Environmental Health & Safety

Electrical Safety Program

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Overview

Electricity has long been recognized as a serious workplace hazard. Accidental or intentional exposure to electricity can result in electric shock, electrocution, burns, fires, explosions and impact injuries. The purpose of this program is to provide a practical safe working area for employees performing work directly on or in the proximity of electrical systems or equipment as well as others who work with electricity indirectly using electrically powered tools and equipment.

Scope and Application

This document addresses minimum safety-related work practices for Yale Facilities employee and contractor operations involving energized and de-energized electrical systems and equipment at Yale University. This includes the installation, maintenance, repair, testing, operation (manipulation of breakers and disconnects) and diagnosis of low and high voltage systems. It also covers operations in which electricity is used in tools or equipment in the performance of non-electrically related tasks. This document does not cover the design of electrical components or systems. Other employees (not Facilities) who perform work involving electrical hazards must have a competent person assigned and approved by Yale Environmental, Health and Safety to oversee the work.

Standards

The federal Occupational Safety and Health Administration (OSHA) has established general industry standards governing electrical safety in Section 29 CFR 1910 Subpart S and PPE requirements in Section 29 CFR 1910.137. Electrical power generation, transmission and distribution safety requirements are found in Section 29 CFR 1910.269. Electrical safety is regulated by OSHA in construction operations in Section 29 CFR 1926 Subpart K. Additional guidelines for safely working with and around electrically energized systems and can be found in NFPA 70E- 2018, Standard for Electrical Safety in the Workplace and the National Electric Safety Code (NESC)- 2017. Both of these standards are updated every few years, by committee.

Responsibilities

Managers and supervisors are responsible for:

- Ensuring overall employee compliance with this program;
- Ensuring contractor and vendor compliance with this program;
- Conducting Risk Assessments;
- Ensuring that employees and contractors under their supervision working with electrical energy are properly trained, and otherwise qualified;
- Ensuring that employees working with electrical energy requiring protection equipment receive necessary training before beginning such work and are provided with the correct equipment;

- Ensuring that approved, maintained, and tested personal protective equipment (PPE) and clothing is provided, available, and used properly;
- Ensuring that Qualified Workers are trained as Safety Watches; and
- Keeping and maintaining records as required.
- Coordinating field work audits with Environmental, Health and Safety. Audits shall be documented and performed at intervals not to exceed 1 year.

Environmental, Health and Safety is responsible for:

- Audit this program at least every three years to evaluate compliance with the latest version of NFPA 70E.
- Auditing field work to verify that the requirements contained in the procedures of the electrical safety program are being followed. Audits shall be documented and performed at intervals not to exceed 1 year.

Covered employees are responsible for:

- Participating in training and understanding the electrical hazards of the work to be performed;
- Participating in training and understanding Control of Hazardous Energy (Lockout/Tagout) Program and procedures;
- Using the electrical protective equipment, tools and supplies provided in an appropriate manner when needed;
- Maintaining personal protection equipment in a safe and sanitary condition;
- Following the procedures outlined in this document when exposed, or potentially exposed to an electrical hazard;
- Reporting unsafe conditions to their supervisor as soon as possible and correcting the conditions to the extent that they are qualified to do so;
- Performing job safety planning and/or risk assessments before starting work that involves recognized electrical hazards; and
- Conducting or participating in job briefings before starting each job that exposes employees to electrical hazards.

Safety Watches are responsible for:

- Remaining in visual and audible range of the person performing the work while the work is in progress while remaining outside the arc flash protection and limited approach boundary;
- Being familiar with the work to be performed and the safety procedures involved;
- Observing the worker(s) and operations being performed to prevent careless acts;
- Knowing the location of the circuit breaker or switch to be turned off, in case of emergency;
- De-energizing the equipment in the event of an emergency and alerting emergency rescue personnel;
- Being equipped with a radio or knowing the location of nearest telephone to summon help;

- Completing training in emergency response procedures, including cardiopulmonary resuscitation (CPR) and means of release of victims from contact with exposed energized electrical conductors or circuit parts; and
- Having no other duties that preclude observing workers and operations, and rendering aid if necessary.

