California Institute of Technology

ELECTRICAL SAFETY PROGRAM FOR CAMPUS FACILITIES

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PURPOSE

The purpose of the Electrical Safety Program is to prevent worker exposure to and injury from electrical hazards created by working around and using electrical energy. The Program has been developed to comply with the California Occupational Safety and Health's (Cal/OSHA's) Electrical Safety Orders. In addition to the California Electrical Orders, this Program follows the intent of the National Fire Protection Association (NFPA) 70E, Electrical Safety in the Workplace, a nationally-recognized standard and NFPA 70B.

This Program will meet the following objectives:

- Define safe work practices and use requirements for all people who work within Facilities with electrically energized equipment as part of their normal job duties.
- Establish training requirements for qualifying and authorizing Caltech employees (i.e., Qualified Electrical Person) who work on or near energized electrical circuits and components.
- Establish a risk assessment process for evaluating the hazards of every potentially energized electrical work task and for determining appropriate hazard controls.
- Establishing a formal process for controlling energized electrical work through assessment and documented energized work authorization and justification.

SCOPE

This Program applies to employees and contractors who work near or on exposed, energized electrical equipment 50 volts or greater or contains a burn (arc flash hazard) greater than 1.2 calories/cm2 incident energy. The Program also applies to unqualified workers such as trades' people and office employees who need to have an awareness level of electrical safety.

For the purposes of this Program, electrical work includes any activity near exposed energized parts or terminals that are capable of being inadvertently touched or approached nearer than the minimum safe distance required to prevent electrical shock, regardless of Personal Protective Equipment (PPE) worn. Such work may include maintenance, repair, diagnostic testing, troubleshooting, validating and testing, and assembly. Definitions applicable to this program are listed in Attachment A.

Qualified, contracted licensed electricians (who are directly managed by a Contractor, not a Caltech Supervisor) must follow an approved written Electrical Safety Program (either Caltech or their own); however, any energized electrical work on Caltech property must be authorized in writing through the use of the Caltech Energized Electrical Work Permit (EEWP) process (or equivalent).

Exceptions:

This Program does not apply to outside electrical utilities (such as switchgears, transformers, distribution boxes, etc.) maintained and controlled by major utility companies such as Pasadena Water and Power.

This Program does not address the electrical design requirements for the facility's electrical power distribution system or work on overhead power lines. Refer to the National Electric Code NFPA 70 for information on these types of systems.

RESPONSIBILITIES

SUPERVISORS

Supervisor's responsibilities under the Program include:

- Establish, implement, and maintain procedures and/or work practices that ensure safe electrical work by their subordinates as outlined in the Electrically-Safe Work Procedures section of this Program, at minimum.
- Maintain a safe work environment for all locations under their jurisdiction.
- Require employees to work “de-energized” or in the “safe work condition” whenever possible.
- Develop task-specific electrical lockout/tagout procedures to ensure all electrical hazards have been removed, isolated, and dissipated so that work can be done safely with the power off. Include the verification of zero energy state in the procedures.
- Select and contract third-party licensed electricians to perform any facility-related energized electrical work where the voltage is beyond the scope and training of the Electricians. Provide them with a copy of this Program and ensure they obtain a Caltech Energized Electrical Work Permit when required.
- Work with the Electrical Inspector to ensure licensed, qualified electricians are informed of various hazards relating to their work (e.g., the specific degree of potential arc flash incident energy). Provide information about relevant Caltech electrical installations so that the licensed, qualified electrician can make the required hazard assessment.
- Work with the Electrical Inspector to authorize an Energized Electrical Work Permits only when justified, compelling reasons require it, and when no feasible method to work de-energized exists.
- For Energized Electrical Work Permits:
  - Obtain Electrical Inspector’s co-approval for justification of energized work,
  - Conduct an electrical pre-job risk assessment of the work, and
  - Specify safety-related work practices for the job.
- Ensure rated electrical meters used by Facilities are properly maintained and calibrated according to manufacturers’ recommendations.
- Take corrective action to control any potentially hazardous operation or condition.
- Ensure that approved, maintained, and tested PPE and clothing is provided, available, and used properly by their subordinates wherever needed or determined by a hazard assessment.
- With Electrical Inspector, arrange for periodic testing of PPE, as needed.
- Assign only “Qualified and Authorized” personnel to perform electrical work.
- Ensure that employees understand how to work safely by conducting a pre-job briefing as necessary.
- Ensure that work-routines, inspections, or surveillances conducted within the limited or restricted approach boundaries are conducted by personnel qualified to work within those spaces.
- Ensure that all injuries are reported as per the campus Injury and Illness Prevention Program (IIPP).
- Complete required training per the requirements of this Program.
- Maintain training documentation.

PROJECT MANAGERS

Project Manager's responsibilities under this Program include:

- Select and contract only licensed electricians to perform any facility-related energized electrical work. Provide them with a copy of this Program and ensure they obtain a Caltech Energized Electrical Work Permit when required.
- Work with the Electrical Inspector to ensure licensed, qualified electricians are informed of various hazards relating to their work (e.g., the specific degree of potential arc flash incident energy). Provide information about relevant Caltech electrical installations so that the licensed, qualified electrician can make the required hazard assessment.

ELECTRICAL ENGINEER

The Electrical Engineer's responsibilities under this Program include:

- Ensure the designs of electrical equipment installations (facilities) are compliant with the requirements of this Program.
- Ensure new electrical installations meeting applicable regulations or consensus standards.

ELECTRICAL INSPECTOR

The Electrical Inspector's responsibilities under this Program include:

- Provide electrical safe-work guidance as needed to any work crew(s) on Caltech property.
- Assist with worker qualifications.
- Review safe work procedures.
- Review of Energized Electrical Work Permits (EEWP).
- Assist in the review and resolution of discrepancies between this Program and a licensed, qualified electrical contractor's own Electrical Safety Program as needed.

ELECTRICAL MAINTENANCE ENGINEER

The Electrical Maintenance Engineer's responsibilities under this Program include:

- Provide technical support for the Caltech's electrical safe work program.
- Develop safe work practices.
- Maintain accurate arc flash hazard warning labels on existing, modified, and new electrical installations.
- Ensure installation, testing and maintenance of electrical equipment is compliant with appropriate regulations and standards.
- Ensure the facility-wide shock and arc flash risk assessments, circuit-breaker device testing, and coordination studies are performed.
- Work with a qualified electrical engineering firm to perform shock and arc flash risk assessments and short circuit fault/device coordination studies.
- Maintain documentation such as training records and electrical reports, to demonstrate compliance with this Program.
- Conduct field audits per the auditing section of this Program.

ELECTRICAL SHOP SUPERVISOR

The Electrical Shop Supervisor's responsibilities under this Program include:

- Ensure training is completed and demonstration of skill to be a Qualified Electrical Person as defined in this Program and NFPA 70E is documented.
- Arrange for training and required demonstration of the Qualified Electrical Persons.
- Identify and obtain the Personal Protective Equipment (PPE) required for electrical and arc flash safety.
- Coordinate periodic testing of PPE.
- Review Program for compliance.

ENVIRONMENT, HEALTH, AND SAFETY OFFICE

The Environment, Health, and Safety Office (EHS) responsibilities under the Program include:

- Provide assistance with electrical safety questions/support to academic departments.
- Provide professional interpretations of Cal/OSHA electrical safety requirements, and act as liaison with Regulatory Agencies regarding Electrical Safe Work within Caltech.
- Be familiar with the responsibilities of the Electrical Engineer and other electricians in the application of the Electrical Safety Program in their work.
- Conduct periodic safety inspections that include electrical safety items such as use of electrical extension cords, blocked electrical panels, use of PPE, etc. Follow guidelines in the National Electrical Code (NEC) and Cal/OSHA for compliance requirements.
- Periodically perform a review of the Electrical Safety Program.

QUALIFIED ELECTRICAL PERSON

Qualified Electrical Person responsibilities under this Program include:

- Be responsible for the safety of their own actions and for monitoring the safety of operations under their jurisdiction.
- Keep Unqualified Persons away from areas where electrical work is being performed.
- Be familiar with and follow applicable electrical safety procedures and guidelines.
- Be familiar with the appropriate PPE and tools for each assigned task and how to inspect them before beginning work.
- Attend required training.
- Complete and document demonstration of skills.

TRADES PEOPLE AND OTHER NON-FACILITY WORKERS (UNQUALIFIED PERSON)

Trades People and other non-facility workers' responsibilities under this Program include:

- Complete required electrical safety training if tasks will result in exposure to potential electrical hazards, as may be the case in the operation of mobile equipment, machinery, use of ladders, etc.
- Refrain from crossing a Limited Approach Boundary unless escorted by a Qualified Electrical Person.

