Chapter 8

Electrical Safety

Related Chapters

1 SLAC ES&H Program

19 Personal Protective Equipment

23 Warning Signs and Devices

24 Training

31 Citizen Committees

Chapter Outline

1 Policy

It is SLAC policy to comply with Occupational Safety and Health Administration (OSHA) regulations, the National Electrical Code (NEC), and other established safety standards to reduce or eliminate the dangers associated with the use of electrical energy. Every person on the SLAC site is exposed to electricity to some extent. The SLAC electrical safety program provides the SLAC community with the minimum knowledge of safety and recommended practices necessary to protect against electrical shock or burns. The electrical safety program also provides hazard awareness information to those who use electrical equipment.

Reading this chapter does not qualify the reader to perform electrical work. Guidelines that are beyond the scope of this document must be established at each work area. They should include, as a minimum, the safety concerns outlined in this chapter.

All electrical wiring and equipment must comply with NEC, OSHA regulations, and numerous other established safety and engineering standards. This chapter should not be construed as a synopsis of all electrical requirements or as a substitute for formal study, training, and experience in electrical design, construction, and maintenance.

2 Responsibilities

All individuals at the site are responsible for their own safety. Specific responsibilities are detailed below.

2.1 Electrical Safety Committee

The Electrical Safety Committee (ESC)[1] provides advice on electrical safety matters and promotes electrical safety at the site. In addition, the ESC is responsible for reviewing new major projects as directed by the Safety Overview Committee. For more information about specific review responsibilities, see Section 7.1, “Equipment Acceptability”, Section 7.5, “Enclosures”, and Section 7.6, “Clearance around Electrical Equipment”. Refer to Chapter 31, “Citizen Committees”, of this manual for more information about the ESC and the Safety Overview Committee.

2.2 Environment, Safety, and Health Division

The Environment, Safety, and Health (ES&H) Division provides technical assistance, coordination and oversight of the electrical safety program. See Section 5, “Training,” in this chapter for more information about the ES&H Division and electrical training issues. Refer to Chapter 1, “The SLAC ES&H Program”, in this manual for more information about the ES&H Division.

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1 Information about the ESC may be found at https://www-internal.slac.stanford.edu/esh/committees/esc/members.htm

2.3 Managers and Supervisors

Managers and supervisors are responsible for maintaining a work environment free from recognized electrical hazards throughout their area of control. Managers and supervisors must

- Be aware of all potentially hazardous electrical activities within their area of responsibility
- Develop an attitude and awareness of electrical safety in the people they supervise and see that individual safety responsibilities are carried out
- Ensure that the personnel they direct are knowledgeable and trained in the electrical tasks they are asked to perform[2]
- Maintain an electrically safe work environment and take corrective action for potentially hazardous operations or conditions
- Ensure that safe conditions prevail in the area, and that area occupants are properly informed of electrical safety regulations and procedures
- Ensure that all workers are properly protected by means such as instructions, signs, barriers, electrical personal protective equipment (PPE), and appropriate lock and tag devices
- Ensure that workers assigned to potentially hazardous electrical work are physically and mentally able to perform the work
- Assign a safety watch person when hazardous work is performed
- Determine if two people are required for an energized work task by OSHA regulations
- Provide necessary outage time frames so that maintenance personnel can provide periodic electrical maintenance and testing of personnel safety devices, such as electrical interlocks and grounding
- Plan activities such that work may be performed in a de-energized state whenever possible

2.4 Personnel

Personnel must

- Become acquainted with all potential electrical hazards in the area in which they work
- Learn and follow the appropriate electrical standards, procedures, and hazard-control methods
- Consult with appropriate supervisors (your own supervisor and the supervisor of the hazardous system) before undertaking a potentially hazardous electrical operation
- Notify a supervisor of any condition, person, or behavior which poses a potential electrical hazard[3]
- Wear and use appropriate electrical personal protective equipment (PPE). Refer to Table 8-2, Table 8-3, and Table 8-4 for information regarding PPE.

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2 The ES&H Division can assist managers and supervisors to determine the appropriate training for individuals they supervise. See Section 5, “Training”, in this chapter for more information.

3 See Chapter 2, “Work Authorization”, (http://www-group.slac.stanford.edu/esh/general/work_authorization/policies.htm) in this manual for more information about unsafe activities.

- Report immediately any electrical shock incident to the SLAC Medical Department and to the appropriate supervisor
- Complete appropriate electrical safety and lock and tag training
- Complete training in emergency response procedures, including cardiopulmonary resuscitation (CPR), if performing work on exposed electrical circuitry of more than 50 volts (AC or DC)

Note *See Section 4, "Qualified and Authorized Personnel", for additional information about qualifications for personnel who work on electrical equipment or systems.*

2.5 Safety Watch Person

When deemed appropriate by the supervisor, a safety watch person (SWP) shall be assigned when hazardous work is performed. The SWP must

- Be in visual and audible range of the person performing the work while the work is in progress
- Be familiar with the work to be performed and the safety procedures involved
- Observe the worker(s) and operations being performed to prevent careless acts
- In an emergency, quickly de-energize the equipment and alert emergency rescue personnel
- Know the location of the corresponding circuit breaker or switch that must be turned off in case of emergency
- Be equipped with a radio or know the location of the nearest telephone to obtain emergency help
- Complete training in emergency response procedures, including cardiopulmonary resuscitation (CPR)
- Have no other duties that preclude observing workers and operations, and rendering aid if necessary

3 Hazards

Electricity is one of the most commonly encountered hazards in any facility. Under normal conditions, safety features in electrical equipment provide protection from hazards. Nonetheless, accidental contact with electricity can cause serious injury or death.

3.1 Electrical Shock

Most electrical systems establish a voltage reference point by connecting a portion of the system to an earth ground. Because these systems use conductors that have voltages with respect to ground, a shock hazard exists for workers who are in contact with the earth and are exposed to the conductors. If workers come in contact with a "live" (ungrounded) conductor while they are in contact with the ground, they become part of the circuit and current passes through their bodies.

The effects of electric current on the human body depend on the following:

- Circuit characteristics (current, resistance, frequency, and voltage – 60 Hz (hertz) is the most dangerous frequency)

- Contact and internal resistance of the body
- The current's pathway through the body, determined by contact location and internal body chemistry
- Duration of contact
- Environmental conditions affecting the body's contact resistance

The most damaging route of electricity is through the chest cavity or brain. Fatal ventricular fibrillation of the heart (stopping of rhythmic pumping action) can be initiated by a current flow of as little as several milliamperes (mA). Nearly instantaneous fatalities can result from either direct paralysis of the respiratory system, failure of the rhythmic pumping action of the heart, or immediate heart stoppage. Severe injuries, such as deep internal burns, can occur even if the current does not pass through vital organs or nerve centers.

Table 8-1 is based on limited experiments performed on human subjects in 1961. These figures are not completely reliable due to the unavailability of additional data and the inherent physiological differences between people. Electricity should be considered potentially lethal at lower levels than those cited.

3.2 Burns

Burns suffered in electrical accidents are of three basic types:

1. Electrical
2. Arc
3. Thermal contact

In electrical burns, tissue damage (whether skin deep or deeper) occurs because the body is unable to dissipate the heat from the current flow. Typically, electrical burns are slow to heal.

Arc burns are caused by electric arcs and are similar to heat burns from high-temperature sources. Temperatures generated by electric arcs can melt nearby material, vaporize metal in close vicinity, and burn flesh and ignite clothing at distances up to three meters (or 10 feet).

Thermal contact burns are those normally experienced from skin contact with the hot surfaces of overheated electric conductors (anything carrying electricity).

Table 8-1 Quantitative Effects of Electric Current on Humans

Effects	Current, mA					
	Direct Current		Alternating Current			
			60 Hz		10 kHz	
	Men	Women	Men	Women	Men	Women
Slight sensation	1	0.6	0.4	0.3	7	5

Effects	Current, mA					
	Direct Current		Alternating Current			
			60 Hz		10 kHz	
	Men	Women	Men	Women	Men	Women
of hand						
Perception threshold	6.2	3.5	1.1	0.7	12	8
Shock – not painful and no loss of muscular control	9	6	1.8	1.2	17	11
Painful shock – muscular control lost by 0.5%	62	41	9	6	55	37
Painful shock – let-go threshold, media	76	51	16	10.5	75	50
Painful and severe shock – breathing difficult, muscular control lost by 99.5%	90	60	23	15	94	63
Possible ventricular fibrillation						
Three-second shocks	500	500	100	100		
Short shocks (where T is time in seconds)			A[b]	A[b]		
High-voltage surges	50[c]	50[c]	13.6[c]	13.6[c]		

Notes:

a. "Deleterious Effects of Electric Shock", Charles F. Dalziel, p. 24. Presented at a meeting of experts on electrical accidents and related matters, sponsored by the International Labour Office, World Health Office and International Electrotechnical Commission, Geneva, Switzerland, October 23-31, 1961. See the study for definitions and details.

b. $A = \frac{165}{\sqrt{T}}$

c. Energy in joules (watt-seconds)

3.3 Delayed Effects

Damage to internal tissues may not be apparent immediately after contact with an electrical current. Delayed internal tissue swelling and irritation are possible. Prompt medical attention can help minimize these effects and avoid long-term injury or death.

3.4 Other Hazards

Voltage sources that do not have dangerous current capabilities may not pose serious shock or burn hazards in themselves and therefore are often treated in a casual manner. However, voltage sources are frequently used near lethal circuits, and even a minor shock could cause a worker to rebound into a lethal circuit. Such an involuntary reaction may also result in bruises, bone fractures, and even death from collisions or falls.

Electricity poses other hazards. An arc is often created when a short circuit occurs or current flow is interrupted. If the current involved is strong enough, these arcs can cause injury or start a fire. Fires can also be started by overheated equipment or by conductors that carry too much current.

Extremely high-energy arcs can cause an explosion that sends fragmented metal flying in all directions. Even low-energy arcs can cause violent explosions in explosive or combustible atmospheres.

4 Qualified and Authorized Personnel

This section applies to individuals who work on electrical equipment.

4.1 General Requirements for a Qualified Person

A qualified person is an individual recognized by SLAC management as having sufficient understanding of the equipment, device, system, or facility to positively control any hazards it presents. Recognition of a person’s qualification for operating complex devices, systems, equipment, and facilities must be determined by the appropriate department head or designee.

Only those persons who are qualified and authorized may install, fabricate, repair, test, calibrate, or modify electrical wiring, devices, systems, or equipment.

Qualification and authorization to perform electrical or electronics work is based on a combination of formal training, experience, and on-the-job training.

