LAFAYETTE COLLEGE

Electrical Safety Program

Public Safety Department
Environmental, Health and Safety (EHS) Division
Standard Operating Procedure (SOP) #17

Purpose

The purpose of this SOP is to prevent electric shock or other injuries resulting from either direct or indirect electrical contacts, when work is performed near or on equipment or circuits which are or may be energized.

Scope

The scope of this program includes employees who may be exposed to electrical hazards from working on, near, or with:

- Any appliance or piece of equipment that uses electricity, either energized or de-energized.
- The wiring/circuits that supply this equipment including the building and premises wiring, wiring for connection to electrical supply from the point of use back to the point of generation.
- Installations of other outside conductors & optical fiber cable.

Exposed employees (see Table 1) are classified as either "qualified" or "unqualified" (see Definitions 1 and 2). Both must understand what this SOP requires, in addition to the basic points of electrical safety.

Table 1 – Typical Occupational Categories of Employees Facing a Higher Than Normal Risk of Electrical Accident
Occupation
Supervisors
Electrical and electronic engineers
Electrical and electronic equipment assemblers
Electrical and electronic technicians
Electricians
Industrial machine operators
Material handling equipment operators
Mechanics and repairers
Painters
Riggers and roustabouts
Stationary engineers
Welders

Note: Workers in these groups do not need to be trained if their work or the work of those they supervise does not bring them or the employees they supervise close enough to exposed parts of electric circuits operating at 50 volts or more to ground for a hazard to exist.

Excluded: The provisions of OSHA's electrical standard (1910.331 through 1910.335) do not apply to work performed by "qualified" persons on or directly associated with the following installations:

1. Generation, transmission and distribution of electric energy (including communication and metering) located in buildings used for such purposes or located outdoors. This work is covered by 1910.269.
2. Communications installations. Installations of communication equipment to the extent that the work is covered under 1910.268.
3. Installations in vehicles. Installations in ships, watercraft, railway rolling stock, aircraft or automotive vehicles other than mobile homes and recreational vehicles.
4. Railway installations. Installations of railways for generation, transformation, transmission, or distribution of poser used exclusively for operation of rolling stock or installations of railways used exclusively for signaling and communication purposes.

Definitions

- Qualified Person - anyone with specialized training in avoiding the electrical hazards of working on or near exposed energized parts. No one is considered qualified unless he or she has been formally trained and designated as such by Lafayette College Facilities Operations Department.
- Unqualified Person - anyone who may be exposed to the risk of electric shock in their duties, but are not permitted to work on or near exposed energized parts.

Responsibilities

- Department Heads will:
  - Ensure that appropriate supervisors and employees (new hires and transfers) are trained and knowledgeable in electrical safety as required by this standard.
  - Be familiar with this SOP and OSHA's electrical safety standard.
  - Follow the steps of this SOP.
  - Hold Supervisors accountable for following this SOP.

- Supervisors will:
  - Ensure that employees (including new hires and transfers) are trained according to the requirements of OSHA's electrical safety standard and the training section of this SOP (page 4).
  - Document the training on Public Safety's training roster, retain a copy and forward the original to Public Safety.
  - Follow the steps of this SOP.

- Public Safety will:
  - Review and update the College's Electrical Safety Program annually.

- Authorized employees will:
  - Attend training as required.
  - Follow the guidelines of electrical safety.

Training

The training required by this section shall be of the classroom or on-the-job type. The degree of training provided shall be determined by the risk to the employee.

- Qualified Persons
  Qualified persons shall be trained in how to avoid the electrical hazards of working on or near exposed, energized parts. They shall also be trained in the Electrical Safety-Related Work Practices (described in the next four sections) and any other safety measures that pertain to the electrical hazards of their jobs. A person can be qualified to work on certain equipment but unqualified to work on other equipment. Refer to the following section for more details.

  To be qualified to work on or around energized (50 volts or more) or de-energized equipment, parts or circuits, the employees must:

  - Demonstrate knowledge of the safety-related work practices/procedures for each of their specific tasks and/or each piece of equipment.
  - Know how to distinguish exposed live parts from other equipment parts and to use test equipment to determine the nominal voltage of these live parts, especially whether it is 50 volts or more.
  - Know the required clearance and approach distances for conductors and the voltages to which they may be exposed.

  An apprentice, who is supervised and trained by a qualified person and who is able to safely perform specific duties, is considered a qualified person only for those duties. The amount of supervision needed will depend on the apprentice's experience and the situation.

- Unqualified Person
  Unqualified persons do not have the training, or their job hazard level doesn't require the training, described above. They shall not work on energized parts of 50 volts or more. They can work on energized parts of less than 50 volts because the National Electric Code limits the amount of current that these circuits can carry. They must be given awareness-type training on the hazards of high voltages, grounding and the lack of it, arcing and any electrical safety practices that are necessary to do their jobs safety. Therefore, they should know who the qualified people are in the department so that they can ask them to do anything that involves opening equipment and creating an exposure to energized parts operating at 50 volts or more.