Definitions

Arc Flash Boundary: When an arc flash hazard exists, and approach limit from an arc source at which incident energy equals 1.2 cal/cm^2 and where a person could receive a second degree burn if an electrical arc was to occur.

Arc Flash Risk Assessment: A study calculating a worker's potential exposure to incident or heat energy (in cal/cm^2), conducted for the purpose of injury prevention and the determination of safe work practices, arc flash boundary, and the appropriate levels of personal protective equipment (PPE).

Arc Rating: The value attributed to materials that describes their performance in an electrical arc discharge. The arc rating is expressed in cal/cm^2 and is reported as the arc thermal performance value (ATPV) or energy of breakopen (E_{BT}) threshold of a given material.

Circuit: A conductor, system of conductors or component through which electrical current is intended to flow.

De-Energized Electrical Work: Work performed on equipment that has been previously energized and is now free from any electrical connection to a source of potential difference and from electrical charges. This is often performed following Lockout/Tagout procedures.

Dielectric: A compound or material that serves as an electrical insulator while undergoing polarization. Listed dielectric compounds can be placed in direct contact with conductors.

Electric Arc: The flow of current between two electrodes through ionized gases and vapors. It is started by flashover or the introduction of some conducting material between energized parts.

Electrical Hazard: A dangerous condition such that contact or equipment failure can result in electric shock, arc flash burn, thermal burn, or blast.

Electrically Safe Work Condition (ESWC): A state in which an electrical conductor or circuit part has been disconnected from energized parts, locked/tagged in accordance with established standards, tested to verfiy the absence of voltage (***zero energy***), and grounded if determined necessary for personnel protection.

Energized Electrical Work: Work On or Near systems while they are energized (i.e. live); including repair, maintenance, troubleshooting, or testing of electrical circuits or components.

Exposed: Capable of being inadvertently touched or approach nearer than a safe distance by a person (or what they may be holding).

Extra-Low Voltage: Electrical voltages of 50 VAC or lower, generally considered to pose non-lethal hazards.

Grounded: Connected to ground or to some conducting body that extends the ground connection.

Ground fault circuit interrupter: A device intended for the protection of personnel that functions to de-energize a circuit or portion thereof within an established period of time when a current to ground exceeds the values established. Ex: A ground fault circuit interrupters trip when current to ground is 6 mA or higher and do not trip when current to ground is less than 4 mA.

Guarded: Covered, shielded, fenced, enclosed, or otherwise protected, by means of suitable covers or casings, barrier, rails or screens, mats or platforms, to remove the likelihood of approach or contact by persons or objects to a point of danger

Hazard: A source of possible injury or damage to health.

High Voltage: Electrical voltages of greater than 600 VAC per NFPA-70E (greater than 1000 VAC per IEC Standards).

Incident Energy: The amount of thermal energy impressed on a surface, a certain distance from the source, generated during an electrical arc event. One of the units used to measure incident energy is calories per centimeter squared (cal/cm^2).

Insulated: Separated from other conducting surfaces by a dielectric (including air space) offering a high resistance to the passage of current.

Limited Approach Boundary: The distance from an exposed energized part within which a shock hazard exists. Used to define where qualified or escorted personnel may work or stand.

Lockout/Tagout: The placement of a lockout device on an energy isolating device, in accordance with an established procedure, ensuring that the energy isolating device and the equipment being controlled cannot be operated until the lockout device is removed. This procedure is performed to safeguard workers from exposure to electrical hazards.

Low Voltage: Electrical voltages greater than 50 volts but less than or equal to 600 volts.

Means of Release: The application of tools, controls, disconnects and/or other methods or devices to safely separate a person from an energized conductor or other electrical component.

Method of Procedure (MOP): A documented step-by-step sequence of critical actions, or switching orders, for executing an operation.

Near (or Proximity): Close enough to require protection from the shock or arc flash hazard presented by the equipment characteristics.

