measured in **amperes**.

Electrons are subatomic particles that have a negative electric charge. All matter has electrons. In metals, there are free electrons that are only loosely bound to their parent atoms. When a voltage is applied to such a metal, these free electrons are forced to move through the metal, resulting in the conduction of current.

At any instant, one side of the voltage source will have a positive electric charge and the other side will have a negative electric charge. A fundamental principle in electricity is that like charges repel and unlike charges attract. Thus the negatively charged electrons will flow toward the positive side of the voltage. For this reason, electron flow is always designated as from negative to positive.

The voltage source can be either a battery or a generator. The battery gives a continuous one-way current called direct current or DC. The generator can produce direct current or alternating current AC. AC is the most useful and therefore the most common in use. The advantages of AC is that it can be easily transported and converted from one voltage to another.

The greater the voltage on the electrical circuit, the more current will flow. The amount of current that flows due to voltage applied is affected by the resistance of the conducting material.

ELECTRICAL INJURIES AND THE CAUSES:

Every year many workers suffer pain, injuries, and death from electric shocks. OSHA estimates that there are more than 100 electrical fatalities in general industry each year. Three out of four injuries on the job caused by electricity involve one or more unsafe conditions. The most common unsafe conditions have been identified as damaged, defective, burned or wet insulation, lack of proper guards or shields, poor or inadequate maintenance, the absence of proper grounding, and loose connections. Learn to respect electricity regardless of the voltage.

OSHA also estimates that unsafe work practices are a factor in more than half of the workplace electrocutions. From April 1984 to December 1986, OSHA recorded 128 deaths from electrocution. During the same time period, 78 other workers were hospitalized for injuries due to electrical accidents. Because of this, OSHA developed rules on electrical safety.

The research OSHA conducted when developing the new standards indicated that electrical accidents usually are caused by a combination of three factors:

1. work involving unsafe equipment and installations
2. unsafe work environment
3. unsafe acts performed by employees

OSHA has combined the first two accident-causing situations into what it terms "unsafe conditions." Therefore, electrical accidents usually are caused by either unsafe conditions or unsafe acts, or a combination of both of these.

Unsafe work environments include those containing flammable vapors, liquids, or gases; those containing corrosive atmospheres; and those which are wet or damp.

Unsafe acts include not de-energizing electric equipment when repairing or inspecting it; using defective or unsafe tools; and using tools or equipment too close to energized parts. Unsafe work practices may result from factors such as in-attentiveness, lack of training, or poor supervision.

Inadequate maintenance also can cause equipment which originally was safe to deteriorate, resulting in unsafe conditions. Workers who inspect equipment need to be trained to look for faulty insulation, improper grounding, loose connections, defective parts, improper ground faults, and unguarded live parts.

TYPE OF INJURIES

An electric current flowing through the human body causes shock and injury; the severity of the injury depends on:

- The magnitude of the current flowing;
- Whether the current is direct or alternating;
- If AC whether the frequency is low or high;
- Whether the current passes near nerve centers and vital organ; and
- The time during which the current flows..

Electricity may cause serious physical injury or death in three ways, and may occur simultaneously:

1. By direct action (electric shock) on the heart and respiratory organs;
2. By burns: electrical burns, arc burns, and thermal contact burns:
    a. Electrical burns result when electric current flows through skin tissue. They may enter skin deep or affect deeper layers, such as muscles or bones.
    b. Arc burns are the result of high temperatures produced by electric arcs or by explosions close to the body. These burns are similar to the burns or blisters produced by any high temperature source.
    c. Thermal contact burns are caused when the skin comes into contact with the hot surface of electric conductors, conduits, or other energized equipment.
3. By the involuntary action of the body as the result of a shock (falling from a ladder or hitting a moving part of a machine)

In most electrical accidents the current flows from hands to feet through the body near the heart. The results are, therefore, serious. The internal resistance of the human body is quite low, though the skin if dry has a high resistance. This is much reduced if the skin is wet, and most fatal accidents occur under these circumstances.

The resistance of a dry skin is rapidly broken down by a high voltage. High voltage causes violent muscle contraction, often so severe that the victim is thrown clear. The less violent contraction caused by lower voltage may, however, prevent the victim from freeing himself or herself, so that the effect is no less dangerous.

Flash burns can be caused by opening switches, removing fuses from energized circuits, or by shorting cables.