  The 50 volt exception is not an absolute criterion. In certain situations these lower voltages can have secondary effects such as falling off of a ladder if one is startled by such contact or burns from arcing.

  Students are considered unqualified because they shall not be permitted to work on or near exposed energized electrical equipment of 50 volts or more.

Selection and Use of Electrical Safety-Related Work Practices

Energized parts to which an employee may be exposed shall be de-energized, locked-out and tagged-out and verified as being de-energized before any employee works on or near enough to these electrical parts to expose themselves to any electrical hazard.

OSHA acknowledges limited exceptions to this regulation that are enumerated in the Work On or Near Exposed Energized Parts section on page 7.

1. **Working on or near Exposed De-Energized Parts**

   The OSHA regulation on Electrical Safety-Related Work Practices (49 CFR 1910.331-.335) and our Lockout/Tagout policy require that electrical equipment be de-energized, locked-out and tagged-out and verified as being de-energized before work can proceed. These OSHA required Electrical Safety-Related Work Practices shall be used by everyone at Lafayette to prevent injuries and deaths caused by electric shock.

   The specific work practices that are chosen for a task should be consistent with the level of hazard and must eliminate or minimize the hazard(s). Refer to the written standard operating procedures (SOPs) that are available from your supervisor, that are in your department's safety plan, or call the Public Safety Office, Environmental, Health and Safety Division at X-5330 for advice in choosing the appropriate work practices.

   Before working on or repairing parts/equipment (energized or not), unqualified persons must review their plans with their supervisor and may be required to work with a qualified person.

   If a qualified person doesn't lock out/tag out de-energized parts, then that qualified person must use the same precautions as working on energized parts/equipment. Written procedures (for specific equipment) that must be followed are available from your supervisor.

   <u>Before Working on Electrical Equipment</u>
   Non-qualified persons must review any proposed work with a "qualified person" before repairing or working on energized, (less than 50 volts and low current) electrical equipment. Then they may need to be supervised by a qualified person. The qualified persons in your department who can review and/or safely perform certain electrical tasks/repairs can be contacted through your supervisor.

   Determine the safe way to de-energize before proceeding. Safe techniques include:
   - Unplug the equipment and tag the plug.
   - Open and Lockout/Tagout the circuit breaker or safety switch.
   - Do not rely on control switches and interlocks. They don't provide the same protection as Lockout/Tagout because these do not protect you from inadvertent re-energization. Lockout/Tagout is still required.
   - Disconnect/de-energize/isolate all sources of electricity supplying live, exposed, electrical parts/equipment.
   - Ask a qualified person to de-energize if the equipment or circuit has 50 or more volts and the equipment can't be unplugged. This qualified person must use the same

precautions as working on energized equipment until the equipment has been de-energized, locked- and tagged-out and verified as being de-energized.

If applicable:

- Release stored electrical energy (charges and capacitive voltage), which could endanger personnel using the same precautions as working on energized equipment. For example, discharge capacitors before working on the equipment.
- Block or relieve stored non-electrical energy, which could re-energize parts, using the same precautions as working on energized equipment. For example, mechanical, steam and water.

2. Application of Locks and Tags (Lockout and Tagout)

In conformance with OSHA regulations and our Lockout/Tagout policy both tags and locks are required to be used on each means of disconnecting the power to equipment/circuits.

All equipment shall be considered energized until it is de-energized, locked-out/tagged-out by a qualified person and they have verified that it is de-energized.

Tagout Only

Before a tag may be used without a lock, the following must be done:

- Determine that a lock can't be used.
- Demonstrate that the tag will provide the same level of safety as the use of a lock.
- Supplement the tag with at least one other safety measure to ensure that operating the tagged device will not energize the equipment or circuit (tags alone are not considered as effective as locks).
- Examples of supplementary measures:
    - Open another disconnect that can be locked-out/tagged-out.
    - Remove a circuit element.
    - Block a control switch.
    - Have someone stand by the disconnect device to prevent accidental actuation.

Lockout Only

A lockout may be used without a tag only under the following conditions:

- Only one circuit or one piece of equipment can be de-energized.
- The lock-out period doesn't extend to the next work-shift.
- The exposed employees (qualified and unqualified) are familiar with the SOP

3. Verification of De-Energized Condition

After equipment is de-energized and locked-out/tagged-out, a qualified person must do the following before any circuits/equipment can be worked on as de-energized:

- Use safe test procedures/precautions as if working live until this verification is finished.
- Verify that the equipment will not start.
- Use test equipment to check that the equipment/circuit are de-energized and that all electrical supply sources have been isolated.
- Verify that the test equipment is operating properly before and after each use.

When the above has been completed, any employee may work without using the protective equipment and clothing required for working on energized electrical equipment.