Personal Protective Equipment (PPE): Clothing, shields, and related equipment designed to mitigate the effects of hazards to which workers might be exposed.

Qualified Worker: Consistent with the appropriate *Electrical Task Matrix (Attachment G)*, an employee who is trained and authorized to perform Work On or Near electrical equipment and components or operate electrical equipment and components with which he or she is familiar and who can demonstrate the ability to identify and avoid the hazards involved. Only appropriately trained Qualified Workers may install, fabricate, repair, test, calibrate, or modify electrical wiring, devices, systems, or equipment. Only appropriately trained Qualified Workers may operate electrical equipment and components.

Restricted Approach Boundary: The distance from an exposed energized part within which there is an increased risk of electric shock (due to electrical arc-over combined with inadvertent movement) for personnel working near the live part and where PPE or shielding must be used.

Risk Assessment: An overall process that identifies hazards, estimates the potential for severity of injury or damage to health, estimates the likelihood of occurrence of injury or damage to health, and determines if protective measures are required.

Safety Watch: If signs and barricades do not provide sufficient warning and protection from electrical hazards, a Safety Watch shall be stationed to warn and protect employees. The primary duty and responsibility of a Safety Watch providing manual signaling and alerting shall be to keep Unqualified Workers outside a work area where the Unqualified Worker might be exposed to electrical hazards. A Safety Watch shall remain in the area as long as there is a potential for employees to be exposed to the electrical hazards. When it is necessary for the Safety Watch to deliver the warning, he/she shall have no other duty.

Shock Hazard: A dangerous condition associated with the possible release of energy caused by contact or approach to energized electrical conductors or circuit parts.

Unqualified Worker: Consistent with the appropriate *Electrical Task Matrix (Attachment G)*, a person with limited electrical knowledge and little or no electrical training on avoiding the electrical hazards associated with Work On or Near exposed energized parts. Unqualified Workers are not trained and/or authorized to operate or perform Energized Electrical Work.

Working Near: Any activity inside the restricted approach boundary of exposed energized electrical conductors or circuit parts that are not put into an electrically safe working condition (i.e. de-energized).

Working On: Intentionally coming in contact with energized electrical conductors or circuit parts with the hands, feet or other body parts, or with tools, probes or test equipment, regardless of the personal protective equipment (PPE) a person is wearing

Electrical Hazards

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

Electrical shock

Most electrical systems use conductors that have voltage potentials relative to ground or to lower voltage conductors. A shock hazard exists for workers who are in contact with a grounding or grounded conductor while exposed to energized ungrounded conductors or circuit components. The hazard also exists between live ungrounded conductors or energized components. In these cases, workers may become part of the circuit and enable current to pass through their bodies.

The effects of electric current on the human body depend on factors including voltage, current, pathway through the body, and duration of contact. The most damaging pathway for 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. The tools section contains a table outlining the quantitative effects of electric current on the human body.

Burns

Electrical accidents can result in three kinds of burns - electrical, arc, and thermal contact.

Electrical Burns

In electrical burns, tissue damage (whether to skin or deeper) occurs because the body is unable to dissipate the heat from the current flow. Typically, electrical burns are slow to heal. Damage to internal tissues may not be evident 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.

Arc Burns

Arc burns are caused by electric arcs and are similar to heat burns from other high-temperature sources. Temperatures generated by electric arcs can melt nearby material, vaporize metal conductors, burn flesh, and ignite clothing. The arc flash temperature can reach greater than 35,000 degrees Fahrenheit.

Thermal Contact Burns

Thermal contact burns are similar to those normally experienced from skin contact with any hot surface, in the case of electrical work, typically the hot surfaces of overheated electric conductors or other electrical equipment.

