This chapter was last reviewed for currency 6/15/2021.
The next thorough review is due 6/15/2024.

Chapter 8

Electrical Safety

Related Chapters

1 General Policy and Responsibilities

2 Work Planning and Control

19 Personal Protective Equipment

44 Penetration Safety

51 Control of Hazardous Energy

Chapter Outline

1 Policy

SLAC complies with California industrial safety (Cal/OSHA) regulations, the National Fire Protection Association (NFPA) *National Electrical Code (NEC)* (NFPA 70), and "Standard for Electrical Safety in the Workplace" (NFPA 70E) 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. Requirements that are beyond the scope of this document must be established at each work area. They should include, at a minimum, the safety concerns outlined in this chapter.

All electrical wiring and equipment must comply with NFPA 70, Cal/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 on-site are responsible for their own safety. Specific responsibilities are detailed below.

2.1 Electrical Safety Officer

The electrical safety officer (ESO) has the following responsibilities:

- Owns the electrical safety and control of hazardous energy (CoHE) programs
- Is the authority having jurisdiction (AHJ) for the *National Electrical Code (NEC)* (NFPA 70) and NFPA 70E, "Standard for Electrical Safety in the Workplace", as delegated by the Department of Energy (DOE) site office and SLAC management
- Is the electrical design and electrical safety subject matter expert (SME) and plans reviewer for the SLAC Building Inspection Office (BIO) for matters related to code compliance and electrical safety
- Provides advice and guidance on compliance with electrical safety program requirements
- Provides advice and guidance on compliance with NFPA 70 and Cal/OSHA requirements for electrical installations
- Advises management of the need to fund and support program requirements
- Prepares or provides the electrical safety training necessary to comply with program requirements
- Performs program self-assessments
- Reviews and updates this chapter as needed

2.2 Electrical Safety Committee

Historically, the Electrical Safety Committee (ESC) provided advice on electrical safety matters and promoted electrical safety. In addition, the ESC was responsible for reviewing new major projects as directed by the Safety Overview Committee. These responsibilities are currently assigned to and performed by the electrical safety officer. The ESC may be convened from time to time as the need arises to review major electrical safety program changes or to provide advice on unique, unusual or particularly complex electrical safety concerns.

2.3 Environment, Safety, and Health Division

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

2.4 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[1]
- 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 Cal/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

2.5 Personnel

Personnel must

1 The ESH Division can assist managers and supervisors in determining the appropriate training for individuals they supervise. See Section 5, “Training”, for more information.

- 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 (their 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 that poses a potential electrical hazard (see Chapter 2, "Work Planning and Control", for more information about stopping unsafe work)
- Wear and use appropriate electrical PPE as prescribed by the most recent version of NFPA 70E. Refer to Table 8-3and Table 8-4 for information regarding PPE.
- Report immediately, by calling extension 5555 or 911 as appropriate, any electrical shock or burn incident and, if treatment by emergency responders is not required, refer the individual to the Occupational Health Center and to the appropriate supervisor
- Complete and remain current in control of hazardous energy/lock and tag training (see Chapter 51, "Control of Hazardous Energy")
- Complete training in emergency response procedures, including cardiopulmonary resuscitation (CPR), if performing work on exposed electrical circuitry of greater than or equal to 50 volts (V) (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.*

2.6 Safety Watch Person

When deemed appropriate by the supervisor, a safety watch person (SWP) must 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 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 (energized, 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 hertz (Hz) 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.

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).

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

Energized electrical work (Section 10.3.4) is extremely rare at SLAC. However, if work on energized components is anticipated, the training of the person who will be doing the work must 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 ensure that qualified electrical workers 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 ESH Division provides an STA to assist managers and supervisors to assist in determining training requirements for their workers. Electrical safety classes are divided into two categories, core and resource. Information about the STA and electrical safety courses is available from SLAC Training.

5.1 Core Courses

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

- ESH Course 205, CPR/AED Training for Qualified Electrical Workers (ESH Course 205)
- ESH Course 205PRA, CPR/AED Practical Training for Qualified Electrical Workers (ESH Course 205PRA)

  These two courses are required for all personnel who

  - Work directly on exposed electrical circuitry greater than or equal to 50 volts (AC or DC)
  - May be exposed to voltages greater than or equal to 50 volts while performing equipment maintenance or repairs
  - Apply test equipment to exposed energized conductors to perform zero voltage verification (ZVV)
- ESH Course 219, Environmental Safety and Health Orientation (ESH Course 219)

  This course is required for persons working at SLAC. This course provides electrical safety guidance to workers who are not qualified electrical workers but might encounter electrical hazards in the course of their work.
- ESH Course 251, Electrical and General Safety Awareness for R&D (ESH Course 251)

  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 greater than or equal to 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 Accelerator Directorate and Technology Innovation Directorate.

  Managers and supervisors who directly supervise personnel who do this work are also required to take this course, or its equivalent.
- ESH Course 274, Electrical Safety–Low/High Voltage Training (ESH Course 274)

  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 greater than or equal to 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.

- ESH Course 136, Control of Hazardous Energy - Affected Employee (ESH Course 136)

  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.

- ESH Course 157, Control of Hazardous Energy (ESH Course 157 and ESH Course 157R)

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

- ESH Course 260, National Electrical Code Training (ESH Course 260 and ESH Course 260R)

  This training is required for electrical engineers, designers, electricians, and others who are involved in the design or installation of electrical systems and equipment, and whose work products must comply with NFPA 70*)*.

- ESH Course 158, Electrical Equipment Inspection Training (ESH Course 158)

  Electrical system designers, electrical engineers, electricians, electrical workers, and other workers who need to achieve or maintain their qualification as inspector in SLAC's electrical equipment inspection program (EEIP)

5.2 Resource Courses

Resource courses are courses that do not have regulatory or policy drivers but are of significant value to SLAC workers. Completion of these supplemental courses is not required and is left to the discretion of the supervisor or the employee. SLAC Training offers some resource courses at SLAC or provides recommendations for off-site courses.

6 Standards

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

- Title 8, *California Code of Regulations*, "Industrial Relations", Division 1, "Department of Industrial Relations", Chapter 4, "Division of Industrial Safety", Subchapter 5, "Electrical Safety Orders"
  - Group 1, "Low-Voltage Electrical Safety Orders" (8 CCR 2299–2599)
  - Group 2, "High-Voltage Electrical Safety Orders" (8 CCR 2700–2989)
- Title 8, *California Code of Regulations*, "Industrial Relations", Division 1, "Department of Industrial Relations", Chapter 4, "Division of Industrial Safety", Subchapter 4, "Construction Safety Orders"
  - Article 3, "General", Section 1518, "Protection from Electric Shock" (8 CCR 1518)
  - Article 15, "Cranes and Derricks in Construction", Section 1612, "Power Line Safety" (including 1612.x sub items) (8 CCR 1612)
  - Article 24, "Fall Protection", Section 1670, "Personal Fall Arrest Systems, Personal Fall Restraint Systems and Positioning Devices" (8 CCR 1670)
  - Article 33, "Electrical Requirements for Construction Work", Section 1760, "Electrical Requirements for Construction Work" (8 CCR 1760)

- Title 8, *California Code of Regulations*, "Industrial Relations", Division 1, "Department of Industrial Relations", Chapter 4, "Division of Industrial Safety", Subchapter 7, "General Industry Safety Orders",
  - Group 1, "General Physical Conditions and Structures", Article 6, "Powered Platforms and Equipment for Building Maintenance", Section 3299, "Personal Fall Protection", Appendix C, "Personal Fall Arrest System" (8 CCR 3299)
  - Group 2, "Safe Practices and Personal Protection", Article 7, "Miscellaneous Safe Practices", Section 3340, "Accident Prevention Signs" (8 CCR 3340)
- Title 8, *California Code of Regulations*, "Industrial Relations", Division 1, "Department of Industrial Relations", Chapter 4, "Division of Industrial Safety", Subchapter 7, "General Industry Safety Orders", Group 2, "Safe Practices and Personal Protection", Article 10, "Personal Safety Devices and Safeguards"
  - Section 3381, "Head Protection" (8 CCR 3381)
  - Section 3384, "Hand Protection" (8 CCR 3384)
  - Section 3385, "Foot Protection" (8 CCR 3385)
  - Section 3390, "Protection from Electric Shock" (8 CCR 3390)
- National Fire Protection Association (NFPA) 70, *National Electrical Code (NEC)* (NFPA 70). SLAC complies with the current edition; future editions will be effective on January 1 of the edition year.
- NFPA 70E, "Standard for Electrical Safety in the Workplace" (NFPA 70E). Refer to the SLAC Injury and Illness Prevention Program for compliance information and the schedule for full compliance for the current and future editions as they are published.