CONTRACTORS AND SUBCONTRACTORS

Contractor and Subcontractor responsibilities under this Program include:

- Possess the necessary licensing and qualifications to perform the contracted work safely, in compliance with regulatory requirements and industry standards.
- Work in the de-energized or “safe working condition” whenever possible.
- Notify the Caltech contact or Electrical Engineer when any work activities may affect the safety of Caltech' facilities and employees or of any hazards identified during the course of the work that were not previously communicated.
- Review the Caltech Electrical Safety Program and compare it with their own to identify any conflicting requirements.
- Obtain authorization to perform energized electrical work through a Caltech Energized Electrical Work Permit when required (contracted licensed electricians may also choose to use their own Company’s work permit in addition to the Caltech permit).
- Maintain required clearances around electrical equipment as determined by the equipment labeling and NFPA 70E.
- Provide PPE, insulated tools, and electrical testing equipment that meet the minimum requirements of applicable electrical safety standards, and inspect and maintain such equipment as required by those standards.
- Train their employees in the hazards communicated by Caltech in addition to providing the basic training required by the consensus standards.
- Communicating measures taken to correct any violations reported by Caltech to prevent reoccurrence.

APPLICABILITY

Compliance with this Program IS NOT intended to be a measure of a person’s electrical qualifications or skill level. This Policy covers Caltech’s requirements for Electrical Safe Work Practices (ESWP) including proper PPE needed to perform electrical work as an employee. This Policy first became effective in November 2017 and includes ESWP requirements associated with the NFPA 70E-2015 standard.

OFFICE WORK

Review Attachment B, Use of Extension Cords.

QUALIFIED ELECTRICAL WORKERS

If you work with electricity, or on equipment that uses electricity as a source of energy for operation, or on equipment that generates electrical current, then portions of this Program describe how you must be “Qualified” and “Authorized" to conduct electrical work.

All of the sections of this Program apply to Qualified Electrical Workers. Some key sections include:

- Program Elements,
- Electrical Safe Work Procedures, and
- Qualified Electrical Person Training

TRADES PEOPLE AND OTHER NON-FACILITY WORKERS

Trades people and non-facility workers are Unqualified Persons as it relates to electrical work. Trades people and non-facility workers will be trained to recognize electrical hazards, understand how exposure to electrical hazards could occur, and how to avoid injury that could result from the exposure.

- Unqualified Persons are prohibited from performing energized electrical work or working near exposed energized conductors.
- All temporary employees are considered Unqualified Persons until additional training has been provided or documentation showing that they meet the qualified persons level of training is provided.
- Workers will perform electrical work only to the level to which they have been trained and authorized.
- Caltech employees and contractors shall complete training and qualification requirements as described in this Section.
- All unqualified personnel who face a risk of injury due to electric shock shall receive general electrical safety training, with a refresher review every 3 years.
- If any of these classifications of personnel are required to do specific electrical tasks, they shall be trained in the specific paragraphs of NFPA 70E relating to the task to be performed and trained as a Qualified Electrical Person.
- Sections of this Program that apply to Trades and other non-facility workers include:
    - Program Elements
        - Pre-Work Electrical Risk Assessments
        - Hierarchy of Hazard Controls
        - Electrically Safe Working Conditions
    - General Electrical Awareness Level Training
    - Attachment C, General Safety-Related Work Practices

ELECTRICAL CONTRACTORS

If you or your department hires contractors to do electrical work on facilities or equipment owned or controlled by you or your department, follow the responsibilities above detailing the necessary qualifications of the contractor(s).

PROJECT MANAGERS

Caltech Project Managers who engage the services of outside electrical contractors must assure they are appropriately “Qualified” before “Authorizing” them to work as outlined in this Program.

PROGRAM ELEMENTS

All of the Program elements below apply to Campus Qualified Electrical Workers as well as Contracted Qualified Electrical Workers. Some of the elements apply to the Trades People and Non-Facility Workers as noted above in the Applicability section of this Program.

PRE-WORK ELECTRICAL RISK ASSESSMENT

Caltech’s Electrical Inspector will define the methods to identify and control electrical hazards relevant to their facility, such as a risk assessment.

The methods of isolation, insulating, and any special PPE to be used shall be detailed in the written assessment based on the hazards present. See Attachment D for Risk Assessment Template.

Upon completion of the Assessment, if the work needs to be completed energized, an Energized Electrical Work Permit shall be completed. This shall include a justification for performing the work energized and shall require a signature by a Responsible Supervisor authorizing the work before it begins. For repetitive tasks, the risk assessment must be reviewed prior to commencement.

Assessments will be maintained and updated appropriately for new and routine tasks.

HIERARCHY OF ELECTRICAL HAZARD CONTROLS

Once the hazards are identified and the risks are assessed, implement risk controls according to the following hierarchy methods:

- Engineering Controls, such as listed panels, shields or barriers, to isolate personnel from the energized components
- Awareness
- Administrative Controls, such as an Energized Electrical Work Permit, training (including hazardous energy control training), and signage
- PPE

Methods of hazard control shall be documented within the Risk Assessment or other equivalent means.

PERSONAL PROTECTIVE EQUIPMENT

Protective equipment provides the last line of defense against inadvertent contact with energized parts or burns resulting from electrical arcs / flash. The purpose of this section is to ensure personnel have an adequate understanding of potential electrical hazards and the knowledge to select and wear the proper PPE based on the hazards.

PPE requirements apply to all persons exposed to potential electrical shock or arc flash hazards. Refer to the tables in NFPA 70E 130.7 and Attachment E for more information.

ELECTRICALLY-SAFE WORKING CONDITIONS

Before beginning any maintenance or construction type work that requires activities on motor control centers, distribution panels, control panels, etc., the equipment must be totally de-energized where the hazardous energy is isolated and controlled in the electrically safe-work condition unless justified and authorized as described below.

- Hard-Wired Equipment (example: production equipment, HVAC unit, electrical panels, motor control centers, etc.):
  - Power down the equipment according to manufacturers' instructions,
  - Dissipate and control any hazardous energy, and
  - Lockout / tagout.

The following measures must be taken when working on cord-and-plug equipment and where all incoming electrical energy can be controlled by the unplugging of the equipment:

- Unplug the equipment to prevent the re-introduction of energy.
- Safely discharge any stored energy in the equipment (as applicable).
- Keep the cord in your exclusive control to prevent someone else from plugging it back in.
- Apply a lockout device to the plug if leaving the plug unattended.

ENERGIZED ELECTRICAL WORK – JUSTIFICATION

Any repair or modification to electrical equipment that cannot be done with the equipment in the "safe working condition" (a fully-de-energized state) must first be justified and then authorized in writing by Responsible Supervision using the Energized Electrical Work Permit (EEWP) process as described in this Program and permit in Attachment F.

Interruption of services to the building, lack of lighting, production, and cost-considerations alone are not acceptable reasons for authorizing or performing energized electrical work.

Energized electrical work is only to be performed by a Qualified Electrical Person, and only after it is justified under one or more of the following circumstances:

- De-energizing the circuit will introduce additional hazards or increased risk (examples allowed by electrical regulations and standards include deactivation of required emergency alarm systems, or the shutdown of ventilation equipment in a hazardous area).
- De-energizing the circuit is not feasible due to equipment design or operational limitation.
- Work on circuits of less than 50 volts and no risk of injury to the Qualified Electrical Person.
- Verifying a zero-energy state before working on locked-out equipment.
- Work can only be performed with the circuit energized, including:
  - Testing voltage, measuring amperage, or trouble-shooting
  - Setting up, tuning, or calibrating equipment where adjacent electrical hazards exist and cannot be guarded
  - Circuit identification

ENERGIZED ELECTRICAL WORK – AUTHORIZATION

Once it has been determined that the electrical work must be done energized and the reasons meet the justifications in the above section, an Energized Electrical Work Permit (EEWP – Attachment F) must be completed and authorized prior to work beginning.

All energized electrical work will be conducted only when all efforts to perform the work in the safe electrical work condition (de-energized) have been exhausted. This work may be conducted by a qualified, outside licensed electrician or a Caltech Qualified Electrical Person.

Work Requiring an EEWP includes:

- Any change of the physical state of the equipment, while energized, requires an EEWP. "Changing the state" includes (list non-exhaustive):
  - Connecting, disconnecting, assembling, disassembling, tightening, or loosening energized connections
  - Circuit breaker removal or installation
  - Fuse removal or installation
- Any work performed inside the Restricted Approach Boundary of exposed energized parts

Work NOT Requiring an EEWP includes:

The following types of energized electrical work do not require an EEWP when performed by a Qualified Electrical Person who follows the applicable safety-related work practices in this Program.