EFFECTS OF ELECTRIC SHOCK

General Effects of 60 Hz passing through the body of an average adult male from hand to foot for 1 second:

AMPERE	HUMAN EFFECT
1 mA	Lowest level of perception
9 - 25 mA	Involuntary muscular control
>20 mA	Direct paralysis of respiratory system (can result in death)
75 mA - 4A	Cessation of rhythmic heart pumping action (ventricular fibrillation of the heart)
> 4A	Immediate cardiac arrest

NOTE: even if the shocking current does not pass through vital organs or nerve centers, severe injuries such as deep internal burns can still occur.

A female's body is more susceptible to electric currents than a male's and the same effects are said to be produced with about 60% the current required in a male.

In most electrical accidents the current flows from hands to feet through the body near the heart. The internal resistance of the body is quite low, though the skin if dry has high resistance. This is much reduced if the skin is wet, and most fatal accidents occur then. See Table Below:

Body Area Resistance ohms*

- Dry Skin 100,000 - 600,000
- Wet Skin About 1000
- Internal, hand to foot 400 to 600
- Ear to ear About 100

* ohms - resistance in a conductor is measured in ohms

PORTABLE ELECTRIC TOOLS

HAZARD

Portable power tools and appliance can be identified as the source of injury in approximately 9% of occupational electrocutions. This has included the use of 110 volt AC tools and appliances and welding equipment which is usually 220 volt or higher AC. Electric drills and saws were the most common tool involved in the electrocutions. Proper provisions of ground-fault circuit interrupter protection, particularly at temporary work sites could have prevented most of the 110 volt AC deaths. Engineering controls for preventing electrocution from portable arc-welding equipment needs to be evaluated.

CONTROLS

There are three different and alternate types of protection against electrocution available to users of portable tools.

1. The use of grounded conductor which gives a low-resistance path to earth. This grounds all parts of a tool which might be held or touched, so that in case of an insulation failure, the holder receives at worst at a very mild shock.
2. The use of low voltage power to reduce the shock potential.
3. The use of double insulation.

Faults in electrical equipment, especially portable tools, cause the housing to be energized. The tool may have a broken connection or internal wiring that touches the tool housing. When the tool is turned on, the user receives a shock when they touch the housing. To minimize this problem with power tools, three-wire systems are used in which one wire in a plug provides a connection to a grounded outlet. Unfortunately, in some instances, the outlets are not grounded properly so that the ground wire on the tool is useless. Because of this, portable tool manufacturers now use double insulation.

Tools have improved double insulation systems which reduce such possibilities to almost zero. However, even double-insulated types are hazardous when they are wet, unless the insulation is of a special type. If the tool is not grounded and a worker who touches the tool is not insulated, the worker may form the connection to ground through which the current will pass.

When portable electric tools are damaged or used improperly hazards can be created.

Portable equipment must be handled in a manner which will not cause damage. Visual inspection of cords, plugs and receptacles shall be made before use on any shift. If equipment is found defective it cannot be used. These requirements protect employees from electric shocks caused by damaged equipment. Such defects as missing grounding prongs on attachment plugs and poor insulation on conductors have caused injuries. Also remember, when your hands are wet you must not plug or unplug energized plugs and receptacles.

WELDING EQUIPMENT

In all of the welding electrocutions studied by NIOSH (National Institute for Occupational Safety and Health) between 1984-1986 it was found that the frame of the welder was not grounded and became energized. Two of the reports showed that the power plug had been wired incorrectly. In another case the power plug was damaged. An ungrounded extension cord was used in one case. A damaged extension cord in one case energized the frame. In some of the cases wet cotton or leather gloves were worn.

The welding apparatus is not usually the case but the secondary circuit.

Special care must be taken when replacing power plugs and cords of welding apparatus to ensure that the ground wire is properly connected and that the notches on the power prongs are not worn off, allowing the plug to be inserted backward.

OVERALL CONTROLS FOR PORTABLE TOOLS AND APPLIANCES:

Prevention of electrical work injuries can be accomplished through the use of administrative and engineering controls. The effectiveness of administrative controls is a function of how well they are implemented and enforced at the work site. Effective controls attack the two main areas of human error responsibility for power tool electrocutions:

1. Working with damage or modified equipment
2. Failure to provide effective grounding

An effective work-site grounding conductor program is needed with preventive maintenance a key to the program. Newer tools such as double insulated provided good protection but if the electric cords are damaged protection may be lost.

Extension cords used to supply power need particular attention because the grounding pin is often removed to accommodate a two-pronged receptacle.

The use of **ground fault circuit interrupters (GFCI)** should be an integral part of the tool or appliance to ensure its use and to physically locate the protection near the worker. The use is then protected from shocks arising from cuts or abrasion to the power cord as well as faults within the tool itself.