Arc Blast

The tremendous temperature of the arc causes the explosive expansion of both the surrounding air and the metal in the arc path. The copper expands by a factor of 67,000 times when it turns from a solid into a vapor. This creates dangerous high pressures, sound and shrapnel. The pressures can easily exceed hundreds to thousands of pounds per square foot, knocking workers off ladders, rupturing eardrums and collapsing lungs. The sound can exceed 160dB. The shrapnel travels at speeds greater than 700mph, fast enough to completely penetrate the human body. (NFPA-2018 70E Annex K.4)

Other Electrical 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, extra-low voltage sources are frequently located near potentially lethal voltage circuits. In addition, accidental contact with an extra-low voltage source may result in involuntary reactions may also result in bruises, bone fractures, and even death from falls (i.e. falling from a ladder after receiving a shock).

Fires may also be caused by overheated electrical circuits or equipment (conductors that carry too much current) or by an electric arc created by a short circuit.

Training Requirements

Qualifications to operate, install, maintain, and/or repair electrical equipment or components is based on a combination of formal training, experience, on-the-job training and licensing. Supervisors are responsible for ensuring employees or contractors under their supervision are qualified to operate or work on de-energized or energized components before they are assigned to such work. Such a person shall be able to perform the job safety planning, identify electrical hazards, assess the associated risk and select the appropriate risk control method for the task. In addition, individuals functioning as a Safety Watch must be trained on emergency response.

Yale University has established three categories of electrical safety training programs:

- Unqualified Workers for non-electrical workers
- Qualified Workers for those who Work On or Near electrical equipment
- Safety Watch for Qualified Workers responsible for providing emergency response and when required by the *Energized Electrical Work Permit*

Training records will be managed in the University' Training Management System (TMS). Training is repeated when changes, such as the introduction of new equipment, make previous training obsolete, or when an employee has not demonstrated the requisite awareness, understanding or skill.

Unqualified Workers

Consistent with the appropriate *Electrical Task Matrix (Attachment G)*, the first category of electrical safety training is for workers who may face a risk of electric shock while conducting their work. For

example, these individuals may operate hand power tools, other electrically powered equipment or work in areas where they are exposed to energized electrical conductors. This first category of training reviews safe work practices associated with working with electrically-powered tools and equipment as well as other general electrical maintenance related safety precautions.

Qualified Workers

Consistent with the appropriate *Electrical Task Matrix (Attachment G)*, the second category of electrical safety training covers all aspects of training for Unqualified Workers plus covers the details necessary for safely operating (equipment doors closed and secured) electrical equipment, serving as a safety watch, and performing Lockout/Tagout procedures. This second category of training reviews safe work practices associated with operating energized and de-energized electrical systems including:

- Expected operation of breakers and disconnects.
- Meaning and use of approach boundaries (limited & restricted)
- Proper use of the special precautionary techniques, personal protective equipment, insulating, and shielding materials.
- Understanding arc flash labeling and its application.
- Understanding the application of grounding devices and their use relative to switching and Lockout/Tagout procedures.

In addition to the above and consistent with the appropriate *Electrical Task Matrix (Attachment G)*, specific employees will be trained to operate higher voltage equipment as well as to install, maintain or repair energized or de-energized systems and equipment that operate at more than 50 volts including motors, transformers, breakers, switches, capacitors, distribution panels, and wiring. This maintenance group includes electricians, certain equipment, refrigeration and control mechanics, and some technicians. As a minimum, all Qualified Workers should attend refresher safety training at intervals not to exceed 3 years. Lastly, all Qualified Workers must be trained and authorized in Lockout/Tagout.

Safety Watch

Employees who perform Safety Watch duties must be trained in First Aid / CPR / AED and means of release of victims from contact with exposed energized electrical conductors or circuit parts. All Qualified Workers must be trained to serve as a Safety Watch. Refresher training is required every two years.

Note: Personnel who only work with communication circuits and DC circuits with a fault current limited to 5 mA (if the energy is less than 10 joules) or less are exempt from the CPR and first aid course requirement.

Procedures

Consistent with the specific job tasks / functions as it relates to operation and/or maintenance of electrical switchgear identified within the *Electrical Task Matrix (Attachment G)*, the following summarizes the general safe work practices for each worker category identified in this program.