- Opening an electrical enclosure for inspection without crossing the Restricted Approach Boundary
- Thermography and visual inspections if the Restricted Approach Boundary is not crossed
- Voltage and current measurements
- Troubleshooting without changing the state of electrical components

JOB BRIEFING

As part of the instructions related to jobs with more than one worker, a Responsible Supervisor, Electrical Inspector technical resource who is familiar with the area and the task to be performed will review and discuss the specific hazards involved with the workers who will perform the task(s) in a Job Briefing. See Attachment G for the Job Briefing and Planning Checklist.

ELECTRICAL SAFE WORK PROCEDURES

ENERGIZED ELECTRICAL WORK

All energized electrical work must only be performed by a Caltech Qualified Electrical Person, or a licensed, qualified electrician, using safety-related work practices, appropriate PPE, clothing and tools suitable for the type and magnitude of hazards to be encountered as described in this Program.

A Pre-Work Electrical Hazard Risk Assessment must be completed as part of the Energized Electrical Work Permit process, prior to work being performed.

Qualified Electrical Persons performing energized electrical work shall follow the General Safety-Related Electrical Work Practices described in Attachment C, along with the other guidance provided below:

Safety Observer

- A Safety Observer must be present when energized electrical work (including testing work) is carried out. The exception is for testing work where a risk assessment shows there is no serious risk associated with the work.
- Any Qualified Electrical Person or licensed electrician serving as a Safety Observer must:
  - Hold current certifications in First Aid, CPR techniques
  - Recognize electrical hazards to avoid shock while assisting a patient
  - Know how to summon Emergency Responders
  - Complete annual First Aid and CPR refresher training

Contact Release Emergency Response Training

- Qualified Electrical Persons shall be trained in methods of safe release of victims from contact with exposed energized electrical conductors or circuit parts. Refresher training shall occur annually, and may be included in the curriculum of the Qualified Persons course.

Insulated Tools

When isolate/insulate precautions are required, rated, insulated tools and equipment shall be used to prevent inadvertent contact and/or minimize the hazard. More information on insulated tools is found in Attachment H.

Access Control and Signage during Energized Work

Persons performing energized work shall provide access control and signage around their work area as described in Attachment I.

Special Precautions for Outdoors and Wet/Damp Locations (use of ground fault circuit interrupters)

Persons performing electrical work must observe the precautions described in Attachment J when working in wet or damp locations, such as bathrooms, kitchens, outdoors, areas with leaks, or anywhere water may be present.

Standard Precautions for Potential Arc Energy over 40 cal/cm^2.

Persons performing electrical work with potential arc energy over 40 cal/cm^2 shall not perform the work energized, but instead observe the precautions described in Attachment K.

Electrical Equipment Preventive Maintenance and Shock and Arc Flash Risk Assessment

Caltech has an established maintenance program of inspecting, testing, assessing, and servicing electrical systems and equipment to maintain safe operations and reduce or eliminate system interruptions and equipment breakdowns.

The electrical maintenance program shall conform to the requirements of *NFPA 70B, Recommended Practice for Electrical Equipment Maintenance*. Some of the preventive maintenance elements are briefly summarized in Attachment L, Electrical Equipment Preventive Maintenance and Shock/Arc Flash Risk Assessment.

Electrical Equipment Safe Work Space Requirements

Sufficient space needs to be provided around electrical equipment to allow access for maintenance and repair work as described in in Attachment M.

Practices for Flexible Cords

Flexible cords are used across campus. For details on their safe use, refer to Attachment N.

Use of Extension Cords

Extension cords provide a convenient method of bringing AC power to a device that is not located near a power source. Guidelines for on campus use are described in Attachment B.

ELECTRICAL SAFETY AUDITING

The Electrical Safety Program will be reviewed to verify that the principles and procedures of the Electrical Safety Program are in compliance with NFPA 70E and Cal OSHA requirements. Reviews will be documented at least every three years.

The Electrical Maintenance Engineer will periodically audit field activities to verify that the requirements contained in this Program are being followed.

QUALIFICATION LEVELS AND REQUIRED TRAINING

GENERAL ELECTRICAL AWARENESS LEVEL – INITIAL TRAINING

A general hazardous awareness-level course in electric shock and arc flash hazards and safety-related work practices will be arranged by the Electrical Shop Supervisor.

The course will be delivered in a classroom-setting to all workers who have the potential to work on or near exposed energized parts, regardless of voltage level, and will enable learners to:

- Understand electrical hazards and effects
- Know where to find codes and standards
- Prevent exposure
- Identify certain unsafe electrical conditions
- Use safe work practices
- Know their responsibilities
- Respect limitations of types of electrical work they can do
- Become familiar with the Caltech Electrical Safety Program

This training is the first step to becoming a Qualified Electrical Person at any level.

The General Awareness Training will be repeated as needed.

QUALIFIED ELECTRICAL PERSON TRAINING

Personnel performing qualified electrical work shall receive training in electrical safe work practices required by NFPA 70E and the Caltech Electrical Safety Program initially when hired with refresher training every 3 years, at a minimum.

After completing initial training as described above, a worker seeking to be a Qualified Electrical Person must successfully complete an Electrical Qualified Person course that corresponds with the duties. The course will cover:

- Proper use of special precautionary techniques
- Personal protective equipment
- Insulating and shielding materials
- Insulated tools and test equipment
- Reading and interpreting control panel schematics to recognize electrical components
- Skills and techniques necessary to distinguish exposed energized parts from other parts of electric equipment and determine the nominal voltage of exposed energized parts
- Decision-making process necessary to determine the degree and extent of the hazard (based upon the hazard, must be able to determine required PPE and job planning to perform the work safely)
    - The Qualified Person Training will be repeated at least every three years.
    - Workers must demonstrate proficiency in safety-related work practices, required skills and knowledge in order to be considered a Qualified Electrical Person.

EMERGENCY RESPONSE

The emergency response training requirements of NFPA 70E require that employees exposed to shock hazards be trained in methods to safely release victims in contact with energized electrical conductors and circuit parts. Details about this training are described in the Safety Observer Section above. In addition to Caltech's Emergency Response Program, the details below describe how emergency response would be handled in the event of an electrical incident.

Outside Medical Response: Caltech relies on the support of Pasadena Fire Department Emergency Responders who are located on campus to provide outside medical response in the event of electrical shock or arc flash.

Internal Emergency Response Team: Key Caltech personnel have been trained in First Aid and Cardiopulmonary Resuscitation (CPR) and automated external defibrillation (AED) techniques. These and other on-site Emergency Response Team members must maintain current certifications.

BARRIER REQUIREMENTS

Lexan covers, "touch proof" terminal strips and other approved non-conductive barriers are acceptable protection against shock from incidental contact. These barriers do not provide protection against arc flash risk. However, voltage-rated barriers reduce the restricted approach boundary (12" at low voltages) to the location of the barrier. Voltage-rated covers can eliminate the need for voltage-rated gloves, thus improving dexterity and lowering the probability of dropped tools or covers. Arc flash protection may still be needed.

Barrier guards should be considered when there may be access to or potential exposure to live electrical components.