4.2 Qualifications for Working on Energized Components

If work on energized components is anticipated, the training of the person who will be doing the work shall cover

- Specific operations in which live work is anticipated
- Features of the equipment including any specialized configuration

- Location of energy-isolating devices
- Techniques, tools, and PPE used for the specific equipment
- Relevant documents such as wiring diagrams, schematics, service manuals, design packages, and operating, testing, and calibrating procedures
- Systems' energy control procedures, including energy-isolating devices, grounding and shorting procedures, and other energy control procedures
- Recordkeeping and logging requirements

Supervisors are responsible for ensuring that employees or others under their supervision are qualified to work on energized components before they are assigned to such work.

5 Training

To determine that personnel are knowledgeable and trained in the electrical tasks they are asked to perform, managers and supervisors must complete SLAC training assessments (STAs) for their workers under the following conditions:

- Upon initial hire of new employees
- Annually with performance appraisals
- Upon significant change in job duties

The ES&H Division provides an STA to assist managers and supervisors to assist in determining training requirements for their workers. Electrical safety classes are offered by the ES&H Division and are divided into two categories, core[4] and resource[5]. Information about the STA and electrical safety courses are available on the web.

5.1 Core Courses

Core courses are courses formally required by regulations or SLAC policies:

- CPR/First Aid

  This course is required for all personnel who work on exposed electrical circuitry of more than 50 volts (AC or DC). Personnel who work with communication circuits and DC circuits with a fault current limited to 5 mA (if the energy is less than 10 joules) or less are exempt from this requirement. Employees who perform safety watch duties must also take this class.

- Electrical Safety for Non-electrical Workers

  This course is required for all employees who are not qualified electrical workers but face a risk of electric shock that is not reduced to a safe level by the electrical installation requirements. For example, if an employee works near exposed energized electrical conductors in equipment or

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4 https://www-internal.slac.stanford.edu/esh-db/training/slaconly/bin/catalog_item.asp?course=239

5 https://www-internal.slac.stanford.edu/esh-db/training/slaconly/bin/catalog_item.asp?course=251

distribution systems such as open junction boxes, then he or she faces a risk of electric shock and needs this training. Typical attendees include mechanics, painters, riggers, carpenters, operators, and their direct supervisors.

- Electrical Safety for R&D Equipment

  This course or equivalent training is required for all personnel who design, operate, maintain, or install Research and Development (R&D) equipment that operates at or more than 50 volts (AC or DC). Such personnel include physicists, engineering physicists, engineering scientists, research technicians, equipment designers and assemblers, test engineers, and technicians from the Electronics & Software Engineering and Mechanical Fabrication Departments.

  Managers and supervisors who directly supervise personnel who do this work are also required to take this course, or its equivalent.

- Electrical Safety, Low- and High-Voltage

  This course is required for all personnel who construct, install, or maintain electrical equipment (other than R&D equipment). This includes electricians and technicians who install, maintain, or repair energized or de-energized systems and equipment that operate at more than 50 volts, including motors, transformers, breakers, switches, distribution panels, and wiring.

  Managers and supervisors who directly supervise personnel who do this work are also required to take this course.

- Lock and Tag Awareness for Affected Employees

  This course is required for all employees who work on or near equipment that may be locked or tagged out during service or maintenance, but who do not apply lock and tag themselves, or who apply lock and tag only after an authorized person has applied lock and tag.

- Lock and Tag for the Control of Hazardous Energy

  This course is required for all employees who will perform maintenance on equipment that poses a hazard if accidentally energized.

5.2 Resource Courses

Resource courses are courses that do not have regulatory or policy drivers, but are of significant value to SLAC employees. Completion of these supplemental courses is not required and is left to the discretion of the supervisor or the employee. The ES&H Division offers some Resource courses at SLAC or provides recommendations for off-site courses.

- Grounding, Electrical

  This training is recommended for electrical engineers and designers who are involved in the design, specification, inspection, or engineering of electrical equipment or distribution systems that carry 50 volts (AC or DC) or more. This type of training is available from several off-site sources.

- National Electrical Code Training

  This training is recommended for electrical engineers, designers, electricians, and others who are involved in the design or installation of electrical systems and equipment. This type of training is available from several off-site sources.

6 Standards

Equipment shall be designed, operated and maintained according to the following safety standards:

- Title 29, *Code of Federal Regulations*, Part 1910 (29 CFR 1910), "Occupational Safety and Health Standards"
- Title 29, *Code of Federal Regulations*, Part 1926 (29 CFR 1926), "Safety and Health Regulations for Construction"
- National Fire Protection Association (NFPA) 70, *National Electrical Code*, current version
- NFPA 70E, "Standard for Electrical Safety Requirements for Employee Workplaces"
- NFPA 101, *Life Safety Code*
- Institution of Electronics and Electrical Engineers (IEEE) IEEE C2, *National Electrical Safety Code*, current version

The Department of Energy (DOE) handbook, *Electrical Safety* (DOE-HDBK-1092-98), can be used as a reference and guideline.

7 General Requirements for Equipment Safety

All equipment should be designed and constructed to protect personnel. First-line and backup safeguards should be provided to prevent personnel from accessing energized circuits. Periodic tests should be established to verify that these protective systems are operative.

7.1 Equipment Acceptability

Electrical equipment is considered safe only when it is used as specifically intended by its listing and design. Equipment must not be altered beyond the original design intent and must not be used for any purpose other than that for which it was constructed.

7.1.1 Re-commissioning Electrical Equipment

Any equipment that is being re-commissioned must be examined or tested, as appropriate, to verify the status of all safety features and the integrity of construction.

7.1.2 Listing or Labeling Electrical Equipment

Electrical equipment must be listed or labeled by a nationally recognized testing laboratory (NRTL). An NRTL is recognized by OSHA as being capable of independently assessing equipment for compliance to safety requirements and applicable standards. As of this printing,

OSHA has accredited the following organizations:

- Canadian Standards Association (CSA)[6]
- Communication Certification Laboratories (CCL)
- ETL Testing Laboratories, Inc. (ETL)
- Factory Mutual Research Corporation (FMRC)
- MET Laboratories, Inc. (MET)
- Southwest Research Institute (SWRI)
- Underwriters Laboratories, Inc. (UL)
- United States Testing Company, Inc. California Division (UST/CA)
- Wyle Laboratories

7.1.3 Custom-made Equipment

For equipment for which no NRTL acceptance exists, such as custom-made, the following alternate methods of ensuring the safety of the product are acceptable:

- The product must be designed and constructed according to applicable American National Standards Institute (ANSI), National Electrical Manufacturers Association (NEMA), Institute of Electrical and Electronics Engineers (IEEE) or UL standards.
- The division or group responsible for the equipment must maintain all documentation pertaining to the design safety features of the equipment, including any test data. This documentation must be available to any SLAC safety inspector (such as a Division or Department safety officer or the ES&H Division).
- The SLAC electrical safety officer may require that equipment that is not NRTL listed undergo inspection or testing for conformance to standards. Such testing should be documented and submitted to the Electrical Safety Committee for approval. The inspection record must specify, at a minimum,
  - Equipment identification
  - Evaluator name, date, mail stop, and extension
  - Standard to which equipment is being evaluated
  - Specific tests, results, and areas of examination
  - Any conditions of product acceptability or limitations of use

7.2 Equipment Safety Practices

All workers must observe the following safety practices regarding equipment and conditions:

7.2.1 Cable Clamping

Use a suitable mechanical-strain-relief device such as a cord grip, cable clamp, or plug for any wire or cable penetrating an enclosure where external movement or force can exert stress on the internal connection. Grommets or similar devices must not be used as strain relief.

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6 CSA acceptance is limited to a range of specific products which conform to US standards.

7.2.2 Emergency Lighting

Make emergency lighting available in the event normal lighting fails when work is being conducted on energized components. Emergency lighting is not necessary for working on low hazard circuits (less than 50 volts or circuits with current limited to 5 mA).

7.2.3 Flammable and Toxic Material Control

Keep the use of flammable or toxic material to a minimum. A catch basin or other approved method must be provided to prevent the spread of these materials if the normal component case fails.

7.2.4 Isolation and Grounding

Isolate all sources of dangerous voltage and current with covers and enclosures. Access to lethal circuits (greater than 50 volts) must be either through screw-on panels or through items such as interlocked doors, panels, or covers. The frame or chassis of the conductive enclosure must be connected to a good electrical ground with a conductor capable of handling any potential fault current.

7.2.5 Lighting

Provide adequate lighting for easy visual inspection.

7.2.6 Disconnecting and Overload Protection

Provide overload protection and well-marked disconnects. Provide local “off” controls whenever possible. All disconnects and breakers shall be legibly marked to indicate purpose unless located and arranged so the purpose is evident. The marking shall be of sufficient durability to withstand the environment involved.

7.2.7 Rating

Operate all items such as conductors, switches, or resistors within their design capabilities. Pulsed equipment must not exceed either the average, the root mean square (rms), or the peak rating of components. The equipment must be derated as necessary for the environment and the application of the components.

7.2.8 Electrical Equipment Rooms

Place an identifying label or sign on the exterior door or panel when equipment that may require servicing, manipulation, or inspection is concealed in an equipment closet or otherwise is obscured behind doors or panels.

7.2.9 Re-use of Circuit Breakers

Do not purchase used or reconditioned circuit breakers from vendors outside SLAC. Re-use of SLAC circuit breakers is permitted only after the circuit breaker has been tested by the Electric Shop in the Conventional and Experimental Facilities (CEF) Department office.

7.2.10 Electronic Devices in Hazardous Areas

Do not use a cellular telephone or a two-way radio or any other electronic device in class one, Division 1 or 2 areas (such as near hydrogen gas storage) unless they are a type especially qualified (such as FMRC approved). Do not replace or change batteries in a hazardous atmosphere. Pagers may be used in hazardous areas if they contain the following message (or equivalent): RAD DEV FOR HAZ LOC.

7.3 Design and Installation

All design and installation of equipment and facilities shall be in accordance with the applicable standards listed in Section 6, “Standards”, and SLAC policies and procedures.

Safety should be considered an integral part of the design process. Protective devices, warning signs, and administrative procedures are supplements to good design, but can never fully compensate for the absence of good design. Completed designs shall provide for safe maintenance.

All systems performing a safety function or controlling a potentially hazardous operation and any modifications made to those systems shall be reviewed and approved at the level of project engineer or above.

Line managers are responsible for ensuring that all electrical installations are in compliance with all safety and code requirements stipulated in this chapter. CEF and the ES&H Division have knowledgeable personnel available to answer specific design and installation questions.

7.4 Documentation

A current set of documentation adequate for operation, maintenance, testing, and safety shall be available to anyone working on potentially hazardous equipment. Keep drawings and prints current. Dispose of obsolete drawings and be certain that active file drawings have the most current corrections. Archive all drawings with MD-Facility Design, Document Control (ext. 4307).

7.5 Enclosures

The following specifications apply to circuits operating at or more than 50 volts or storing more than 10 joules. An enclosure may be a room, a barricaded area, or an equipment cabinet.