Work Practices for Unqualified Workers

The following are the general electrical safe work practices to be followed by Unqualified Workers:

- Do not perform work involving electrical hazards
- Do not cross the limited approach boundary (for shock hazards), unless accompanied by an appropriately trained Qualified Worker. For circuits between 50 and 750 volts, the limited approach boundary is 3.5 feet.
- Know how to respond to emergencies such as electrical shock incidents and fires.
- Do not reset a circuit breaker or replace a fuse.
- Always review and follow the manufacturer's instruction for use and maintenance of all electrical tools and appliances and keep equipment operating instructions on file.
- Inspect all electrical equipment and tools prior to use for defects or damage.
- Avoid touching an electrical appliance and a grounded component, such as plumbing, at the same time.
- Ensure all electrical devices are properly grounded with approved three wire plugs unless they are "double insulated" (Grounding provides a safe path for electricity to the ground, preventing leakage of current in circuits or equipment).
- Never use electrical equipment in wet areas, in close proximity to water sources or run cords across wet floors unless they are protected by a ground fault circuit interrupter (GFCI).
- When working around electrical equipment, ensure energized parts operating at 50 volts or more are guarded against accidental contact.
- Extension cords provide a convenient method of bringing AC power to a device that is not located near a power source and are also used widely as temporary power sources. However, extension cord use at Yale University must meet the following requirements and employees must utilize the following work practices:
    - Only use approved (by Underwriter Laboratories or another nationally-recognized testing laboratory) cords and ensure they are properly maintained with no exposed live parts, exposed ungrounded metal parts, damage, or splices.
    - Only use heavy-duty (14 gauge) or extra-heavy-duty (12 gauge) rated cable. An undersized cord is a fire hazard.
    - Must be three-conductor (grounded)–even if the device has a two-conductor cord. Never use two-conductor extension cords.
    - Must be protected by a GFCI if used in damp areas, where subject to damage, or in an area where a person may be in direct contact with a solidly grounded conductive object (such as working on a metal surface). The GFCI can consist of a special circuit breaker, a GFCI outlet, or a short extension cord with a built-in GFCI.

- Must be destroyed and discarded if damaged (such as abraded insulation, a missing ground or corroded).
- Must be protected from damage if run through a doorway for short term use and be removed immediately when no longer in use.
- Must not pose a tripping hazard (run overhead or use appropriately designed covers if run across walkways).
- Keep all electric cords away from heat, oil and sharp edges.
- Grasp the plug body on the cord to remove it from the socket, not by pulling the cord.
- DO NOT:
  - Use in place of permanent wiring.
  - Plug too many pieces of equipment into the same circuit or outlet as the circuit or outlet could become overloaded.
  - Daisy-chain cords (one extension cord plugged into another extension cord or plug strip). Instead, plug them directly into outlets.
  - Use flat or light-duty cords.
  - Overload cords (the wire size must be sufficient for the current drawn).
  - Use a cord with the ground prong removed or compromised.
- GFCI protection must be used whenever operating electrical equipment outdoors, in a wet area or within 6 feet of a water source. GFCI units must be tested before use and defective equipment taken out of service.

Work Practices for Qualified Workers

In addition to the basic work practices described above for Unqualified Workers and consistent with the appropriate *Electrical Task Matrix (Attachment G)* and the voltage levels specified, the following are the general electrical safe work practices to be followed by Qualified Workers while operating electrical equipment or components:

- Provide local or remote operation of electrical equipment (i.e., manipulation of breakers and disconnects).
- Monitor all entry and exits to all marked switchgear rooms when work is underway inside.
- Initiate and implement Lockout/Tagout procedures.
- Lockout/Tagout switches that control lights before putting in new lamps (if old lamps are intact) as allowed for under the *Electrical Task Matrix (Attachment G)*. Contact Facilities Operations for assistance in identifying and controlling the energy source.
- Prior to re-energizing equipment, conduct visual inspections to verify that all personnel are in the clear and that all tools, grounds, and other devices have been removed so that the circuit(s) and equipment can be safely re-energized. Ensure appropriate shock and arc flash PPE is worn while re-energizing the system.
- Help enforce proper PPE requirements for all electrical rooms and special locations within the power plants with fellow workers and outside contractors / vendors.

