BROOKHAVEN
NATIONAL LABORATORY

Electrical Safety I

Student Guide for the Challenge Examination

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ENABLING OBJECTIVES:

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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.

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Explain capacitor and inductor storage and hazards.

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Describe devices that have low voltage with high current hazards.

List the steps to take in handling an electrical fire.

INTRODUCTION

BNL safety policy is in conformance with:

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)

This safety policy is documented in BNL ES&H Standards: 1.5.0, Electrical Safety; 1.5.1, Lockout/Tagout Requirements; & 1.5.2, Design Criteria for Electrical Equipment. The BNL Electrical Safety Committee is the Authority Having Jurisdiction. They set the Laboratory electrical safety policy; oversee electrical work on site; provide clarification and guidance on electrical safety issues, and investigate electrical accidents. There is also a Laboratory Electrical Safety Officer, Terry Monahan of the Occupational Safety and Health Group of the Safety and Environmental Protection Division. Terry acts as the Authority Having Jurisdiction in the field and reports back to the Laboratory Electrical Safety Committee. He provides clarification and guidance to Departments and Divisions regarding the interpretation and implementation of the codes and standards referenced above. He provides clarification and guidance on the need for written procedures for Lockout/Tagout and Working Hot Permits. He approves submitted procedures for personnel protection from electrical hazards and guides line organizations with training for working hot procedures when requested and is responsible for reviewing annual Critical Systems list updates submitted by line organizations.

The Laboratory Electrical Safety Officer is responsible for maintaining the files of the Electrical Safety Committee and BNL electrical safety documents.

Accident Statistics

Typically, there are over 200 electrically related occurrences each year in DOE Government Owned Contractor Operated (GOCO) facilities. One recent event at another GOCO facility resulted in the hospitalization of an individual who remains comatose. From 1983 to 1992, approximately 130 DOE or DOE contractor personnel reported shocks or burns from contact with electricity in the workplace. Electrocution killed four people at DOE sites during these years. In the U.S., about 1,100 deaths occur each year, mostly at voltages less than 600 VAC. The proper use of Lockout/Tagout (LOTO) procedures could have prevented many of these accidents.

Electrical accidents occur because of exposure to live parts (failure to install covers and guards), improper installation of equipment (wired backwards) improper use of equipment (typically test equipment), faulty design, and because of poor maintenance of equipment, especially grounds.

Foundation Of A Major Injury

According to Hertzberg=s accident pyramid, for every major injury there are:

29 minor injuries, 300 no-injury accidents, 2000 employee mishaps.

<u>And these are just the reported incidents</u>. It is believed that many accidents and near-misses go unreported.

Common Elements In Electrical Accidents

The following are common elements in electrical accidents:

1. Rush/stress (Number 1 contributor)

2. Accidents and near-misses occur during maintenance and trouble-shooting, especially where on/test/off/adjust operations occur.

3. Lack of a means of verification to ensure that equipment is de-energized.

4. Undocumented modifications and design changes that present unexpected hazards contribute to accidents.

5. New equipment designs that have inherent or potential hazards that are not carefully reviewed.

6. Inadequate documentation of operating equipment and systems including schematics and manuals.

7. Lack of an experienced observer (safety watch/two man rule) when working with potentially hazardous, exposed energized equipment can increase accident potential.

8. Key people absent or unavailable increases the accident potential because of the loss of their knowledge and ability.

9 Training was inadequate, incomplete, or not provided for the work

10. Distraction/loss of attention.

11. Experienced employees, because of their previous exposure experience, may develop a more casual approach to electrical and electronic work.

12. Inadequate or no safety plan, no SOP (Standard Operating Procedure), no Aworking hot permits@, or inadequate or no Job Hazard Analyses.

13. People involved are not aware of BNL and/or group safety policies and standards.

14. People involved do not believe that safety policies and standards apply to them or their work.

Human Effects Of Electrical Shock

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.