7.5.1 Access

Lock, interlock, or label items easily opened, such as doors or hinged panels that allow ready access to exposed energized components, to prevent people from coming in contact with live circuits.

7.5.2 Heat

Mount heat-generating components, such as resistors, so that heat is safely dissipated and does not affect adjacent components.

7.5.3 Isolation

Ensure that the enclosure physically prevents contact with live circuits. The enclosure can be constructed of conductive or nonconductive material. If conductive, the material must be electrically bonded and connected to a live electrical ground. These connections must be adequate to carry all potential fault currents.

7.5.4 Seismic Safety

Secure all racks, cabinets, chassis, and auxiliary equipment against movement during earthquakes.

7.5.5 Strength

Ensure that enclosures are strong enough to contain flying debris caused by component failure.

7.5.6 Temporary Enclosure

Temporary enclosures (of less than six-month duration) not conforming to the normal requirements may be used if approved by the Electrical Safety Committee, but must be provided with a sign identifying it as temporary, and with date of installation and scheduled removal.

7.5.7 Ventilation

Ensure that ventilation is adequate to prevent overheated equipment and to purge toxic fumes produced by an equipment fault. Ventilation openings must not be obstructed.

7.6 Clearance around Electrical Equipment

Maintain clearance space around power and lighting circuit breaker panels, motor controllers, and other electrical equipment. This clearance space ensures safe access for personnel who inspect, adjust, maintain, or modify energized equipment.

The clearances shall be in accordance with OSHA, NEC, and the National Electrical Safety Code (NESC). These working clearances are not required if the equipment is not likely to require examination, adjustment, servicing, or maintenance while energized. However, sufficient access and working space is still required to work on equipment in a de-energized state.

Clearance space must not be used for storage or occupied by bookcases, desks, workbenches, or similar items.

7.6.1 Electrical Equipment Rated at 600 Volts or Less

For equipment operating at 600 volts (nominal) or less to ground, the minimum required clearance is an unobstructed space 36 inches deep, 30 inches wide, and 78 inches high (measured from the floor). Some installations may require greater clearance. For more complete information, see the NEC.

Some buildings at SLAC, because of their age, have power and lighting circuit breaker panels that were installed prior to present working clearance codes and regulations. These installations may be acceptable, but must be evaluated to determine whether additional safety measures are necessary. The division occupying the building space should contact the Electrical Safety Committee for evaluation.

If a reduction in clearance is granted, a caution sign stating Inadequate Working Clearance must be attached to the equipment. This sign is available from the SLAC stores.[7]

7.6.2 Electrical Equipment Rated at More Than 600 Volts

The NEC lists the minimum clearance required for working spaces in front of high-voltage electrical equipment such as switchboards, control panels, circuit breakers, switchgear, or motor controllers.

8 Safety Requirements for Commonly Used Electrical Equipment

This section describes safety requirements for electrical equipment used throughout the site by all members of the SLAC community.

8.1 Flexible Cords

This section covers use of flexible cord as a wiring method and cord and plug assemblies that provide AC power for machines, laboratory equipment, and other scientific research equipment. Flexible cords are commonly used by most individuals at SLAC. Improper use of flexible cords can lead to shock hazards or fires due to overheated equipment.

8.1.1 Flexible Cord Use

In compliance with NEC, flexible cords and cables may be used at SLAC for the following purposes only:

- Connections of portable lamps, portable and mobile signs, or appliances
- Connecting stationary equipment that requires frequent interchange
- An appliance or equipment with fastenings and mechanical connections specifically designed to permit-ready removal for maintenance and repair and intended or identified for flexible cord connection
- Pendants
- Wiring of fixtures
- Elevator cables
- Crane and hoist wiring
- Preventing transmission of noise or vibration
- Data processing cables as permitted by the NEC

7 The SLAC stores catalog is available at http://www-bis1.slac.stanford.edu/main/stores.asp

- Connecting moving parts
- Temporary wiring as permitted in the NEC

8.1.2 Flexible Cord Policy

The SLAC policy on flexible cords is based on the NEC. The policy consists of the following conditions:

- When flexible cords and cables are used in the first three conditions above, they must be equipped with an approved attachment plug and energized from a receptacle outlet.
- Only qualified persons may install cord caps on flexible cords.
- Flexible cord and cable, attachment plugs, and receptacles must be of the proper type, size, and voltage and current rating for the intended application.
- Branch circuits that feed cord and plug connected equipment must be designed in accordance with the NEC, have overcurrent protection in accordance with the NEC, and be properly grounded in accordance with the NEC.

8.1.3 Disallowed Uses of Flexible Cords

Based on the NEC, the following uses of flexible cords and cables are not permitted at SLAC:

- Flexible cords used as a substitute for the fixed wiring of a structure
- Flexible cords run through holes in walls, structural ceilings, suspended ceilings, dropped ceilings, or floors
- Flexible cords run through doorways, windows, or similar openings
- Flexible cords attached to building surfaces. (See the NEC for details.)
- Flexible cords concealed behind building walls, structural ceilings, suspended ceilings, dropped ceilings, or floors
- Flexible cords installed in electrical raceways, unless specifically allowed by NEC provisions covering electrical raceways

8.2 Extension Cords

Extension cords provide a convenient method of bringing AC power to a device that is not located near a power source. They are also used as temporary power sources. As such, extension cords are heavily used. They are also often involved in electrical code and safety violations.

Improper use of extension cords can lead to shock hazards. In addition, use of an undersized extension cord results in an overheated cord and insufficient voltage delivered to the device, thus causing device or cord failure and a fire hazard.

8.2.1 Extension Cord Policy

The policy for use of extension cords at SLAC:

- Extension cords must be approved (by Underwriter Laboratories or another NRTL) and properly maintained with no exposed live parts, exposed ungrounded metal parts, damage, or splices.
- Extension cords must be made of a heavy-duty or extra-heavy-duty rated cable and must be a continuous length.
- Around construction sites, in damp areas, or in an area where a person may be in direct contact with a solidly grounded conductive object such as working in a vacuum tank, extension cords must be protected by a ground fault circuit interrupter (GFCI). The GFCI can consist of a special circuit breaker, a GFCI outlet, or an extension cord with a built-in GFCI. (Section contains more information about GFCIs.)
- Extension cords must be of sufficient current-carrying capacity to power the device. An undersized cord is a fire hazard.
- Extension cords must be three-conductor (grounded)–even if the device has a two-conductor cord. Never use two-conductor extension cords at SLAC. (Equipment grounding conductors that are part of flexible cords or used with fixture wires shall not be smaller than 18 AWG copper and not smaller than the circuit conductors.)
- Only qualified personnel may make repairs of extension cords.

8.2.2 Disallowed Uses of Extension Cords

The following uses of extensions cords are not permitted at SLAC:

- Extension cords used in place of permanent facility wiring
- Extension cords run through doors, ceilings, windows, or holes in the walls. If it is necessary to run a cord through a doorway for short term use, the extension cord must be:
  - Protected from damage
  - Removed immediately when no longer in use
  - Not a tripping hazard
- Extension cords that are daisy-chained (one extension cord plugged into another extension cord)
- Overloaded extension cords. The wire size must be sufficient for the current required.
- Extension cords with removed or compromised ground prong or ground protection
- Extension cords with ground conductors that have less current-carrying capacity than the other conductors. (Equipment grounding conductors that are part of flexible cords or used with fixture wires shall not be smaller than 18 AWG copper and not smaller than the circuit conductors.)
- Extension cords that are frayed or damaged

8.2.3 Acceptable Combinations

There are very few acceptable combinations of extension cords and devices. Some acceptable combinations are

- Extension cord to device (electrical equipment)
- Power strip to device
- Surge protector (with cord) to device

- Direct surge protector to extension cord to device
- Direct surge protector to power strip to device

For examples of acceptable and unacceptable combinations of extension cords and power strips, see Figure 8-1. The examples have been chosen as representative of applications found at SLAC, however acceptable and unacceptable combinations are not limited to the examples. For questions on a particular application of extension cord or power strip use, please contact your department safety coordinator, division ES&H coordinator, the ES&H Department, or the Electrical Safety Committee.

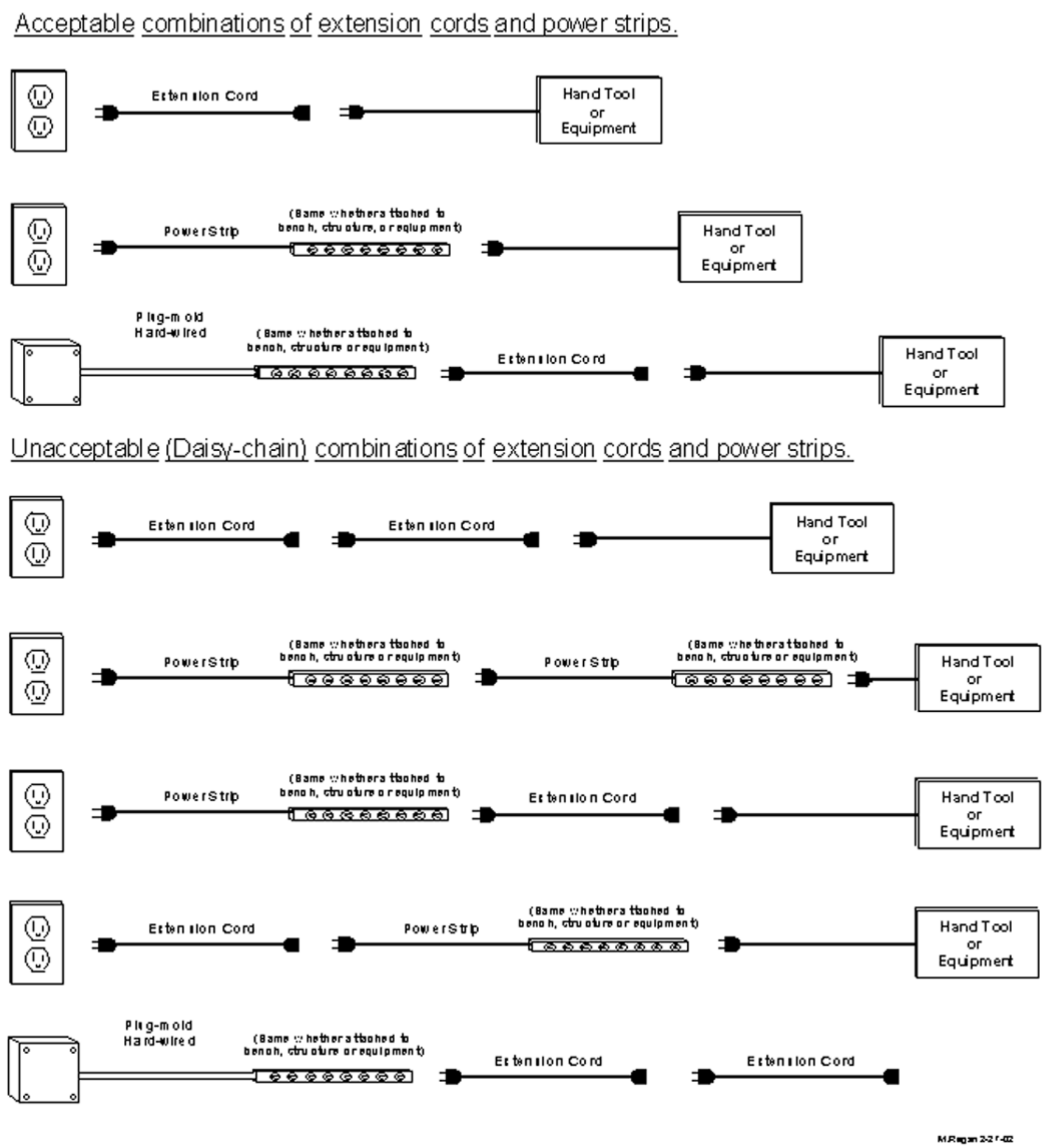

Figure 8-1 Examples of Extension Cord Combination Usage

8.3 Power Strips

A power strip is a variation of an extension cord, where the cord terminates in a row or grouping of receptacles. Power strips are commonly used in offices to provide multiple receptacles to office equipment. In general, the policies pertaining to extension cords also apply to power strips.