4. Re-Energizing Equipment

When the job is finished, employees must follow the written safety procedures, in the order listed below, before re-energizing. This is to ensure that no one will be hurt when the Lock-Out is removed and the equipment is re-energized.

- A qualified person must inspect the area to ensure that all materials and tools are clear of the equipment/circuit.
- Warn qualified and unqualified people in the area to stay away from the equipment/circuit that is going to be re-energized.
- Remove Lock/Tag. This should be done by the employee who applied it. If it is determined that this person is not available at the workplace follow the instructions in our Lockout and Tagout procedure.
- Visually determine that no one is near the equipment just before re-energizing. Use radios if the area can't be seen.
- If 50 or more volts are involved, ask a qualified person to re-energize.

5. Work On or Near Exposed Energized Parts

Energized equipment can be worked on/repaired only when it meets the test of the following OSHA permitted exceptions:

- The employer can demonstrate that additional hazards (life-threatening) may be created. For example:
  - fire and emergency alarms
  - life-support systems, (may include animal facilities)
  - ventilation of hazardous locations (fume hoods)
  - removal of illumination
  - testing of circuits that can only be done energized
- It is unfeasible due to equipment design.
- The equipment is operating at less than 50 volts to ground.
- Only Qualified Persons will work on energized equipment/parts of 50 volts or more. A Qualified Person is anyone with specialized training in avoiding the electrical hazards of working on or near exposed energized parts. No one is considered qualified unless he or she has been formally trained and designated as such by Lafayette College Facilities Operations Department.
- If the task has been reviewed and formally approved in writing by a supervisor or another person designated and qualified to approve such work. Supervisors should not grant any exception without first considering and rejecting alternative methods.
- If all the OSHA required protective measures are done.

6. Overhead Power Lines

This is a special case. Supervisor must consult with the Public Safety Office because further consideration of OSHA standards is necessary before assigning this type of work.

7. Illumination

Do not enter/work in any area with exposed live parts if the illumination is too dim.

8. Confined or Enclosed Work Spaces with Energized Parts

Protective shields, barriers, or insulating materials must be provided and used to avoid accidental contact with energized parts. Secure doors (etc.) to prevent them from swinging and pushing an employee into energized parts.

9. Conductive Materials and Equipment

Employees must safely handle conductive materials to avoid accidental contact with exposed, energized parts.

10. Portable Ladders

These must be non-conductive fiberglass, etc.

11. Conductive Apparel

Employees must remove all metal watches/bands, jewelry, key chains, metal headgear, conductive clothing and personal protective equipment if they may be exposed to energized parts. This is to prevent severe burns that could result if current flows through conductive apparel.

12. Housekeeping/General Maintenance

Generally, exposed energized parts shall be de-energized, locked out, etc. before employees may do housekeeping or maintenance (this includes tasks like pesticide spraying and tree trimming). When it isn't possible to de-energize, lock out, etc. before working near exposed energized parts, the supervisor must provide adequate safeguards, like insulating equipment or barriers. In this case, employees may not use electrically conductive cleaning materials, tools, or solutions unless precautions are taken to prevent electric shock.

13. Defeating Interlocks

This can be done only under the following conditions:

- A qualified person follows the SOP for working on or near exposed, energized parts
- Temporary basis--while the qualified person is working on the (normally interlocked) equipment.
- Before the equipment can be left unattended, the interlock must be restored.
- When the work is completed, the interlock must be tested to verify that it is functioning and it provides an adequate level of safety.

Use of Portable Electric Equipment

This section applies to cord and plug-connected equipment and extension cords.

1. **Handling Guidelines**

    - Do not raise or lower equipment using the cord.
    - Do not use staples to fasten a cord.
    - Do not damage the equipment's casing or the cord's insulation.

2. **Inspect Before Use**

    - Check for external and internal defects.
    - Remove damaged equipment from service by attaching a "do not use" or similar tag and giving it to your supervisor.
    - Before plugging into a receptacle or an extension cord, check that these match (3 prong or polarized 2 prong are preferred)

3. **Grounding-Type Equipment**

    - Use cords with 3 prong plugs. The continuity of the grounding conductor may not be disrupted by cutting off the third prong or by using adopters, attachment plugs, receptacles, etc.

4. **Work Locations that Contain Conductive Liquids**

    - Employees must use ground fault interrupters, (GFIs, either extension cords or receptacles) when working with portable electrical equipment in areas that are flooded or where contact with conductive liquids is likely (pools, basements, man-holes).

5. **Connecting Attachment Plugs**

    - Employees must have dry hands when plugging in/unplugging energized portable equipment and/or extension cords into receptacles.
    - Employees must wear insulated gloves and other personal protective equipment if the cord or receptacle is wet.
    - Locking-type connectors shall be properly secured after connection.

Electric Power and Lighting Circuits

1. **Routine Opening/Closing of Circuits**

    - Employees must use properly designed devices (circuit breakers, load-rated switches, etc.) to open, reverse and close circuits under load.