The majority of electrical current will flow through the path of least resistance. If that path is through a persons body, serious injury or death can occur. There are critical pathways of electrical current flow through a person: hand-to-hand, hand-to-foot, and hand-to-head shock paths.

Factors Of Electrical Shock

There are several factors that can determine how serious an injury caused by electrical shock will be.

1. Amount and duration of current - The higher the amount of current and the longer the current flowing through a persons= body, the greater the physical damage.

2. 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.

3. Wet/damp conditions - Water will conduct electricity. If a person is working is in a wet/damp area, or perspiring, it can reduce the person=s body resistance increasing the likelihood of injury.

4. Contact with ground or grounded objects - 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; back to that source.

5. Area and pressure of body contact - The greater the area and/or pressure of body contact, the greater the conductivity.

6. Age, size, and physical condition of person - In general, very young and old people are less tolerant to the effects of electric shock. The general health of the person prior to shock is a factor.

7. Personal protective equipment - Workers who use proper personal protective equipment can reduce or eliminate the possibility of electric shock.

8. Metal objects such as jewelry - Gold and silver are excellent conductors and will heat when they are in contact with electricity. These heated object can cause serious burns. Do we want to deal with it as part of conductive pathway?

9. Frequency is in Hertz (Hz) - People are more susceptible to injury from electrical energy when the frequencies are between 8 Hz and 400 Hz.

Ohm's Law

There is a relationship between current flow, voltage, and resistance. Ohm=s Law was named for the German physicist Georg Ohm who was the first to experimentally verify this relationship. Ohm=s Law states that the current flow is equal to the voltage divided by the resistance.

Stated as a formula:

$$\textbf{Current (amperes)} = \frac{\textbf{Voltage (Volts)}}{\textbf{Resistance (ohms)}}$$

Current Flow Though A Worker

Normally, dry, unbroken skin has high resistance, approximately 100,000 ohms. When the skin becomes wet, resistance may be reduced significantly, to approximately 1,000 ohms. If a worker with wet hands should come in contact with a live 120 VAC electric line, 0.120 Amps of current would flow through the worker.

$$\text{Amps} = \frac{120 \text{ Volts}}{1{,}000 \text{ ohms } (\Omega)}$$

$$\text{Amps} = 0.120$$

The following table shows current flow for varying conditions, resistance and voltage

VOLTAGE / CURRENT FLOW / HUMAN EFFECT

CONDITION / PATH	RESISTANCE	VOLTAGE	CURRENT	HUMAN EFFECT
DRY SKIN / HAND to HAND	100,000 Ω	120 VOLTS 440 VOLTS	1.2 mA 4.4 mA	PERCEPTION PAINFUL
GRIPPING HANDS	5,000 Ω	120 VOLTS 440 VOLTS	24 mA 88 mA	CANNOT LET GO FIBRILLATION POSSIBLE
WET HANDS	750 Ω	120 VOLTS 440 VOLTS	160 mA 587 mA	FIBRILLATION MAY OCCUR FIBRILLATION CERTAIN
BROKEN SKIN / HAND to HAND	500 Ω	120 VOLTS 440 VOLTS	240 mA 880 mA	FIBRILLATION CERTAIN

Let-Go/No-Let-Go Frequency

Normally, when a person becomes part of an electrical pathway, their muscles contract. If a person is holding a defective electric tool (with fault to the case of the tool) and a grounded object, the person may not be able to let go of the tool and/or grounded object because of the muscular contractions. This can be true for current flow as low as 10 milliamps. But the frequency of the source is also an important consideration in determining whether or not the person will be injured by the shock. At frequencies between 8 and 400 Hertz (Hz), people are more susceptible to injury from electric shock. The effect could be anywhere from a slight tingle to a fatality, depending on the voltage, current, and body=s resistance. If the current flow was less than 10 milliamps, the person should be able to pull their body part away from the electrical source, thus minimizing any permanent injury. If the source was below 8 Hz or greater than 400 Hz, the person may not perceive that they were receiving an electric shock, even though electricity was flowing though their body. If the person could not perceive the current, they would stay in contact with the electric source longer. Longer contact with the source could cause permanent damage to body organs.