Additional requirements are

- Only UL (or other NRTL) approved device can be used.
- Power strips cannot be permanently mounted to any facility surface. Power strips may hang from screws or hooks if they are manufactured with slots or keyholes.
- In equipment racks, the preferred method of supplying 120/208-volt utility power to rack-mounted instruments is via a special power strip specifically designed to be rack-installed.

8.4 Test Benches

Test benches are used for testing, repairing, assembling, or disassembling electrical or electronic devices. They inherently involve testing equipment with exposed energized components and have the potential for electric shock, arcing, or fire.

8.4.1 Test Bench Policy at SLAC

Dielectric insulating matting must be placed on the floor to insulate personnel from electrical shock while working on test benches. Dielectric matting must be

- Placed around all test benches that are used for testing equipment with exposed energized parts
- Placed such that personnel are standing only on the matting and are never in direct contact with the floor or any other grounded metal parts while working on or near exposed energized parts
- Used in addition to all other personal protective equipment (PPE) that is required by OSHA when working with exposed energized parts
- Inspected regularly to ensure that it is not damaged. (Inspection of dielectric matting does not need to be documented.)

8.4.2 Sources for Dielectric Matting

Dielectric matting designed to provide insulation from electrical hazards up to 30,000 volts is available from SLAC Stores. Dielectric matting designed to provide insulation from electrical hazards above 30,000 volts should be obtained from an outside vendor.

9 Safety Requirements for On-site Electrical Equipment

The following section describes electrical equipment installed throughout the SLAC site.

9.1 Ground Fault Circuit Interrupters

Ground fault circuit interrupters (GFCIs) are designed to protect people from electric shock when they simultaneously contact a "live" (usually 120 volt) wire or part and a grounded object. The GFCI works by sensing a difference between the supply (hot) and return (neutral) currents. When the difference exceeds 5 mA – indicating that current is flowing to ground (through the person) – the device switches off.

Although the GFCI is an effective safety device, it is not a guarantee against shock in every situation. The GFCI does not protect against a line-to-neutral or a line-to-line shock. Also, if GFCI-protected equipment contains transformers, a ground fault (shock) on the secondary side of the transformer may not trip the GFCI.

GFCIs are normally installed as either circuit breakers or receptacles. In either case, the GFCI may be wired to protect multiple receptacles. Individual GFCI plug-in adapters are also available.

SLAC also uses ground fault interrupt (GFI) devices. GFI and GFCI are different devices with different purposes and should not be confused. The GFIs protect equipment from excessive currents, while GFCIs protect personnel from excessive currents. (GFIs should be tested according to the manufacturer's recommendations.)

9.1.1 GFCI Requirements

SLAC requires GFCI protection for the following conditions:

- Any 120-volt convenience outlet located within 6 feet of a sink
- Any 120-volt convenience outlet located outdoors
- Any 120-volt convenience outlet located within 6 feet of a building entrance
- Any extension cord providing power for construction activities. Outdoor receptacles must be enclosed with weatherproof (preferably metal) covers

Note *Receptacles located in wet locations that are used, or intended to be used, unattended with a device plugged in (such as an electric cart plugged in to charge the batteries) must have an enclosure that is weatherproof with the attachment plug cap inserted or removed. See the NEC for more information.*

9.1.2 Testing Requirements

Testing is required for all indoor and outdoor GFCIs.

Warning Do not use the external GFCI tester for regular testing of GFCI outlets. The tester can cause the outlet housing and mounting structure to become energized. When testing GFCI outlets, use the built-in test button on the outlet. If an external GFCI tester is being used, the user shall wear electrical safety gloves (and have proper training for using personal protective equipment) to protect against the outlet housing becoming energized.

Testing requirements are divided into the following three types:

1. Local Test Button

GFCI-protected outlets and devices with a local test button must be tested before each use.

To facilitate this, all GFCI outlets or devices must be labeled “GFCI Device: Test Before Use”.

2. Remote Test Button Remote

   GFCI devices (such as GFCI breakers and GFCI outlets protecting downstream outlets), must be tested monthly by the building or facility manager (or designate).

   To facilitate this, all outlets or devices protected by a remote GFCI device must be labeled “GFCI Protected: Test Monthly”.

3. GFCI Outlets in Continuous Use

   GFCI outlets in continuous use (such as an outlet used to power small appliances located within six feet of a sink) must be tested monthly by the building or facility manager (or designate).

   To facilitate this, all GFCI outlets or devices in continuous use must be labeled “GFCI Protected: Test Monthly”.

Exceptions to the testing requirements will be allowed where testing would disrupt SLAC programs or where the monthly implementation is not practical. In these cases, a testing schedule consistent with SLAC program requirements or practicality can be used provided the documented testing cycle does not exceed six months. In circumstances when a machine run exceeds six months, the testing must be completed immediately upon the first opportunity for machine entry. The testing schedule must be submitted to the Electrical Safety Committee for review and approval.

Caution Testing of a GFCI will disconnect all receptacles protected by the GFCI. Before testing, determine which receptacles are protected. Verify that the interruption of power will not adversely affect other activities.

9.2 Electrical Cables

The following section applies to all cables at SLAC, including

- Cables used at more than 600 volts
- Cables used at or less than 600 volts
- Cables for fire protection (power limited and non power limited)
- Class 1, class 2 and class 3 remote control, signaling, and power limited circuits, as defined in the NEC
- Communication circuits (telephone lines, for example)
- Computer cables
- Optical fiber cables

9.2.1 Electrical Cable Policy

All cables in a new facility (installed after October 1994) or a major modification in an existing facility at SLAC shall be installed in compliance with the applicable NEC regulations.

9.2.2 Policies for Cable Installation

The following are some of the most important issues from the applicable regulations, however, this list is not inclusive. When installing cables, please refer to the NEC.

- Cable trays and raceways shall be supported directly from the structure.
- Do not use raceways to support other raceways, cables, or non-electric equipment except in specific conditions stated in the NEC.
- Do not wrap cables around conduits, bus ducts, or any other type of raceway. Wrapping raceways with cable may block heat dissipation from the raceway. (Raceways include conduits, wireways, and busways. Cable trays are not raceways.)
- Do not use sprinkler piping to support cables and wires.
- Do not overfill cable trays (refer to the NEC to determine fill requirements).
- Do not place extension cords in raceways. Extension cords are not allowed in cable trays unless they are specifically approved for installation in trays.
- Do not place any pipe or tube used for non-electrical purposes (water, gas, or drainage, for example) in cable trays or raceways containing electrical conductors.
- Do not install cables rated at more than 600 volts in the same cable tray with cables rated 600 volts or less, unless they are separated by a solid fixed barrier. Metal clad cables rated at more than 600 volts may be combined with cables rated 600 volts or less.
- Multi-conductor cables rated 600 volts or less may be installed in the same cable tray. This rule does not include low voltage (class 2) signal cables.
- Do not place conductors of class 2 and class 3 circuits in the same cable or cable tray with conductors of electric light, power, class 1, and non-power-limited fire protective signaling circuits.
- Install cables used for special purposes (such as fire protection, computers, and radio frequency signals) according to the NEC.
- Install only the specific types of cables in cable trays as allowed by the NEC

9.2.3 Policies for Upgrading Existing Facilities

In areas of the upgraded facility where installation of new cable is required but sufficient space for new tray and/or conduit is unavailable, overfill in the existing cable tray shall be permitted with the review and approval of the SLAC Director with advice from the Electrical Safety Committee and from the Fire Protection Safety Committee. Enhanced fire detection and/or fire suppression devices, as deemed necessary, shall be used to ensure safety to personnel and equipment.

For coax, heliax, and specialty cables used for experimental research and development equipment where the installation of new cable plant is required, every effort should be made to meet NEC tray rating requirements for cable types installed. Where NEC tray-rated-cable types which meet the technical requirements of the installation are not available, the non-tray-rated cables shall be permitted with the review and approval of the SLAC director with advice from the Electrical Safety Committee and from the Fire Protection Safety Committee. Enhanced fire detection and/or fire suppression devices, as deemed necessary, shall be used to ensure safety to personnel and equipment.

9.3 Power Supplies

Because a wide range of power supplies are used at SLAC, no single set of considerations can be applied to all cases.

9.3.1 Hazards of Power Supplies

The following classification scheme may be helpful in assessing power-supply hazards:

1. Power supplies of 50 volts or less with currents greater than 5 mA

   Because they are not "high voltage", these power sources are often treated without proper respect. In addition to direct shock and burn hazards, a risk of injury also exists when trying to get away from the source of a shock. Cuts and bruises, and even serious or fatal falls have resulted from otherwise insignificant shocks.

2. Power supplies of 50 volts or more (high voltage), with current capability over 5 mA

   These power supplies have the same hazards cited above to an even greater degree because of the higher voltage. In addition to the risk of injury from recoil, the higher voltage is considered to be a shock hazard. The high voltage combined with current capability can be lethal. Consequently, all such power supplies must be treated with extreme caution.

3. Power supplies of 50 volts or more (high voltage) with current capability under 5 mA (non-dangerous current capability)

   These power supplies are often treated in a casual manner because of their low current capability. However, they are frequently used near lower-voltage lethal circuits, and a minor shock from the power supply could cause a recoil into such a circuit. Also, an involuntary reaction to a minor shock could cause a serious fall (for example from a ladder or experimental apparatus).

9.3.2 Safety Considerations for Power Supplies

9.3.2.1 Primary Disconnect

A means of positively disconnecting the input shall be provided. This disconnect shall be clearly marked and located where the workers can easily lock or tag it out while servicing the power supply. If provided with a built-in lock-out device, the key must not be removable unless the switch or breaker is in the OFF position.