2. **Emergency Procedures**

- Consult with your Supervisor and Environmental, Health and Safety.

3. **Reclosing Circuits after Protective Device Operation**

   - Before closing circuits that were tripped by a fault condition (not an overload), employees must determine if it is safe to manually energize the equipment and/or circuits that were de-energized by a GFI, circuit breaker surge protector or other circuit protective device.

4. **Modifying Overcurrent Protection**

   - Employees shall not do this, even temporarily.

5. **Test Instruments and Equipment (refer to Verification of De-Energized Conditions)**

   - Only qualified people may test circuits/equipment.
   - Visually inspect the test equipment before using it.
   - Remove damaged equipment from service.

6. **Rating and Design of Test Equipment**

   - Must be appropriate to the environment where the equipment will be used.

7. **Use of Flammable Liquids**

   - Consult with EHS to discuss plans to use flammable liquids and consider safer alternatives.

Safeguards for Personnel Protection

1. **Use of Personal Protective Equipment**

   Employees shall be provided with and shall wear all personal protective equipment that is appropriate for their work, such as when they may be exposed to energized parts, arcs, flashes, explosions, etc. They shall wear:
   - Approved, non-conductive head protection
   - Approved eye and/or face protection

   Periodically, inspect, test and maintain personal protective equipment in a safe condition. Insulating personal protective equipment shall have an approved, protective outer layer.

2. **General Protective Equipment and Tools**

   When working near exposed, energized parts, employees shall only use insulated tools and handling equipment such as the following:
   - Tools that are in good repair, double-insulated, and grounded
   - The insulating material must be protected from damage

- Insulated, fuse handling equipment (when working with energized fuses)
- Non-conductive ropes and hand-lines (caution--wet ropes are conductive)
- Protective, insulated shields/barriers

3. Alerting Techniques

Use the following to warn and protect everyone from electrical hazards:

- Signs and tags (refer to the Lockout/Tagout section).
- Both non-conductive barriers and signs to limit access to exposed, energized parts, conductors.
- Guards or attendants in addition to the above means if these will not provide adequate protection.

Appendix A – Electrical Hazards

Electric Shock
Shock happens when the body becomes part of an energized electrical path and energy is transferred between parts of the body, or through the body to a ground or the earth.

In order for shock to occur, a potential difference or stored electrical charge must be present to cause the current to flow. Current flowing through the highly sensitive central nervous system can, under certain conditions, cause serious injury to death. Some of the conditions which govern the severity of a shock are mentioned below.

Type of Current
The type of current involved alternating current (AC) or direct current (DC) is important. Low voltage up to 40 volts, of direct current (DC) circuits does not normally present a hazard to human life. Under some circumstances, however severe burns can result (See Table 1, which summarizes some possible effects on the body when the current path is from hand to hand). Even at low voltage, alternating current (AC) circuits can be dangerous and present a lethal threat.

At commercial frequencies (50-60 cycles or hertz) and intermediate voltages (50 to 600 volts), lethal current may be conducted through the body (See Tables 1 and 2).

Resistance
The resistance of the body and the degree to which the skin is insulated from the ground govern the amount of current flowing through the body. The skin offers the principle resistance which the human body presents to the flow of current. Table 2 shows how skin resistance decreases with increased voltage. Current flow through the body is also given with resultant body sensations noted. The current path is from hand to hand, with the palms of the hands moist. If the skin is wet or moist, the resistance is lowered (See Table 3) and therefore the greater flow of current and the severity of shock.

Time
The length of time the body is in the circuit is also important, particularly with respect to the severity of burns. Burns break down the skin, thereby lowering the resistance. The more extensive the burn, the less resistance provided.

Time becomes critical when current flowing through the body causes loss of muscular control, contraction of the chest (which affects breathing), and ventricular fibrillation of the heart. When the last occurs, the heart's pumping rhythm becomes irregular and it ceases to function properly. Table 1 shows the effect of time and current on fibrillation thresholds at 60 hertz or cycles.

Current
Both the magnitude and path of the current flowing through the body are of primary importance. When the path of the current is hand-to-hand or hand-to-foot, vital organs (brain, heart, lungs, spinal cord) are affected, possibly with serious consequences.

The age and physical and emotional condition of the person involved can also effect the severity of an electrical shock.

Emergency Measures for Shock

Everyone engaged in electrical or electronic work should be capable of carrying out the following measures:

- Contact emergency personnel when necessary. Call Public Safety at (610) 330-4444.
- Free any person involved from the live circuit. If a person is "frozen" to a live electrical contact, shut off the current if possible. If this cannot be done, use wood boards, poles, or sticks, a belt, piece of dry rope, an article of clothing, or any non-conducting material of sufficient length to pull the body away from the contact. Act quickly, and remember to protect yourself during this operation.
- Cut off the power. Because of the dangers involved in being caught in a live circuit, know how to cut off the power anywhere in your work area.
- Immediately report any shock received, no matter how slight, to your supervisor or appropriate authority. Promptly report any "popping" or sparking as well as any noticeable defects or hazardous conditions that could cause injury, property damage, or interference with service.