  Workers should always follow the PPE requirements of the current edition of NFPA 70E per Section 10.3 of this chapter.
- NFPA 101, *Life Safety Code* (NFPA 101)

The following may be used for reference and guidance:

- Federal Occupational Safety and Health Administration (OSHA) Letter of Interpretation, December 19, 2006, "'Continuous industrial processes' and the infeasibility of de-energizing equipment under 29 CFR 1910.333". [1910.333; 1910.333(a)(1)]
- American National Standards Institute (ANSI) Z244.1, "Control of Hazardous Energy Lockout/Tagout and Alternative Methods" (ANSI Z244.1)
- Institute of Electronics and Electrical Engineers (IEEE) C2, *National Electrical Safety Code (NESC)* (IEEE C2)
- Department of Energy Handbook 1092, "Handbook for Electrical Safety" (DOE-HDBK-1092)

7 General Requirements for Equipment Safety

All equipment must 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 Cal/OSHA as being capable of independently assessing equipment for compliance to safety requirements and applicable standards.

7.1.3 Custom-made and Unlisted Equipment

All custom-made electrical equipment and other electrical equipment for which no NRTL acceptance exists (that is, *unlisted* equipment) must be inspected and approved for use as described in the SLAC Electrical Equipment Inspection Program (EEIP). New unlisted equipment must be inspected and approved for use before first energization.

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.

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 milliamperes).

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 or equal to 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 must be legibly marked to indicate purpose unless located and arranged so the purpose is evident. The marking must 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 molded case circuit breakers. Refurbished switchgear breakers from reputable vendors are acceptable for use at SLAC. The refurbished breaker(s) must pass primary current injection testing at SLAC prior to installation. Re-use of SLAC circuit breakers is permitted only after the circuit breaker has been tested by the Electric Shop in the Facilities and Operations Division. Consult the electrical safety officer for re-use of circuit breaker types not discussed above.

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.

7.2.11 Exposed De-energized Electrical Parts

De-energized electrical parts that have not been locked out and verified de-energized by test in accordance with Chapter 51, “Control of Hazardous Energy”, must be treated as energized. Only individuals who join the lockout are protected from hazardous energy. Workers not participating in the lockout must treat de-energized electrical equipment as energized and remain outside the limited approach boundary and arc flash protection boundary of exposed electrical parts.

To avoid inadvertent exposure, exposed electrical parts and exposed severed conductors should never be left in the open where workers could inadvertently contact them. Exposed conductive parts must be enclosed, insulated, guarded or otherwise rendered inaccessible. Severed conductors with exposed ends must be removed back to the source or safed off.

7.2.12 Out-of-Service Equipment

Out-of-service electrical equipment should be placed in a safe state that is economical to monitor and maintain for an extended period, until the eventual decommissioning of the equipment. Maintaining equipment in a safe state ensures that potential hazards to workers, the public, and the environment are minimized. Elimination or mitigation of hazardous energy in out-of-service equipment should occur as soon as practicable following removal of equipment from service. Contact the electrical safety officer for additional guidance on mitigation of hazardous energy in out-of-service equipment.

7.2.13 Demolition of Electrical Equipment

The equipment must be permanently disconnected from all sources of electrical energy. Electrical conductors must be removed or disconnected and safed off at both ends. Do not disconnect at only one end. Conductors that are disconnected but not removed must be modified or secured in a manner that precludes ready reconnection. Lifting and taping off exposed conductor ends is not sufficient; the conductors could be readily reconnected.

7.2.14 Safety-related Maintenance of Electrical Equipment

Safety-related maintenance is maintenance that preserves or restores the condition of electrical equipment for the safety of employees who work where exposed to electrical hazards. NFPA 70E requires that electrical equipment be maintained in accordance with manufacturers' instructions or industry-consensus standards to reduce the risk of failure and the subsequent exposure of employees to electrical hazards.

Workers and their supervisors must consider the condition of maintenance of electrical equipment before operating the equipment. Improper or inadequate maintenance can result in increased equipment failure rates, including increased opening time of overcurrent protective devices, thus increasing arc-flash incident energies. Where equipment is not properly maintained, the worker's personal protective equipment may not provide adequate protection from arc-flash hazards.

SLAC departments that are responsible for electrical equipment maintenance must establish and execute maintenance programs that preserve or restore the condition of the equipment to a state that does not present an undue hazard to workers during equipment operation. Workers are responsible to notify their line manager or supervisor if they have concerns regarding the maintenance status of equipment to be operated. The manager or supervisor must address these concerns before operation of the equipment.

7.2.15 Accelerator Beam Line Electrical Equipment

Beam line electrical equipment must be grounded as required by NFPA 70, Article 250, Section VI, "Equipment Grounding and Equipment Grounding Conductors". In addition, beam line electrical equipment must be connected to the grounding electrode system with supplementary equipment grounding conductors per Article 250.96, as required by Accelerator Directorate policy. This requirement applies to all beam line electrical equipment, including power electronics enclosures, racks, magnet cores, and cable trays and equipment stands that support electrical equipment.

7.3 Design and Installation

All design and installation of equipment and facilities must 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 must provide for safe maintenance.

All systems performing a safety function or controlling a potentially hazardous operation and any modifications made to those systems must 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. Facilities and Operations and the ESH 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 must 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 in SEDA.

7.5 Enclosures

The following specifications apply to circuits operating at greater than or equal to 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 easily opened items 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 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 must be in accordance with Cal/OSHA, NFPA 70, and IEEE C2. 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.

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 NFPA 70, 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 NFPA 70
- Connecting moving parts
- Temporary wiring as permitted in NFPA 70

8.1.2 Flexible Cord Policy

The SLAC policy on flexible cords is based on NFPA 70. 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 NFPA 70, have overcurrent protection in accordance with NFPA 70, and be properly grounded in accordance with NFPA 70.

8.1.3 Disallowed Uses of Flexible Cords

Based on NFPA 70, 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 NFPA 70 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 NFPA 70 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 Underwriters' 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 9.1 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 must 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 must 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 the following:

- 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 ESH coordinator or the electrical safety officer.