Dangerous Electrical Values

Electrical hazards at BNL are divided into four ranges. See Attachment 1, (ES&H Standard 1.5.0, Table 1, Electrical Hazard Ranges and Requirements) for a complete listing of explanations.

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

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 (high voltage);

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

NOTE: A large majority of the electrocutions are caused by voltages of less than 600 V, (600 V is considered high voltage) which include 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 Procedures For Electrical Accidents

If you should come upon an electrical accident the first thing that you should do is to **stop and evaluate** the situation before you act. **YOU DO NOT WANT TO BECOME THE SECOND VICTIM.** You should then act rapidly. If possible, shut off the electric power. The objective is to remove the victim from live contact as quickly as possible. If the power cannot be shut-off, use non-conductive material to move the victim from the contact, or move the energized items from the victim. Once the victim has been removed from the electric source, call for help or, if possible, have someone call for you. You can call the emergency telephone extension 911 or 2222, or pull the nearest fire alarm pull box, or use any other method of communication. For users of cellular phones, the number is 344-2222. Remember, time is critical, seconds count. If you have been trained to do so, begin CPR or first aid, as appropriate. Stay at the scene until help arrives.

Grounding

Proper grounding consists of conducting connections that have sufficiently low impedance and sufficient current-carrying capacity to prevent the buildup of voltages that may result in undue hazards to equipment or persons. It provides equal potential on the exterior surface for all metallic or electrically powered components. These components are connected together in a continuous path to the source of an electrical system where it is grounded to earth, or something which serves the place of earth.

Why Use It

Grounding prevents differences in potential (voltage) in components and surroundings. When grounding, all enclosures should be continuously connected together. This connection is extended to the source or to earth. If the insulation covering conductors were to break down, the enclosure could become energized if it were not grounded. Grounding provides a Aground-fault path@ of low impedance which should cause a fuse to melt or a circuit breaker to trip by increasing current draw.

Results Of Bad Or No Ground

If the grounding circuit is bad, or if there is no grounding circuit, enclosures (such as raceways, cabinets, tools, etc.) could become energized. Current will take any available path back to the source. A person touching an energized enclosure could provide an alternate path to ground. 	Grounding will not do its job if the grounding prong from a plug 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.

Grounding Requirements

OSHA and the National Electrical Code says:

> AThe 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 1910.134 (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 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. The fuses would melt, opening the circuit. Grounding conductors should be sized to safely carry the maximum expected electric current. Grounding/shorting hooks are to be designed and built for the operating voltage and the maximum expected fault current they are likely to have imposed on them.

Grounding Terminology:

Ground - bring to earth potential or approximately zero voltage.

Bond - permanently connect to another device or other devices to keep them at the same voltage.

Neutral - power return path but, because of differences in the power 			system, this may not be grounded.

Common - a connection path used by more than one circuit, this may not be grounded.

Overcurrent Protection

There are three circuit overcurrent conditions which would cause a protective device to de-energize a circuit; overload, short circuit, and ground fault. Overload is when the load draws more current (amperes) than the circuit was designed to handle. A short circuit is when the electrical circuit is completed prior to the load. A ground fault is 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 electricity should cause the protective devices to open the circuit. There are two types of devices used to protect equipment; circuit breakers and fuses. It is important to emphasize that the primary purpose of circuit breakers and fuses is to protect equipment. The secondary purpose is to protect personnel. When a circuit has be de-energized by a protective device, do not manually re-energize the circuit without investigating the cause. Do not perform repetitive manual re-closing of breakers or replacing of fuses. It is permissible to attempt **ONE** manual re-closing of 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 (equipment protection)

When current flow exceeds the capacity of the circuit breaker, the breaker Atrips@, 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 have the capability of being locked with a padlock for the application of lockout/tagout.

