TRAINING & QUALIFICATIONS PROGRAM OFFICE BROOKHAVEN NATIONAL LABORATORY	Course Code: OSH150C Control No.: 01 Revision No. 1

ELECTRICAL SAFETY 1 STUDY GUIDE

Electrical Safety 1

Study Guide

for the

Challenge Exam

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Electrical Safety 1
Study Guide

Course Objective:
Describe engineering and administrative controls for minimizing electrical hazards in accordance with BNL's ES&H Standard 1.5.0, Electrical Safety and applicable electrical codes and regulations.

Enabling Objectives:

- Identify various common elements in electrical accidents. State several human effects of electrical shock.
- List the actions to be taken in the event of an electrical injury to an individual.
- Define proper grounding.
- Explain the importance of proper grounding.
- Explain how a ground fault can result in an electrical shock hazard.
- Explain capacitor and inductor hazards.
- List the Electrical Worker Categories
- Explain the purpose of lockout/tagout (LOTO)
- Define what is a Critical System.
- Explain the purpose of a Control Zone.
- Define "Working Hot" and when a working hot permit is required.
- Describe electrical warning signs and devices.
- Identify various general safety guidelines for working around electrical systems and equipment.
- Explain the importance of using approved flexible cords.
- State several safety requirements for design and construction.
- Describe what is a "Classified Hazardous Location"
- List several non-approved cleaning materials.
- Define conditions contributing to static electricity hazards.
- Describe devices that have low voltage with high current hazards.
- List the steps to take in handling an electrical fire.

Introduction
In an effort to increase employee awareness of the hazards involved, Brookhaven National Laboratory requires that all personnel who work on or near electrical equipment and could possibly come in contact with an energized conductor, be trained on electrical hazards and how to avoid them.

The BNL Electrical Safety Program was established to meet the needs and requirements of several electrical safety documents, including:

- DOE - Department of Energy (Electrical Safety Handbook)
- OSHA - Occupational Safety & Health Administration (Subparts O, R, and S)
- NFPA - National Fire Protection Association (National Electrical Codes)
- ANSI - American National Standards Institute (National Electrical Safety Code)

To respond to these requirements, the BNL Laboratory Electrical Safety Committee established the present BNL Electrical Safety Program and Electrical Safety Standards, which include:

- ESH 1.5.0 Electrical Safety
- ESH 1.5.1 Lockout/Tagout Requirements

- ESH 1.5.2 Design Criteria for Electrical Equipment
- ESH 1.5.3 Interlock Safety for Protection of Personnel

Each member of the Laboratory Electrical Safety Committee is experienced in electrical safety matters. Membership includes representatives from Safety and Health Services, Plant Engineering, and operating line organizations.

The BNL Laboratory Electrical Safety Committee:
- Acts as the "Authority Having Jurisdiction" for all electrical safety issues as defined by the National Fire Protection Association (NFPA).
- Periodically reviews the BNL Electrical Safety Policy and associated SBMS Standards.
- Acts as the principal Advisory Committee to the BNL Directorate, Safety and Health Services Division staff, and to individual operating organizations on electrical safety issues, lockout/tagout, and interlock systems.
- Reviews electrical accident and incident reports for applicable "lessons learned."
- Reviews and approves the objectives and content of BNL electrical safety-related training programs.

The Laboratory Electrical Safety Officer (LESO) acts as the authority having jurisdiction in the field and reports back to the Laboratory Electrical Safety Committee.

The LESO:
- Provides clarification and guidance to BNL organizations regarding the interpretation and implementation of the codes and standards listed above.
- Provides clarification and guidance on the need for written procedures for electrical work, lockout/tagout, and working hot permits.
- Approves submitted procedures for personnel protection from electrical hazards.
- Assists line organizations with training in organizational working-hot procedures when requested.
- Reviews annual Critical Systems List updates that are submitted by line organizations.
- Maintains all files of the Laboratory Electrical Safety Committee and BNL electrical safety documents.

Accident Statistics
The National Center for Health Statistics estimates there are approximately 1,000 electrocutions per year. Electrocution is the fifth leading cause of death in the workplace, after motor vehicle accidents, homicide, industrial equipment, and falls.

Each year, more than 200 electricity-related reportable incidents occur at DOE Laboratories. It was noted in a recent DOE Electrical Safety Conference that while the overall number of industrial accidents is decreasing, the number of electrical fatalities is increasing.

Why do these incidents occur? Electrical incidents occur from failure to install covers and guards, improper installation or use of equipment, incomplete reviews, or faulty designs and poor maintenance.

Some examples include:

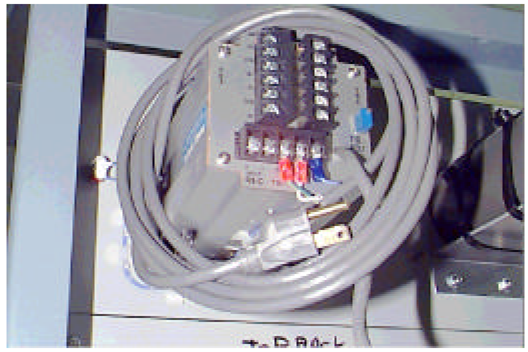


Figure 1. Power circuit and exposure to potentially energized terminals.

Figures 2 and 3. Improper installation or use of equipment, power supply cord and power control switch.

Figure 4. Poor maintenance of equipment: frayed power cord.

Proper work practices, including correctly implemented Lockout/Tagout (LOTO) procedures would prevent many of these incidents.

Common Elements in Electrical Incidents
In order to raise awareness of what contributes to electrical incidents and how to avoid potential problems, workers should recognize that most incidents share several common contributing elements. These include:

- The job is rushed or undue stress is put on the worker to complete the job as soon as possible (this is the number 1 contributor).
- Accidents and near misses occur during maintenance and trouble-shooting, especially where on/test/off/adjust operations occur.
- Undocumented modifications and design changes have been made that create unexpected hazards.
- New equipment designs with inherent or potential hazards have not been carefully reviewed.
- Inadequate documentation of operating equipment and systems, lacking schematics and manuals.
- Lack of an experienced observer to serve as a “safety watch” when working with potentially hazardous, exposed energized equipment.
- Key people are either absent or unavailable.
- Training was inadequate, incomplete, or not provided for the work.
- The worker is distracted or loses concentration.
- Experienced employees, because of their previous work experience, may develop a more casual approach to electrical and electronic work.
- Inadequate or no safety plan, no Standard Operating Procedure, no "working hot permits," or inadequate or no Work Planning or Experimental Review.
- People involved are not aware of BNL and/or group safety policies and standards.
- People doing the work believe that safety policies and standards are for “other workers” or do not apply to experimental work.

Remember, if the job cannot be done safely, do not do it! Instead, speak to your supervisor, ESH Coordinator, another member of your organization’s management, or the Laboratory Electrical Safety Officer.

Human Effects of Electrical Shock:
Most fatal electrical shocks happen to people who should know better. Here are some electro-medical facts that should make you think twice before taking chances:

First, remember that it is not the voltage, but rather the current that kills. The real measure of a shock's intensity lies in the amount of current (in milliamperes) passing through the body. Any electrical device used on a house wiring circuit can, under normal conditions, transmit a fatal amount of current.