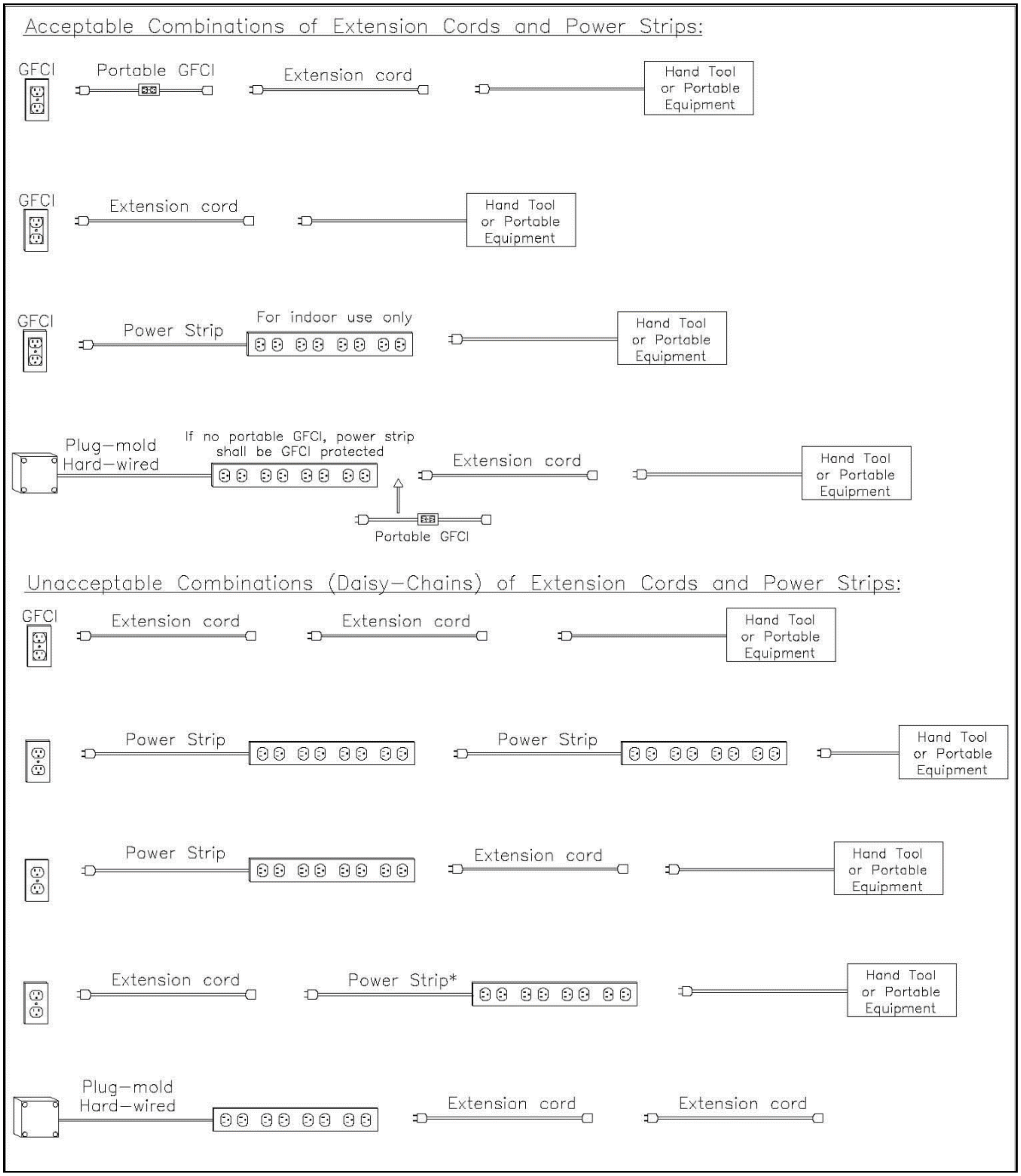

Figure 8-1 Examples of Extension Cord Combination Usage

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

- Only UL (or other NRTL) approved device may be used.
- Power strips may not 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, and 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 PPE that is required by Cal/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.)

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 milliamperes – 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 maintenance or 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 NFPA 70 for more information.*

9.1.2 Testing Requirements

Testing is required for all indoor and outdoor GFCIs.

Testing requirements are divided into the following three types:

1. Local Test Button

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

2. Remote Test Button Remote

   Accessible GFCI outlets protecting downstream outlets must be tested monthly by the building or facility manager (or designate).

3. GFCI Outlets in Continuous Use

   Accessible 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).

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 the testing interval should not exceed one year. In circumstances when a test interval exceeds one year, the testing must be completed at the next opportunity or before next use.

Caution Testing of a GFCI will disconnect all downstream 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 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 NFPA 70
- 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 must be installed in compliance with the applicable NFPA 70 standards.

9.2.2 Policies for Cable Installation

The following are some of the most important issues from the applicable regulations. When installing cables please refer to NFPA 70.

- Cable trays and raceways must 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 NFPA 70.
- 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 NFPA 70 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 NFPA 70.
- Install only the specific types of cables in cable trays as allowed by NFPA 70.

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 will be considered with the review and approval of the SLAC electrical safety officer and the SLAC fire marshal. Enhanced fire detection and/or fire suppression devices, as deemed necessary, must 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 NFPA 70 tray rating requirements for cable types installed. Where NFPA 70 tray-rated-cable types which meet the technical requirements of the installation are not available, the non-tray-rated cables will be permitted with the review and approval of the SLAC electrical safety officer and the SLAC fire marshal. Enhanced fire detection and/or fire suppression devices, as deemed necessary, must 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 Hazardous Power Supplies

Electrical hazard thresholds as applied to power supply outputs:

1. Power supplies with output voltage ≥ 50 V and short circuit output current ≥ 5 mA
2. Power supplies with output voltage < 50 V and output power ≥ 1000 W
3. Power supplies with stored energy capacity > 10 J
4. Power supplies that meet one or more of the above thresholds are deemed hazardous and the safe work practices called out in this chapter apply. The outputs of power supplies that do not meet any of the above thresholds are considered nonhazardous.

9.3.2 Safety Considerations for Power Supplies

9.3.2.1 Primary Disconnect

A means of positively disconnecting the input must be provided. This disconnect must 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 lockout 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 milliamperes 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 re-verify 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 (less than 50 volts) must 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 must 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 must 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 10 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 be seriously hurt if they came in contact with one.

A magnet is hazardous if it is powered from a hazardous power supply (see Section 9.3.1), or if the total stored energy of the power supply and magnet combined is greater than 10 joules. A magnet may be a startle hazard due to arcing if the combined stored energy of the power supply and magnet is greater than 0.25 joules and less than or equal to 10 joules.

Note *For some quadrupole magnets it has been shown by analysis that the magnet terminals are not hazardous when connected to and energized from their power supply. For these magnets an electrical hazard exists only when power supply cables are disconnected from the magnet terminals. To control the hazard, disconnection of the power supply cables from the magnet terminals must be performed under lockout/tagout. Contact the electrical safety officer for additional information on the quad magnet hazard analysis.*

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 that 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 gauss.

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 gauss.

9.5.2.10 Limit Magnetic Field Exposure

Restrict personnel exposure to magnetic fields greater than 600 gauss.

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 Hazardous Magnets

All hazardous magnets must have:

- Magnet terminal covers that prevent contact with the exposed terminals, or
- A lockout/tagout protocol in place such that magnet terminal hazards are de-energized, locked out and zero-voltage-verified in accordance with Chapter 51, “Control of Hazardous Energy”, before workers enter the vicinity of the exposed terminals. Workers must join the lockout before approaching the magnets.

  Note *Non-hazardous magnets are not required to have terminal covers.*[2]

- Labels that describe the hazard and the associated protective measures. A notice label must be used for non-hazardous magnets and electrical hazard labels must be used for hazardous magnets, with additional information depending upon the hazard type (high energy or high voltage) provided

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

2 A non-hazardous magnet has a terminal voltage less than 50 volts and less than 10 joules of total stored energy for the power supply and magnet.

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 amperes.