LABELING

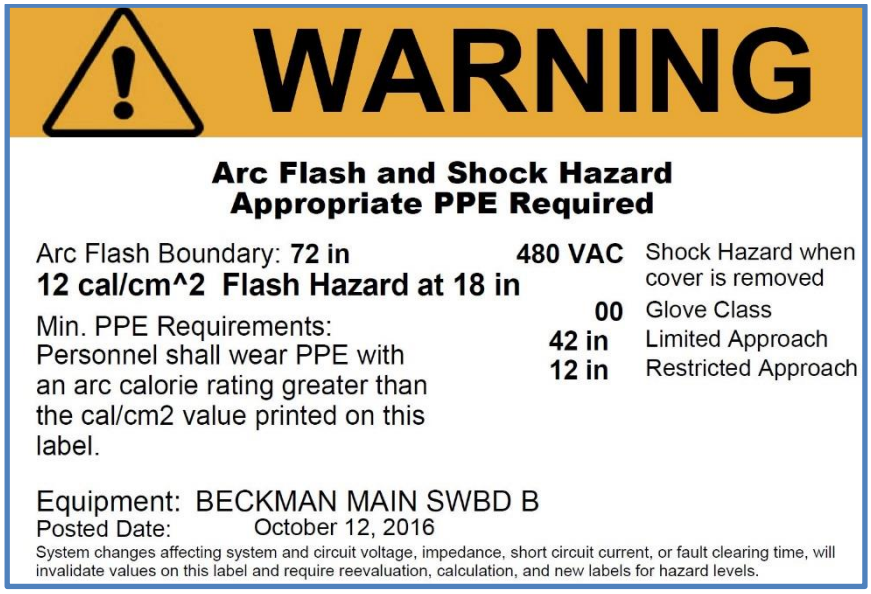
Electrical equipment installations shall include permanent labels as described below:

- Disconnecting means, panelboards, and control panels shall be permanently labeled to indicate its purpose (what it disconnects), voltage, and where it originates (the next upline disconnect). Circuit breakers located in 240/120 volt panels need only be labeled with what they control. This can be on a circuit directory located on the panel's face or inside of the panel door.
- Electrical equipment such as switchboards, panelboards, industrial control panels, meter socket enclosures, and motor control centers that are likely to require examination, adjustment, servicing, or maintenance while energized must be field marked with the following information:
    - Nominal system voltage
    - Arc Flash Boundary

At least one of the following:

- Results of the incident energy analysis or arc flash PPE category as listed in the respective tables in 130.7, but not both
- Minimum arc flash rating of clothing
- Site-specific level of PPE
- All electrical equipment operating at 600 volts nominal or less and likely to require examination, adjustment, servicing, or maintenance while energized shall include a permanent label indicating the minimum working space about the equipment. The floor shall also be taped or painted to indicate the working area required.

- Labels used on electrical equipment must be suitable for the environment with consideration given to chemicals and weather conditions, i.e. – sunlight, rain, etc.
- Enclosures shall be labeled using a label similar to the one below.



RECORDKEEPING

Documentation related to the Electrical Safety Program will be kept in accordance with Caltech's Retention Policy, and must be made available for review to EHS upon request.

The following records will be maintained in Facilities:

- Qualified Electrical Person Proficiency Demonstration Checklists
- Qualified Electrical Person Experience and Education Documentation Form
- Electrical General Hazard Awareness Training content and completion records
- Qualified Person training content and completion records
- Licensed Electrician records
- PPE and insulated equipment testing records
- Electrical equipment maintenance records
- Facility-wide Shock and Arc Flash Hazard Risk Assessments
- Completed Energized Electrical Work Permits

REFERENCES AND RELATED DOCUMENTS

- Cal OSHA Title 8 California Code of Regulations Subchapter 5 – Electrical Safety Orders – Low Voltage and High Voltage
- Industry Resources
  - NFPA 70B, Recommended Practice for Electrical Equipment Maintenance
  - NFPA 70E, Standard for Electrical Safety in the Workplace
  - NFPA 70E, Handbook for Electrical Safety in the Workplace
  - NFPA 70E, Electrical Safety Program Guide
  - American Society for Testing Materials (ASTM) F 1236, Standard Guide for Visual Inspection of Electrical Protective Rubber Products

- ASTM D120, Standard Specification for Rubber Insulating Gloves
- ASTM F 1505, Standard Specification for Insulated and Insulating Hand Tools
- ASTM F 1506, Standard Performance Specification for Flame Resistant and Arc Rated Textile Materials for Wearing Apparel for Use by Electrical Workers Exposed to Momentary Electric Arc and Related Thermal Hazard
- ASTM D178, Standard Specification for Rubber Insulating Matting
- ASTM D1048, Standard Specification for Rubber Insulating Blankets
- ASTM D1051, Standard Specification for Rubber Insulating Sleeves
- ASTM F696, Standard Specification for Leather Protectors for Rubber Insulating Gloves and Mittens
- ASTM F712, Standard Test Methods and Specifications for Electrically Insulating Plastic Guard Equipment for Protection of Workers
- IEEE 1584, Guide for Performing Arc-Flash Hazard Calculations
- IEEE 1584a, Guide for Performing Arc Flash Hazard Calculations, Amendment 1
- IEEE 1584b, Guide for Performing Arc-Flash Hazard Calculations, Amendment 2
- IEEE 1584.1, Guide for the Specification of Scope and Deliverable Requirements for an Arc-Flash Hazard Calculation Study in Accordance with IEEE Std. 1584

REVISION LOG

Current Revision		
Revision:	**Originator(s):**	**Change Details:**

Revision History *Add or Remove Lines as Required*			
Revision:	**Date:**	**Originator(s):**	**Change Details:**
A			Initial Release
B			
C			
D			
E			

ATTACHMENTS

Attachment A: Definitions

Attachment B: Use of Extension Cords

Attachment C: General Safety-Related Electrical Work Practices

Attachment D: Work Risk Assessment Template

Attachment E: Personal Protective Equipment

Attachment F: Energized Electrical Work Permit and Checklist

Attachment G: Job Briefing and Planning Checklist

Attachment H: Insulated Tools

Attachment I: Access Control and Signage during Energized Work

Attachment J: Special Precautions for Outdoors and Wet/Damp Locations (use of GFCI)

Attachment K: Standard Precautions for Potential Arc Energy over 40 cal/cm2.

Attachment L: Electrical Equipment Preventive Maintenance and Shock/Arc Flash Risk Assessment

Attachment M: Work Spaces Requirements

Attachment N: Practices for Flexible Cords

ATTACHMENT A: DEFINITIONS

Arc Flash Boundary – When an arc flash hazard exists, an approach limit at a distance from a prospective arc source within which a person could receive a second degree burn if an electrical arc flash were to occur. (Informational Note: A second degree burn is possible by an exposure of unprotected skin to an electric arc flash above the incident energy level of 5 J/cm^2 (1.2 cal/cm^2)).

Construction – The addition of new equipment, wiring, or control devices not currently in operation, or major alterations to existing systems.

Daisy-Chain – Interconnecting extension cords or power strips.

Enclosure – The case or housing of apparatus that prevents personnel from accidentally contacting energized parts.

Energized Electrical Work (Live Work) – Any work on electrical equipment, circuits, devices, systems, or any other energized part(s) where a worker is required to deliberately, or could accidentally, place any body part, tool or material into or around such electrical devices where the voltage has been deemed to be in excess of 50 volts. Energized electrical work does not include activities such as the normal use of electrically-powered equipment such as power tools, appliances, computers, analyzers, fans, heaters, machines, etc. where energized components are shielded and covers are in place to prevent inadvertent contact.

Exposed – Capable of being inadvertently touched or approached nearer than a safe distance by a person. It is applied to parts not suitably guarded, isolated, or insulated.

High Voltage – More than 600 volts.

Isolate/Insulate – Installation of physical barriers and/or rated insulating materials that provide worker protection equivalent to de-energization.

Incident Energy Analysis – A component of an arc flash risk assessment used to predict the potential incident energy of an arc flash for a specified set of conditions. The calculated or computed incident energy from the installation-specific assessment is the predicted energy that an employee will be exposed to if an arc flash incident occurs. This information will be used to determine the PPE based on the conditions associated with the task being performed.

Limited Approach Boundary – A distance from an exposed live part within which a shock hazard exists. All Unqualified Persons must remain outside this distance unless escorted by a low voltage qualified person.

Lockout/Tagout – The placement of a lock and tag on an energy-isolating device in accordance with an established procedure. Lockout is one way in which hazardous energy control can be achieved.

Low Voltage – Less than or equal to 600 volts.

Low Voltage Qualified Person – A person familiar with the construction and operation of electrical equipment up to 600 volts and has received safety training on the hazards involved, or an electrical apprentice working directly with a Qualified Electrical Person.

Maintenance – Work performed on existing equipment and systems to repair or replace.

Non-Facility Workers – Unqualified Person.

Rated, Insulated Tools – Tools encased within material of composition and thickness that is recognized as electrical insulation and is certified by the manufacturer to conform to recognized industry standards.

Responsible Supervisor or technical resource – One knowledgeable, trained, and experienced in the construction, maintenance, and operation of electrical low voltage equipment and systems (600 volts and below) and the hazards involved in the area of the work assignment.

Restricted Approach Boundary – Applies only to Qualified Electrical Persons. It is a distance from an exposed live part within which an increased risk of shock is present. Work within this boundary requires additional PPE.

Qualified Electrical Person – A Caltech person who is authorized and permitted to work within the limited approach boundary of exposed live parts operating at 50 volts or more and who has demonstrated skills and knowledge related to the construction and operation of electrical equipment and installation and has received safety training to identify and avoid hazards involved.