Other Hazards

- Electric arcs can generate enough energy to cause shock, sufficient heat to cause severe burns, and ample ultraviolet light at certain wavelengths to cause serious and painful injury to the eyes even after a very brief exposure.
- To avoid such injuries, never close a switch or circuit breaker slowly or hesitatingly, (as arcing may occur) and keep your face turned away to avoid exposing your eyes and skin.
- Vacuum and cathode ray tubes present a danger of possible implosion. Wear eye and face protection when handling them.
- Soldering requires use of safety glasses or eye shields.
- Lift power supplies, oscilloscopes, chassis, and other heavy materials in such a way as to prevent back strains and hernias.
- Tripping hazards can be avoided by running power cables in cableways, beneath floors, or overhead.

Table 1: Effects of Electrical Current on the Human Body (current in milliamperes)						
	Direct Current (DC)		Alternating Current (AC)			
			60 Hertz		10,000 Hertz	
Effect	Men	Women	Men	Women	Men	Women
Slight sensation on hand	1	0.6	0.4	0.3	7	5
Perception threshold	5.2	3.5	1.1	0.7	12	8
Shock – painful, muscular control not lost	62	41	9	6	55	37
Shock – painful and severe, let go threshold	76	51	20	10.5	75	50
Shock – painful and severe, muscular contractions, difficulty breathing	90	60	23	15	94	63
Shock – possible ventricular fibrillation effect from 3 second shock	500	500	100	100		
Short shock lasting "t" seconds			165/t	165/t		
High voltage surges	50	50	13.6	13.6		
*energy "n" watt-seconds or joules						

Table 2: Human Resistance to Voltage			
Applied Voltage (60 Hz)	**Resistance (Ohms)**	**Current (milliamperes)**	**Effect**
10	10,000	1	Tingling
20	10,000	2 – 2.4	Strong tingling
30	2,500	12 – 15	Painful, muscular contractions
40	2,000	19 – 22	Extremely painful

Table 3: Human Resistance to Electrical Current	
Body Area	**Resistance (Ohms)**
Dry skin	100,000 – 600,000
Wet skin	1,000
Internal body, hand, and foot	400 – 600
Ear to ear	About 100

Appendix B – Electrical Hazard Prevention

When working with or around electrical equipment you should assume responsibility for your own safety and that of those working with you. The following information, principles, and good working practices will help you to avoid electrical shock and injury.

Proper Wiring

- All new, permanent, or temporary electrical installations, or the replacement, modification, repair or rehabilitation of any electrical installation must be made in compliance with the requirements of the National Electrical code (NEC) of the National Fire Protection Association (NFPA).

- Every effort must be made to eliminate potential hazards in research or development work that involves the design and construction of new systems so that equipment or apparatus will function safely in normal operations.

- Electrical power distribution systems must be equipped with over-current protection such as fuses or circuit breakers, which must never exceed the rated capacity of the circuit.

- All other sources of electrical potential for either service or experimental work must also be adequately fused and grounded.

- All newly installed receptacles must be of the grounding type.

- Multi-outlet bench strips must be grounded and should be equipped with fuses and pilot lights. They must be properly affixed to a bench, or chassis frame.

- A switch must be provided in a readily accessible and convenient location for disconnecting the main power to apparatus in the event of an emergency. This switch must be legibly marked to indicate voltage, current, wattage, and the equipment it controls, unless it is located and arranged so that its purpose is evident. Everyone working in the area or on the particular project should know where the switch is located.

Grounding and Bonding

- Grounding eliminates a difference in electrical potential between a conductive object and the ground by connecting them. Grounding will protect you from electrical shock by providing a path which offers less resistance to the current than you do. Bonding eliminates a difference of potential between conductive objects.

- All exposed non-current-carrying metal parts of fixed and portable equipment which are liable to become energized must be grounded.

- Ground paths from circuits, equipment, and conductor enclosures must be permanent and continuous, having ample current-carrying capacity, and their impedance be low enough to facilitate the operation of over-current devices in the circuit (Article 250-51, NEC).

- Bonding keeps separate pieces of conducting material at the same grounded electrical potential. All conducting material, such as metal floor plates, equipment chassis, bench tops, tables, piping, and conduits, should be bonded to each other.

- Use suitable lugs, pressure connectors, clamps, or other approved connecting means. Connections that depend upon solder must not be used in grounding or bonding.

- Where an adapter must be used to fit an old, ungrounded outlet, attach the pigtail on the adapter to the face plate screw before plugging in the adapter. Contact Public Safety EHS when this condition is discovered. Then the department should make arrangements with Facilities Operations to have the receptacle replaced with a grounded type.