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, Cal/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
  - 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.[3]

- 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

---

3 Additional information describing employee responsibilities as related to stopping an unsafe work is in Chapter 2, "Work Planning and Control".

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

- Maintain for safety

  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 must conduct a job briefing with the employees involved. The briefing must 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 8 CCR 2940 for more details).

10.2 Emergency Preparedness

All personnel who work on exposed electrical circuitry of greater than or equal to 50 volts (AC or DC) must be trained in emergency response procedures, including CPR.

10.3 Electrical Work Practices

The preferred mode of work is in the "electrically safe" state (de-energized, locked out, and zero-voltage-verified in accordance with Chapter 51, "Control of Hazardous Energy"). If de-energizing the equipment is not practical, work must 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 must be documented and be monitored for effectiveness per requirements in Chapter 2, "Work Planning and Control". In addition, all electrical work at SLAC requires the prior completion of an electrical work plan (EWP) or equivalent work planning and control (WPC) documentation. For certain energized work, an energized electrical work permit (EEWP) is also required (see Section 10.3.4).

Safe work practice guidance and requirements summarized in this chapter are taken from 8 CCR 2299–2599, and 8 CCR 2700–2989, NFPA 70E, and DOE-HDBK-1092. The electrical safety officer is available to provide advice in applying these standards and is available to review procedures for situations not covered in these standards.

10.3.1 Exceptions for Non-hazardous Electrical Equipment

Hazard thresholds for electrical equipment:

1. Equipment with voltage ≥ 50 V and short circuit output current ≥ 5 mA
2. Equipment with voltage < 50 V and output power ≥ 1000 W
3. Equipment with stored electrical energy capacity > 10 J

Electrical equipment that does not meet any of the above thresholds is deemed non-hazardous and is exempt from the provisions of Section 10.3 above.

10.3.2 General Requirements

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 approach boundary limits to exposed energized components. 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 summarize 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 for guidance). To aid workers, the results of this analysis must 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, "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 (see Chapter 51, "Control of Hazardous Energy").
- Use the appropriate PPE and tools to accomplish isolation, discharge of stored energy, zero voltage verification and grounding, if required, to place equipment in an electrically safe condition.
- When placing equipment in the electrically safe condition the following steps must be performed, in the order specified. Perform each step in its entirety before moving on to the next step.
  a. Perform energy isolation
  b. Apply LOTO lock and tag
  c. Perform zero energy checks, including zero voltage verification, when required
  d. Apply personal protective grounds (medium- and high-voltage equipment only) or grounding hooks/ground wires (R&D power electronics with the potential for stored hazardous electrical energy).
- 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 an electrical work plan (EWP) or equivalent work planning and control (WPC) documentation and an energized electrical work permit (EEWP), if applicable.

Two classifications of equipment are defined in the NEC (NFPA 70), Article 100, "Premises Wiring and Utilization Equipment".

- Premises wiring is the physical electrical distribution system wiring and equipment from the master substation 230 kilovolt (kV) bus to the electrical outlets (for fixtures or cord-and-plug-connected equipment), or to the point at which the field wiring terminates on the utilization equipment.
- Utilization equipment is the equipment connected to the premises wiring.

Sections 10.3.5 and 10.3.6 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 and locking out electrical circuits, it is recognized that to operate the laboratory efficiently and effectively, qualified personnel have reason to access or operate energized panel boards and equipment housings for inspection, testing or troubleshooting.

An electrical work plan (EWP) that includes a hazard analysis is required for all electrical work activities (both premises wiring and utilization equipment). The purpose of the EWP is to document that appropriate safe work practices and PPE 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 and control documents, lockout procedure, or other maintenance and servicing procedure that includes a job safety analysis (JSA).

The EWP must

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

10.3.3.1 Required Approvals

The EWP must 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 must not be the same as the originator. Additional approval by the electrical safety officer and senior management may be required for certain energized electrical work, as described in Section 10.3.4.

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.

10.3.3.2 Routine Activities

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

10.3.3.3 Distribution and Recordkeeping

An approved EWP is required prior to starting work. After the EWP is approved the original must be kept at the worksite and, upon completion of work, retained by the workgroup for at least 12 months.

10.3.4 Energized Electrical Work Permit

An energized electrical work permit (EEWP) is required for all manipulative energized work. Manipulative work is work that includes assembly, disassembly, tightening, adjusting, or rearrangement of components while they are energized.

Note *Work on energized non-hazardous equipment as specified in Section 10.3.1, as well as testing, troubleshooting, and voltage measuring on energized hazardous equipment, are exempt from the required EEWP per NFPA 70E, Article 130, provided that safe work practices and personal protective equipment are used.*

Energized electrical work presents a significant personnel safety hazard and must be allowed only under extraordinary circumstances. The justification for performing energized work must be safety-based, that is it must be shown that it is safer to perform the work energized than to perform the work de-energized. Convenience may not be used as the justification for energized work.

10.3.4.1 Required Approvals

EEWPs must be approved by the electrical safety officer (ESO), chief safety officer (CSO), directorate (associate laboratory director or director), and Laboratory Director's Office (laboratory director or laboratory deputy director) before beginning work.

Note *For work on energized batteries and battery banks CSO, directorate, and Laboratory Director's Office approvals are NOT required. (See the energized electrical work permit [EEWP].)*

10.3.4.2 Distribution, Closeout, and Recordkeeping

The approved EEWP and EWP or JSA must be at the jobsite while performing work. The lead worker or fist-line supervisor must closeout the permit within seven days after completion of the work by reviewing the process and procedures for improvements. Upon completion of the work a copy of the EEWP (with the electrical work plan (EWP) or job safety analysis (JSA) must be submitted to the electrical safety officer (ESO).

10.3.5 Utilization Equipment

This section covers electrical work by SLAC qualified electrical workers and subcontractor qualified electrical workers on electrical equipment other than premises wiring. For this section, 600 volts means 600 volts direct current (VDC) 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. EWPs for routine, repetitive, processes are permitted. Such EWPs must be renewed every 12 months. 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.

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 supervisor and department/group head.

For all other activities on exposed energized utilization equipment an EEWP per Section 10.3.4 is required.

10.3.6 Premises Wiring

Work on premises wiring must be performed only by qualified SLAC or subcontractor electricians. For this section, 600 volts means 600 VAC. 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 equipment operating at less than 600 volts and all de-energized electrical circuit verifications are allowed with a supervisor approved EWP. EWPs for routine, repetitive, processes are permitted. Such EWPs must be renewed every 12 months. 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.

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 supervisor and department/group head.

For all other activities on exposed energized premises wiring and equipment an EEWP per Section 10.3.4 is required.

10.3.7 Two-person Rule

At least two qualified workers must be present when work is being performed within the restricted approach boundary (see Table 8-1 and Table 8-2) 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 5 milliamperes and above
  - 20 kilojoules of stored energy and above

The safety watch person (SWP) as specified in Section 2.6 of this chapter must 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 and arc flash 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 Table 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 convenience, Table 8-4 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.

10.3.8.1 General PPE Requirements

- PPE must be maintained in a safe, reliable condition.
- PPE must be visually inspected before each use.
- PPE must be stored in a manner to prevent damage and to protect the PPE from moisture, dust, or other deteriorating agents.

10.3.8.2 Specific Requirements for Electrical Insulating Gloves

- Before each used, electrical insulating gloves must be given an 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 must be worn over electrical insulating gloves to avoid damage to the electrical insulating glove material and to provide increased hand protection from arc flash.