The GFCI is a fast acting circuit breaker that senses small current leakage to ground and, in a fraction of a second, shuts off the electricity and interrupts its faulty flow to ground. Placed between the electrical service and the tool it serves, the GFCI continually matches the amount of current going to the tool against the amount of current returning from the tool along the normal path of the circuit conductors. It is important to know that GFCI will not protect the employee from line-to-line contact hazard (when a person holds two “hot wires” or a hot and neutral wire in each hand). Its protection is from line-to-ground fault. It also provides additional protection against fires, overheating, and destruction of insulation on wiring.

The GFCI system does not protect a welder because a standard GFCI would not sense a fault because the supply and return current are always on the same side. The use of insulated work gloves would protect the welder’s hands from contact with the secondary welding circuit.

At construction activities OSHA Division 3 Construction rules require the use of Ground Fault Protection. These requirements include:

1. That all on-site equipment should be tested:
    a. Before each period of use;
    b. After the equipment has been repaired ;
    c. If the equipment has become damaged; and

d. At a minimum of 3-month intervals.

2. Records must be kept that identify every receptacle, cord set, and cord-connected equipment. The records must indicate whether tests have been passed and date of the latest test. These records must be kept available on the job site.

HOW TO DISTINGUISH EXPOSED LIVE PARTS AND NOMINAL VOLTAGE

Workers who inspect or repair equipment must understand that when they dissemble equipment, normally enclosed electrical parts are exposed and create a hazard. Whenever it is possible, equipment should be de-energized as the primary method of protecting workers. Lockout and tag-out procedures then should be used to prevent re-energizing the equipment. If de-energizing is not possible then protective guarding combined with personal protective equipment must be utilized. Always check the circuit panel and the electric tag on the equipment to identify the operating voltage of the equipment.
The first step in assuring that there are no live parts in the equipment is to shut off the equipment at both the main circuit (if possible) and the equipment switch.

The next step is to bleed off the store electrical energy and then attempt to operate the equipment. To determine if the circuit is opened, operate the controls for the equipment supplied by the circuit. This method has the advantage of not exposing employees to possibly energized parts.

The last step is to test the equipment to ensure that all parts of the circuit which an employee will be exposed is de-energized. It is possible to interrupt a portion of the circuit so the equipment will not operate even though the rest of the circuit is still alive. This testing is also necessary because under certain conditions, it is possible to feed circuits from the "load" side and the test will detect any voltage back-feed that might be present.

Voltages over 600 volts are more likely than lower voltages to cause test equipment itself to fail, leading to false indications of no-voltage conditions. Consequently the OSHA rules require checking operation of the test equipment immediately before and after use, if voltages over 600 volts are involved.

When working on exposed live parts follow the LOCKOUT/TAGOUT POLICY.

DE-ENERGIZING AND RE-ENERGIZING PROCEDURES

When you are working with electric equipment, you must use safe work practices. Safe work practices include keeping a prescribed distance from exposed energized lines, avoiding the use of electric equipment when you or the equipment are wet, and locking out and tagging equipment which is de-energized.

There are three options allowed by the OSHA regulations in order to protect employees working on electric circuits and equipment:

1. De-energize the equipment involved and lock out its disconnecting means,
2. De-energize the equipment and tag disconnecting means, if it can be shown that the tagging is as safe and locking;

3. Work the equipment energized if the employer can demonstrate that it is not feasible to de-energize.

The use of lock out is the best work practice to provide protection to any employee working on electric equipment. Lock out is intended to cover any employee exposure to electrical hazards which might occur from the unexpected energizing of circuit parts and does not cover other equipment-related hazards which do not involve exposed live parts.

The circuits and equipment on which work is to be performed are then required to be disconnected from all energy sources. This ensures that the circuits are completely disabled. Because they do not completely de-energized entire circuits, control devices are not permitted to be used as the sole disconnecting means. Lastly, capacity elements in the circuit are required to be relieved of their stored energy and are required to be short circuited and grounded if necessary.

RE-ENERGIZING

After de-energizing the part, locks and tags are to be applied to the disconnecting means. This will prevent the unauthorized re-energizing of a circuit on which work is being performed. A lock and tag is to be placed on each disconnecting means. The tags must also contain a statement prohibiting unauthorized operation of the disconnecting means and prohibiting removal of the tag. This helps to ensure that employees are informed of the purpose of the lock and tag.

The next step is to verify that the correct circuits have been de-energized. Operate the controls for the equipment supplied by the circuit. Then a qualified person must use test equipment to ensure all parts of the circuit that an employee is exposed to are de-energized.