Currents between 100 and 200 milliamperes (0.1 ampere and 0.2 ampere) are fatal. Anything in the neighborhood of 10 milliamperes (0.01 ampere) is capable of producing painful to severe shock. Estimated effects of 60 Hz AC currents that pass through the chest are shown in the table below from the National Institute for Occupational Safety and Health (NIOSH):

Effects of 60 Hz AC Currents

- 1 mA - Barely perceptible
- 16 mA - Maximum current an average man can grasp and "let go"
- 20 mA - Paralysis of respiratory muscles
- 100 mA - Ventricular fibrillation threshold
- 2 Amps - Cardiac standstill and internal organ damage
- 15/20 Amps - Common fuse or breaker opens circuit*

* Note: Contact with 20 milliamps of current can be fatal. As a frame of reference, a common household circuit breaker may be rated at 15, 20, or 30 amps.

There are two basic types of human effects of electrical shock: primary effects and secondary effects.

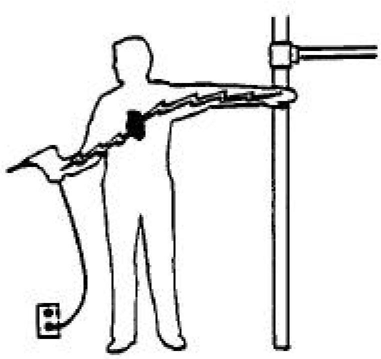
Primary effects include shocks, burns (the body tissue can literally be cooked from the point of entry to the point of exit), loss of vision (due to electric arcs or from neurological damage), and death. Death can occur from nerve and/or organ damage (vital organs can be cooked or perforated, causing internal hemorrhage); muscular contractions in a person's chest (the victim stops breathing); or from ventricular fibrillation (rapid irregular contractions of the heart muscle).

Secondary effects include falls (falling off of ladders or scaffolds) and thrown tools.

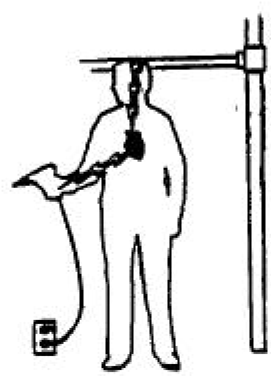
Factors of Electrical Shock:

Electrical current will flow through the path of least resistance. If that path is through a person's body, serious injury or death can occur. Critical pathways that electrical current flows through a person are hand-to-hand, hand-to-foot, and hand-to-head. In all cases, there is potential for the current to pass through the chest, near the heart.

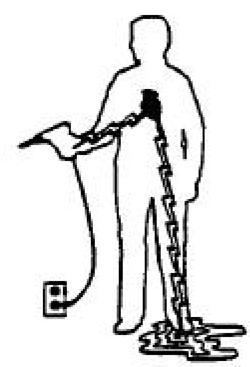
Hand-to-hand shock path



Hand-to-head shock path



Hand-to-foot shock path



There are several factors that can determine the seriousness of an injury due to electrical shock.

- Amount and duration of current - The higher the amount of current and the longer the current flowing through a person's body, the greater the physical damage.
- Path of current through the body - If the current flows through a vital organ, such as the heart or head, serious injury is likely to occur.
- Wet/damp conditions - Water conducts electricity. If a person is working in a wet/damp area, or perspiring, it reduces the person's body resistance, increasing the likelihood of injury.

- Contact with ground or grounded objects - Path of electrical current flow is determined by resistance back to ground (source). If a person is in contact with a ground or a grounded object, they could complete a low resistance path to ground.
- Area and pressure of body contact - The greater the area and/or pressure of body contact, the greater the conductivity.
- Age, size, and physical condition of the person - In general, very young and old people are less tolerant to the effects of electric shock. People who exercise regularly may experience greater effects of a shock because well-conditioned muscles conduct electricity better than fatty tissue.
- Personal protective equipment - Workers who use proper personal protective equipment can reduce or eliminate the possibility of electric shock.
- Metal objects, such as jewelry, increase the area of contact if the object the person is wearing comes in contact with an energized conductor.
- Frequency is in Hertz (Hz) - People are less susceptible to injury from electrical energy when the frequencies are below 8 Hz and above 400 Hz. The 60 Hz frequency of our AC power is in the most dangerous part of the range.

Ohm's Law

Defines the relationship between current flow, voltage, and resistance. Ohm's Law states that the current flow is directly proportional to the applied voltage divided by the resistance.

Stated as a formula, this translates to:

Current (in amps) = Voltage (volts) / Resistance (ohms)

Current Flow Through a Worker:

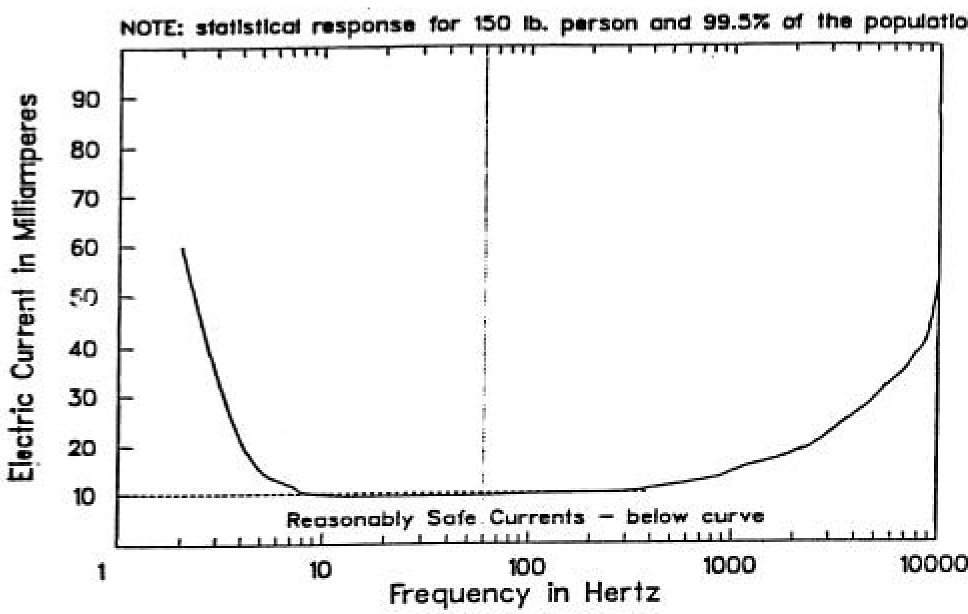
Normally, dry, unbroken skin has a high resistance of approximately 100,000 ohms. When the skin becomes wet, resistance can be reduced significantly, to approximately 1,000 ohms.
If a worker with wet hands comes in contact with a live 120 VAC electric line, 0.120 Amps amperes (120 mA) of current would flow through the worker, possibly leading to ventricular fibrillation.

Ability to Let-Go

When a person becomes part of an electrical pathway, muscles contract. If a person is holding a defective electric tool (with electricity energizing the case of the tool) and a grounded object, the person may not be able to let go of the tool and/or the grounded object because of the muscular contractions. This can happen for current flow as low as 10 milliamps.