Fuses (equipment 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 ranging from fast acting to time delay response. Replacement of fuses must be done by authorized personnel. 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. Use personal protective equipment that your department requires when replacing fuses. When pulling the handle on a disconnect switch, it is recommended that you use your left hand and keep 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 all the switch blades have disconnected. These switches have been known to fail whereby the handle was in the OFF position and one or more of the switch blades was still making contact. Use caution, 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 because they detect fault currents that are too small to trip a circuit breaker or blow a fuse. 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. They are recommended for use in all laboratory and shop areas when using hand-held electrical equipment.

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

Electrical Power Tools

When using electrical power tools, the tools should be either grounded or double insulated. Grounded tools have a grounding prong (third prong) on the power cord. 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 ground fault does develop. Prior to the use of any electrical power tool, the tool should be inspected for any visible signs of damage. Power cords should be in good condition with no signs of deterioration. All three of the prongs of tools with grounding plugs should be in place. Never use a tool if the grounding plug has been removed. Inspect the case of double insulated tools and tag for repair if cracked or showing other obvious signs of damage. When using an electrical powered tool and you receive a shock, or even if you feel a slight tingle, **IMMEDIATELY DISCONTINUE USE**. Tag the tool as defective and have it repaired or replaced.

Capacitors

Capacitors are energy storage devices. They store electrical energy as a DC voltage between two parallel plates that are insulated from each other. They come in many sizes. Common uses for capacitors include motor starters and power supplies.

Capacitor 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. **Assume a capacitor is charged if it is not shorted.** Avoid touching even small capacitors if they are not discharged and shorted. Un-shorted capacitors may recharge due to internal material effects. Capacitors can catastrophically fail with internal fault; resulting in an explosion. The exploding case of a capacitor could send shrapnel flying. If a fire were to occur, toxic fumes (phosgene gas), could be released if the capacitor contains PCBs. Even leaks of insulating fluids can be harmful if it contains PCBs. Not all capacitors are labeled and unlabeled capacitors should be considered to contain PCBs until proven otherwise.

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.

Inductor 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. Inductors can induce electrical currents in adjacent equipment, and may disturb the operation of the circuits of pacemakers and other medical implants. Inductors may store large amounts of electrical energy, and current may continue to flow for long periods after the power is removed (i.e., superconducting magnets). Inductors can also attract loose magnetic materials with their magnetic field and impair the operation of instrumentation operating within that field such as Pacemakers and other electronic medical implants.

Safety Around Electrical Equipment

Electrical Worker Categories

Electrical distribution work from LILCO tie-ins to wall 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. Work on complex scientific equipment should only be performed by personnel classified as *Research Workers.*

These categories are further defined as Qualified Workers and Authorized Workers. Qualified Workers are personnel, either an employee or a contractor, who has 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

Personnel who may accidentally encounter energized components must be protected by a control zone. Personnel who work within a control zone shall be protected by:

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

Lockout/Tagout (LOTO)

Lockout/Tagout is a program requiring the practices or procedures necessary to disable machinery or equipment and to prevent the unexpected release of potentially hazardous energy during maintenance servicing or construction (not to prevent normal use).

Potentially hazardous energy does not only apply to electricity, but to eight different energy sources; electrical, hydraulic, pneumatic, potential, thermal, mechanical, chemical and radiation.

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

BNL uses dedicated Master locks with red bands around the base of the lock accompanied by red tags imprinted with the word HOLD, DO NOT OPERATE in large black letters.

The BNL ES&H Manual, Section 1.5.1, ALockout/Tagout Requirements@ outlines the responsibilities and training requirements for two types of employees; Affected and Authorized. Additional on-the-job training and certification at the Department/Division level is needed before an employee is authorized to lockout and tagout equipment they work on.