Table 8-1 Approach Boundaries for Shock Protection for Exposed Energized AC Electrical Conductors or Circuit Parts

Voltage Range (Phase to Phase)	Limited Approach Boundary Distance (Exposed Fixed Circuit Part)	Restricted Approach Boundary Distance (Exposed Fixed Circuit Part)
Below 50 volts	None specified	None specified
50–150 volts	3 ft. 6 in.	Avoid contact
> 150–750 volts	3 ft. 6 in.	1 ft. 0 in.
> 750–15,000 volts	5 ft. 0 in.	2 ft. 2 in.
> 15,000–36,000 volts	6 ft. 0 in.	2 ft. 7 in.
> 36,000 volts	See NFPA 70E	See NFPA 70E

Table 8-2 Approach Boundaries for Shock Protection for Exposed Energized DC Electrical Conductors or Circuit Parts

Voltage Potential Difference	Limited Approach Boundary Distance (Exposed Fixed Circuit Part)	Restricted Approach Boundary Distance (Exposed Fixed Circuit Part)
Below 50 volts	None specified	None specified

50–300 volts	3 ft. 6 in.	Avoid contact
> 300–1000 volts	3 ft. 6 in.	1 ft. 0 in.
> 1,000–5,000 volts	5 ft. 0 in.	1 ft. 5 in.
> 5,000–15,000 volts	5 ft. 0 in.	2 ft. 2 in.
> 15,000–75,000 volts	8 ft. 0 in.	2 ft. 9 in.
> 75,000 volts	See NFPA 70E	See NFPA 70E

Notes

1 Workers must review the electrical hazard label affixed to the equipment to determine if an arc flash hazard exists. The hazard label will identify the shock protection PPE and, if an arc flash hazard exists, the required arc flash protection PPE.

2 This table is based on NFPA 70E-2018. PPE requirements could change when updates to NFPA 70E are published (three year cycle). Workers should check the date on electrical hazard labels and, for outdated labels, refer to the current version of NFPA 70E for PPE requirements.

3 NFPA provides online access to the current version of NFPA 70E at NFPA.org. Workers who take ESH Course 274 receive a copy of the current version of NFPA 70E every three years. Workers may also procure a copy of NFPA 70E or the NFPA 70E Handbook using department funds.

Table 8-3 Personal Protective Equipment (PPE) [from NFPA 70E, Article 130]

Arc Flash PPE Category	Required Clothing	Required PPE
1	▪ Arc-rated clothing, minimum arc rating of 4 cal/cm^2 ▪ Arc-rated long-sleeve shirt and pants or arc-rated coverall ▪ Arc-rated face shield or arc flash suit hood ▪ Arc-rated jacket, parka, rainwear, or hard hat liner (as needed)	▪ Hard hat ▪ Safety glasses or safety goggles ▪ Hearing protection (ear canal inserts) ▪ Heavy duty leather gloves ▪ Leather footwear
2	▪ Arc-rated clothing, minimum arc rating of 8 cal/cm^2 ▪ Arc-rated long-sleeve shirt and pants or arc-rated coverall ▪ Arc-rated flash suit hood or arc-rated face shield and arc-rated balaclava ▪ Arc-rated jacket, parka, rainwear, or hard hat liner (as needed)	▪ Hard hat ▪ Safety glasses or safety goggles ▪ Hearing protection (ear canal inserts) ▪ Heavy duty leather gloves ▪ Leather footwear
3	▪ Arc-rated clothing, minimum arc rating of 25 cal/cm^2 ▪ Arc-rated long-sleeve shirt ▪ Arc-rated pants ▪ Arc-rated coverall ▪ Arc-rated arc flash suit jacket ▪ Arc-rated arc flash suit pants ▪ Arc-rated arc flash suit hood ▪ Arc-rated gloves ▪ Arc-rated jacket, parka, rainwear, or hard hat liner (as needed)	▪ Hard hat ▪ Safety glasses or safety goggles ▪ Hearing protection (ear canal inserts) ▪ Leather footwear

Arc Flash PPE Category	Required Clothing	Required PPE
4	▪ Arc-rated clothing, minimum arc rating of 40 cal/cm^2 ▪ Arc-rated long-sleeve shirt ▪ Arc-rated pants ▪ Arc-rated coverall ▪ Arc-rated arc flash suit jacket ▪ Arc-rated arc flash suit pants ▪ Arc-rated arc flash suit hood ▪ Arc-rated gloves ▪ Arc-rated jacket, parka, rainwear, or hard hat liner (as needed)	▪ Hard hat ▪ Safety glasses or safety goggles ▪ Hearing protection (ear canal inserts) ▪ Leather footwear

Notes

1 Arc Flash PPE Category 0 was removed from NFPA 70E-2018. SLAC hazard labels that pre-date this change will not be updated to remove Category 0. Workers should treat equipment labeled as Arc Flash PPE Category 0 as “n/a” or “no arc flash hazard”

2 PPE requirements could change when updates to NFPA 70E are published (three-year cycle). Workers should check the date on electrical hazard labels and, for outdated labels, refer to the current version of NFPA 70E for PPE requirements.

3 Underlayers (underwear). Non-melting, flammable fiber garments (eg, cotton) must be permitted to be used as underlayers to arc rated clothing. Meltable fibers such as acetate, nylon, polyester, polypropylene, and spandex must NOT be permitted in fabric underlayers next to the skin.

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 must 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 (for example, accidental shorting). Additional precautions are required to protect from injury.

For batteries not exempted in Section 10.3.1:

- Remove jewelry and watches from hands and wrists before working on or near exposed conductors

- For batteries and battery banks under 750 VDC, use Class 00 (minimum) gloves from Table 8-4 (note additional PPE may be required, for example protection from acid for lead-acid batteries).

For capacitors not exempted in Section 10.3.1:

- Remove jewelry and watches from hands and wrists before working on or near exposed conductors
- For capacitors at voltages under 750 VDC, use Class 00 (minimum) gloves from Table 8-4. For capacitors over 750 VDC, use gloves as specified in the Table 8-4.
- To protect against injury, stored energy in capacitors must be safely discharged as part of an equipment lock out procedure for working on or near that capacitor. (Refer to Chapter 51, "Control of Hazardous Energy", for lockout/tagout requirements.)
- When in storage, capacitors with the potential to store 10 joules or more must have a shorting jumper installed connecting the terminals to prevent static buildup of stored charge.

10.3.10 Testing Equipment Classifications

The work environment can expose test equipment to different aberrant voltage levels (voltage spikes caused by lightning 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 (for example, multi-meters) to withstand certain levels of these transients depending on the expected usage location of the equipment. These categories are listed in Table 8-5.

- Testing equipment must 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. Because facilities at SLAC are often quite close to the 12 kilovolt (kV) distribution lines, testing equipment must 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 in Chapter 51, "Control of Hazardous Energy".

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.

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 Facilities and Operations Division.

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 must

- Obtain approval for energized work as per Section 10.3.3. 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 10.3.8.1.
- Ensure that a safety watch person has been designated. See Section 2.6, "Safety Watch Person," for more details.
- Use battery, air, or hydraulic powered tools to the maximum extent possible.
- Cord-and -plug connected tools and equipment must be supplied from a GFCI-protected outlet.

10.5 Lock and Tag Procedures

For working on electrical equipment in de-energized condition see Chapter 51, "Control of Hazardous Energy".