- Ungrounded electrical fixtures or equipment should be located so that a person cannot touch them and a water pipe or other grounded object at the same time.

Insulation

- If you work continually with or around electricity, you should wear rubber-soled footwear to guard against slipping and to provide insulation.

- Use rubber floor mats and adequately insulated tools when working with "hot" lines or equipment.

- When working on high-voltage equipment, have properly rated gloves and matting available for protection.

- Checks the voltages stamped on the gloves and never use them for higher voltages. Also make sure that the gloves are in good condition. They can be checked by holding the end closed and forcing air into the fingers; this enables you to see the cracks or spots that are worn thin. Discard the gloves if these are visible. Never use unstamped gloves.

- Portable tools or appliances protected by an approved (Underwriters' Laboratories, Factory Mutual) system of double insulation or its equivalent need not be grounded. Where such a system is employed, the equipment must be distinctly marked.

- Many devices are equipped with commutators; these commutators and contacts can cause a lethal shock if soaked by rain or immersed in water.

Isolation

- All electrical equipment or apparatus that may require frequent attention must be capable of being completely isolated electrically.

- Live parts on electrical equipment operating at 50 or more volts or 10 joules must be guarded by approved means against accidental contact (OSHA).

- Enclose all power supplies so that accidental bodily contact with power circuits is impossible. All access doors must be provided with interlocks which will disconnect all power to conductors and short out capacitors when any access door is opened.

- In every experimental setup, provide an enclosure to protect personnel against accidental contact with electrical circuits. Enclosures must be provided, even in temporary arrangements.

Lockout

- Before you start work on any system or circuit, it is your responsibility to make a personal inspection to assure yourself that it is de-energized. Opening a switch is not enough. To insure that all appropriate systems are isolated it is necessary that all possible sources of power be investigated and de-energized.

- To isolate a system and guarantee that it remains de-energized, OSHA requires that all appropriate disconnecting switches be locked open and tagged with the name of the individual responsible. These locks and tags must be removed only by the person who placed them on the switches.

- Before anyone begins work on a de-energized circuit or system it should be checked out by the use of a reliable voltage tester or other appropriate device to verify that it is "dead".

- After making repairs or alterations, never close a circuit until all personnel are clear of mechanical equipment and circuit breakers. Do not close and switch until you are certain that it is safe to energize the circuit and all of the equipment on it.

- Before putting equipment to use, test for adequate insulation resistance and ground connections.

- Always close and open circuits with apparatus suitable for the circuits involved.

- Never work alone around energized electrical equipment.

- Keep personnel away from dangerous situations or places unless their work requires them to be there.

Safe Work Practices

- Keep hands off connected electrical apparatus with which you are not directly involved or familiar.

- Do not permit unauthorized people to work in hazardous areas. Do not hesitate to question unfamiliar faces. Institute employees entering areas in which they do not usually work should check with whoever is in charge, state their reasons for being there, and receive clearance to perform their duties or to visit.

- Question the methods or procedures of fellow workers if they violate any safety practices or otherwise work in an unsafe manner.

- Provide signs and barriers to warn people of high voltage hazards, particularly on breadboard setups. Use danger signs and flashing lights wherever conditions require them. They should

not be used promiscuously, or left where danger no longer exists, as this detracts from their effectiveness.

- Maintain safe working distance around energized equipment at all times. A minimum of 30 inches widths should be maintained on all working sides of equipment operating at 600 volts or less.

- A neat, clean work space is essential where work on electrical equipment is to take place. Space behind and under consoles or power supplies should never be used for storage, and always be kept clear of rubbish or unnecessary equipment.

- Equipment which is found to be defective should be labeled as such before storing. List defects on a tag. The tag must remain on this equipment until it is repaired, junked or dismantled.

- Safe wiring practices call for the use of appropriate insulation, adequate spacing, and proper placement of conductors. When selecting an area for circuits and grounding, avoiding dangerous locations. The electrical assembly must be installed in a neat and professional manner. Work deliberately and carefully. Verify your connections as you proceed and be sure that they are secure.

- Avoid exposed wiring and placing any part of your body in a circuit, either to ground or across terminals.

- Always connect from the load to the source. Disconnect first at the source and work toward the load.

- Check the supply circuit voltage to see that it is what you expect, either AC or DC - before closing circuits.

- Avoid using electrical equipment or tools where there is moisture present. If it is unavoidable to do so, use ground fault circuit interrupters.

- Rigidly observe the "one hand" habit when throwing open switches, removing leads, pulling plug leads from apparatus such as terminal distribution boards, operating line power rheostats, measuring volatiles, or when testing circuits where any voltage may be present.

- Do not wear rings, metal wrist bands, watches, key chains or other metal objects around exposed conducting material.

- Do not use metal rulers, metal flashlights, or metallic pencils when working with or around electricity.