Affected Employee

Their job requires the employee to operate or use machinery, on which maintenance, servicing or construction is performed under lockout or tagout or working in an area where LOTO is in progress. They are trained to identify locks, tags and recognize that energy control procedures have been implemented. They also know they are not to attempt to start or use the equipment. An affected employee is not allowed to implement LOTO.

Authorized Employee

An authorized employee is a person who has been trained to recognize hazardous energy sources, to control the 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 Department/Division and thereby become authorized to perform LOTO. BNL defines two classes of "authorized employees".

"Knowledgeable Employee" - A knowledgeable employee is authorized to conduct LOTO for their own protection. They are limited in that they cannot initiate "group or operations locks and/or tags". They are authorized to attach additional locks and tags in "operations lock" situations provided that their lock and tag is not the first 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 Departmental 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, which if de-energized would introduce additional or increased hazards or are not capable of being de-energized due to equipment design or operational limitations. Examples of critical systems are life support devices, hazardous area ventilation equipment, fire protection systems, emergency egress illumination devices, and access control systems. Each Department/Division 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 is to be reviewed and updated annually.

Control Zone

A control zone is a sufficiently large area surrounding exposed energized circuitry to prevent injury or minimize exposure to unqualified personnel. The four major control zones; Flash Protection Boundary, Limited Approach Boundary, Restricted Approach Boundary, and Prohibited Approach Boundary with their respective dimensions are fully described in Attachment 2 (ES&H Standard 1.5.0, Table 2, Electrical Work Clearances (Control Zones)). Personnel working within the *Flash Protection Boundary*, are to be advised of that hazard by the cognizant engineer/manager and the appropriate personal protective equipment is to be made available. 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 may 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 personal protective equipment.

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"*** parts could cause serious injury or death. Work 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 a Department Chair/Division Head or formal designee may issue "Working Hot Permits" to respond to operational or emergency situations, or for situations which 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 Attachment 1 (ES&H Standard 1.5.0, Table 1, Electrical Hazard Ranges and Requirements) to find requirements for written procedures, working hot permit authorization, training, safety watch and/or 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: 1. A generic approved work procedure is in place. 2. 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. 3. 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 Permit must be issued each time the procedure is used subject to the following restrictions:* 1. A generic approved work procedure is in place. 2. 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. 3. The Working Hot Permit contains the names of those who will be performing the task. 4. 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:* 1. A task specific approved work procedure, as defined in Section V of ES&H Standard 1.5.0, is in place. 2. 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. 3. The Working Hot Permit contains the names of those who will be performing this specific task. 4. The permit shall only be issued after independent review as defined in ES&H Standard 1.5.0. 5. A person with current training in Cardiopulmonary Resuscitation (CPR) is required as a *Safety Watch.*

Alerting Techniques

Markings, labels, and hazard warning signs indicating immediate danger shall be prominently displayed and are to be installed or mounted as 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 appropriate hazard warning lettering is to appear in the bottom panel. The words "High Voltage" indicates the hazard is due to more than 600 Volts. 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 warning must give clear meaningful instructions. If the hazard is removed, the warning sign or label should be removed also. 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. However, as a warning indicator, NEVER TRUST AN UNLIT LAMP. Consider everything to be energized.

General Safety Guidelines

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

1. All electrical tasks are 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 supervisor. This pre-work planning should include: a) the scope of the work to be performed; b) analysis of the hazards involved; and c) necessary controls to mitigate identified hazards. Only then are employees to perform the assigned tasks while keeping within the defined controls. Appropriate feedback is needed for improvement.

2. Personnel trained to the level of this course are not expected to work on energized equipment.

3. Approach electrical systems and equipment as if they are energized. Maintenance and operational check-out of electrical systems and equipment often require removing protective barriers and potentially exposing personnel to energized components.