10.6 Operating and Resetting Circuit Breakers

Operating breakers and disconnect switches at SLAC is the purview of qualified electrical workers. In some cases permission to operate a limited set of breakers or disconnect switches may be granted to workers who are not day-to-day electrical workers (for example, mechanical workers and building managers). For such permission to be granted several conditions must be met:

- Creation of a supervisor-approved job-safety analysis (JSA) or activity training and authorization (ATA) that addresses the switching hazards and that identifies the specific breakers or switches for which operation will be allowed
- Successful completion of electrical safety officer-specified electrical safety training

- Permission from the equipment custodian/equipment owner to operate the specified breakers or disconnects
- Supervisor authorization

Note *Contact the electrical safety officer to initiate a request for permission to operate breakers or disconnect switches.*

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 damage the breaker or the downstream load. 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 the Facilities Service Desk) if you have any need to enter a substation.

10.8 Safety Watch Person

A safety watch person must be assigned while working on very hazardous work when deemed appropriate by the supervisor. See Section 2.6, “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 that 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.

Electrical Work Plan Form

Product ID: 249 | Revision ID: 2312 | Date Published: 15 June 2021 | Date Effective: 15 June 2021
URL: https://www-group.slac.stanford.edu/esh/eshmanual/references/electricalFormEWP.pdf | docx

ENVIRONMENT, SAFETY & HEALTH DIVISION

All electrical work at SLAC requires the prior completion of an electrical work plan (EWP) or equivalent work planning and control (WPC) documentation. For certain energized work, an energized electrical work permit (EEWP) is also required. (See Chapter 8, "Electrical Safety", Section 10.3.)

Job / activity:		Start date:	Valid through: (1 year max)
Prepared by (print):	Signature:		Date:
Person in charge (print):	Signature:		Date:
Other reviewer (print):	Signature:		Date:
Scope of work summary:			

1 Hazard Analysis *(add rows as needed)*

Step or Task	Step or Task Description	**Hazard** (include shock and arc flash hazard information from the hazard label affixed to the equipment or from the electrical analysis engineer)	**Control** (include electrical safety PPE based on the electrical hazard information)
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			

2 Authorization

Authorizer (administrative or functional supervisor, foreman, POC). I have reviewed the steps, hazards and controls described in this EWP. Workers are qualified (that is, licensed or certified, as appropriate, and in full compliance with SLAC training requirements) to perform this activity.		
Name (print):	Signature:	Date:

3 Release

Area or building manager Red work? ☐ Yes. Document release via WIP and tailgate meeting. ☐ No. I have communicated unique area hazards, boundary conditions, and so on with the authorizer or listed worker(s) and have coordinated this job with affected occupants. Listed workers are released to perform described scope of work.		
List boundary conditions, notes, etc:		
Name (print):	Signature:	Date:

4 Worker Acknowledgement *(add rows as needed)*

Worker. I understand and will adhere to the steps, hazards, and controls in this EWP. I understand that performing steps out of sequence may pose hazards that have not been evaluated nor authorized. I will contact the person who authorized my work before continuing if the scope of work changes or new hazards are introduced. I understand my stop work authority and responsibility.

Name (print)	Signature	Date

5 Electrical Work Procedure

(optional: insert or attach procedure(s), LOTO energy isolation plan(s) and associated drawings/sketches below)

5.1 [Heading 2]

[Body Text]

5.1.1 [Heading 3]

[Body Text]

5.1.2 [Heading 3]

[Body Text]

5.2 [Heading 2]

[Body Text]

5.2.1 [Heading 3]

[Body Text]

5.2.2 [Heading 3]

[Body Text]

ENVIRONMENT, SAFETY & HEALTH DIVISION

Chapter 8: Electrical Safety

Energized Electrical Work Permit Form

Product ID: 247 | Revision ID: 2311 | Date Published: 15 June 2021 | Date Effective: 15 June 2021

URL: https://www-group.slac.stanford.edu/esh/eshmanual/references/electricalFormEEWP.pdf | docx

An approved energized electrical work permit (EEWP) is required for all manipulative energized work on hazardous electrical equipment (see Chapter 8, "Electrical Safety", Section 10.3.4). *Manipulative energized work* includes assembly, disassembly, tightening, adjusting or rearrangement of components while they are energized.

Work on energized non-hazardous equipment as specified in Chapter 8, "Electrical Safety", Section 10.3.1, as well as testing, troubleshooting, and voltage measuring on energized hazardous equipment, is exempt from the required EEWP per NFPA 70E, Article 130, provided that safe work practices and personal protective equipment are used.

Instructions

Important The justification for performing energized work must be **safety-based**, that is it must be shown that it is **safer to perform the work energized** than to perform the work **de-energized**. **Convenience may not be used** as the sole justification for energized work.

- Complete sections 1 and 2 with verifications and attach supporting documents before seeking approving authority signatures:
  - Section 1 must be complete before Section 2 and 3 approval signatures are obtained.
  - The approved EEWP and EWP or JSA must be at the jobsite while performing work.
  - A closeout signature in Section 4 is required within seven days after completion of the work.
  - Upon completion of work provide a copy of the EEWP (with Section 4 complete) and the electrical work plan (EWP) or job safety analysis (JSA) to the electrical safety officer (ESO).
- Approvals are granted only for the specific work planned, period, location, personnel, and conditions described. **Any changes to the planned work once energized electrical work proceeds will immediately void any authority to continue work**. It is essential that the energized electrical work be completely understood in advance and be thoroughly planned, with strict compliance to the authorized procedures and process.

- Approvals required:
  - Electrical safety officer (ESO)
  - Chief safety officer (CSO)[1]
  - Directorate (associate laboratory director or director)[1]
  - Laboratory Director's Office (laboratory director or laboratory deputy director)[1]

1 Exception: for work on energized batteries and battery banks, CSO, directorate, and Laboratory Director's Office approvals are **not** required.

Section 1 Request for Energized Electrical Work across Approach Boundaries *(complete in full)*

Requester's name *(print)*:	Phone:	Date:
Describe the electrical equipment and scope of energized electrical work: *(be specific)*		
Compelling need to support a request to do work on energized electrical equipment: *(the justification must be safety-based; that is, explain why it is safer to perform the task energized than de-energized)*		
Alternatives to avoid doing work on energized electrical equipment:		

Department request – review and approval

Approving authority: ☐ system engineer or ☐ system owner	
Name *(print)*:	
Approval / disapproval: ☐ Yes, proceed ☐ No, do not proceed	
Signature:	Date:

Department request – review and approval

Approving authority (department head)	
Name *(print)*:	
Approval / disapproval: ☐ Yes, proceed ☐ No, do not proceed	
Signature:	Date:

Section 2 Energized Electrical Work Approach Boundaries and Supporting Information *(complete in full)*

Circuit location building:	Panel or equipment / circuit:	
Energized components exposed to workers:		
Nominal circuit potential (volts):	Frequency (hertz):	Short circuit current (amperes):
Boundary access intrusion limit (in inches) for flash:	Limited:	Restricted:
Arc flash protection boundary is from arc flash analysis (calculated): Yes ☐ *(if no arc flash analysis exists then one must be performed)*		
Describe safe work procedures, hazard analysis, access control, and mitigating PPE in detail on an attached electrical work plan (EWP) or non-routine job safety analysis (JSA).		
Brief work description:		
Start work date:	End work date:	
Expected duration of actual boundary intrusion (hours):	Number of workers crossing boundary:	
SLAC department / group performing or directing energized work:	Phone:	
Subcontractor performing energized work (if any):	Phone:	
First qualified electrical worker (in charge):	Phone:	
Second qualified electrical worker (backup):	Phone:	
Safety watch qualified worker:	Phone:	
Names of other workers:		
For the following three confirming verifications, project lead or supervisor normally signs. Verification may NOT be signed by the qualified workers listed above or by any person named in request Section 1.		
A non-routine job safety analysis (JSA) or electrical work plan (EWP) is attached: ☐ Yes ☐ No		
The JSA / EWP has been reviewed in detail and discussed by the affected qualified workers and is adequate for the energized electrical work described.		
Verified by *(print)*:	Signature:	Date:
Current training reports for the qualified electrical workers listed are attached: ☐ Yes ☐ No		
Qualified electrical worker training is current and adequate for the energized electrical work described.		
Verified by *(print)*:	Signature:	Date:
Current personal protective equipment (PPE) electrical test reports are attached: ☐ Yes ☐ No		
All required PPE is listed on the JSA / EWP, is certified by test to be safe, is usable during the period of the work, is in the possession of the listed workers qualified to use it, and is adequate for the energized electrical work described.		
Verified by *(print)*:	Signature:	Date:

Section 3 Approvals

Electrical Safety Officer *(required for all EEWPs)*

Approving authority (electrical safety officer)		
Name *(print)*:		
Approval / disapproval: ☐ Yes, proceed ☐ No, do not proceed		
Signature:	Date:	Time:

Chief Safety Officer *(not required for work on energized batteries and battery banks)*

Approving authority (chief safety officer)		
Name *(print)*:		
Approval / disapproval: ☐ Yes, proceed ☐ No, do not proceed		
Signature:	Date:	Time:

Directorate *(not required for work on energized batteries and battery banks)*

Approving authority (associate laboratory director or director, or designee)		
Name *(print)*:		
Approval / disapproval: ☐ Yes, proceed ☐ No, do not proceed		
Signature:	Date:	Time:

Laboratory Director's Office *(not required for work on energized batteries and battery banks)*

Approving authority (laboratory director or laboratory deputy director or designee)		
Name *(print)*:		
Approval / disapproval: ☐ Yes, proceed ☐ No, do not proceed		
Signature:	Date:	Time:

Section 4 Closeout *(complete and submit to ESO within seven days)*

Following completion of energized electrical work, the lead worker or fist-line supervisor or manager has reviewed the process and procedures implemented to determine if improvements are indicated that would increase the safety of that work if it were attempted again, or similar work if it were done in the future.		
Verified by name *(print)*:	Signature:	Date:
Brief summary of review findings: *(attach detailed summary as needed)*		
Brief summary of indicated improvements: *(attach detailed summary as needed)*		

Section 5 Adequacy Review

Review authority (electrical safety officer)		
Name *(print)*:		
Approval / disapproval: ☐ Yes, work safety adequate ☐ No, improvements are warranted (describe):		
Signature:	Date:	Time:

ENVIRONMENT, SAFETY & HEALTH DIVISION

Chapter 8: Electrical Safety

Flexible Heating Device Requirements

Product ID: 240 | Revision ID: 2313 | Date published: 15 June 2021 | Date effective: 15 June 2021
URL: https://www-group.slac.stanford.edu/esh/eshmanual/references/electricalReqHeaterTape.pdf

1 Purpose

The purpose of these requirements is to ensure the safe use of flexible heating devices, such as heater tape and heater blankets. They cover installing and operating such devices. They apply to workers.

Flexible heating devices are typically used for baking out vacuum systems, controlling the temperature of gas cylinders, and de-icing. These devices can pose several hazards. By design, they can become hot enough to cause burns or possibly ignite combustibles (such as clothing and fabric). The electrical elements in them can pose a potential shock hazard to personnel if not used properly. With prolonged use, these elements can fray to the point where strands of heating wire protrude through the protective insulation. In addition, the insulating material used in these devices poses a hazard: fiberglass and aluminosilicate fiber insulation can cause irritation to the skin or respiratory tract. Other potential hazards can arise from the device design or installation methods.

2 Requirements

2.1 Installation

All installations must follow the following minimum precautions.

2.1.1 Before Installation

- Conduct a hazard analysis before each installation to identify unique hazards.
- All systems composed of electrically conductive elements must be properly grounded before applying flexible heating devices. ESH coordinators or the SLAC electrical safety officer can provide guidance on proper equipment grounding.
- De-energize and follow lock-out/tag-out procedures for the heating device's energy source before installation or removal. (See Chapter 51, "Control of Hazardous Energy".)
- Use proper personnel protective equipment (PPE) as required to mitigate hazards posed by the insulating materials. ESH coordinators or ESH industrial hygiene staff can provide guidance on the proper handling of these materials.
- Use one of the following personnel protection methods to prevent or mitigate electrical shock hazards:
  - Use a ground-fault circuit interrupter (GFCI) on all installations. If the heating device is used with a Variac, the GFCI must be placed upstream of the autotransformer to operate properly.

   – Cover the installation with a grounded conductive shield. Only personnel who have completed electrical safety training can then work on the system.

2.1.2 During Installation

- Follow the manufacturer's installation and operating instructions carefully.
- Do not cut or alter the heater tape length. Altering the tape's length will change wattage, and can cause overheating.
- Do not cross or lap heater tape directly over itself or another tape. Excessive heating could occur and the heater tape would burn out.
- The installation must be clearly marked with safety signs to identify the hazards (for example, VOLTAGE PRESENT – DO NOT TOUCH, or DANGER – HIGH TEMPERATURES PRESENT).

2.2 Operation

- Before each use, inspect the device. Replace it if there are any signs of excessive wear, brittleness, or deterioration (discolored or burnt surfaces, especially at the plug); charring, cuts, breaks, or unraveling in insulation; or exposed conductors.

3 Forms

The following forms and systems are required by these requirements:

- None

4 Recordkeeping

The following recordkeeping requirements apply for these requirements:

- None

5 References

SLAC Environment, Safety, and Health Manual (SLAC-I-720-0A29Z-001)

- Chapter 8, "Electrical Safety"
- Chapter 51, "Control of Hazardous Energy"

Other SLAC Documents

- Industrial Hygiene Program

Other Documents

- Underwriters Laboratories (UL) 943, "Ground-Fault Circuit-Interrupters" (UL 943)

851>Cal/OSHA Implementation Plan: Electrical Safety

This form is for documenting changes to a program and the program's supporting resources (ESH Manual chapter or similar program description, training courses, databases, and so on) resulting from the adoption of the model Revolutionary Working Group (RWG) contract (see below) and the associated DOE variance from 10 CFR 851, "Worker Safety and Health Program". The purpose is to ensure consistent, concise descriptions of the resulting changes. The form is to be completed by the program manager and sent to the DOE as a cover sheet with the revised documents. The general process is as follows:

1. Program manager completes form
2. Changes to program resources made and reviewed following normal revision processes
3. DOE sent draft form and revisions
4. Changes to program resources published
5. DOE sent final form and revisions

1 Introduction

The RWG model contract and 10 CFR 851 variance are intended to simplify and improve the implementation of worker safety and health requirements by tailoring the laws, regulations, and standards that apply while achieving a level of protection equivalent to the requirements of 10 CFR 851. This mostly entails replacing federal Occupational Safety and Health Administration (OSHA) regulations (29 CFR 1910 and 1926) with Cal/OSHA regulations (8 CCR) as external requirements to be complied with but may also involve other laws and regulations and either different versions of industry standards than those cited in 10 CFR 851 or entirely different standards. (One purpose of this form is to capture the specific changes in external requirements for each program.) (For more information on this effort, see the variance application in 851>Cal/OSHA resources.)