Safety Observer – A Qualified Electrical Person or licensed, qualified electrician who acts as an observer during energized work for the purpose of preventing an accident, and who renders assistance in the event of an accident.

Shock – Injury that occurs when external electrical current passes through the body.

Trades People – Unqualified Persons.

Troubleshooting / Diagnostic Testing – Performing diagnostic readings of voltage and amperage, visual inspections, or using Programmable Logic Controller (PLC) interface on or near energized parts.

Unqualified Persons – A person who is not a Qualified Electrical Person. Trades people and non-facility workers would be considered Unqualified Persons.

Working Space – The area in front of electrical equipment installation that must remain clear and free of material to allow safe access to electrical components.

ATTACHMENT B: USE OF EXTENSION CORDS

Extension cords provide a convenient method of bringing AC power to a device that is not located near a power source.

Guidelines for the Safe Use of Extension Cords:

- Use only approved and properly maintained extension cords that have no exposed live parts, exposed ungrounded metal parts, damage, or splices.
- Use only heavy-duty or extra-heavy-duty rated cable.
- Use extension cords that are protected by a ground fault circuit interrupter (GFCI) around construction sites, in damp areas, or in an area where a person may be in direct contact with a solidly grounded conductive object (e.g., working in a vacuum tank). The GFCI can consist of a special circuit breaker, a GFCI outlet, or an extension cord with a built-in GFCI.
- Always use three-conductor (grounded) extension cords—even if the device has a two conductor cord. *Never use two-conductor extension cords.*
- Do not cut off the ground pin of an extension cord or compromise the ground protection in any way.
- Ensure that the extension cord is of sufficient current-carrying capacity to power the device. Use of an undersized cord may result in an overheated cord and insufficient voltage delivered to the device, thus causing device or cord failure and a fire hazard.
- Do not use extension cords with a ground conductor that has less current-carrying capacity than the other conductors.
- Do not use extension cords in place of permanent facility wiring.
- Extension cords are for temporary use: In general, roll-up the cord at the end of the day. If an extension cord is required for the same work at the same location on a continual basis, you should call Facilities to install an additional receptacle where you actually need the power, or move the equipment.
- Do not "daisy-chain" or interconnect extension cords or power strips. Check the cord and power strip for damage each time you use it.
- If extension cords cross foot-traffic aisles, use cord protectors of a bright color, preferably orange or yellow, to highlight the cord and protect it against impact. For very temporary installations, use brightly colored duct tape to tape the cord to the floor making sure the cord is straight without kinks or loops.
- If extension cords cross vehicle traffic aisles or roadways, use cord protectors strong enough to prevent vehicle contact with the cord.
- Avoid running extension cords through doors, ceilings, windows, or holes in the walls. If it is necessary to run a cord through a doorway for short term use, ensure that the cord is:
    - o Protected from damage.
    - o Removed immediately when no longer in use.
    - o Not a tripping hazard.
- Relocatable Power Strips / Power Taps (for Office and Lab Bench Tops Only): A relocatable power tap (also referred to as a "Power Strip") is a variation of an extension cord, where the cord terminates in a row or grouping of receptacles. Relocatable power taps are commonly used in offices to provide multiple receptacles to office equipment.
  In general, all rules pertaining to extension cords also apply to relocatable power taps. Additional considerations are:
    - Relocatable power taps are not rated for heaters, refrigerators, toaster ovens, or other high power, high-current drawing devices. They may be used only for office equipment

such as computers, printers, etc.

- The total load on the relocatable power tap must not exceed 1440 watts or 12 amperes. Any single load (single receptacle) must not exceed 600 watts (5 amperes).
- Do not permanently mount relocatable power taps to any facility surface.
- Relocatable power taps are classified as temporary devices. It is acceptable to hang them from screws or hooks if they are manufactured with slots or keyholes.
- In equipment racks, the preferred method of supplying 120/208V utility power to rack mounted instruments is via a special relocatable power tap specifically designed to be rack installed.

ATTACHMENT C: GENERAL SAFETY-RELATED WORK PRACTICES

- Exposed live parts must be de-energized
    - Unless de-energization introduces additional or increased hazards,
    - De-Energization is not possible due to equipment design or operational limitations.
        - If not de-energized, other safety-related work practices, as listed below, shall be used to protect against electrical shock and arc flash.
    - Interruption of services to the building, lack of lighting, production, and cost-considerations alone are not acceptable reasons for authorizing or performing energized electrical work.
- Obtain an approved Energized Electrical Work Permit (EEWP) when required.
- Hold a pre-job briefing between the workers and responsible supervision (or designee) for jobs involving more than one Qualified Electrical Person. The briefing must cover the results of the risk assessment, details on hazards present, PPE to be worn, specific tools to be used, mitigations to be taken to perform the work safely, and the information on the EEWP (if one is required).
- Do not leave energized equipment open or exposed while unattended.
- Equipment used for testing, calibration or troubleshooting must be rated for the voltages and hazard classification.
- Any person working on or near energized electrical equipment must be wearing and/or using the minimum PPE per this document, as defined by NFPA 70E.
- Where feasible, use shielding or auxiliary guards listed for application over exposed energized components that will not be actively worked on.
    - *Example:* Flexible insulated matting covering energized equipment, with holes cut in areas to be worked on.
- Remain alert, focused on the work being performed, and aware of the proximity of grounded objects to your body.
- Do not wear a cell phone or other signaling device, as these may cause a dangerous startle reflex.
- Do not wear conductive apparel such as watches, rings, metal-rimmed eyewear, key chains, necklaces, metal belts, metal headgear (e.g. inside hardhats), flashlights, or other metal accessories.
- Wear appropriate clothing in accordance with the consensus standard. Clothing and other apparel (such as hard hat liners and hair nets) made from materials that do not meet the requirements of 130.7(C)(11) regarding melting or made from materials that do not meet the flammability rating must not be worn. Consider materials used for clothing such as fabrics and zippers.
- Protect loose wire ends with shielded wire nuts.
- Do not conduct energized electrical work at unprotected heights. Instead, perform the work within the protective guardrails of work platforms (e.g., scaffolding, scissor or Genie lifts) and avoid performing energized work from ladders.
- If the equipment has electrical flow interlocks, do not bypass these interlocks unless all of the following conditions are true:
    - The bypass is necessary to conduct the work, not just for convenience;
    - A risk assessment has been conducted to determine likelihood and severity of possibly injury;
    - The work is approved by an Energized Electrical Work Permit; and

- Lockout/tagout is used, if appropriate.

- For low voltage work (≤ 600 volts), a Safety Observer is advisable but not mandatory.
  - The low-voltage Safety Observer must be a licensed electrician or Qualified Electrical Person but not necessarily authorized on the particular equipment being worked on.
- For high voltage work (>600 volts), a Safety Observer is mandatory.
  - The Safety Observer must be a licensed electrician or Qualified Electrical Person-in-training, and must be authorized on the equipment involved.
- The Safety Observer must take responsibility for the following:
  - Plan work with primary worker
  - Remain outside of the Restricted Approach Boundary for the duration of the work
  - Observe and warn the primary worker of potential unsafe acts or conditions that occur as work is performed
  - Note problems that require assistance
  - Prevent Unqualified Persons from entering the work area
  - Minimize distractions to the primary worker
  - During an emergency, extract the victim from a live circuit, and use the correct disconnect devices, shepherd's hook, or insulating device
  - Anticipate emergency response actions and notify ERT
  - Remain adjacent to the work yet outside the Limited Approach Boundary unless wearing appropriate PPE
  - Have no other responsibilities while the work is performed
- Opening or closing high voltage knife switches and circuit breakers (over 600 volts) may represent an arc flash hazard.
  - Determine the appropriate PPE category of the equipment to be operated (consult hazard warning label, Operations Manager, or NFPA 70E as applicable).
  - Wear PPE and arc-rated clothing appropriate for the PPE category for that equipment.