Consistent with the appropriate *Electrical Task Matrix (Attachment G)*, those specific employees trained and authorized to operate higher voltage equipment as well as to install, maintain or repair energized or de-energized systems and equipment will be required to adhere to the work practices detailed below while performing electrical work.

De-Energized Electrical Work

If feasible, electrical systems must only be worked on in the de-energized state, following the work practices described in Yale University's Control of Hazardous Energy (Lockout/Tagout) Program. (Systems having voltages less than 50 volts and stored energy less than 10 joules, as well as systems with a fault current limited to five milliamperes are exempt from this requirement.)

The process for controlling electrical energy prior to working on an electrical system is outlined below. Yale's "Control of Hazardous Energy" safety program contains additional details and requirements. **All electrical work is to be considered potentially energized until verified at zero energy.**

Steps in de-energizing an electrical system:

- Worker evaluates electrical hazard risk (See *Attachment F*).
- Worker and Manager (For complex switching and tagging evolutions) document a Method of Procedure and submit to appropriate Facilities manager for review, approval, rejection and/or revision. Determine the level of documented procedures to follow for de-energizing systems in the plants or distribution systems. Utilize appropriate Lockout/Tagout, Method of Procedure and log books to capture how systems get de-energized. Prior to de-energizing power plant systems always consult the shift Watch Engineer or UBIM.
- For complex switching and tagging evolutions, at least one documented job briefing is held with the Qualified Workers doing the tasks and Facilities management representatives regarding the work. Submit evidence of the job briefing to the appropriate Facilities trade manager to review for completeness before starting each job. For Utilities, document this job briefing in the plant log book and in all cases review with Utilities Plant Management and the Watch Engineer on shift.
- Verify contact numbers for emergency services.
- Inspect personal protective equipment (PPE) for defects or damage.
- Establish limited approach and arc flash boundaries. Set alerting techniques with signs, barricades or other approved methods.
- Disconnect circuits and equipment to be worked on from all electric energy sources and lock them out as necessary.
- Place stored electrical energy that could endanger personnel in an electrically safe working condition (ESWC). Discharge capacitors and short-circuit and ground high-capacitance elements if the stored electrical energy could endanger personnel. Verify zero energy is present with a meter within its voltage category
- Block or relieve stored non-electrical energy in devices that could re-energize unexpectedly or in an uncontrolled manner.

- Apply additional Lockout/Tagout procedures based on equipment to be worked on to safeguard employees from injury while Working On/Near de-energized circuits and equipment. Verify that all live circuits, parts, and other sources of electrical energy, including any mechanical energy, have been disconnected, released, or restrained. Verify zero energy.
- Operate the equipment operating controls, perform voltage verification, inspect open switches, and draw-out breakers, etc. to assure the isolation of energy sources, depending upon voltage level.
- Don required PPE and test the circuit elements and electrical parts of equipment with test equipment to which employees will be exposed to verify that the circuit elements and equipment parts are de-energized and at zero energy. Such tests also determine if a hazardous energized condition exists as a result of induced voltage or voltage back fed after specific parts of the circuit have been de-energized.
- Check the test equipment for proper operation immediately before and immediately after this test. Testing is performed as if the circuit is energized. The selection and use of the voltage verification device and PPE must be based on the assumption that the system is energized.
- Apply personal protective grounds of proper short circuit rating on circuits of 600 V and above and on lesser voltages where residual charges may accumulate. Select and install personal protective grounds in accordance with appropriate standards. When possible, apply protective grounds on either side of the circuit where work is being performed. Give consideration to step and touch potentials near temporary ground connections.
- Prior to re-energizing equipment, conduct tests and visual inspections to verify that all personnel are in the clear and that all tools, electrical jumpers, shorts, grounds, and other devices have been removed so that the circuit(s) and equipment can be safely re-energized. Don appropriate shock and arc flash PPE prior to re-energizing the system.