- Use a fiberglass ladder instead of a metal one, if work requires the use of a ladder around electrical equipment.

Appendix C – Capacitor Discharge

Provisions should always be made to discharge capacitors capable of storing more than 0.1 joule when shutting down equipment.

It has been found that a discharge of energy exceeding 10 joules into the human body can be hazardous to life, while 0.25 joule gives a heavy shock.

Keep each spare of disconnected capacitor individually short circuited, by a robust connection, when not in use. Similarly, capacitors built into equipment which is not in use must also be individually short-circuited, as they present a shock hazard from discharge, whether wired in series or parallel. Remember that "new" capacitors have already been energized for test purposes, and should also be kept short-circuited when stored.

All high-grade capacitors, if left on an open circuit after discharge, will recover a considerable proportion of the original charging energy. This is particularly true of large-energy storage capacitors, such as those used in pulsed capacitor banks. As much as 10% of the original voltage may be recovered, and 30-kilovolt capacitor may build up as much as 2 or 3 kilovolts in 10 minutes. Dangerous voltages can build up in open-circuited high-capacitors over a period of many months after they have been discharged. This is particularly true where inexpensive paper dielectrics have been used.

It is recommended that all discharged capacitors carry a label adjacent to their terminals, for example, "WARNING: Keep short-circuited when not in use."

Appendix D – Electrical Fires

Fires can have electrical causes. The following are some possible sources of electrical fires and ways to prevent them from becoming hazards:

- Soldering irons should be disconnected when unattended and not in use. Keep them in metal holders when in use. Bench tops should be made of fire-resistive material.
- Motors should have thermal protection devices to protect them against excessive heating due to motor overloads or failure to start [Article 430(c), NEC].
- Ignitable materials should not be stored in electrical closets [Article 240-16(c), NEC].
- Poor contact between plugs and receptacles can cause arcing, leading to a serious fire hazard. Make sure that contacts are secure.
- Overload circuits can, by overheating, be a cause of fires. Do not overload them by using extension cords or cube taps.
- Static electricity is generated when a fluid flows through a pipe into a tank. When the fluid is a flammable liquid, the vapors can be ignited by a spark discharge caused by static electricity. Grounding and bonding of flammable liquid containers is necessary to prevent static electricity from causing an explosion or fire.
- Make special provisions for electrical service or equipment installed in areas where hazardous mixtures of explosive gasses, vapors, or dust are present (Article 500, NEC). Specially designed equipment is available for use in these and other hazardous locations. Explosion and dust-proof equipment, intrinsically safe circuits, purged enclosures, and positive ventilation are most commonly used. Use equipment of this type in and around:
    - Solvent and flammable liquid storage rooms
    - Paint spray booths
    - Ventilating systems
    - Compressed gas storage
    - Motors for stirrers of flammable liquids and oil baths
    - Centrifuges used for flammable liquids
    - Exhaust fan motors
    - Refrigerators storing flammable liquids

Appendix E – Ground Fault Circuit Interrupters (GFIs)

Circuits and equipment monitored by fixed or portable GFIs are intended to offer personal protection against electrical shock. If you should contact a GFI-protected circuit conductor or energized surface while part of your body is grounded, the GFI will respond by cutting off power before shock or serious injury can occur.

Ground Faults
Ground faults occur when current-carrying parts of a circuit accidentally contact any grounded conducting material. GFIs provide electric shock protection against this type of accident.

High-current ground faults cause an immediate massive current flow to ground. This current, being lower than the rating of the fuse or circuit breaker, will not cause over current devices to cut off the circuit power. Low-current ground faults of 60 cycles (AC) can be extremely dangerous. Just 0.01 of an ampere (10 milliamperes) can freeze a victim to a power source until the amount of current received reaches lethal proportions. If the current passes through the heart, breathing may become arrested at 18 milliamperes. If the current increases to 60 milliamperes, ventricular fibrillation of the heart can occur. A house current of 60 milliamperes can kill a person in seconds.

GFI Operation
This device monitors both the current flowing to the load (hot wire) and the current flowing from it (neutral wire). Under normal circumstances, these should be equal. When a ground fault occurs, the GFI senses an imbalance between the hot and neutral wires, caused by the leakage of current to ground, and trips out, cutting off the supply of current. Most GFIs are designed to trip within 30 milliseconds after current imbalance of only 5 milliamperes or more had been detected. While harmless, even the common 5-milliampere trip-level shock can have hazardous secondary effects caused by reflex actions or the body (for instance, falling off a ladder).

Portable and fixed GFIs are available in various type and trip levels. Devices can be purchased that will trip at levels as low as 0.2 milliamperes or as high as 20 milliamperes.