4. All personnel are expected to follow Lockout/Tagout (LOTO) procedures unless they are required to work on a Critical System.

5. Always use the appropriate meters to take measurements on electrical equipment.

6. Make sure that no part of your body, especially your head, touches energized

equipment. Wear appropriate protective equipment when required, including headgear.

7. Avoid wearing metal such as rings or metallic watch bands when working with electrical equipment or near induction or dielectric heating equipment.

8. Use suitably insulated tools or matting rated for the voltage encountered when working on energized equipment.

9. Regard concrete and brick walls as conductive and grounded. Floors are also to be considered as conductive and grounded.

10. De-energize equipment and use proper rated fuse handling equipment to remove and install fuses.

11. Use only non-conductive ropes and hand lines near exposed energized parts.

12. Use maintenance manuals for equipment being serviced.

13. Manholes and handholds should have no bare, ungrounded, current-carrying metal parts exposed to accidental contact. Use precautions when working in confined spaces that contain energized parts.

14. Use precautions when working in elevated positions or when driving vehicles that can be elevated near energized overhead lines.

15. Provide grounds for equipment in the field, including equipment in trailers. There should be an automatic indication if trailer grounds are lifted.

16. Remain outside the Control Zone except when necessary to perform the assigned task.

17. Use appropriate warning signs and barricades to protect passersby.

18. Use caution when handling long metallic objects in areas where they could become energized.

Flexible Cords

Flexible cords include 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 the rated amperage. Cords are required to be traceable, viewable, and accessible. Know the circuit panel and number associated with the cord. Do not hoist or lower portable tools or equipment by the 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 which remain connected and not exposed to damage need not be inspected until relocated (wall clock, water cooler). Only hard usage or extra hard usage "S" Cords are permitted: 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). The use of metal-jacketed plugs used on 110 and 220 VAC single phase circuits or plugs with exposed connections on their face are not permitted. 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 have to contain an equipment grounding conductor and have appropriate grounding conductors on the attachment plugs and connectors.

Prohibited Uses

Do not use cords to power a new outlet from an existing outlet (male-to-male connection). Cords must not be concealed or attached to buildings. Do not run cords through walls, ceilings, or floors. Also, cords are not to be used in place of permanent or semi-permanent wiring.

NOTE: For single task oriented activities, provide blocking or similar protection for cords run through doors or windows.

Safety Requirements for Design And Construction

BNL requires that the same standards are used by everyone (employees, guests, and contractors). All equipment must be free from recognized hazards. The equipment must be durable and suitable for its intended use. Equipment must be installed correctly. Insulation and arc control must be used so personnel are not exposed to bare conductors. Conductors must be adequately sized to prevent overheating. Personnel shall be warned of the hazards with appropriate labels. Controls are to be identified and accurately labeled.

Equipment must be identifiable. Know the operating limitations of electrical and electronic equipment before using them. For commercial equipment, the manufacturers nameplate should be visible. BNL built equipment should have an adequate identification plate or label permanently attached to the equipment. Equipment without identification should not be used. All commercially built electrically powered equipment must have permanent marking from a nationally recognized testing laboratory such as being UL listed.

Working and access clearance must be provided around equipment for normal operation, routine servicing and emergency work.. Working in an congested area is a contributor to accidents. Consideration should be given to exit paths away from or around potentially hazardous equipment when it is being designed and installed. Use ES&H Standard 1.5.0, Table 2 for dimension of safety control zones.

Hazardous Locations

There are some environments that are not compatible with conventional electronic and electrical equipment. Corrosive atmospheres can damage equipment. 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 ignition sources.

Special corrosion resistant electrical hardware as well as special plated electrical connections are used in corrosive atmospheres. UL approved hardware, certified for gas or dust is 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 1 - 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.

Housekeeping and Janitorial Duties

Housekeeping and janitorial cleaning is not to be performed next to energized components unless there are adequate safeguards. Cleaning materials 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, metallic cloth, conductive liquid solutions, or silicon carbide abrasives.