Utilities Electrical Method of Procedure

Utilities Electrical Method of Procedures shall apply to all electrical distribution switchgear from the site incoming power source (i.e., United Illuminating Feeders) or point of generation (i.e., Power Plants) to the load center breakers including load center transformers, main breakers and tiebreakers throughout the campus electrical distribution system. Utilities Electrical Method of Procedures applies during all repairs, maintenance, modifications, installations, and switching activities. The Utilities Electrical Method of Procedure outlines the responsibilities and steps to be taken for proper switching of electrical switchgear as well as the required notifications and record keeping associated with the same.

Work on Energized Systems

Permit Exemption

Work on Energized Systems greater than 50 volts may be performed by a Qualified Worker using appropriate safe work practices and PPE under the following conditions:

- Testing, troubleshooting, and voltage measuring

- Thermography and visual inspections if the restricted approach boundary is not crossed
- Access to and egress from an area with energized electrical equipment if no electrical work is performed and the restricted approach boundary is not crossed
- General housekeeping and miscellaneous non-electrical tasks if the restricted boundary is not crossed

Permit Requirements

In all other cases, Yale's policy is to de-energize and verify zero energy on all circuits over 50 volts prior to working on conductors or circuit components. In the rare event that a task requires work on an energized conductor or circuit component, it must meet NFPA 70E/ OSHA/ NESC justification standards for allowing energized work. Work on energized systems may only be performed when it has been demonstrated that de-energizing the system will introduce additional or increased hazards or is infeasible because of equipment design, equipment operational limitations, or significant impacts to critical life and health systems. Examples of activities for which Work On or Near energized equipment may need to be performed include:

- Any situation where system de-energizing would interrupt life support, remove critical lighting (which can't be temporarily replaced), deactivate other critical systems such as emergency alarms or ventilation in hazardous locations, or otherwise create a greater hazard to life and health.

If a task meets the energized work justification standards and all other hierarchy methods of risk controls have been deliberatively exhausted, an *Energized Electrical Work Permit (Attachment B)* must be completed so that appropriate PPE, equipment, and work practices can be identified.

- Energized electrical work must only be performed by appropriately trained and authorized Qualified Workers in situations where the use of Lockout/Tagout practices either increases the hazard(s) to the employee and/or equipment, or if de-energizing is not feasible due to equipment design or operational limitations.
- An *Energized Electrical Work Permit (Attachment B)* outlining the justification must be submitted to the appropriate Facilities trade manager or Utilities Power Plant Manager for approval, rejection or revision directives.
- The permit must be reviewed by the supervisor of the person(s) doing the work prior to the initiation of work. The supervisor will approve, reject or send it back for revision(s).
- A Safety Watch may be required at the discretion of the supervisor when hazardous work is performed (for example, work on energized systems greater than 600 volts or when a significant arc flash hazard exists).
- The steps outlined in the table below are followed.
- The completed permit must be kept at the job site for the duration of work, and posted or otherwise made readily visible to other workers, supervisors, or emergency responders.

The permit completion process is outlined in Figure 2.