ATTACHMENT D: RISK ASSESSMENT TEMPLATE

Groups Activities and Hazards						Pre-Control			Current Controls	Post-Control				
PROCEDURE	ACTIVITY DESCRIPTION	VOLTAGE / AMPS	WORKING SURFACE	TOOLS	HAZARDS	Frequency of Exposure	Severity	Risk	Identify Controlling Procedure or Training	ADD SAFETY REQUIREMENTS	Frequency of Exposure	Severity	Risk	Notes/ Recomm-endations

ATTACHMENT E: PERSONAL PROTECTIVE EQUIPMENT

- Wear proper PPE. Selection of PPE must be based on the hazards identified on the electrical equipment hazard label. In the absence of such a label, select PPE based on the hazards identified from the Shock and Arc Flash Risk Assessment.
- For energized work over 50 volts or greater or which contains a burn (arc flash hazard) greater than 1.2 calories/cm2 incident energy, wear the following minimum PPE:
  - Non-metal eye protection (ANSI rated safety glasses or goggles only; metal-rimmed glasses may not be worn under protective goggles)
  - Insulating gloves (rated for the level of voltages encountered and meeting ASTM D120, Standard Specification for Rubber Insulating Gloves)
  - Leather protective gloves over the insulating gloves, when the work activities may cause damage to the primary insulating gloves, or if the voltage to be encountered exceeds 600 volts. Leather protectors must meet American Society of Testing and Materials (ASTM) Standard F696 Standard Specification for Leather Protectors for Rubber Insulating Gloves and Mittens.
  - Any other protection as needed to prevent contact with energized parts
- If there is potential for arc flash, wear specialized PPE and arc-rated clothing within the arc flash protection boundary. Consult NFPA70E for additional details on hazard- and task-based PPE selection. Note: The arc-flash PPE level may be determined from either the results of an incident energy analysis, or by PPE category using the tables in NFPA70E 130.7(C)(15), but not both. (NFPA 130.5 (C))
  - Examples of arc-flash PPE and clothing include:
    - ANSI-approved polycarbonate safety glasses with side shields
    - Arc-rated full-face shield
    - Electrically-rated hard hat
    - Electrical safety boots
    - Hearing protection (ear canal inserts)
    - Arc rated protective clothing to cover the arms, torso, legs, neck, and head
- Maintain and store PPE in a safe, reliable condition.
- Before each use, and again immediately following any incident where the equipment may have been damaged:
  - Visually inspect PPE for:
    - holes, tears, punctures or cuts
    - ozone damage (checking, cutting)
    - embedded foreign objects
    - textural defects such as swelling, softening, hardening, or stickiness
    - other defects that degrade insulating quality
  - Inflate insulating gloves by blowing into the glove and then sealing off the cuff area or rolling up the sealed cuff. Listen and feel for air escaping. If usable, the glove will stay inflated with no leakage.
- Replace PPE if damaged

- Discard the damaged PPE so others do not inadvertently use it

- Rubber insulating PPE must be sent in for electrical testing according to the following schedule. Each Qualified Electrical Person should have access to a second set of equipment to use while the primary set is out for testing.

Rubber Insulating Equipment Test intervals (8 CCR 2940.6)

Type of equipment	When to test
Rubber insulating line hose	When found to be damaged or defective
Rubber insulating covers	When found to be damaged or defective
Rubber insulating blankets/mats	Before first issue and every 12 months thereafter (1).
Rubber insulating gloves	Before first issue and every 6 months thereafter (1)
Rubber insulating sleeves	Before first issue and every 12 months thereafter (1).
Footnote 1: Gloves, sleeves, and blankets that have been electrically tested but not issued for service shall not be placed into service unless they have been electrically tested within the previous twelve months.	

Gloves, sleeves, and blankets shall be marked to indicate compliance with the re-test schedule and shall be marked with either the date tested, or the date the next test is due.

ATTACHMENT F: ENERGIZED ELECTRICAL WORK PERMIT AND CHECKLIST

California Institute of Technology	**Energized Electrical Work Permit**

Requestor Name:		Request Date:	

Energized Electrical Work (EEW) Details

Panel/Equipment to be Worked On:		Attached Documentation:	☐ Electrical Work Permit Checklist		
Location:		Source Panel ID: Circuit ID:		Voltage(s):	
Work Start Date/Time:		Work Finish Date/Time:		Amps:	

Frequent EEW Tasks - Check all that apply and describe below:	
Circuit breaker installation in branch/distribution/MCC panel	☐
Conduit installation in branch/distribution/MCC panel (drill/punch hole and install conduit)	☐
Pull wire into branch/distribution/mcc panel	☐
Other – Describe Below	☐

Description of the EEW Work and Procedure to be Performed (attach additional pages as needed)

Safety-Related Work Practices to be used - Check all that apply:	
Notify all Affected and Other Workers	☐
Secure work area to restrict access to Unqualified Persons	☐
Use of PPE per Electrical Safety Written Program requirements, NFPA70E, and as necessary for work task and area. Note: If work is performed by an outside licensed electrician, their PPE must meet or exceed requirements	☐

Shock and Arc Flash Risk Assessment Results

Shock Hazard Voltage:		Arc Flash Working Distance:	
Shock Protection Boundaries:		Arc Flash Incident Energy: (Work over 40 cal/cm^2 prohibited) or PPE Category	
Voltage Rated Tools Required:		Arc Flash Protection Boundary:	
PPE Required:	Rubber Insulated Matting: Yes_____ No _____ Rubber Insulated Gloves: Yes_____ No _____ Leather protective gloves over the insulating gloves: Yes_____ No _____ Electrical-rated Safety Glasses with side shields: Yes_____ No _____ Electrical Safety Boots: Yes_____ No _____ Hearing Protection (ear plugs/canal inserts): Yes_____ No _____ Arc-rated Face Shield: Yes_____ No _____ Arc Rated Clothing: Yes_____ No _____ PPE Category _____ Arc Rated Blankets: Yes_____ No _____ **Additional PPE:** Yes _____No _____ Description _____		

EEW Compelling Reasons per OSHA/NFPA70E

De-energizing would result in an increased or additional hazard:	☐ Emergency Alarm ☐ Life Safety Support Systems	☐ Ventilation Equipment ☐ Other (explain below)
De-energizing is infeasible due to equipment design or operational limitations:	☐ Testing/Troubleshooting - required to be energized ☐ Infeasible Shutdown (explain below)	

Interruption of services to an area of the building, inconvenience, lack of lighting, or production-, and cost-considerations alone are not acceptable reasons for authorizing or performing energized electrical work.

Detailed explanation of compelling reason (attach equipment-specific justification as required)

Authorization and Signatures ☐ **Permit Approved** ☐ **Permit Denied**

I authorize Energized Electrical Work because of the above justified and compelling reason(s) and concur with the attached hazard risk assessment and safe work procedure needed to ensure worker safety.

Electrical Engineer	Print: Sign:	Date	
Responsible Supervisor	Print: Sign:	Date	

Qualified Electrical Person(s) or Licensed Electrician Performing the Work

Energized electrical work must be performed by a Qualified Electrical Person or outside licensed electrician.

I certify that I am qualified to carry out the work described above, and I understand the EEWP checklist and shock/arc risk assessment results provided to me. I will follow the safety-related work practices necessary to prevent shock and arc flash (as applicable). I acknowledge that Responsible Supervision has determined that de-energizing the circuit to create a safe electrical work condition is not possible in this case.

Qualified Electrical Person	Print:	Sign:	Date:	
Safety Observer	Print:	Sign:	Date:	

Caltech Energized Electrical Work Permit Checklist

(To be filled out by Qualified Electrical Person immediately prior to starting work)

____ A. Current EMERGENCY telephone number - **626-395-5000**

____ B. Location of nearest telephone or cell _____ (fill in)

____ C. Location and availability of shepherd's hook, automated emergency defibrillator determined (if available)

____ D. CPR-trained personnel notified of energized electrical work and are immediately available (max four minutes response time)

____ E. *For Panel Distribution systems:* Up line breaker has been tagged for work on panel distribution systems: Yes _____ No _____

Location of up line source of power Elec. Rm. _____ Panel _____ Circuit _____

____ F. Location of Emergency Power Off (EPO) buttons or disconnect switches verified

____ G. Safety equipment and test meters available, tested for reliability and accuracy, and calibrated

____ H. The Safety Observer is to do no other work than observe and ensure safety procedures are followed

____ I. Updated copy of the panel schedule is attached to this permit (if applicable to work)

____ J. Safety issues and hazards in work area reviewed, including potential for shock and arc flash

____ K. All work procedures reviewed (If possible, open equipment in de-energized state and review work to be done)

____ L. Access to area restricted to keep Unqualified Persons clear of Limited Approach Boundary and Arc Flash Protection Boundary, as applicable (barriers, signs, attendants)