Static Electricity

Static electricity is an accumulation of electrical charge. 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 static electricity include the friction of walking on carpet or on non-conductive floors. Static electricity may also be generated by chutes or conveyors, or moving vehicles.

Gasoline or other chemicals falling into a container can transfer enough electric charge to provide a source of ignition if it discharges. When transferring liquid chemicals you should prevent charge buildup by connecting the supply container and container you are filling together in a continuous circuit to ground. In addition to bonding, a conductive dip tube from supply to container should also be used.

Low Voltages With High Currents

Batteries

A single battery is a low voltage source that can generate a high current discharge if short circuited. This discharge can melt and throw metal causing severe burns.

Multiple battery banks should be treated as a dangerous electrical power source. They can typically have voltages of up to 250 volts. Multiple batteries can also generate substantial currents. Batteries can also be explosion hazard as well because of the generation of hydrogen gas when charging and discharging. This is why good ventilation around batteries is essential. In addition to good ventilation, a suitable fire extinguishing agent must be present as well as an emergency shower and eyewash station.

Power Supplies

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

Electrical Fires

If you observe a fire involving energized electrical equipment, the first thing that you should do is notify workers in the immediate area. Then summon the BNL Fire/Rescue

Group by pulling the nearest fire alarm pull box or by calling the Laboratory emergency telephone extension 911 or 2222. If possible, de-energize the equipment involved. If you think you can fight the fire, if the fire is not spreading and you are not going to get trapped, use a Class C extinguisher (CO_2 or dry chemical). Don't use water on an electrical fire or touch the burning object. Stay in the vicinity to direct the BNL Fire/Rescue Group to the scene of the fire.

Electrical Hazard Ranges and Requirements

ES&H Standard 1.5.0, Table 1

Range (See not 1)	Criteria (See note 3)	Written Procedure	Working Hot Permit	Training	Safety Watch and/or 2 Man Rule (See note 7 and 8)
A - Low Hazard Operation [See notes 5 & 6]	(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 "A" Hazard; but falling into either of the following: AC voltages less than or equal to 250 Vac rms; or DC voltages less than or equal to 1,000 Vdc; with greater than 10 mA 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 LockOut / TagOut (LOTO)	N/A
C - Hazardous Operations	(Potential for severe injury or death is greater) characterized by voltages greater than "B" Hazard; but falling into either of the following: AC voltages less than or equal to 600 Vac rms; or DC voltages less than or equal to 6,000 Vdc; with greater than 10 mA of available current or capable of an instantaneous release of greater than 10 Joules of energy.	Generic	Job Specific Issued by Dept Chair or formal Designee [See note 2]	Relative to task (document personnel who work on job). BNL Electrical Safety Course LockOut / TagOut (LOTO)	2 Man Rule [See note 7]
D - High Hazard Operations	(Potential for severe injury or death is greatest) characterized by voltages greater than "C" Hazard as described below: AC voltages above 600 Vac rms; or DC voltages above 6,000 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 Independant review required. [See note 2]	Relative to task (maintain list of authorized personnel). BNL Electrical Safety Course LockOut / TagOut (LOTO) Cardiopulmonary Resuscitation (CPR)	Safety Watch (Total of 2 or more persons at the work site) [See note 8]

Notes:

1. In cases where electric devices do not fit clearly into any of the above ranges, a review of the line Department/Division and S&EP 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 "A" are capable of delivering greater than 10 ma of current and more than 10 Joules of instananeous energy.
5. Injury is possible from flash hazards and non electrical secondary effects.
6. High voltage sources with fault currents less than 10ma and less than 10 Joules of available energy are considered Range "A" hazards (e.g. ion pump power supplies).
7. The ***Two Man Rule*** states that the person shall not work alone on energized circuits of Range "C" or "D". 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 saftey 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.