9.3.2.2 Overload Protection

Overload protection must be provided on the input, and should be provided on the output.

9.3.3 Hazards of Floating Power Supplies

Some research equipment employs ungrounded (floating) power supplies. This equipment may operate in voltages ranging from 50 volts to kilovolts with output capacities in excess of 5 mA and must be considered a lethal electrical hazard. Users of such equipment must take precautions to minimize electrical hazards.

9.3.4 Safety Considerations for Floating Power Supplies

Follow all manufacturers' instructions for equipment use, testing, and training. The following general guidelines also apply:

- Locate equipment away from water and large metal areas.
- Do not use connectors and jack fittings that allow accidental skin contact with energized parts.
- Interlock readily accessible enclosures.
- Use non-metallic secondary containment if liquids or gels are involved.
- Verify the power supply is floating when commissioned, and reverify that the power supply is floating on an annual basis.

9.4 Capacitors

Only those capacitors that have more than 10 joules stored energy are discussed in this section.

9.4.1 Hazards of Capacitors

Capacitors may store hazardous energy even after the equipment has been de-energized and may build up a dangerous residual charge without an external source. Grounding capacitors in series, for example, may transfer rather than discharge the stored energy.

Another capacitor hazard exists when a capacitor is subjected to high currents that may cause heating and explosion. Capacitors may be used to store large amounts of energy. An internal failure of one capacitor in a bank frequently results in explosion when all other capacitors in the bank discharge into the fault. The energy threshold for explosive failure for metal cans is approximately 104 joules.

Because high-voltage cables have capacitance and thus can store energy, they should be treated as capacitors.

The liquid dielectric in many capacitors, or its combustion products, may be toxic.

9.4.2 Safety Considerations for Capacitors

9.4.2.1 Automatic Discharge

Permanently connected bleeder resistors should be used when practical. Capacitors in series should have separate bleeders. For very large capacitors, use automatic-shorting devices that operate when the equipment is de-energized or the enclosure is opened. The time required for a capacitor to discharge to safe voltage (50 volts or less) shall not be greater than the time needed for personnel to gain access to the voltage terminals. In no case must it be longer than five minutes.

In some equipment an automatic, mechanical-discharging device is provided which functions when normal access ports are opened. This device shall be contained locally within a protective barrier to ensure wiring integrity, and should be in plain view of the person entering the protective barrier so that the individual can verify its proper functioning. Protection also must be provided against the hazard of the discharge itself.

9.4.2.2 Fusing

Capacitors used in parallel should be individually fused when possible to prevent the stored energy from dumping into a faulted capacitor. Care must be taken in placement of automatic-discharge safety devices with respect to fuses. If the discharge will flow through the fuses, a prominent warning sign must be placed at each entry indicating that each capacitor must be manually grounded before work can begin. Special knowledge is required for high-voltage and high-energy fusing.

9.4.2.3 Unused Terminal Shorting

Terminals of all unused capacitors representing a hazard or capable of storing 10 joules or more shall be visibly shorted.

9.4.2.4 Safety Grounding

Clearly mark grounding points and provide fully visible, manual-grounding devices to render the capacitors safe while they are being worked on. Caution must be used when grounding to prevent transferring charges to other capacitors.

9.4.2.5 Ground Hooks

All ground hooks must:

- Have conductors crimped and soldered
- Be connected such that impedance is less than ohm to ground
- Have the cable conductor clearly visible through its insulation
- Have a cable conductor size of at least #2 extra flexible or, in special conditions, a conductor capable of carrying the potential current
- Be in sufficient number to conveniently and adequately ground all designated points
- Be grounded and stored in the immediate area of the equipment in a manner that ensures they are used

9.5 Inductors and Magnets

Only inductors and magnets that have more than or equal to joules stored energy or operate at 50 volts or more are discussed here.

9.5.1 Hazards of Inductors and Magnets

While some magnets may be non-hazardous, others may be very dangerous. Without proper protection or labeling, employees could assume that a magnet is non-hazardous and could get seriously hurt if they came in contact with one.

A magnet is an electrical hazard if the terminal voltage is greater than or equal to 50 volts, or the total stored energy of the power supply and magnet is greater than or equal to 10 joules. A magnet is a startle hazard due to arcing if the total stored energy of the power supply and magnet is greater than or equal to joules. The SLAC Electrical Safety Committee has determined that at this energy level the potential for arcing is significant and could cause injury.

The following are some hazards peculiar to inductors and magnets:

- Damage to inductors due to overheating caused by overloads, insufficient cooling, or failure or possible rupture of cooling systems
- Production by electromagnets and superconductive magnets of large external force fields that may affect the proper operation of the protective instrumentation and controls
- Attraction by magnetic fields of nearby magnetic material, including tools and surgical implants, causing injury or damage by impact
- Production of large eddy currents in adjacent conductive material whenever a magnet is suddenly de-energized causing excessive heating and hazardous voltages. This state may cause the release or ejection of magnetic objects
- Uncontrolled release of stored energy due to interruption of current in a magnet. Engineered safety systems may be required to safely dissipate stored energy. Large amounts of stored energy can be released in case of a quench (loss of superconductivity) due to system or component failure in a superconducting magnet
- Production of high voltage potential upon interruption of current

In addition, workers should be cognizant of the potential health hazards. The American Conference of Governmental Industrial Hygienists recommends that routine occupational exposure to static magnetic fields should not exceed 600 gauss (G) whole-body exposure.

This is a level which is believed that nearly all workers may be repeatedly exposed day after day without any adverse health effects.

Safety hazards may exist from the mechanical forces exerted by the magnetic field upon ferromagnetic tools and medical implants. Cardiac pacemaker and similar medical electronic device wearers should not be exposed to field levels exceeding 5 G.

9.5.2 Safety Considerations for Inductive Circuits

9.5.2.1 Automatic Discharge

Use freewheeling diodes, varistors, thyrites, or other automatic shorting devices to provide a current path when excitation is interrupted.

9.5.2.2 Connections

Pay particular attention to connections in the current path of inductive circuits. Poor connections may cause destructive arcing.

9.5.2.3 Cooling

Protect liquid-cooled inductors and magnets with thermal interlocks on the outlet of each parallel coolant path. Include a flow interlock for each device.

9.5.2.4 Eddy Currents

Units with pulsed or varying fields must have a minimum of eddy-current circuits. If large eddy-current circuits are unavoidable, they should be mechanically secure and able to safely dissipate any heat produced.

9.5.2.5 Grounding

Ground the frames and cores of magnets, transformers, and inductors.

9.5.2.6 Rotating Electrical Machinery

Beware of the hazards of residual voltages that exist until rotating electrical equipment comes to a full stop.

9.5.2.7 Protective Enclosures

Fabricate protective enclosures from materials not adversely affected by external electromagnetic fields. Researchers should consider building a nonferrous barrier designed to prevent accidental attraction of iron objects and prevent damage to the cryostat. This is especially important for superconducting magnet systems.

9.5.2.8 Bracing

Provide equipment supports and bracing adequate to withstand the forces generated during fault conditions.

9.5.2.9 Pacemaker Warning Signs

Provide appropriate warning signs to prevent persons with pacemakers or similar devices from entering areas with fields of greater than 5 G.

9.5.2.10 Limit Magnetic Field Exposure

Restrict personnel exposure to magnetic fields greater than 600 G.

9.5.2.11 Verify De-energization

Verify that any inductor is de-energized before disconnecting the leads or checking continuity or resistance.

9.5.3 Electrical Safety Requirements for Magnets

All magnets installed after December 2, 1996, shall have the following two-fold protection:

- Physical protection consisting of:
  - Magnet covers[8] for magnets that are electrical hazards, or terminal boots for magnets that are only startle hazards or
  - An interlock (for example, a personnel protection system (PPS) that would keep employees from coming directly into contact with the hazard)

8 See the *Magnet Terminal Cover Guidelines* (SLAC-I-730-0A11S-003) for details at https://www-internal.slac.stanford.edu/essg/pdf/magcovgdlns.pdf.

Note *Non-hazardous magnets are not required to have a cover or interlock.*[9]

- Labels that describe the hazard and the associated protective measures. A “Notice” label shall be used for non-hazardous magnets and “Caution” label shall be used for hazardous magnets, with additional information depending upon the hazard type (high energy or high voltage) and the type of protection (cover or interlock) provided

Because magnet covers can be removed, labels should be placed on the frame of the magnet so that employees will always be reminded of the potential hazard and maintenance personnel will be reminded to replace the cover.

Labels shall be color coded (yellow for Caution, white with blue panel for Notice) according to ES&H Manual Chapter 23, “Warning Signs and Devices”. Pre-printed labels can be obtained from SLAC stores.[10] (Label content may be modified to specify different conditions, such as the use of interlocks other than PPS.)

Note *Absence of a label indicates that the magnet may be a hazard and that employees should use caution.*

Use one of the four labels displayed in Figure 8-2.

9 A non-hazardous magnet has a terminal voltage less than 50 volts and less than 0.5 joules of total stored energy for the power supply and magnet.

10 The SLAC Stores catalog is available on line at http://www-bis1.slac.stanford.edu/main/stores.asp

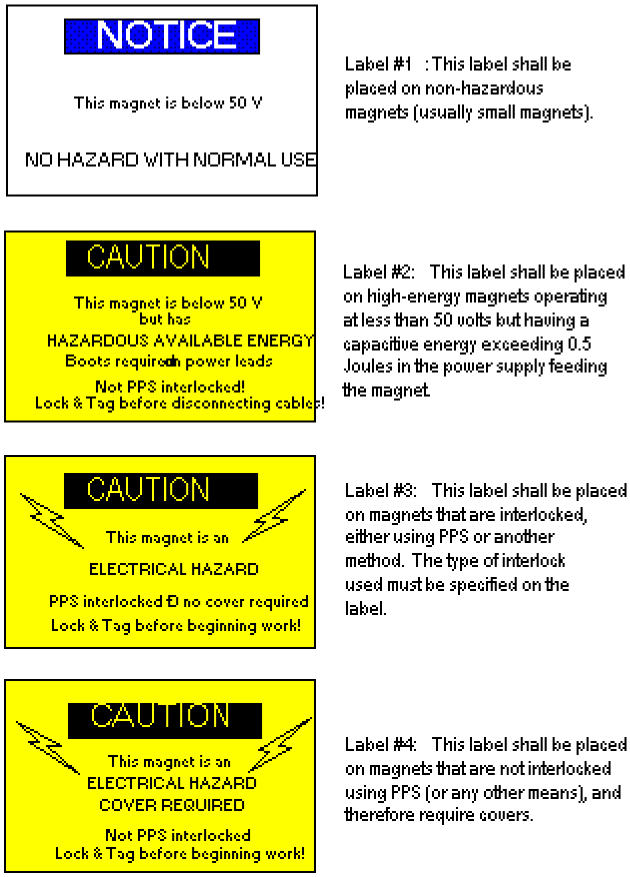

Figure 8-2 Required Magnet Labels

9.6 Control and Instrumentation

Proper philosophy is vital to the safe design of most control applications. Use the following checklist as a guide for designing control applications.