Once the work has been completed, it will be necessary to re-energize the circuit. The first step that must be taken is an inspection or test (or both) of the circuits and work areas to ensure that all tools, jumpers, grounds, and other devices have been removed. Otherwise, energizing the circuits involved could result in a short circuit condition and injury to employees. Next warn all affected employees to stay clear. The locks and tags must then be removed. After all locks and tags have been removed, a visual determination that employees are clear of danger is required. Once these procedures have been followed, it is safe to re-energize the circuits.

EXCEPTIONS

Under certain conditions, however, de-energizing need not be employed. Employees may be allowed to work on or near energized parts, if the College can demonstrate that de-energizing:

- Would be infeasible; or,
- Would introduce additional or increased hazards.

Extreme safety precautions must be taken under these circumstances that include use of safe work practices, personnel protective equipment, and safety barriers, or other protective equipment.

WORKING SPACE/CLEARANCE DISTANCES

Minimum clear distances are the shortest distances, which must be provided to afford a worker enough room to work safely near energized electrical equipment. Specifically, these distances are established according to the type of electrical hazard presented by the arrangement of equipment. Sufficient access and working space shall be provided and maintained about all electric equipment to permit ready and safe operation and maintenance of such equipment. There shall be a 36 inch minimum of clearance in front and 30 inches minimum across the front of all Control cabinets and enclosures,

The following shall have a 6 foot 6 inch of vertical clearance:

- Safety Switches (lockable disconnects)
- Emergency Stop Switches
- Operator Control Switches.

Minimum clear distances are the shortest distances which must be provided to afford a worker enough room to work safely near energized electrical equipment. The distances are established according to the electrical hazard presented by the arrangement of the equipment and the guarding provided.

WORK NEAR OVERHEAD POWER LINES

WORKING CLEARANCES for *QUALIFIED EMPLOYEES- (ALTERNATING CURRENT*)

VOLTAGE RANGE *MINIMUM APPROACH DISTANCE (FEET)*

300V or less avoid contact over 300V, not over 750V 1 Over 750V, not over 2kV 1.5 Over 2kV, not over 15kV 2 Over 15kV, not over 37kV 3 Over 37kV, not over 87.5kV 3.5 Over 87.5kV, not over 121kV 4 Over 121kV, not over 140kV 4.5

These distances are intended to provide protection from arc-over with a significant safety factor for employees who are familiar with construction and operation of overhead electric lines and the hazards involved.

NOTE: THESE DISTANCES DO NOT APPLY TO NON-ELECTRICAL WORKERS. Employees not trained to perform electrical work on overhead lines are not to be closer than 10 feet from electrical conductors without a safety watcher. (Oregon OSHA 437-03-165 Safety Watcher for Non-electrical Workers)

CAPACITORS

Circuits that contain capacitors, such as radio frequency (RF) equipment, store electrical charges that create very high potentials between their terminals. When the power to the system is turned off, the capacitors may remain charged unless grounded. Very high voltages may be involved but currents are usually quite low. The shock may therefore be painful and surprising but is generally not as injurious as a shock from an activated circuit. In addition, once the discharge occurs it is nonrecurring.

Safe practice is to provide resistance grounds to de-energize the system. If the resistance is high enough, it will prevent all charges from draining off, allowing the circuit to perform properly at its designed potential. When resistance is low, then discharge of capacitance will occur within a few seconds after the system is deactivated. De-energizing by grounding eliminates the possibility of a person being shocked by touching a charged capacitor.

All capacitors, except surge capacitors or capacitors included as a component part of other apparatus, shall be provided with an automatic means of draining the stored charge after the capacitor is disconnected from its source of supply.

Capacitors store electrical charge and can be a source of severe shock unless that charge is drained when the capacitors are disconnected from the power source. Unless some type of automatic discharge is designed into a system, devices such as resistors must be permanently attached across the terminals of the capacitors to drain the charge when the circuit is open (de-energized). Most capacitors are manufactured with this type of discharge resistor already built in. Surge capacitors, which act like lightning rods, do not require an automatic means for draining the charge.

CONFINED OR ENCLOSED WORK SPACE

It is prohibited to "blind reach" into areas containing live exposed parts. If the live parts cannot be seen, it would be difficult to avoid contact with them. Consequently if you cannot see the exposed parts because of obstructions or poor lighting then this work must not be permitted.

Some installations of electrical equipment provide little working space. Such cramped conditions can lead to an employee backing or moving into exposed live parts. To prevent this from occurring, precautions are required to be taken to assure that accidental contact with the parts does not occur. For example, protective blankets could be used to shield some of the live parts, or portions of the electrical installation could be de-energized. Also, doors and panels are required to be secured if they could knock into an employee and cause contact with exposed energized parts.