The effect result could be anywhere from a slight tingling sensation to death, depending on the voltage, current, and body's resistance. If the current flow is less than 10 milliamps, the person should be able to pull away from the electrical source, thus minimizing any permanent injury. If the source is below 8 Hz or greater than 400 Hz, the person may not perceive that they are receiving an electric shock, even though electricity is flowing though their body. (Regular, “household” AC current is 60 Hz.) If the person cannot sense the current, he or she could stay in contact with the electric source longer, causing permanent damage to body organs.

The chart below shows how reasonably safe currents change with frequency (in Hertz). Reasonably safe currents are shown below the curved “threshold line.” Notice how the threshold increases if the source is below 8 Hz or above 400 Hz, as mentioned earlier.



Dangerous Electrical Values

BNL has divided electrical hazards into four ranges:

- **Range A** - Low Hazard
  AC or DC Voltage less than or equal to 50 V
  Less than 10 mA of available current or incapable of an instantaneous release of 10 Joules* or more of energy

* 1 Joule: a unit measure in the Metric system for measuring an amount of energy or work. Technically, one Joule is equivalent to one Newton of force causing a displacement of one meter. Ten Joules is equivalent to a mechanical potential energy of 7 foot-pounds.

- **Range B** - Medium Hazard
  AC Voltage less than or equal to 250 VAC
  DC Voltage less than or equal to 1000 VDC
  Greater than 10 mA of available current or capable of instantaneous release of 10 Joules or more of energy.

- **Range C** - Hazardous
  AC Voltage less than or equal to 600 VAC
  DC Voltage less than or equal to 6000 VDC
  Greater than 10 mA of available current or capable of instantaneous release of 10 Joules or more of energy.

- **Range D** - High Hazard
  AC Voltages above 600 VAC
  DC Voltages above 6000 VDC
  Greater than 10 mA of available current or capable of instantaneous release of 10 Joules or more of energy.

Table 1 from ES&H Standard 1.5.0 (Electrical Hazard Ranges and Requirements), reproduced below, contains a complete listing of explanations.

Table 1. Electrical Hazard Ranges and Requirements

Range [See Note 1]	Criteria [See Note 3]	Written Procedure	Working Hot Permit [See Section V.D. of this Standard]	Training	Safety Watch and/or 2 Man Rule [see note 7 & 8]
A [See notes 5 & 6] Low Hazard Operation	(Injury not likely) characterized by the following: AC and/or DC voltages less than or equal to 50 volts	N/A	N/A	New Employee Orientation	N/A
B Medium Hazard Operations	(Potential for severe injury or death) characterized by voltages greater than range AA@ hazard; but, falling into either of the following: AC voltages less than or equal to 250Vac rms; or DC voltages less than or equal to 1000 Vdc; with greater than 10mA of available current or capable of an instantaneous release of greater than 10 Joules of energy.	Generic	Generic Issued by Dept. Chair or formal designee [See Note 2]	Relative to Task (maintain list of authorized personnel). BNL Electrical Safety Course and Lockout/Tagout Training.	N/A
C Hazardous Operations	(Potential for severe injury or death is greater) characterized by voltages greater than range AB@ hazard; but, falling into either of the following: AC voltages less than or equal to 600Vac rms; or DC voltages less than or equal to 6000Vdc; with greater than 10mA of available current or capable of an instantaneous release of greater than 10 Joules of energy.	Generic	Job Specific Issued by Dept. Chairman or formal designee [see note 2]	Relative to Task (Document personnel who work on job). BNL Electrical Safety Course and Lockout/Tagout Training.	2 Man Rule [see note 7]
D High Hazard Operations	(Potential for severe injury or death is greatest) characterized by voltages greater than range AC@ hazard; as described below: AC voltages above 600 Vac rms; or DC voltages above 6000 Vdc; with greater than 10 mA of available current or capable of an instantaneous release of greater than 10 Joules of energy.	Job Specific	Job Specific Issued by Dept. Chair or formal designee. Independent review required. [see note 2]	Relative to Task (Document personnel who work on job) BNL Electrical Safety Course and Lockout/Tagout Training. Cardiopulmonary Resuscitation (CPR)	Safety Watch (Total of 2 or more persons at work site) [see note 8]

Note:

1. In cases where electric devices do not fit clearly into any of the above Ranges, a review by the line department/division and SEP is required.
2. Lockout/Tagout Procedures or accountable key interlock are the preferred methods to be used when working on these electrical circuits.
3. These values are meant as guidelines only, and are not intended to be absolute limits.
4. It is assumed that all AC sources above Range AA@ are capable of delivering greater than 10 ma of current and more than 10 Joules of instantaneous energy.
5. Injury is possible from flash hazards and non electrical secondary effects.
6. High voltage sources with fault currents less than 10 ma and less than 10 Joules of available energy are considered Range AA@ hazards (e.g., ion pump power supplies).
7. The ***Two Man Rule*** states that personnel shall not work alone on energized circuits of Range AC@ or AD@. Both workers shall be authorized and familiar with the approved procedures and emergency responses.
8. A ***Safety Watch*** is a person trained in emergency response procedures; but not involved in the actual work in progress. The safety watch=s sole function is to remain alert for potential hazards and summon assistance should the need arise. When feasible the person should remain outside the control zone. When a safety watch is used to satisfy the 2-man rule, the Safety Watch shall be an authorized worker.

NOTE: A large majority of electrocutions are caused by voltages of less than 600 Volts, which includes the most common voltages in the workplace. At 110-120 Volts, fibrillation can start in 3 to 4 seconds of current flow. The higher the voltage and current flow, the shorter the time before fibrillation starts. At 110-120 Volts and a current flow exceeding 10 mA, it is likely you will not be able to let go once you receive the initial shock. This is called the "let-go threshold."

Emergency Procedure for People Being Shocked
If you should come upon an electrical incident where a person is experiencing an electrical shock, the first thing that you should do is stop and evaluate the situation before you act.
YOU DO NOT WANT TO BECOME THE SECOND VICTIM!
You should then act rapidly to remove the victim from live contact as quickly as possible. Attempt to shut off the power. If the power cannot be shut-off, use non-conductive material to separate the victim from the contact, or move the energized item(s).

Once the victim has been removed from the electric source, call for help or, if possible, have someone call for you. Call the emergency telephone extension 2222 or 911, pull the nearest fire alarm pull box, or use any other method of communication. For users of cellular phones, you need to dial all eleven digits, (631) 344-2222.

Only then should you administer CPR. Seconds count! If you have been trained to do so, begin CPR or first aid, as appropriate.

Stay at the scene until help arrives. Provide as much information as possible regarding the event, including what was the voltage, current, point of entry, point of exit, and how long the current was flowing.

Grounding

Grounding is the connection of a piece of electrical equipment to the earth or some conducting body that serves in place of the earth such as the steel frame of a building or a piping system. The National Electrical Code defines proper grounding as conducting connections that have sufficiently low impedance and enough current-carrying capacity to prevent the buildup of voltages that may result in undue hazards to connected equipment or personnel.