____ M. Other forms of Hazardous Energy not required for work are properly locked out/tagged out

____ N. Confirmed adequate illumination (flashlights are not acceptable)

____ O. All conductive personal articles removed (including metallic-rimmed glasses)

____ P. Metal fasteners on clothing (zippers, snaps, buttons & pins) on the torso and arms are not exposed

____ Q. Clear evacuation path identified

____ R. Tools in good condition (check insulation on handles)

____ S. Appropriate Personal Protective Equipment in place:

Rubber Insulated Floor Mats: Yes_____No, explain_____

Rubber Insulated Gloves: Yes_____No, explain_____

Approved Insulated Tools: Yes_____No, explain_____

Electrical-rated Safety Glasses: Yes_____No, explain_____

Hearing Protection (ear plugs): Yes_____No, explain_____

Arc Rated Face Shield: Yes_____No, explain_____

Arc Rated Blankets: Yes_____No, explain_____

Arc Rated Clothing: Yes_____No, explain_____

Additional PPE:_____

____ T. Electrical hazard risk assessment and safety-related work practices completed and attached to this permit.

____ U. Job briefing conducted between Responsible Supervision and Qualified Electrical Persons

After Completing Work - Post Service Checklist

Please check each of the following as they are completed:

____ 1. Visual inspection/test done to verify all tools, jumpers, grounds, etc. are removed and equipment is in good condition to return to service

____ 2. Affected associates exposed to hazards associated with equipment are notified of changing system status

____ 3. Visually confirmed all associates are clear of circuits and equipment

____ 4. Equipment returned to service

____ 5. Barriers removed

____ 6. PPE visually inspected then returned to storage location or if damaged, discard the damaged PPE so others do not inadvertently use them, then replace with appropriate PPE

____ 7. EEWP and upline warning tags (if used) removed and returned to the Campus Electrical Engineer

____ 8. Panel schedule updated (if applicable).

Qualified Electrical Person			
	Print Name	*Signature*	*Date*
Qualified Electrical Person			
	Print Name	*Signature*	*Date*
Safety Observer			
	Print Name	*Signature*	*Date*

ATTACHMENT G: JOB BRIEFING AND PLANNING CHECKLIST

Job Briefing and Planning Checklist

Identify

- ❑ Hazards
- ❑ Voltage levels involved
- ❑ Skills required
- ❑ Any "foreign" (secondary source) voltage source
- ❑ Number of people needed to do the job
- ❑ Shock protection boundaries
- ❑ Available incident energy
- ❑ Potential for arc flash (conduct an arc flash hazard analysis)
- ❑ Arc flash boundary

Ask

- ❑ Can the equipment be de-energized?
- ❑ Are back feeds of the circuits to be worked on possible?
- ❑ Is a standby person required?

Check

- ❑ Job plans
- ❑ Single-line diagrams and vendor prints
- ❑ Status board
- ❑ Information on plant and vendor resources is up to date
- ❑ Safety procedures
- ❑ Vendor information
- ❑ Individuals are familiar with the facility

Know

- ❑ The details of the job - discuss
- ❑ Communicate to all affected people
- ❑ Who is in charge?

Think

- ❑ What is the unexpected event?
- ❑ Lock – Tag – Test – Try
- ❑ Test for voltage – FIRST
- ❑ Use the right tools and equipment, including PPE
- ❑ Install and remove temporary protective grounding equipment
- ❑ Install barriers and barricades
- ❑ Other thoughts?

Prepare for an Emergency

- ❑ Is the standby person CPR trained?
- ❑ Is the required emergency equipment available?
- ❑ Where is the nearest telephone?
- ❑ Where is the fire alarm?
- ❑ Is confined space rescue available?
- ❑ What is the exact work location?
- ❑ How is the equipment shut off in an emergency?
- ❑ Are the emergency telephone numbers known?
- ❑ Where is the fire extinguisher?
- ❑ Are radio communications available?

ATTACHMENT H: INSULATED TOOLS

Qualified Electrical Persons and contracted licensed electricians must use at least energy category "III" electrical meters rated for a minimum of 1000 volts, which have been maintained and calibrated according to manufacturers' recommendations, or at least annually.

- Use only insulated tools when performing energized electrical work.
- Ensure that these tools meet the requirements of ASTM F 1505, Standard Specification for Insulated and Insulating Hand Tools.
- Ensure that these tools are rated for at least the voltages to be encountered.
- Inspect tools for damage or wear prior to each day's use.
- Replace tools if insulating capacity is damaged.
  - Discard the damaged tools so others do not inadvertently use them.

ATTACHMENT I: ACCESS CONTROL AND SIGNAGE DURING ELECTRICAL WORK

- Mark entrances to locations that contain exposed energized parts with conspicuous warning signs forbidding entry other than to Qualified Electrical Persons.
- To protect workers in the general work area, use hazard awareness techniques (e.g., safety signs, tags, labels, cones, tapes, barricades, in addition to safe personal work practices) when normally enclosed live parts are exposed for any type of energized work (including voltage measurement, troubleshooting, etc.) and subsequent de-energized maintenance and repair as necessary to preserve a safe work zone.
- Warnings must indicate the nature of the hazard, the limited approach or arc flash protection boundary (whichever is greater), and provide concise hazard avoidance information.
- Use protective shields, barriers, or insulating materials to protect Unqualified Persons from coming into contact with an energized part that is left unattended.
  - *Example:* If the Qualified Electrical Person must leave an energized part unattended, the energized part must be effectively guarded to prevent Unqualified Persons from coming into contact with it (via a locked door or secured protective cover with warnings posted, etc.)
- Only Qualified Electrical Persons are allowed within the applicable approach boundaries when working on or near exposed energized electrical equipment.
- If Unqualified Persons must access an area within the Limited Approach Boundary (3 ½ feet for up to 750 volts) of an exposed energized part, that individual must be escorted by a Qualified Electrical Person and all electrical work must cease until the area is cleared.
- Lock entrances to buildings, rooms, or enclosures containing high voltage electrical equipment, and post these entrances with permanent and conspicuous warning signs reading “Danger – High Voltage – Keep Out” or similar wording. The entrances may only be unlocked when under the control of a Qualified Electrical Person.

ATTACHMENT J: SPECIAL PRECAUTIONS FOR OUTDOORS AND WET/DAMP LOCATIONS

- When using portable tools within six feet of a water source, or while working in damp locations or outdoors, use a ground fault circuit interrupter (GFCI) unit. The GFCI may be part of a fixed outlet, part of an in-line extension cord, or a separate unit (e.g., a multiple outlet GFCI-protected spider box).
- Do not work in wet locations unless absolutely critical and authorized by a manager who oversees the work.
- When removing standing water, observe the following precautions:
  - In general, remove standing water with power disconnected.
  - Ensure that electrical equipment used to remove water is rated for wet work and is connected to a GFCI-equipped power source.
  - Ensure that extension cords have molded end caps free of defects in their insulation.
  - Postpone other electrical work until standing liquid is cleaned-up to a dry condition.
- Qualified Electrical Persons performing electrical work in damp locations shall observe the following precautions:
  - Minimize electrical work except for testing or metering to verify de-energized conditions until the area can be properly dried.
  - Ensure that equipment is powered through GFCI-equipped circuits.
  - If using a portable GFCI, place the unit as close as possible to the point of use to minimize the potential for its safety system to engage or activate (spurious tripping) due to line leakage through a power cord or cord caps.
  - If a GFCI cannot be used, have a manager evaluate and approve the power supply arrangement to ensure adequate grounding protection for the particular application. Acceptable alternatives to a GFCI unit include using isolation transformers in temporary power cords or using low-voltage equipment (working voltage typically 12 volts).

ATTACHMENT K: STANDARD PRECAUTIONS FOR POTENTIAL ARC ENERGY OVER 40 CAL/CM^2

If potential arc energy could exceed 40 cal/cm^2, the work must not be performed energized. Every option must be explored to avoid exposure to this level of potential arc energy. In an effort to achieve an electrically safe work condition and Lockout/Tagout, even the action of opening or closing a circuit breaker may result in a high energy arc flash and blast, so special precautions are required while de-energizing the circuit in these situations.

For opening and closing circuit breakers with cubical doors shut, and for verification of a zero-energy state and installing personal protective grounds as required to produce an electrically-safe work condition, the following special precautions are required:

- The Lockout/Tagout shall be performed according to an approved written procedure.
- Prior to operating energy-isolating means, two qualified electricians shall review and verify the proposed isolation points and sequence.
- Isolation, locking, and tagging of energy control points shall be performed by two qualified electricians.
- The minimum PPE required to expose live parts, perform zero energy state verification and install personal protective grounds (if required) will be the same as that for equipment with an incident energy of 40 cal/cm^2.
- If bolted covers must be removed from the equipment, a minimum of two qualified electricians shall perform the removal and reinstallation of the covers.
- Prior to taking any verification measurement with a contact meter, a proximity meter attached to a minimum three-foot hot stick shall be used first.