Protection not provided by GFIs
GFIs will not provide protection if you should contact the hot and the neutral wire while you are not grounded (line-to-line short). As the current through you is not flowing to ground, the GFI will not operate, and you will be at the mercy of the system's overcurrent protection devices. These will trip only if the current is high enough (overload) and serious damage to you may occur before they go into operation. However, should some of the current passing through the body also flow through a grounded object to the earth or ground (simultaneous fault) the GFI will trip the circuit open as with a normal ground fault.

The GFI also will not work if faults in another line circuit occur. If a saw or drill penetrates wiring of a circuit other than the one supplying its own power, the operator can be aided only by the protective devices in the penetrated circuit. GFIs or over current devices in the circuit supplying the tool cannot stop this flow of current.

GFIs have proved so efficient in a variety of applications that there is a tendency to place undue reliance on them as a source of protection. It should be emphasized that this device, while extremely reliable, is not designed to be failsafe should an internal failure develop. The installation of a GFI does not obviate the need for recognized practices and procedures developed through the years to insure safe electrical work.

Where GFIs May be Used

Electricity is not limited to following the path of least resistance; it will take every other route to ground open to it. Operators of equipment can be subjected to shock hazards due to fault grounding, worn insulation, or bypassed isolation methods. GFIs can minimize the hazards caused by these conditions, and they must be used as follows:

- For residential occupancies all 120-volt, single-phase, 15- and 20-ampere receptacle outlets installed outdoors and in bathrooms must have approved ground fault circuit protection for personnel [Article 210-22 (d) NEC].
- All outdoor receptacles located between 10 and 15 feet of the inside walls of a swimming pool must be protected by GFIs (Article 680-6 NEC).

GFIs should also be used in the locations and on equipment listed below:

- Underground installations, or concrete slabs or masonry in direct contact with the earth.
- Locations exposed to weather.
- Partially exposed areas (under canopies or roofed open shelters) and locations subject to a moderate degree of moisture.
- Outdoor receptacles, or any receptacles that are used by an operator standing on the ground.
- All electrical equipment mounted in or on tow tanks, pools, docks, or in any body of water where the possibility of human contact with water and leakage current exists.
- On all receptacles within 10 to 15 feet of the preceding items.
- In all damp or wet locations, such as basements, or in rooms where water pickup using powered water vacuums or electric cleaning equipment (as in showers) is required.
- In conductive locations (inside metal tanks, ducts, or boilers) or in any area where a person can be easily grounded.
- In vehicle repair or washing area.

Appendix F – Extension Cords

One of the most frequently occurring violations cited during safety inspections is the use of extension cords. This problem is common to all areas of activity. Because of its universal nature, the use of extension cords is an issue that needs clarification and guidelines in determining the permissibility of its usage.

The National Electrical Code (NEC) does not refer to extension cords specifically but does assign the concept other names where appropriate specifications are outlined. As commonly used, extension cords are alluded to in the NEC in an oblique manner where their utilization is either in violation of, or in compliance with one or more stated NEC standards. It would be beyond the scope or intent of this outline to attempt any detailed defining of all the above stated standards mentioned in the NEC.

THE NEC STANDARDS MAY BE SUMMED UP IN A GENERAL WAY BY SAYING THAT THE USE OF AN EXTENSION CORD REPRESENTS A CONFLICT WITH THE CODE BECAUSE IT SERVES AS A SUBSTITUTE FOR A RECEPTACLE THAT SHOULD BE LOCATED NEAR THE APPLIANCE OR EQUIPMENT.

The primary consideration in determining the legal application of extension cords is that they are intended for temporary use with portable appliances, tools and similar equipment which are not normally used at one specific location. When using extension cords and their connectors care should be taken to insure that they are of the proper type and rating for their particular location as a normal source of supply indicates the need for a permanent receptacle outlet. Equipment being supplied by the cord must be properly grounded where applicable. Listed below is a guideline which can be applied to the use of extension cords and their related equipment.

- Extension cords shall be used only as temporary extensions for portable equipment. These devices may be acceptable in applications where they supply equipment not routinely used in an area where permanently wired receptacles are not available or installed.
- Cords shall be unplugged when not in use and never left plugged in while unattended.
- Extension cords and their plugs shall be or a type suitable for the application, location and conditions under which they are to be used.
- Zip cords and light extensions made up of AWG 18 wire are rated for only 6 to 10 amps. In normal use these zip cords and light extensions are plugged into a 20 amp fused line and therefore offer no over current protection and are susceptible to overheating thereby creating a potential fire hazard when supplying loads nearing their rated current.
- All cords and plugs should be maintained in a safe condition. Splices are prohibited. Worn out cords should be replaced.
- Cords should be checked for proper strain relief connections to the plug so that tension will not be transmitted to the joints or terminal screws.
- Plugs should be checked to insure that the covers for wire terminations are mechanically secure.
- This equipment must be use in a safe manner, so as not to constitute a tripping hazard.
- Cords should not be draped near open flames nor used in areas where chemical or other physical damage may be a danger, not wet locations which increase the potential shock hazard.