9.6.1 Checkout

Check interlock chains for proper operation after installation, after any modification, and during periodic routine testing.

9.6.2 Fail-Safe Design

Design all control circuits to be fail-safe. Starting with a breaker or fuse, the circuit should go through all the interlocks in series to momentary on-off switches that energize and close a control relay. Any open circuit or short circuit will de-energize the control circuit and must be manually reset.

9.6.3 Interlock Bypass Safeguard

Establish a systematic procedure for temporarily bypassing interlocks. A follow-up procedure should be included to ensure removal of the bypass as soon as possible.

9.6.4 Isolation

Isolate control power from higher power circuits by transformers, contactors, or other means. Control power should be not more than 120 volts, AC or DC. All circuits should use the same phase or polarity so that no hazardous additive voltages are present between control circuits or in any interconnect system. Control-circuit currents should not exceed 5 A.

9.6.5 Voltage Divider Protection

The output of voltage dividers used with high voltages must be protected from over-voltage-to-ground within the high-voltage area by spark gaps, neon bulbs, or other appropriate means.

9.6.6 Current Monitors

Measure currents with a shunt that has one side grounded or with current transformers that must be either loaded or shorted at all times.

9.6.7 Instrument Accuracy

Check instrumentation for function and calibration on a routine basis.

9.7 Anti-restart Device

Equipment that is dependent upon electricity for its power source will stop working when the electrical power is interrupted. Once power is restored, some equipment may restart automatically. Equipment may restart automatically if

- The switch is left in the ON or CLOSED position.
- It can be restarted through a computer.
- It has instrumentation, such as a level switch, which will re-set itself, allowing the machine to restart once power has been restored.
- It is wired to a different power source for control power.

Note *When there are two separate sources of power, and a local electrical outage occurs for the main power circuit, the “control power” remains energized even though the main power is off. This means that the start will remain energized, or in the CLOSED position. When the main power is restored, the equipment will restart because the starter is already energized.*

9.7.1 Safety Requirements for Equipment Restarting Automatically

Whenever equipment starts automatically, a hazardous situation exists for any personnel in the immediate vicinity. To protect personnel, OSHA requires that equipment that has the capability of restarting automatically must be fully guarded or provided with an anti-restart device (ARD).

ARDs are not required for machines:

- The moving parts of which are fully guarded
- That have a magnetic starter, and do not have
  - computerized auto start feature
  - Automatic re-setting instrumentation such as a level switch
  - Separate power source for the control circuit

Note *An ARD must not be installed on equipment which is required to be on-line constantly, such as HVAC, sump pumps, or refrigerators. This type of equipment must be fully guarded.*

10 Safe Work Practices

This section applies to individuals who work on or near electrical equipment or systems.

10.1 General Safety Rules

Follow the general safety rules described below.[11]

- Practice proper housekeeping and cleanliness

  Poor housekeeping is a major factor in many accidents. A cluttered area is likely to be both unsafe and inefficient. Employees are responsible for keeping a clean area, and supervisors are responsible for ensuring that their areas of responsibility remain clean.

- Identify hazards and anticipate problems

  Before beginning a work activity, think about what might go wrong and the consequences of an action. Individuals should not hesitate to discuss any situation or question with their supervisors and co-workers.

- Resist pressure to rush work

  Program pressures should not cause workers to bypass thoughtful consideration and planned procedures.

- Maintain for safety

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11 Additional information describing employee responsibilities as related to stopping an unsafe activity is available in Chapter 2, "Work Authorization", (http://www-group.slac.stanford.edu/esh/general/work_authorization/policies.htm), of this manual.

Good maintenance is essential to safe operations. Establish maintenance procedures and schedules for servicing and maintaining equipment and facilities, including documentation of repairs, removals, replacements, and disposals.

- Job briefing

  Before starting each job, the supervisor or designee shall conduct a job briefing with the employees involved. The briefing shall cover subjects such as hazards associated with the job, work procedures involved, special precautions, energy source controls, and PPE requirements. (Refer to NFPA 70E and 29 CFR 1910 for more details).

10.2 Emergency Preparedness

All personnel who work on exposed electrical circuitry of more than 50 volts (AC or DC) shall be trained in emergency response procedures, including cardiopulmonary resuscitation (CPR).

10.3 Electrical Work Practices

The preferred mode of work is in the electrically de-energized state. If de-energizing the equipment is not practical, work shall be performed only after first taking the following specific measures:

1. Evaluate risks
2. Analyze and eliminate hazards
3. Establish mitigating controls
4. Obtain specific reviews, approvals, plans, and permits

Hazard mitigating procedures and controls shall be documented and be monitored for effectiveness per SLAC Policy 2004-02.[12] All electrical work at SLAC requires the prior completion of a Job Hazard Analysis and Mitigation (JHAM)[13] process and an Electrical Work Plan (EWP, see Section 10.3.2).[14] For certain energized work, an Energized Electrical Work Request and Approval Permit (EEW)[15] is also required (see Section 10.3.1, "Exceptions").

Safe work practice guidance and requirements summarized in this chapter are taken from Title 29, *Code of Federal Regulations*, Part 1910, Subpart S and Part 1926, Subpart S, National Fire Protection Association (NFPA) 70E, "Standard for Electrical Safety Requirements for Employee Workplaces", and the DOE handbook, *Electrical Safety*. The electrical safety officer is available to provide advice in applying these standards, and together with the Electrical Safety Citizen's Committee, is available to review procedures for situations not covered in these standards.

10.3.1 Exceptions

1. Work on the following electrical systems is exempt from the provisions of this section:

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12 http://www-group.slac.stanford.edu/esh/general/hazanalysis/documents/JHAM_policy_final.pdf

13 http://www-group.slac.stanford.edu/esh/general/hazanalysis/jhamcreate.htm

14 http://www-group.slac.stanford.edu/esh/forms/ewp.pdf

15 http://www-project.slac.stanford.edu/ilc/safety/eew.pdf

a. Systems with a fault current limited to five milliamperes (startle hazard and other hazards may still exist and must be addressed)

b. Systems having voltages less than 50 volts and stored energy less than 10 joules

c. Other systems may be exempted upon approval of the electrical safety officer (for example household batteries nine volts and under, which have a limited energy discharge rate, are exempted)

2. Operating circuit breakers with covers on is exempted, but proper personal protective equipment (PPE) is required, as defined by the NFPA 70E.

10.3.2 General Guidelines

To prevent injury from shock or burns while working on or near exposed energized equipment, a series of boundaries are defined with increasing training, PPE, and work practice requirements as the worker approaches the hazards. NFPA 70E specifies these approach boundary limits to exposed energized components.[16] The approach boundaries are related to the available voltage (for shock hazard) as well as energy (for arc flash hazard). Tables 8-2 and 8-3 in Section 10.3.8 of this chapter summarize some of the PPE requirements at the shock hazard approach boundaries for different voltages. The arc flash hazard boundary for a particular situation must be determined by an analysis of the available fault currents and circuit interrupter clearing times (see NFPA 70E, Article 130.3 for guidance). To aid workers, the results of this analysis shall be posted on the electrical equipment. To prevent injury from shock or burn while working within the shock or arc flash approach boundaries, the following precautions must be taken:

- Workers must be properly qualified to perform the work (see Section 4 of this chapter, "Qualified and Authorized Personnel"). Check with your supervisor to ensure that you are qualified to perform work on or near exposed energized electrical systems.
- Determine the shock protection and arc flash protection boundaries for the task
- Treat electrical equipment as if it were energized until the equipment has been verified to be in an electrically safe condition.
- Use the appropriate personal protective equipment (PPE) and tools to accomplish isolation, discharge, verification and grounding to place equipment in an electrically safe condition
- Re-verify that the equipment is de-energized each time the equipment has been left unattended
- Use appropriate PPE, tools, and procedures for work on energized equipment.
- Obtain the required reviews and approvals by completing the SLAC Job Hazard Analysis and Mitigation process (JHAM); the SLAC Electrical Work Plan Form (EWP); and the SLAC Energized Electrical Work Request and Approval Permit (EEW), if applicable. Forms can be obtained by calling the contact person for "Safety-Related Forms and Permits" on the ES&H Resource List[17] or directly from the web.[18]

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16 Refer to NFPA 70E, Article 130, Section 130.2, "Approach Boundaries to Live Parts", and Section 130.3, "Flash Hazard Analysis".

See the SLAC Library, http://www.slac.stanford.edu/library/, for available standards. NFPA standards are available online from a SLAC login (see http://www.slac.stanford.edu/library/eresources/slac.htm for the link and instructions); some hard copies are also available.

17 http://www-group.slac.stanford.edu/esh/resource.pdf

18 http://www-group.slac.stanford.edu/esh/forms/

Because the hazards associated with energized electrical circuits depend on many factors, two work categories have been developed to provide guidance: premises wiring and utilization equipment. These work categories are defined in *National Electric Code*, Article 100.

- Premises wiring is the physical alternating current (AC) electrical distribution system from the incoming AC utility power to the first disconnecting means (disconnect switch, breaker, or outlet) viewed from utilization equipment.
- Utilization equipment is the equipment, connected to the premises wiring, that SLAC uses to perform its functions.
- Sections 10.3.4 and 10.3.5 of this chapter detail specific requirements for these two categories.

10.3.3 Electrical Work Plan and Work Approvals

While the preferred mode of work at SLAC requires de-energizing electrical circuits, it is recognized that to operate the laboratory efficiently and effectively, qualified personnel have reason to open energized panel boards and equipment housings.

An electrical work plan (EWP) is required for all energized electrical work activities (both premises and utilization). The purpose of the EWP is to document that appropriate work practices and personal protective equipment are being used. The scope, from specific equipment to routine activities, and necessary approvals for EWPs vary depending on the hazard, as described below. The supervisor of the person(s) doing the work is responsible for ensuring the EWP is completed. Note that the EWP may be incorporated into other work planning documents such as the JHAM, Equipment Lock Out Procedure, or other maintenance and servicing procedure.

The EWP shall

1. Describe the work to be done
2. List the hazards associated with the work
3. Detail how each hazard will be mitigated, for example identifying
   a. Specific voltages and currents
   b. Specific PPE requirements
   c. All other associated safety issues
   d. Lock and tag requirements

Required Approvals. The EWP shall be approved by the supervisor of the person(s) doing the work. The department/group head may also require his or her approval. To ensure adequate review, the person approving shall not be the same as the originator. Additional approval by the electrical safety officer and by the directorate may be required for certain electrical work, as described in sections 10.3.4 and 10.3.5.