ATTACHMENT L: ELECTRICAL EQUIPMENT PREVENTIVE MAINTENANCE AND SHOCK/ARC FLASH RISK ASSESSMENT

Inspections

Each switchgear, panelboard, motor control center, and industrial control panel must be inspected for contamination, corrosion, loose or weakened parts, missing fasteners or protective panels, etc. Inspections must take place at least once every three years and corrective actions taken as necessary to ensure safe electrical equipment according to the electrical preventive maintenance program.

Circuit Breaker Testing

Service and feeder circuit breakers (277 volt or greater) shall be performance tested per the manufacturer or as defined by *NFPA 70B, Recommended Practice for Electrical Equipment Maintenance*. If there is no available recommendation by the manufacturer, then performance testing should be done every three – five years. This provides a degree of assurance that the breakers will perform as expected (i.e., trip within the expected number of cycles when a fault occurs).

Infrared Testing

After all circuit breaker overcurrent protection devices have been performance tested, then each switchgear, panelboard, motor control center, and industrial control panel must have infrared thermography performed to be sure that there are no unexpected “hot spots” either at terminations or within internal components. This testing must be performed annually. (When electrical components are heat-stressed, the flexible metal parts become crystalline and brittle, thereby increasing the chances of arcing. Infrared inspections of electrical systems are beneficial to reduce the number of costly and catastrophic equipment failures and unscheduled shutdowns). Caltech also ensures that electrical equipment enclosures are vacuumed out during infrared testing.

Facility-wide Shock and Arc Flash Hazard Risk Assessment

In coordination with a qualified electrical engineering firm, Caltech shall conduct a facility-wide shock and arc flash hazard risk assessment initially and every five years thereafter. This assessment shall be conducted according to NFPA 70E 130.5, and shall include power distribution components such as switchboards, panelboards, industrial control panels, meter socket enclosures, and motor control centers that are likely to require examination, adjustment, servicing, or maintenance while energized.

The arc flash hazard risk assessment should be conducted in three parts: 1) short circuit fault study to determine the amount of available fault current, 2) a coordination study to determine the interruption times for the overcurrent protection devices, and 3) the calculation of the incident energies and arc flash boundaries. Since all of the distribution equipment and wiring must be assessed during this step to perform the necessary calculations, this would also be the ideal time for the engineering firm for performing the arc flash study to further evaluate compliance with the National Electrical Code.

After the electrical system has been properly modeled and the software program run, the engineering firm shall provide suggestions to reduce arc flash hazards (as needed), provide for proper selective over current device coordination, and determine what changes to the electrical system should be performed to bring it up to code (e.g., increase capacities, add upstream main fused disconnects to buildings, correctly wire several electrical feeders, and grounding electrode systems, etc.). These recommendations should then be placed within the electrical distribution software model to show the resultant reductions in any existing arc flash hazards.

The results of the assessment (which includes the determination of shock and flash protection boundaries and potential incident energies) will be documented in a written report along with recommendations for reducing electrical hazards and PPE categories where possible.

The values obtained from the shock and flash hazard risk assessment above can only be relied upon after completion of the required inspections and preventive maintenance described in this section.

Perform necessary improvements to the electrical distribution system to correct electrical code violations and reduce to arc flash hazards.

Infrared Testing (post upgrade)

After the upgrades and changes to the electrical system have been completed, perform an infrared thermographic analysis of all electrical distribution and utilization equipment, including switchboards, panelboards, and industrial control equipment, as recommended by NFPA 70B. Subsequent infrared assessments should be performed annually.

Labeling

Based on the report findings, Caltech shall ensure that all existing and future switchboards, panelboards, industrial control panels, meter socket enclosures, and motor control centers are labeled to warn of the potential shock and flash hazard involved with opening the cover and working on the electrical conductors.

Hazard warning labels shall include at a minimum:

- Nominal system voltage
- Restricted approach boundary
- Limited approach boundary
- Arc flash boundary
- EITHER the available incident energy (in calories per cm2) at the corresponding working distance OR the arc flash PPE category, but not both)
- Minimum arc rating of clothing
- Site-specific level of PPE
- Date study prepared
- Study preparer name and address

Electrical Demolition

Old wiring insulation may contain asbestos. Contact EHS for sampling and additional assistance prior to beginning any work on insulation.

When demolishing, removing, or replacing electrical wiring or equipment, consideration must be given to the protection of employees and equipment.

- Identify, insulate, and protect exposed wires.
- Remove unnecessary wiring as equipment is being removed.
- Prior to removing your lock and tag, exposed tape or insulated wires must be concealed in junction boxes.

ATTACHMENT M: ELECTRICAL EQUIPMENT SAFE WORK SPACE REQUIREMENTS

Sufficient space is provided and maintained about electrical equipment to permit ready and safe operation and maintenance. Where energized parts are exposed, the minimum clear work space is never less than 6 ½ ft. high (measured vertically from the floor) or less than 3 ft. wide (measured parallel to the equipment). Higher voltage motor control centers must have a larger clearance out in front.

The depth is shown in the following table and in all cases the work space will permit at least a 90-degree opening of doors or hinged panels. This table is based on the National Electric Code (NEC) and Cal/OSHA regulations.

Table 2340.16. Minimum Depth of Clear Working Space at Electrical Equipment, 600 V or Less

Nominal Voltage to Ground	Minimum Clear Distance		
	Condition 1	Condition 2	Condition 3
0-150	3 Feet (0.9 Meters)	3 Feet (0.9 Meters)	3 Feet (0.9 Meters)
151-600	3 Feet (0.9 Meters)	3.5 Feet (1.0 Meters)	3.5 Feet (1.2 Meters)

Notes to Table 2340.16:

Where the "Conditions" are as follows:

Condition 1 - Exposed live parts on one side and no live or grounded parts on the other side of the working space, or exposed live parts on both sides effectively guarded by suitable wood or other insulating materials. Insulated wire or insulated busbars operating at 300 volts or less shall not be considered live parts.

Condition 2 - Exposed live parts on one side and grounded parts on the other side. Concrete, brick, or tile surfaces shall be considered as grounded surfaces.

Condition 3 - Exposed live parts on both sides of the work space (not guarded as provided in Condition (1)) with the operator between.

EXCEPTION: Minimum clear distances may be 2.5 ft. (0.7 m) for installations built before April 16, 1981.

ATTACHMENT N: PRACTICES FOR FLEXIBLE CORDS

Flexible cords are those that are exposed, flexible, unsecured, and more susceptible to damage than fixed wiring. *This guidance does not cover portable hand-operated power tools, small kitchen appliances, office equipment, electronic instruments, personal computers, and other similar equipment.*

Flexible cords and cables may be used for:

- Pendants
- Wiring of fixtures
- Connections of portable lamps or appliances
- Elevator cables
- Crane and hoist wiring
- Connecting stationary equipment that requires frequent interchange
- Preventing transmission of noise or vibration
- An appliance or equipment with fastenings and mechanical connections specifically designed to permit removal for maintenance and repair, and intended or identified for flexible cord connection
- Power cables (ac) for data-processing equipment
- Connecting moving parts

When flexible cords and cables are used for lamps or appliances they must be equipped with an approved attachment plug and energized from a receptacle outlet. Only qualified persons may install cord caps (the attachment plug) on cords.

Flexible cord and cable, attachment plugs, and receptacles must be of the proper type, size, voltage and current rating for the intended application.

Branch circuits that feed cord-and-plug connected equipment must be designed, have over current protection, and be grounded in accordance with the National Electrical Code.

All cord-and plug-connected equipment must be grounded with a correctly sized and identified equipment-grounding conductor that is an integral part of the ac power cord or cable. Exception: Listed equipment that is protected by a double insulation system or its equivalent.

It is Caltech's policy to allow cord-and-plug connection of equipment that operates at 250V or less and has a maximum circuit rating of 30 A. Any equipment operating at higher voltages or currents should be permanently connected. (Exception; portable arc welders)

Forbidden Uses of Flexible Cables:

- Substituted for the fixed wiring of a structure.
- Run through holes in walls, ceilings, or floors.
- Run through doorways, windows, or similar openings.
- Attached to building surfaces.
- Concealed behind building walls, ceilings, or floors.
- Installed in electrical raceways, unless specifically allowed by NEC provisions covering electrical raceways.

Except for the temporary wiring provisions of the NEC, the NEC does not allow the cord-and-plug connection of equipment to be energized from extension cords. Extension cords are not acceptable substitutes for the fixed wiring of a structure such as a receptacle outlet.

In industrial locations, such as shops, a suitable guard or cover must protect the interface between attachment plug and receptacle from intrusion of process waste or other foreign material, such as cutting oils and machining chips.

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