Why Use It

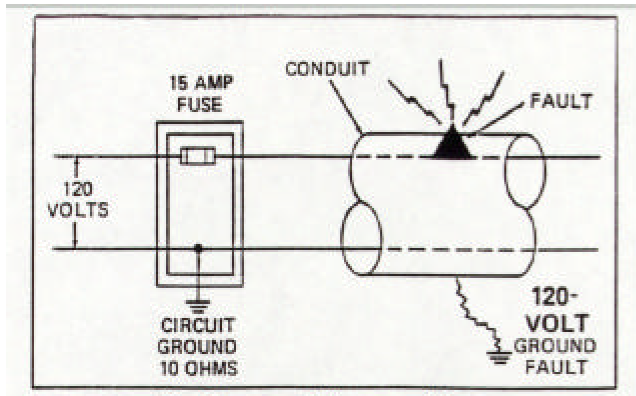
Grounding prevents differences in potential (voltage) between electrical enclosures and surroundings. When grounding, all metal enclosures (such as raceways, cabinets, tool housings, etc.) should be continuously connected together by metal strapping or other conductive material, and then extended to the electrical source or to earth. If the electrical current's isolation were to break down and contact the enclosure, the enclosure could become energized if it were not grounded.

Adequate grounding also provides a "ground-fault path" of very low impedance that should cause the circuit's fuse to melt or the circuit breaker to trip by increasing the high current that attempts to flow through the fault. This action will rapidly disconnect electrical power from a short circuit.

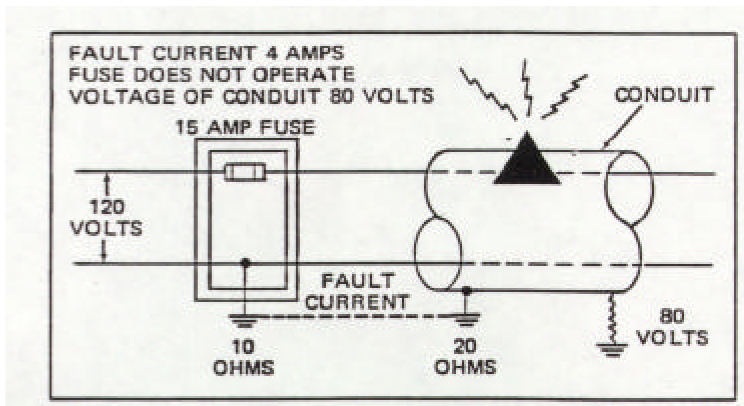
Results of Bad or No Ground

If the grounding circuit has significant independence, which hinders the flow of electricity, or if there is no grounding circuit at all, enclosures could become energized. Current from an energized enclosure will take any available path back to the source. A person touching an energized enclosure could provide that alternate path to ground. Most tools and machinery have three-pronged plugs to ensure a good ground, but the plug will not do its job if the grounding prong is removed or missing. Grounding will also not do its job if the ground fault path has high impedance. If the ground fault path has high impedance, current flow would not increase enough to melt a fuse or trip a breaker. In order to be effective, the ground fault path must have low impedance.

Two examples of bad grounding



Circuit grounded - conduit not grounded allows the fault to energize conduit to 120 volts creating a serious shock hazard.



Circuit and conduit poorly grounded allows 4 amp fault current to flow creating a hazardous condition - arcing, sparking, possible fire and serious shock hazard while not causing 15 amp fuse to blow.

Grounding Requirements

OSHA and the National Electrical Code State:

"The path to ground from circuits, equipment, and metal conductor enclosures shall (1) be permanent and electrically continuous, and (2) shall have ample capacity to conduct safely any fault currents likely to be imposed on it, and (3) shall have sufficiently low impedance to limit the potential above ground and to facilitate the operation of the overcurrent devices in the circuit." (Reference: OSHA - 29 CFR 1910.1304 (f) (4) and NEC Article 250-51)

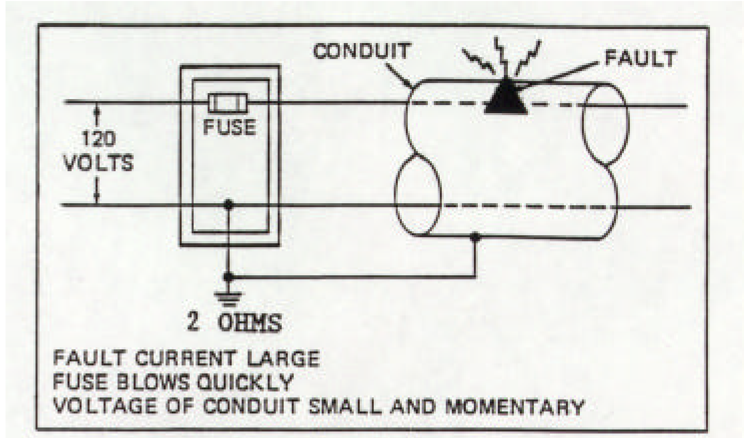
Features of Good Grounding

In a good grounding system, the electrical connections of the grounding path are permanent and continuous. Grounding conductors are clearly identified by having green insulation or by using a bare copper wire or strap. If a ground fault were to develop in a system with a low impedance-grounding path, the current flow would increase past the capacity of the fuses or circuit breakers protecting the circuit. The fuses would melt, opening the circuit.

Grounding conductors should be sized to safely carry the maximum expected electric fault current safely. The maximum expected fault current is the same as the rating of the circuit breakers or fuses protecting the circuit.

Grounding/shorting hooks used to furnish a temporary ground connection are to be designed, built, and tested for the operating voltage and the maximum expected fault current they are likely to have imposed on them.

An example of good grounding



Circuit and Conduit connected to common ground

Grounding Terminology: (sometimes confusing when used interchangeably)

- Ground - bring to earth potential or approximately zero voltage.
- Bond - permanently connected to another device or other devices to keep them at the same voltage.
- Neutral - power-return path. Because of differences in the power system, this may or may not be grounded. Some systems do not have a neutral conductor. In 120-volt systems, the power-return path identified by white insulation or white markings. Some systems may not have a neutral conductor; e.g., connections to three-phase motors.
- Common - a connection path used by more than one circuit. This may not be grounded.

Overcurrent Protection

There are three circuit over-current conditions that would cause a protective device to de-energize a circuit:

- Overload
- Short circuit
- Ground fault

Overload occurs when the load draws more current (amperes) than the circuit was designed to handle. A short circuit takes place when the electrical circuit is completed at some point prior to the intended load connections. A ground fault occurs when the current flow is diverted from the intended circuit to an alternate path leading to ground.

In all three of these conditions, the increase in the flow of electrical current should cause protective devices to open the circuit. There are two types of protective devices used to shield equipment circuit wiring against overload: circuit breakers and fuses. It is important to emphasize that the primary purpose of circuit breakers and fuses is to protect the wires from overheating and causing fires.

When a circuit has been de-energized by a protective device, do not manually re-energize the circuit without first investigating the cause. Do not perform repetitive manual re-closing of breakers or replacing of fuses.

BNL electrical protocols allow ONE attempt to manually re-close a breaker that has tripped. If the breaker trips again after this attempt, the cause of the trip must be investigated. Personnel should be aware that circuit breakers contain thermal elements which require a cooling-off period before an attempt can be made to re-close the circuit.