It is recognized that certain special or emergency instances may arise where obtaining an approved, written EWP is neither practical nor possible. In such instances, work may proceed provided the designated approvers are consulted and assent to the work and an EWP is generated and approved at the earliest reasonable opportunity.

Routine Activities. The EWP may cover routine activities for an extended period of time but shall be reviewed at least annually.

Distribution. An approved EWP is required prior to starting work. After the EWP is approved the original shall be kept on file in the department or at the worksite, a copy shall be sent to the electrical safety officer.

10.3.4 Energized Electrical Work Request and Approval Permit

An approved SLAC Energized Electrical Work Request and Approval Permit (EEW) is required for all work at SLAC where the work includes assembly, disassembly, or re-arrangement of components while they are energized. Work below 50 volts, as well as testing, troubleshooting, and voltage measuring, are exempt from the required permit per NFPA 70E, Article 130.1(A)(3), provided that adequate work practices and personal protective equipment are used.

10.3.5 Utilization Equipment

This section covers electrical work at SLAC by qualified SLAC employees, subcontractors, and users on all electrical equipment other than premises wiring. For this section, 600 volts means 600 volts direct current (DC) or 600 volts rms. Inspection and testing activities include

- Measuring voltage and currents with proper equipment
- Verifying de-energized electrical circuits
- Tracing circuits
- Troubleshooting defective circuits or components
- Assessing hazards in the equipment by inspection
- Tuning circuit elements (including tuning of modulators and pulsed power supplies)

All test, measurement, and inspection activities for energized utilization equipment operating at less than 600 volts and all de-energized electrical circuit verifications are allowed with a supervisor approved EWP. If the particular activity or situation has been deemed by the supervisor or department/group head to present a significant hazard, additional approvals may be required as listed below. EWPs for routine, repetitive, processes can be obtained through this procedure.

Test, measurement, and inspection activities for energized utilization equipment operating at 600 volts or greater or these activities in situations deemed to present a significant hazard are allowed with an EWP approved by the electrical safety officer and by the directorate, in addition to the supervisor and department/group head.

For all other activities on exposed energized utilization equipment, the following additional requirements apply:

1. This electrical work presents a significant hazard and shall be allowed only under extraordinary circumstances, shall be justified (convenience shall not be a justification), and shall require approval of the electrical safety officer and the directorate.
2. For each such justified circumstance, the following is required:
3. A non-routine JHAM
4. A Energized Electrical Work Request and Approval Permit (EEW)

10.3.6 Premises Wiring

Work on premises wiring shall be performed only by qualified SLAC or subcontractor electricians. For this section, 600 volts means 600 volts rms. Inspection and testing activities include

- Measuring voltage and currents with proper equipment
- Verifying de-energized electrical circuits
- Tracing circuits
- Troubleshooting defective circuits or components
- Assessing hazards in the equipment by inspection

All test, measurement, and inspection activities for energized premises wiring and equipment operating at less than 600 volts and all de-energized electrical circuit verifications are allowed with a supervisor approved EWP. If the particular activity or situation has been deemed by the supervisor or department/group head to present a significant hazard, additional approvals may be required as listed below. EWPs for routine, repetitive, processes can be obtained through this procedure.

Because of the greater potential energies available in premises wiring, all inspection and testing work on premises wiring at 600 volts or greater, including racking of breakers, activities in situations deemed to present a significant hazard are allowed with an EWP approved by the electrical safety officer and by the directorate, in addition to the supervisor and department/group head.

For all other activities on exposed energized utilization equipment, the following additional requirements apply:

1. This electrical work presents a significant hazard and shall be allowed only under extraordinary circumstances, shall be justified (convenience shall not be a justification), and shall require approval of the electrical safety officer and the directorate.
2. For each such justified circumstance, the following is required:
3. A non-routine JHAM
4. A Energized Electrical Work Request and Approval Permit (EEW)

10.3.7 Two-person Rule

At least two qualified workers shall be present when work is being performed within the restricted approach boundary (as defined in NFPA 70E) or on exposed energized parts that meet these conditions:

- AC circuits 600 volts and above
- DC circuits meeting all three of the following conditions:
  - 50 volts and above
  - Fault currents of five milliamperes and above for one second or more
  - 20 kilojoules of stored energy and above

The safety watch person (SWP) as specified in Section 2.5 of this chapter shall not be counted as one of the two persons under this rule.

There are three exceptions to the two-person rule:

1. Routine switching of circuits required for normal operations and maintenance if site conditions allow this work to be performed safely
2. Operations performed with live-line tools if the worker is positioned outside the restricted approach boundary of the exposed energized parts
3. Emergency switching necessary to protect personnel in immediate danger

10.3.8 Energized AC and DC Safety Requirements

NFPA 70E, Article 130 provides detailed requirements for the PPE required when working on or near energized components. This information has been summarized in Tables 8-2 and 8-3 for shock protection. The arc flash hazard associated with exposed energized components cannot be easily generalized in a table and must be analyzed for each situation to determine the appropriate arc flash boundary and necessary PPE. NFPA 70E, Article 130.3 gives the arc flash protection requirements and guidance for doing the analysis. For systems 600 VAC or less with bolted fault currents less than 50 kA and clearing times less than 6 cycles (0.1 seconds), the arc flash protection boundary shall be four feet (this may be reduced by a detailed calculation).

Note that for certain voltage ranges and arc flash classes, appropriate PPE may not be available from SLAC Stores and must be purchased from vendors by the department that performs the work. For convenience, Table 8-3 gives the voltage range for the various electrical insulating glove classes, refer to manufacturer's labeling information for the appropriate voltage range and arc flash category for other equipment.

All PPE shall be inspected to be free from defects or damage that may impair performance prior to each use. Specific requirements apply to electrical insulating gloves:

- Before each used, must be given and air test: filled with air, electrical insulating glove air leakage is detected by either listening for escaping air or holding the electrical insulating glove against the tester's cheek to feel air releasing
- Before use each day, electrical insulating gloves must be examined to confirm they have a qualifying retest date
- Electrical insulating gloves being used in the field must be electrically retested every six months to be certified as acceptable for continued use
- Protective leather outer gloves shall be worn over electrical insulating gloves to avoid damage to the electrical insulating glove material and to provide increased hand protection from arc flash

10.3.8.1 Acronyms and General Comments for Tables 8-2 and 8-3

Approvers: Dir = directorate or designate, DH = department/group head, DS = direct supervisor, ESO = electrical safety officer. Needed approvals are specified in Section 10.3.4 and 10.3.5.

PPE: SG = safety glasses with side shields or safety goggles, GLV = electrical safety gloves (see Table 8-3 for voltage ranges), SHLD = face shield, SLV = sleeve

Note: These tables are for quick reference, additional PPE may be required based on the specific hazards associated with the task (e.g. arc flash hazards, environmental conditions including wet locations, etc).

Table 8-2 Safety Requirements for Shock Protection Working on or near Exposed Energized AC Electrical Systems (Guidance from NFPA 70E)

	Limited Approach Only Qualified Personnel may cross this boundary			Restricted Approach			Prohibited Approach		
Standard	NFPA 70E Table 130.2(C)			NFPA 70E Table 130.2(C)			NFPA 70E Table 130.2(C)		
Voltage Range Phase to Phase	Boundary Distance[a]	PPE	Approval[b]	Boundary Distance	PPE	Approval[b c]	Boundary Distance	PPE	Approval[b c]
Below 50 volts	Note d	Note d	Note d	Note d	Note d	Note d	Note d	Note d	Note d
50–300 volts[ef]	3.5 ft	FRC, SG	None	Avoid contact	FRC, SG, GLV	ESO DS	Avoid contact	FRC, SG, GLV	ESO, DS, & DH
>300–750 volts[b]	3.5 ft	FRC, SG	None	1 ft	FRC, SG, GLV, SHLD[g], SLV	ESO & DH	1 in	FRC, SG, GLV, SHLD[g], SLV	ESO, DS, DH & Dir
>750–15,000 volts[b]	5.0 ft	FRC, SG	None	2 ft 2 in	FRC, SG, GLV, SHLD[g], SLV	ESO & DH	7 in	FRC, SG, GLV, SHLD[g], SLV	ESO, DS, DH & Dir
>15,000–36,000 volts[b]	6.0 ft	FRC, SG	None	2 ft 7 in	FRC, SG, GLV, SHLD[g], SLV	ESO & DH	10 in	FRC, SG, GLV, SHLD[g], SLV	ESO, DS, DH & Dir
>36,000 volts[b]	See NFPA 70E	FRC, SG	None	See NFPA 70E	FRC, SG, GLV, SHLD[g], SLV	ESO & DH	See NFPA 70E	FRC, SG, GLV, SHLD[g], SLV	ESO, DS, DH & Dir

a. The Limited Approach Boundary for shock protection given is for Exposed Fixed Circuit Part. For the Limited Approach Boundary for Exposed Movable Conductor reference NFPA 70E Table 130.2(C).

b. The supervisor shall assign a safety watch person (SWP) when certain hazardous work is performed and shall also determine if the two-person rule applies.

c. JHAM and EWP required as part of approval

d. No PPE or approval is required to work on live parts less than 50 volts meeting the exemptions listed in Section 10.3. When the exemptions are not met hazardous arcing can result. Consult your supervisor or the ESO if you are unsure of the arc hazard potential. If an arcing hazard exists, use appropriate clothing, non-melting, flammable materials or fire resistant clothing; safety glasses with side shields or safety goggles; and electrical safety gloves.

e. Because energy in the arc is limited due to the distribution network impedance in lower voltage circuits, use appropriate clothing, non-melting, flammable materials or fire resistant clothing; safety glasses with side shields or safety goggles; and electrical safety gloves are required to cross the Flash Protection Boundary for less than 300 volts, unless work is performed on or near transformers rated greater than or equal to 75 kVA

f. Working on or near a transformer of greater than or equal to 125 kVA, or a distribution panel fed by such a transformer, is hazardous and requires PPE to cross the Flash Protection Boundary. (NFPA 70E 130.3 and IEEE Std 1584 sec. 9.3 pp. 25)

g. A face shield is required when inserting or extracting plug-in / rack-in devices on energized equipment.