2 Plan

Field Number	Field Name	Field
1.	Program name	Electrical Safety
2.	Program manager	Stickney, Doug
3.	LBNL counterpart	Stephanie Collins 510-926-1720 (SME list) (LBNL Phonebook)
4.	Program documents	*The following is a list of existing program documents, to be reviewed by the program manager to determine which will need to be revised to reflect 851>Cal/OSHA changes.* ▪ ESH Manual Chapter 8: Electrical Safety ▪ Electrical Safety: Energized Electrical Work Permit Form ▪ Electrical Safety: Electrical Work Plan Form ▪ Electrical Safety: Flexible Heating Device Requirements
5.	Training courses	*The following is a list of existing training courses, to be reviewed by the program manager to determine which will need to be revised to reflect 851>Cal/OSHA changes.* *Course materials are available for review.* ▪ ESH Course 138, First Aid/CPR/AED/BBP Training (ESH Course 138)

Field Number	Field Name	Field
		▪ ESH Course 219, Environmental Safety and Health Orientation (ESH Course 219) ▪ ESH Course 251, Electrical and General Safety Awareness for R&D (ESH Course 251) ▪ ESH Course 274, Electrical-Low/High Voltage (ESH Course 274) ▪ ESH Course 136, Control of Hazardous Energy - Affected Employee (ESH Course 136) ▪ ESH Course 157, Control of Hazardous Energy (ESH Course 157) ▪ ESH Course 157R, Control of Hazardous Energy (CoHE) Refresher (ESH Course 157R) ▪ ESH Course 157PRA, Control of Hazardous Energy Practical (ESH Course 157PRA) ▪ ESH Course 260, National Electrical Code Training (ESH Course 260) ▪ ESH Course 260R, National Electrical Code Refresher Training (ESH Course 260R) ▪ ESH Course 158, Electrical Equipment Inspection Training (ESH Course 158)
6.	Other program resources	*The following is a list of existing program resources, to be reviewed by the program manager to determine which will need to be revised to reflect 851>Cal/OSHA changes.* ▪ None
7.	Current external requirements	*The following is a list of current external requirements for this program, as identified in the program documents above.* ▪ Title 29, Code of Federal Regulations, “Labor” , Subtitle B, “Regulations Relating to Labor (Continued)”, Chapter 17, “Occupational Safety and Health Administration, Department of Labor” (Continued), Part 1910, “Occupational Safety and Health Standards” (29 CFR 1910) ▪ Title 29, Code of Federal Regulations, “Labor” , Subtitle B, “Regulations Relating to Labor (Continued)”, Chapter 17, “Occupational Safety and Health Administration, Department of Labor” (Continued), Part 1926, “Safety and Health Regulations for Construction” (29 CFR 1926) ▪ National Fire Protection Association (NFPA) 101, Life Safety Code (NFPA 101) ▪ Institute of Electronics and Electrical Engineers (IEEE) C2, National Electrical Safety Code (NESC) (IEEE C2) ▪ Department of Energy Handbook 1092, “Handbook for Electrical Safety” (DOE-HDBK-1092) ▪ Title 29, Code of Federal Regulations, "Labor", Subtitle B, "Regulations Relating to Labor" (Continued), Chapter 17, "Occupational Safety and Health Administration, Department of Labor (Continued)", Part 1910, "Occupational Safety and Health Standards", Subpart S, "Electrical" (29 CFR 1910 Subpart S) ▪ Title 29, Code of Federal Regulations, "Labor", Subtitle B, "Regulations Relating to Labor" (Continued), Chapter 17, "Occupational Safety and Health Administration, Department of Labor (Continued)", Part 1926, "Safety and Health Regulations for Construction", Subpart K, "Electrical" (29 CFR 1926 Subpart K) *The following is a list of current external reference/guidance documents.* ▪ American National Standards Institute (ANSI) Z244.1, "Control of Hazardous Energy Lockout/Tagout and Alternative Methods" (ANSI Z244.1)
8.	Proposed external requirements	*List all the external requirements that will apply to this program. To determine, start by looking up existing external requirements in 851>Cal/OSHA resources (variance, gap analysis, and contract) and finding replacements (for example a specific section in 29 CFR 1910 to a specific section in 8 CCR or a current version of an industry standard).Where Cal/OSHA requirements are less stringent than those of 10 CFR 851, check with Jeremy Sawyer on which to use.* ***Enter “no changes” if none.*** ▪ National Fire Protection Association (NFPA) 70, *National Electrical Code (NEC)*

Field Number	Field Name	Field
		▪ National Fire Protection Association (NFPA 70E) Electrical Safety in the Workplace ▪ Cal/OSHA Electrical Safety Orders Subchapter 5, Group 1. Low-Voltage Electrical Safety Orders (Sections 2299 - 2599) ▪ Cal/OSHA Electrical Safety Orders Subchapter 5, Group 2. High-Voltage Electrical Safety Orders (Sections 2700 - 2989) ▪ §1518. Protection from Electric Shock. ▪ §1612. Power Line Safety (including 1612.x sub items) ▪ §1670. Personal Fall Arrest Systems, Personal Fall Restraint Systems and Positioning Devices. ▪ §1760. Electrical Requirements for Construction Work. ▪ §3381. Head Protection. ▪ §3385. Foot Protection. ▪ §3390. Protection from Electric Shock. ▪ §3384. Hand Protection. ▪ 3299 Appendix C Personal Fall Arrest System ▪ §3340. Accident Prevention Signs *The following is a list of proposed external reference/guidance documents.* ▪ Occupational Safety and Health Administration (OSHA) Letter of Interpretation, December 19, 2006, "Continuous industrial processes' and the infeasibility of de-energizing equipment under 29 CFR 1910.333". [1910.333; 1910.333(a)(1)] ▪ Institute of Electronics and Electrical Engineers (IEEE) C2, National Electrical Safety Code (NESC) (IEEE C2) ▪ Department of Energy Handbook 1092, "Handbook for Electrical Safety" (DOE-HDBK-1092) ▪ American National Standards Institute (ANSI) Z244.1, "Control of Hazardous Energy Lockout/Tagout and, Alternative Methods" (ANSI Z244.1)
9.	Proposed substantive changes	*Describe (list) the substantive changes to be made in the program, based on the new external requirements.* ***Enter "no changes" if none.*** ▪ No substantive changes
10.	Additional proposed substantive changes	*Describe (list) the substantive changes to be made in the program, in addition to those based on the new external requirements. For example, those due to stakeholder input, other reviews and audits, operating experience.* ***Enter "no changes" if none.*** ▪ No substantive changes
11.	Affected program documents	*List program documents affected by the changes above.* ***Enter "no changes" if none.*** ▪ ESH Manual Chapter 8: Electrical Safety
12.	Affected training courses	*List training courses affected by the changes above.* ***Enter "no changes" if none.*** ▪ Possible minor changes to ESH Course 251, Electrical and General Safety Awareness for R&D (ESH Course 251) for electrical worker fall protection and to update references to Cal OSHA Electrical Safety Orders. ▪ ESH Course 138, First Aid/CPR/AED/BBP Training, has been replaced for electrical workers by ESH Course 205, CPR/AED/Training for Qualified Electrical Workers, and 205PRA, CPR/AED/ Practical Training for Qualified Electrical Workers
13.	Other affected program resources	*List other program resources affected by the changes above.* ***Enter "no changes" if none.***

Field Number	Field Name	Field		
		▪ None		
14.	Comments/Questions/Issues	Any comments or questions regarding applicable requirements or changes. *Add any comments or questions regarding applicable requirements or changes.* CalOSHA fall protection requirements for electrical workers are more stringent than Fed OSHA (4 feet vs 6 feet). See Subchapter 5, Group 1, Article 3, §2320.8. Fall Protection Chapter 45 Fall Protection and Courses 200 and 201 must be reviewed and updated accordingly.		
15.	Status	☒ Initial draft (proposed changes)	☒ Draft (for DOE review)	☒ Final (published changes)
16.	Date completed	Date (of form, PM to complete) 8/1/2020 (revised 3/15/2021)	6/9/2021	6/15/2021