Circuit Breakers (circuit wiring protection)
When current flow exceeds the capacity of the circuit breaker, the breaker "trips," opening the circuit and stopping the current flow. Circuit breakers must be clearly marked as to what equipment they control at the circuit breaker panel. In the United States, the convention for circuit breakers and switches that are mounted vertically is that when the handle is up, the circuit is energized (ON). Circuit breaker installations built after 1990 must also have the capability of being locked with a padlock for the application of lockout/tagout.

Fuses (circuit wiring protection)
Fuses generally have a higher interrupting current capability and faster response than a circuit breaker. When the current flow exceeds the rating of the fuse, heat builds up and the fuse element will melt or vaporize, stopping the flow of current. There are many types of fuses, ranging from fast-acting to time-delay response.

Only authorized and qualified personnel are allowed to replace fuses. When replacing fuses, the identical replacement must be used. Fuses must be replaced with ones having the same ratings of current, voltage, and current-interrupting rating. When replacing fuses, you must use safety glasses, rated fuse pullers, and any additional Personal Protective Equipment (PPE) required by your organization.

Fused Disconnect Switches
When pulling the handle on a disconnect switch, it is recommended that you consider the possibility of an arc explosion and turn your face away from the cover of the box. After turning the disconnect to the "OFF" position, open the cover to the box and visually check to make sure that all of the switch blades have been disconnected. These switches have been known to fail whereby the handle was in the OFF position, but with one or more of the switch blades still making contact. Use caution: Always test to confirm there are NO exposed conductors that MIGHT be powered. Treat all electrical circuits as if they were energized until proven otherwise. After de-energizing the circuit, test it using an appropriately rated meter to ensure that it is de-energized. Use a fuse puller rated for the fuse. The rating is marked on the puller.

Ground Fault Circuit Interrupter (people protection)
GFCI's are designed to protect people. GFCI's help to prevent electrocutions by detecting fault currents that are too small to trip a normal circuit breaker. They can detect a difference in current as small as 5 mA, and act to open a circuit in as little as 25 milliseconds. They do not prevent closed loop shocks.

GFCI's are available in different types and sizes. They can be permanently installed in place of standard receptacles or as a combination circuit breaker/GFCI in circuit-breaker panels. They can also be used as portable devices plugged into unprotected outlets or mounted at the ends of extension cords. GFCI's are mandatory on construction sites, for all outdoor work, and within 6 feet of sinks and other water sources. It is recommended they be used in all laboratory and shop areas when using hand-held, wall-outlet powered electrical equipment.

NOTE: GFCI's are no substitute for safe work practices

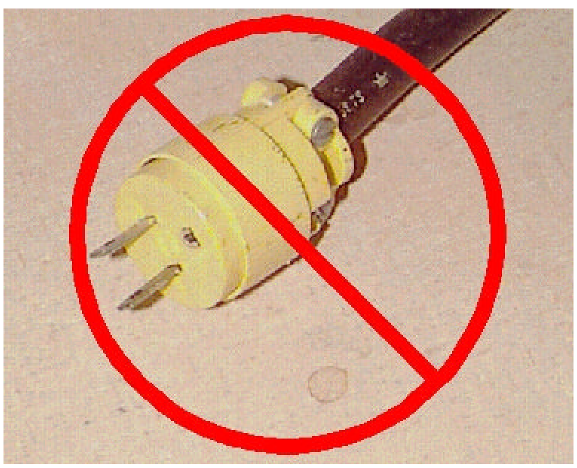
Electrically Powered Tools

When using electrically powered tools, they should be either grounded or double insulated. Grounded tools have a grounding prong (third prong) on the power cord, while double-insulated tools have an outer insulated case and an inner insulated shell to protect a worker from electrical shock in the event that a fault develops that could cause the "tool" housing to become energized.

Improper: Two-conductor Zip Cord wired into Grounded Plug

Prior to use, inspect any electrically powered tool for any visible signs of damage. Power cords should be in good condition with no signs of deterioration or damage. All three prongs of tools with grounding plugs must be in place. Never use a tool if the grounding prong has been removed.

Grounding does not do the job if the grounding prong is missing or the ground fault path has high impedance.

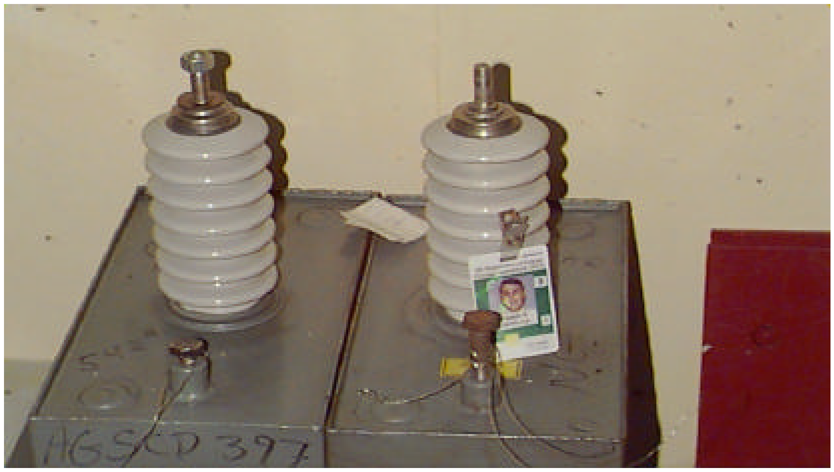


Electrically powered tools that use a three-wire power cord and a grounding plug should be regularly tested to ensure the ground circuit is capable of carrying the maximum expected fault current.

Tag any tool for repair if it shows any obvious signs of damage. If you receive a shock when using any electrically powered tool, or even if you feel a slight tingle, DISCONTINUE USE IMMEDIATELY. Notify your supervisor, tag the tool as defective, and have it repaired or replaced.

Capacitors
Capacitors are energy-storage devices. They internally store electrical energy as a DC voltage between two parallel metal plates that are insulated from each other. Capacitors come in many sizes and are used in motor starters and power supplies.

Hazardous Practice: Stored Unshorted Capacitors



Hazards:
When dealing with capacitors, it is important to realize that they may not be fully discharged unless a shorting jumper or bleeder circuit is in place. You should slowly discharge through a resistor and short any capacitor before touching it.

Always assume that a capacitor is charged if it is not shorted. Avoid touching even small capacitors if they have not been discharged and shorted. Un-shorted capacitors may recharge due to internal material effects.

Be aware that capacitors can catastrophically fail due to an internal fault, which can result in an explosion. The exploding housing of a metal-encased capacitor could send shrapnel flying in all directions. If a fire were to occur, toxic fumes would be released from the burning insulating materials. Leaks of insulating fluids can also be very harmful if they contain Poly-Chlorinated Biphenyls (PCBs). Although many capacitors are not labeled with the warning “Contains PCBs,” always assume that they contain PCBs unless they are labeled Non-PCB.

Inductors
Inductors are energy storage devices that store electrical energy as current. Common uses for inductors include electromagnets, motors, fluorescent lamp ballasts, and relay coils.