Table 8-3 Safety Requirements for Shock Protection Working on or near Exposed Energized DC Electrical Systems with Fault Current >Five Milliamps and Energy Level < 20 kJ (Guidance from NFPA 70E)

	Limited Approach Only Qualified Personnel may cross this boundary			Restricted Approach			Prohibited Approach		
Standard	NFPA 70E Table 130.2(C)			NFPA 70E Table 130.2(C)			NFPA 70E Table 130.2(C)		
Voltage Range Point to Point	Boundary Distance[a]	PPE	Approval[b]	Boundary Distance	PPE	Approval[b c]	Boundary Distance	PPE	Approval[b c]
Below 50 volts	Note d	Note d	Note d	Note d	Note d	Note d	Note d	Note d	Note d
50–300 VDC	3.5 ft [e f]	Notes e, f	None	Avoid contact	SG[e], GLV	DS	Avoid contact	SG, GLV	DS
>300 <600 VDC	3.5 ft [e f]	Notes e, f	None	1 ft	SG[e], GLV	DH	1 in	SG[e], GLV	DS & DH
600–1,500 VDC	5.0 ft [e f]	Notes e, f	None	2 ft 2 in	SG[e], GLV	DH	7 in	SG[e], GLV	ESO, DS, DH & Dir
>1.5–15 kVDC	5.0 ft [e f]	Notes e, f	None	2 ft 2 in	SG[e], GLV	DH	7 in	SG[e], GLV	ESO, DS, DH & Dir
>15–35 kVDC	6.0 ft [e f]	Notes e, f	None	2 ft 7 in	SG[e], GLV	DH	10 in	SG[e], GLV	ESO, DS, DH & Dir
>35 kVDC	See NFPA 70E	Notes e, f	None	See NFPA 70E	SG[e], GLV	DH	See NFPA 70E	SG[e], GLV	ESO, DS, DH & Dir

a. The Limited Approach Boundary for shock protection given is for Exposed Fixed Circuit Part. For the Limited Approach Boundary for Exposed Movable Conductor reference NFPA 70E Table 130.2(C).

b. The supervisor shall assign a safety watch person (SWP) when certain hazardous work is performed and shall also determine if the two-person rule applies.

c. JHAM and EWP required as part of approval

d. No PPE or approval is required to work on live parts less than 50 volts meeting the exemptions listed in Section 10.3. When the exemptions are not met hazardous arcing can result. Consult your supervisor or the ESO if you are unsure of the arc hazard potential. If an arcing hazard exists, use appropriate clothing, non-melting, flammable materials or fire resistant clothing; safety glasses with side shields or safety goggles; and electrical safety gloves.

e. When working with circuit energy potentials less than or equal to 20 kJ, there is no Flash Protection Boundary requirement as there is limited energy in the flash. For the same reason, fire resistant clothing is not required to cross the restricted or prohibited boundaries. However, fire resistant clothing and safety glasses with side shields or safety goggles, and electrical safety gloves are recommended.

f. When working with circuit energy potentials greater than 20 kJ, the department doing the work shall calculate the Flash Protection Boundary on a case by case basis. (NFPA 70(E), 2004, 130.3) Fire resistant clothing, and safety glasses with side shields or safety goggles shall be required to cross the flash protection boundary. Fire resistant clothing shall be required, in addition to the PPE shown above to cross the restricted and prohibited approach boundaries.

Table 8-4 Insulating Glove Application

Insulating Glove (Class)	Rated Use Voltage (AC[1] / DC[2,3])	Proof-test Voltage (AC[1] / DC[2,3])
00	500 / 750	2,500 / 10,000
0	1,000 / 1,500	5,000 / 20,000
1	7,500 / 11,250	10,000 / 40,000
2	17,000 / 25,500	20,000 / 50,000
3	26,500 / 39,750	30,000 / 60,000
4	36,000 / 54,000	40,000 / 70,000

Notes:

1 American Society for Testing and Materials (ASTM) Standard D-120

2 International Electrotechnical Commission (IEC) Standard 60903

3 DC applications: when gloves do not have an IEC DC voltage rating, the AC rating shall be used as the DC voltage rating

10.3.9 Stored Energy Considerations

Electrical energy stored in capacitors and batteries can present a significant shock or arc flash hazard if that energy is released quickly and unexpectedly (e.g. accidental shorting). Additional precautions are required to protect from injury.

For batteries with stored energy greater than 10 joules not exempted in section 10.3:

- Remove jewelry and watches from hands and wrists before working on or near exposed conductors
- For batteries and battery banks under 50 VDC, use PPE specified for 50 volts from Table 8-2 (note additional PPE may be required due to construction of battery, for example protection from acid for lead-acid batteries). For over 50 VDC, used protection as specified in the Table 8-2.

For capacitors with stored energy greater than 10 joules not exempted in section 10.3:

- Remove jewelry and watches from hands and wrists before working on or near exposed conductors
- For capacitors at voltages under 50 VDC, use PPE specified for 50 volts from Table 8-2. For over 50 VDC, used protection as specified in the Table 8-2.
- To protect against injury, stored energy in capacitors shall be safely discharged as part of an Equipment Lock Out procedure for working on or near that capacitor.
- When in storage, capacitors with the potential to store 10 joules or more shall have a shorting jumper installed connecting the terminals to prevent static buildup of stored charge.

10.3.10Testing Equipment Classifications

The work environment can expose test equipment to different aberrant voltage levels (voltage spikes caused by lightening strikes or upstream faults) depending on how close the work is to the utility transmission lines. To protect workers from injury resulting from the transient voltages, manufacturers have designed their testing equipment (e.g. multi-meters) to withstand certain levels of these transients depending on the expected usage location of the equipment. These categories are listed in Table 8-4.

- Every category of testing equipment and associated probes may not be available from SLAC Stores and must be purchased from vendors by the department that performs the work.
- Testing equipment shall be tested each day before use to ensure that they function properly for the intended measurements to be taken
- The lowest categories (Class I and II) testing equipment are intended for use far away from the power source so that steep wave-front transients will be attenuated in the circuit impedance between the power source transformer and the multi-meter location. Because facilities at SLAC are often quite close to the 12 kV distribution lines, testing equipment is recommended to be rated at least a Class III.

Table 8-5 Testing Equipment Classifications

Class	Use Location					Proof-test Transient Voltage Range					
I[1]	Lab /Office – Bench / Desk					500	1,500	2,500	4,000		
II[1]	Lab / Office – Room						1,500	2,500	4,000	6,000	
III	Lab / Office – Building							2,500	4,000	6,000	8,000
IV	Site – Utilities								4,000	6,000	8,000
Class	Max. Use Voltage Range					Testing Equipment Category					
I[1]	150	300	600	1,000		I[1]	I[1]	I[1]	I[1]		
II[1]		300	600	1,000			II[1]	II[1]	II[1]	II[1]	
III			600	1,000				III	III	III	III
IV			600	1,000					IV	IV	IV

Notes:

1 Classes I and II not advised

2 Classes from IEC Standard 61010-1

10.4 Working in Wet Areas and near Standing Water

10.4.1 Beware of Wet Areas

While performing tasks with liquids (such as washing, mopping, and spraying) exercise extra care to avoid contact with electrical outlets or devices. Cover electrical openings if liquids can penetrate them. If the openings cannot be covered, the power must be disconnected and locked out using appropriate lockout procedures.[19]

Occasionally, water collects in the beam housing tunnels or other SLAC facilities. Any exposed, energized electrical system presents a potential shock hazard, and this hazard becomes even more severe when the circuit is located in or near standing water.

19 Found in the *SLAC Lock and Tag Program for the Control of Hazardous Energy* (SLAC-I-730-0A10Z-001), http://www-group.slac.stanford.edu/esh/hazardous_activities/lockout_tagout/locktag.pdf

All employees who become aware of standing water or plugged drains near electrical systems in their building should inform either their building manager or the CEF Department.

10.4.2 Shock Hazard

If there is standing water in the vicinity of the electrical system and it is not feasible to drain the water and dry the floor or de-energize the system, individuals performing this work shall:

- Obtain approval for energized work as per Section 10.3.3, “Electrical Work Plan and Work Approvals”. In addition, any work involving electrical systems located in or near standing water also requires written job-specific approval.
- Stand on a dry, insulated surface (such as a fiber glass step stool or ladder placed in a stable position, or a dry, insulated pan) while performing the work
- Wear rubber boots, in addition to the required PPE described in Section 10.3, “Electrical Work Practices”
- Ensure that a safety watch person has been designated. See Section 2.5, “Safety Watch Person,” for more details

10.5 Lock and Tag Procedures

Use the *SLAC Lock and Tag Program for the Control of Hazardous Energy* (SLAC-I-730-0A10Z-001) for working on electrical equipment in de-energized condition.

10.6 Resetting Circuit Breakers

Re-set circuit breakers only after the problem has been corrected.

When a circuit breaker or other overcurrent device trips, it is usually due to an overload or fault condition on the line. Repeated attempts to re-energize the breaker under these conditions may cause the breaker to explode. Do not attempt to re-set a circuit breaker unless the problem has first been identified and corrected or isolated.

10.7 Access to Substations

Special keys have been issued for substations to prevent entry except by trained, authorized electricians. This is done because the high voltage and high short circuit currents are very hazardous to not only untrained personnel but also trained personnel who are not familiar with a particular substation. Access by people other than those who have been issued keys is strictly controlled and requires escorts or special procedures and training on a case-by-case basis. Contact CEF (ext. 3730) if you have any need to enter a substation.

10.8 Safety Watch Person

A safety watch person shall be assigned while working on very hazardous work when deemed appropriate by the supervisor. See Section 2.5, “Safety Watch Person”, for a description of specific responsibilities.

10.9 Hi-pot Testing

Hi-pot testing is a procedure used to test the insulation integrity of electrical equipment and circuits by applying voltage that is greater than the operating voltage of the equipment or circuit being tested. Hi-pot testing is a very hazardous procedure and may be performed only when all of the following requirements are met:

- There is a written procedure for performing the test.
- Trained qualified employees perform the testing.
- At least two employees trained on the appropriate electrical procedures and hazards are present.
- Test equipment is visually inspected for defects or damage before use.
- Defective or damaged items are not used until repaired.
- Barricades and safety signs which are appropriate for the test voltages being used are placed where it is necessary to prevent or limit access to electrical contact hazards. For further information on safety considerations when working with test instruments and equipment, see NFPA 70E.

10.10Accelerator and Detector Areas

The working environment in the accelerator and detector facilities offers more electrical hazards. Operations staff must exercise extreme caution in working around equipment to avoid these hazards. Please refer to *SLAC Guidelines for Operations*, chapters “Electrical Safety” and “Control of Work on Electrical Devices in Beam Housings”.

10.11Two-Person Rule

Supervisors must review each energized work task and determine if two people are required for the job, based on OSHA regulations.

1. For AC circuits 600 volts and above

   OSHA requires that at least two qualified employees shall be present while working on or near (within “Restricted Approach” or “Prohibited Approach”) exposed energized parts at more than 600 volts AC.

2. For special DC circuits with all three of the following:

   a. 50 volts and above

   b. Fault current 5 mA and above

   c. 20 kJ stored energy and above

Work on or near these energized exposed circuits is hazardous. Two people are required for working on these live circuits.

Exception is allowed for the following:

1. Routine switching operations required for normal operations and maintenance. (This does not include operations such as breaker racking, fuse changes, etc.)
2. Emergency repairs to the extent necessary to safeguard the general public