NOTE: Underground vaults or spaces that are not ventilated and have limited access such as a manhole entrance are not to be entered without a Confined Space Entry Permit. The permit system is designed to assure that adequate oxygen and no hazardous atmosphere exists. Further specific regulations on entry safeguards, training, and emergency retrieval are required. Contact your safety representative prior to planning an entry into a confined space that presents a hazardous atmosphere or lack of oxygen. See chapter 5.

CONDUCTIVE MATERIALS AND LOCATIONS

Handling ladders and other conductive materials in the vicinity of overhead lines is a leading cause of occupational electrocutions. To protect employees while handling conductive tools or materials near exposed live parts, the handling practices must be such that the equipment is prevented from contacting energized parts. Example, carrying long metal pipes in a horizontal plane if there are overhead energized conductors in the area.

Portable electric equipment used in highly conductive locations (those inundated with water) are to be approved for the use. This ensures that the equipment is appropriate for the serious hazards presented by the use of electric equipment in these areas.

LADDERS

Though electrical equipment may be installed according to all the regulations (NEC and Building Codes), an employee can still be exposed to electrical hazards. An unsafe work practice can increase the gravity of the hazards, which under normal conditions would be controlled and would pose no serious risk to the worker. For example, an employee carrying a ladder could approach exposed live parts that are guarded by installation above the normal reaching distance. An employee bringing the ladder close to the live parts exposes him or her to hazards much greater than those present under usual working conditions.

The OSHA regulations state that the portable ladder shall have nonconductive side rails if it is used where the employee or the ladder could contact exposed energized parts.

CONDUCTIVE OBJECTS

An employee must not wear conductive objects such as jewelry if it could come in contact with exposed live parts. These metal objects short circuit live parts; and, as current flows through the objects, the employee wearing them can be severely burned. Protective methods include wrapping the conductive apparel with nonconductive tape, the use of rubber gloves, and the use of insulation on the live part, as well as removal of the conductive object.

TEST EQUIPMENT

The use of test equipment can expose an employee to live parts of electric circuits. Consequently a visual inspection must be made of the test equipment before use. It must be repaired before using if the equipment is found to be damaged or defective. Using test equipment in improper environments or on circuits with voltages or currents higher than the rating of the equipment can cause the equipment's failure.

PROTECTIVE DEVICES AND TOOLS

When employees are working with electrical equipment, they must use safe work practices. Such safety-related work practices include keeping a prescribed distance from the exposed energized lines, avoiding the use of electric equipment when you or the equipment is wet, and locking out and tagging the equipment which is de-energized for maintenance.

Another important safety practice involves the use of electrical protective devices, such as rubber gloves and rubber mats for the purpose of insulation against live parts, or live-line tools for purposes of both insulation and manipulation of energized parts from a distance. However, to assure the protection of the worker, this equipment must be properly manufactured and maintained.

Along with the gloves the OSHA rules require wearing of non-conductive head protection whenever there is danger of head injury from electric shock or burns due to contact with exposed energized parts. Workers must also wear eye or face protection if there is a potential of injury to the eyes or face from electric arcs or flashes or from flying objects resulting from an electrical explosion.

Accidents occur every day in which persons are electrocuted because of lack of care when working near energized bare conductors. One of the most common causes of such electrical fatalities is contact with overhead lines. This can happen when using hoisting equipment.

When working near live parts it is important that the proper tools and equipment, specially designed for this work are used. Examples of these include insulating barriers and insulated aerial lifts.

Other types of protective equipment include, fuse handling devices, nonconductive rope, protective shields and barriers. This equipment must be used and be appropriate to provide protection for the work being performed.

FLAMMABLE OR IGNITABLE MATERIAL

Electric equipment can also be used under circumstances that pose unexpected hazards. For example, using an ordinary electric drill, a worker can ignite flammable vapors from a solvent being used nearby.

If flammable and ignitable materials are occasionally used in work locations, suitable protective measures must be taken against those hazards. Energized electric equipment where it might ignite flammable or ignitable material, are prohibited from being used unless suitable protective measures are taken. Protective measures include ventilation and clearing accumulations of combustible dust.

ALERTING TECHNIQUES

To inform employees about electrical hazards to which they are exposed, safety signs and symbols are required.

If it is necessary to prevent or limit employees' access to work areas where there are exposed energized parts, then barricades must be used. If the barricades don't work to keep employees out of the area then an attendant must be stationed at the barricade.