Hazards
Electrical current flow in inductors does not stop or start instantly. They may induce voltages on adjacent components creating potential shock hazards. Inductors have hazards similar to capacitors. They can induce electrical currents in adjacent equipment and may disturb the operation of nearby circuits. Inductors may store large amounts of electrical energy, causing current to flow for long periods after the power is removed (e.g., superconducting magnets).

Inductors can also attract loose magnetic materials with their magnetic field and impair the operation of instrumentation operating within the magnetic field, such as Pacemakers and other electronic medical implants.

Safety Around Electrical Equipment

Electrical Worker Categories

Work on BNL's electrical distribution network from Long Island Power Authority (LIPA) tie-ins to receptacles should be performed only by personnel classified as **Utility Workers**. Personnel classified as **Service Workers** should only work on commercial equipment for which they have been trained, such as motors, welders, and machine tools. Personnel classified as **Research Workers** should only perform work on complex scientific equipment.

Each of these worker categories must have further qualifications defined as **Qualified Workers** and **Authorized Workers**.

Qualified Workers are BNL employees or contractors who have relevant electrical education or experience to do their assigned tasks. Electrically related tasks are to be assigned only to Qualified Workers.

Authorized Workers are Qualified Workers who have been formally identified (listed) by their Organization as authorized to perform Lockout/Tagout and permitted to Work Hot when the appropriate permit is in place. Authorized Workers are limited to working only on the categories of equipment for which they have been authorized.

Personnel Protection

A control zone must be established to protect personnel who may accidentally encounter energized components. Personnel who work within a control zone must be protected by:

1. Training in accordance with BNL organization-specific procedures, or
2. Lockout/Tagout (LOTO), and/or
3. A barricade

Lockout/Tagout (LOTO)

Lockout/Tagout is a program of practices and procedures necessary to disable machinery or equipment and to prevent the unexpected release of potentially hazardous energy during maintenance, servicing or construction.

Lockout/Tagout applies to securing all sources of energy, including hydraulic, pneumatic, mechanical, and others, including sources or radiation. The driving source of energy for many devices is ultimately electrical, through motor drives or power supplies. For the purpose of this Electrical Safety I course, the balance of the lockout/tagout discussion applies only to electrical energy.

By locking out power going to equipment or by isolating or blocking the power within equipment and verifying that it is controlled, we can bring the equipment to a zero energy state, so that it may be worked on safely.

BNL uses dedicated Master padlocks with red bands around the base of the lock, accompanied by red tags imprinted with the words HOLD, DO NOT OPERATE in large black letters. Lockout/Tagout is not intended to prevent unauthorized use, such as use of an overhead crane, which is administratively controlled by using locks that are different from Lockout/Tagout locks, along with caution tags that are yellow.

The BNL Lockout/Tagout program is described in ES&H Standard 1.5.1, Lockout/Tagout Requirements.

ES&H Standard 1.5.1 outlines the responsibilities and training requirements for two types of employees: Affected and Authorized. Additional on-the-job training and certification at the BNL organization level are needed before an employee is authorized to lockout and tagout equipment they work on.

Affected Employee
Affected employees often operate or use equipment that may be locked or tagged out periodically for maintenance, servicing, or construction, or they may work in an area where LOTO is in progress. These employees are trained to identify locks and tags, and recognize that energy-control procedures have been implemented. They are also taught that they are not to attempt to start or use any equipment that has been locked or tagged out of service. An affected employee is not allowed to apply to or remove a LOTO from equipment.

Authorized Employee
An authorized employee is anyone who has been trained to recognize hazardous energy sources, to control that energy to prevent unexpected release, and to verify that the energy is controlled. Only after they demonstrate this knowledge will they become listed by their organization and thereby become authorized to perform LOTO.

BNL defines two classes of "authorized employees," Knowledgeable Employees and Responsible Employees.

Knowledgeable Employee
A knowledgeable employee is authorized to conduct LOTO for his or her own protection. While they cannot initiate "group or operations locks and/or tags" where a lock and tag are placed to protect a group of workers, knowledgeable employees can attach additional locks and tags in "operations lock" situations provided that their lock and tag is not the first one on or the last one removed.

Responsible Employee
A responsible employee has been trained to exercise group and system-level judgments. These employees are authorized to lockout and tagout (LOTO) any equipment for which they have organizational approval. If coordinated multiple locks and tags are applied by more than one employee, those of a "responsible employee" must be the first applied and the last to be removed.

Critical Systems
Critical Systems are systems that either cannot be de-energized due to equipment design or operational limitations, or if they were de-energized, would introduce additional or increased hazards. Examples of critical systems are life-support devices, hazardous area ventilation equipment, fire protection systems, emergency egress illumination devices, and access control systems. Each BNL organization is required to develop a list of what they consider to be Critical Systems in their control and submit this list to the Laboratory Electrical Safety Officer. This list must be reviewed and updated annually.

Control Zone
In order to prevent injury or minimize exposure to unqualified personnel, a large, designated area called a control zone must be set up around exposed energized circuitry. The four major control zones are:

- Flash Protection Boundary
- Limited Approach Boundary

- Restricted Approach Boundary
- Prohibited Approach Boundary

Their respective dimensions are fully described in ES&H Standard 1.5.0, Table 2, Electrical Work Clearances (Control Zones), reproduced below.

Table 2. Electrical Work Clearances (Control Zones)

This table was derived from NFPA 70E Standard for Electrical Safety Requirements for Employee Workplaces.

Column Number 1		2	3	4	5	6
Requirements for work within listed distances		Warning & Appropriate Personnel Protective Equipment made available				
			Qualified level training required			
					Authorized Personnel ONLY	
						WORKING HOT
Nominal System Voltage Range ***(Phase to Phase)***		***Flash Protection Boundary***	***Limited Approach Boundary***		***Restricted Approach Boundary***	***Prohibited Approach Boundary***
			Exposed Movable Conductor(s) (Overhead lines)	**Exposed Fixed Circuit Part(s)**		
	Typical BNL Hazard Range	**Energized Part to Employee - Distance in Feet - Inches**				
Up to 50 V	AA@	0'-6"	0"	0"	0"	0"
50 v to 300 V	AB@	3'-6"	10'-0"	3'-6"	0'-1"	Avoid Contact
300 v to 750 V	AC@	3'-6"	10'-0"	3'-6"	1'-0"	0'-3"
750 V to 2 KV	AD@	4'-0"	10'-0"	4'-0"	2'-0"	0'-7"
2 KV to 15 KV	AD@	16'-0"	10'-0"	5'-0"	2'-2"	0'-10"
15 KV to 36 KV	AD@	19'-0"	10'-0"	6'-0"	2'-7"	1'-5"
36 KV to 48.3 KV	AD@	21'-0"	10'-0"	8'-0"	2'-10"	2'-1"
48.3 KV to 72.5 KV	AD@	25'-0"	10'-0"	8'-0"	3'-3"	2'-8"

Clearances required by OSHA for construction projects may be greater than stated above, as per OSHA 1926.416(g)(2)(i,ii).
Consult the Laboratory Electrical Safety Officer for required clearances of construction activities in areas containing high voltages or for voltages greater than those listed above.
Clearances as stated above are required for work on or adjacent to live sources capable of either fault currents greater than 10 mA or instanteous release greater than 10 joules.

Example: An authorized worker may use a test probe on a 208V, 3F (Range B) circuit as long as (s)he does not make un-barriered physical contact with the energized component. If however the voltage is 480V, 3F (Range C) the same worker would require a valid Working Hot Permit to enter into the 3 inch Prohibited Approach Boundary.

Personnel working within the Flash Protection Boundary must be advised of that hazard by the cognizant engineer/manager and provided with appropriate Personal Protection Equipment (PPE). Hazards within the Flash Protection Boundary include arcing, heat, light, and thrown molten metal.

All personnel working within the Limited Approach Boundary are to be trained to the level of a qualified worker. Only personnel authorized by their Line Organization for work on that specific equipment are allowed to work within the Restricted Approach Boundary.

All work within the Prohibited Approach Boundary of an energized circuit is considered Working Hot, which requires extreme caution, a valid Working Hot Permit, and approved procedures including the use of required PPE.

The perimeter of the Limited Approach Boundary is to be marked or barricaded so that people passing by are warned and protected. If barricades are insufficient, then an additional person must be present to warn passersby.

Working Hot

Working Hot is defined as working on or adjacent to energized components within the Prohibited Approach Boundary where contact with "live" components could cause serious injury or death. Working with voltages in Range A is not considered Working Hot. Working around energized components sufficiently barriered from contact or distanced, such that accidental contact by personnel or from dropped materials will not result in an electrical hazard, is also not considered Working Hot.

Only Level II or higher management, or their formal designees, may issue "Working Hot Permits" to respond to operational or emergency situations, or for situations that involve working within the Prohibited Approach Boundary control zone, providing that the rules noted below are implemented. Working Hot is only justified when working on a Critical System. Refer to ES&H Standard 1.5.0, Table 1 to find requirements for written procedures, working hot permit authorization, training, safety watch, and two-man-rule information.

Summary of Working Hot Rules

- Range "A" or low-hazard work
  No Working Hot Permit required.
- Range "B" or medium-hazard work
  Use of generic Working Hot Permit is allowed subject to the following restrictions:
  - A generic approved work procedure is in place.
  - Only authorized workers, as defined in Section V of ES&H Standard 1.5.0, are allowed to work on energized equipment and then only under a valid Working Hot Permit.
  - The generic Working Hot Permit contains the names of those who will be performing the task.
- Range "C" or hazardous work
  Use of generic Working Hot Permit is not allowed, except for testing and diagnostic work. Generic Working Hot Permits may be granted ONLY for testing and diagnostic work. Specific Working Hot Permits must be issued each time the procedure is used subject to the following restrictions:
  - A generic approved work procedure is in place.
  - Only authorized workers, as defined in Section V of ES&H Standard 1.5.0, may work on energized equipment and then only under a valid Working Hot Permit.
  - The Working Hot Permit contains the names of those who will be performing the task.
  - The two-man rule is invoked.
- Range "D" or high-hazard work
  Use of generic Working Hot Permits is not allowed! Task-specific Working Hot Permits must be issued each time the procedure is performed, subject to the following restrictions:
  - A task specific approved work procedure, as defined in Section V of ES&H Standard 1.5.0, is in place.
  - Only authorized workers, as defined in Section V of ES&H Standard 1.5.0, may work on energized equipment and then only under a valid Working Hot Permit.

- The permit shall only be issued after independent review as defined in ES&H Standard 1.5.0.
- A person with current training in Cardiopulmonary Resuscitation (CPR) is required as a Safety Watch.

Warning Signs and Other Alerting Techniques

Markings, labels, and hazard warning signs indicating immediate danger must always be prominently displayed and are to be installed or mounted as new systems are assembled. These labels and signs are to be environmentally and mechanically durable and be suitably fastened to the mounting surface.

The standard sign indicating there are electrical hazards to personnel is a red oval in the top panel with white letters. The minimum size is 10 inches high by 14 inches wide for locations accessible by pedestrians. Smaller sizes may be used on equipment surfaces.

The appropriate hazard warning words or phrase must appear in the bottom panel. The words "High Voltage" indicates the hazard is due to more than 600 Volts. The warning must give clear, meaningful instructions. If the hazard is removed, the warning sign or label should also be removed.

Where the electrical hazard is not due to high voltage, the same type of sign reading "Electrical Hazard" may be used or orange color labels with the voltage noted may be used to draw attention to areas where shock potential exists.

Lights, ropes and barricades can provide information, warning and barriers. When using warning lights, they should be clearly visible so that they will attract attention and should be used in conjunction with warning signs.

But even with this requirement, NEVER TRUST AN UNLIT LAMP AS A WARNING INDICATOR. Consider everything to be energized.

General Safety Guidelines

The following are general safety guidelines for working around electrical systems and equipment:

- All electrical work is to be pre-planned. Pre-work planning and discussion of the task, relative to the hazard level, is to be held between employees performing the work and their line supervision. This pre-work planning should include:
  - The scope of the work to be performed
  - Analysis of the hazards involved
  - Necessary controls to mitigate identified hazards.

Only then are employees to perform the assigned tasks while keeping within the defined scope and hazard controls. Appropriate feedback is needed for improvement.

- Personnel trained to the level of this course are not expected to work on energized equipment.
- Approach electrical systems and equipment as if they are energized. Maintenance and operational checkout of electrical systems and equipment often require removing protective barriers and potentially exposing personnel to energized components.
- All personnel are expected to follow Lockout/Tagout (LOTO) procedures outlined in ESH Standard 1.5.1 “Lockout/Tagout Requirements," unless they are required to work on a Critical System.
- Always use the appropriate meters to take measurements on electrical equipment. See your supervisor for further guidance.
- Make sure that no part of your body, especially your head, touches energized equipment. Wear appropriate protective equipment when required, including headgear.
- Avoid wearing metal such as rings or metallic watchbands when working with electrical equipment or near induction or dielectric heating equipment.
- Use suitably insulated and tested tools or matting rated for the voltage encountered when working on energized equipment.
- Regard concrete and brick walls and floors as conductive and grounded.
- De-energize equipment and use properly rated fuse-handling equipment to remove and install fuses.
- Use only non-conductive ropes and hand lines near exposed energized parts.
- Use maintenance manuals for equipment being serviced.
- Manholes and handholes should have no exposed, ungrounded, current-carrying metal parts that might result in accidental contact. Use precautions when working in such restricted spaces that contain energized parts.
- Exercise caution when working in elevated positions or when driving vehicles that can be elevated near energized overhead lines.
- Ensure adequate grounding of equipment used in the field, including equipment in trailers. There should be an automatic indication if trailer grounds are lifted.
- Remain outside the Control Zone except when necessary to perform the assigned task.
- Use appropriate warning signs and barricades to protect passersby.
- Use caution when handling long metallic objects, such as ladders, in areas where they could come in contact with energized conductors.

Flexible Cords

The following precautions must be followed whenever using any flexible cords, including extension cords and equipment power cords:

- Flexible cords must be protected from electrical and mechanical damage.
- When using flexible cords, do not exceed 80% of their rated amperage.
- Cords are required to be traceable, viewable, and accessible.
- Always know the circuit panel and circuit number associated with the cord.
- Never hoist or lower portable tools or equipment by their electrical power cord.
- Do not hang cords using staples or drape them over sharp or abrasive surfaces that could damage the insulation or cut the wires.
- Avoid creating stumbling/tripping hazards by getting cords off the floor.
- Strain relief connectors are necessary at all plug and equipment connection points.
- Portable cord-and-plug-connected equipment and extension cord sets are to be inspected at the beginning of each shift or before use by the individual using them.

- Cord-and-plug-connected equipment such as a wall clock or water cooler that remains connected and not exposed to damage need not be inspected until it is relocated.
- Use only hard usage or extra hard usage "S" Cords: Type S, SO, SJ, SJO, SJT, SJTO, ST, and STO (approved cords are marked with the wire size, number of conductors, S type designation and UL symbol).
- Never use metal-jacketed plugs on 110 and 220 VAC single-phase circuits or plugs with exposed connections on their face.
- All flexible cords are to be equipped with an attachment plug and are to be energized from an approved receptacle of the same configuration.
- Modification of attachment plugs or the use of adapters is not permitted.
- All extension cords must have an equipment-grounding conductor and have appropriate grounding conductors on the attachment plugs and connectors.

Prohibited Uses of Flexible Cords

- Use of cords with male connectors at both ends.
- Cords concealed or attached to buildings.
- Cords run through walls, ceilings, or floors.
- Cords run in place of permanent wiring.
- For single-task oriented activities, provide blocking or similar protection for cords that pass through doors or windows.

Safety Requirements for Design and Construction

BNL requires that everyone use the same electrical safety standards. These include:

- All equipment must be free from recognized hazards.
- The equipment must be durable and suitable for its intended use.
- Equipment must be installed correctly.
- The equipment must be designed so that personnel are not exposed to bare conductors.
- Conductors must be adequately sized to prevent overheating.
- Equipment must be identifiable with a permanently attached label or tag.
- All commercially built, electrically powered equipment must have a permanent marking with the manufacturer's nameplate, as well as a label from a nationally recognized testing laboratory, such as Underwriter's Laboratory (UL listed).
- BNL-built equipment should have an adequate identification plate or label.
- Controls are to be identified and accurately labeled.
- Personnel shall be warned of the hazards with appropriate labels.
- Workers must know the operating limitations of electrical and electronic equipment before its use. Equipment without identification should not be used.
- Working and access clearance must be provided around equipment for normal operation, routine servicing and emergency work.
- Avoid working in a congested area, as these contribute to accidents.
- Plan exit paths away from or around potentially hazardous equipment when that equipment is being designed and installed.
- Reference ES&H Standard 1.5.0, Table 2 to determine the size of safety control zones.

Hazardous Locations

Some environments are not compatible with conventional electronic and electrical equipment. These include, but are not limited to:

- Corrosive atmospheres, which can damage equipment.

Special corrosion resistant electrical hardware, as well as special plated electrical connection, are to be used in corrosive atmospheres.

- Flammable atmospheres can be ignited by sparks generated by the electrical equipment causing fires or explosions. Conductor overloads, insulation failures, and contact arcing are potential sources of ignition.
- UL-listed hardware, applicable for gas or dust, must be used in flammable atmospheres. This hardware is explosion-proof, dust-tight, or vapor-tight as required for the specific application.

Hazardous locations are broken down into three classes:
Class I - Flammable gasses or vapors - typically flammable liquid storage and dispensing areas.
Class II - Combustible dust - typically combustible metal finishing or fertilizer milling areas.
Class III - Fibers or flyings - typically woodworking or fabric handling areas.

Rules for Housekeeping and Janitorial Duties Around Energized Components

- Do not perform housekeeping and janitorial cleaning next to energized components unless there are adequate safeguards.
- Cleaning materials that are capable of conducting electricity are not to be used unless safety procedures are followed.
- Do not use electrically conductive cleaning materials such as:
  - Metallic wool, such as steel wool
  - Metallic cloth
  - Conductive liquid solutions
  - Silicon carbide abrasives.

Static Electricity

You walk across the rug, reach for the doorknob and……ZAP!!! You get a shock.
Or, you come inside from the cold, pull off your hat and……BOING!!! All your hair stands on end.
Both are the result of static electricity.

"Static electricity" is actually an imbalance in the amounts of positive or negative charges in the surface of an object. Static means that the charge is at rest, the electrons are not flowing. The charge could be either negative or positive, depending on the material.

Things that could cause the buildup of static electricity include the friction of walking on carpet or non-conductive floors, motion of materials in chutes or on conveyors, or moving vehicles.

Gasoline or other flammable liquid chemicals being poured from one contained into another can transfer enough electric charge to provide a source of ignition if it discharges. When transferring flammable liquid chemicals you should prevent charge buildup by bonding and grounding the supply container you are filling together in a continuous circuit as follows:

- Connect one clamp of the bonding jumper to a bare metal surface on the metal container with the greatest quantity of ignitable liquid. Scrape the clamp side-to-side to scratch through paint if necessary to ensure a good connection.
- Connect the other clamp to a metal surface on the other container.
- Connect one clamp of the grounding jumper to a bare metal surface on the container being filled.
- Connect the other clamp on the grounding jumper to a known ground, such as a metal pipe.
- In addition to bonding, a conductive dip tube from the supply container should also be used.
- After the transfer, disconnect the bonding and grounding jumpers in reverse order.

Low Voltages With High Currents

Batteries

A lead-acid storage battery is a low-voltage source that can generate a high-current discharge if short-circuited. This discharge can melt and throw metal fragments, causing severe burns.

Several batteries connected together (a "battery bank") should be treated as a dangerous electrical power source and may have voltages up to 250 volts as well as the capability of delivering substantial currents.

Storage batteries present an explosion hazard as well because they generate hydrogen gas when charging and discharging. Good ventilation is essential to prevent explosions in areas where storage batteries are used. A suitable fire-extinguishing agent must also be present as well as an emergency shower and eyewash station.

Power Supplies

Power supplies are a source of low voltages with high currents. There are many power supplies for experimental work or welding that operate at voltages below 40 volts. These can generate substantial current when shorted. Know the characteristics of the power supplies that you work around. If they can produce high currents when shorted, consider the low voltage connections to be potentially hazardous when the supply is energized.

Electrical Fires

If you discover a fire involving electrical equipment:

- Notify workers in the immediate area to evacuate the area. The smoke produced by burning electrical insulation is highly toxic. No one should inhale this smoke.
- Immediately summon the BNL Fire/Rescue Group by pulling the nearest fire alarm pull box or by calling the Laboratory emergency telephone extension 2222 or 911.
- If possible, de-energize the equipment involved, but only if it can be done safely and without exposing yourself to the smoke.
- If, and only if:
  - The fire is small, fully visible, contained, and not producing much smoke; and
  - You have a clear path of escape; and
  - You think you can fight the fire.
- Use a Class C extinguisher [Carbon Dioxide or Dry Chemical]
- Never use water on an electrical fire, or touch the burning object.
- If the fire is inside a cabinet, do not open the cabinet to get better access or attempt to spray the extinguisher into air vents.
- Stay in the vicinity, out of the smoke to be able to direct the BNL Fire/Rescue Group to the scene of the fire and provide information as to what is burning.