Figure 2. OVERVIEW OF ENERGIZED ELECTRICAL WORK PERMIT SYSTEM FOR LOW VOLTAGE (<600V) ELECTRICAL WORK		
Step	*Person*	*Action*
Planning		
1.	Qualified Worker	• Determines if the work can be conducted in a de-energized state. If it can be justified that it is not, and it meets the criteria requiring an Energized Electrical Work Permit, conducts a review of the hazards and associated controls with assistance, as necessary.
2.	Qualified Worker	• Verifies that all required equipment and personnel are available.
Pre-activity		
3.	Qualified Worker	• Documents the pre-activity process by completing the Energized Electrical Work Permit.
4.	Qualified Worker	• Ensures that the PPE to be worn and tools to be used are sufficient to protect employees from electrical shock and arc flash hazards and that all testing and calibrations are up to-date.
5.	Qualified Worker	• Secures the work site as appropriate by: ▪ Installing barriers and/or controls for vehicular and pedestrian traffic, as needed; ▪ Posting warning signs and any required permit(s) at the work location; and ▪ Taking measures to prevent additional hazards near the work area, including task lighting and protecting egress routes.
6.	Qualified Worker and Supervisor	• Conducts a pre-activity briefing for all personnel involved in the energized electrical equipment activity that includes at a minimum these topics: ▪ Work to be performed ▪ Anticipated hazards ▪ Hazard control measures, special precautions, PPE requirements • Verifies that all control measures, procedures and equipment specified in the Permit are in place. • Signs appropriate section of the Permit.
Activity		
7.	Qualified Worker	• Inspects and dons required PPE and performs work safely, using other protective equipment, as required.
8.	Safety Watch as deemed necessary by Supervisor.	• Observes Qualified Worker and operations being performed to help prevent unsafe acts. • Controls access to the area. • In an emergency, quickly de-energizes the equipment and alerts emergency personnel.
Post-activity / Documentation		
9.	Supervisor	• Keeps the Permit on file for a minimum of two years

Approach and Protection Boundaries

Where Work On or Near exposed energized equipment must occur, the series of three boundaries defined under NFPA 70E must be adhered to in order to prevent injury from shock or burns. Increased training, PPE and work practice hazard controls are required as the worker approaches the exposed energized components or crosses these boundaries.

The three boundaries are defined as follows:

- **Limited approach boundary** is the closest distance an Unqualified Worker can approach unless accompanied by and under the control of an appropriately trained Qualified Worker within which a shock hazard exists.
- **Restricted approach boundary** is the closest distance to exposed live parts that an appropriately trained and authorized Qualified Worker can go without additional PPE and insulated tools. When working this close, a slight error in movement could result in touching live parts.

Figure 1. Approach Boundaries to Energized Fixed Electrical Conductors or Circuit Parts for Shock Protection

Nominal System Voltage	*Limited Approach Boundary*	*Restricted Approach Boundary*
50 to 150V	3 ft 6 inch	Avoid Contact
151 to 750V	3 ft 6 inch	1 ft 0 inch
751 to 15 kV	5 ft	2 ft 2 inch
15.1 kV to 36 kV	6 ft	2 ft 9 inch
36.1 kV to 46 kV	8 ft	2 ft 9 inch

Extracted from NFPA 70E [See NFPA 70E Table 130.4 (D) (a)]

- **Arc flash protection boundary** an approach limit from an arc source at which incident energy equals 1.2 cal/cm². This is where unprotected skin will sustain at least a second-degree burn during an arc fault event. This distance is dependent on the short-circuit current available from the immediate upstream transformer, as well as the upstream device interruption time.
    - If an arc flash risk assessment has been performed, this distance will be shown on the label affixed to the cover of the equipment.
    - If no assessment has been performed, refer to *Attachment D* for the equipment-specific arc flash boundary requirements.

To prevent injury from shock or burns while working within the shock or arc flash approach boundaries, the following precautions must be taken:

- Check with your supervisor to determine if you are properly qualified to perform the specific work involved.
- Complete an *Energized Electrical Work Permit* when working on systems up to 600 volts.
- Use appropriate PPE, tools, and procedures for work on energized equipment. The *Energized Electrical Work Permit* and associated tables provides guidance on shock and arc flash protection requirements, as well as electrical safe work practices.
- Prior to working on energized circuits, the following conditions must be met:
    - Completion of a risk assessment and energized work justification by the Qualified Worker using the *Energized Electrical Work Permit*. The worker then submits the permit to his/ her supervisor for review, approval, rejection or re-editing.
    - Physical Plant employees – receipt of prior written authorization from the appropriate Facilities Manager
    - Utilities employees – review of work scope with Power Plant Manager for authorization.
    - Attendance at a documented job briefing (as outlined earlier in "Steps in de-energizing an electrical system").
    - Insulation of the energized part from the worker employee and from any other conductive object at a different potential.
    - Worker is insulated from any other exposed conductive object

High Voltage Energized Electrical Work

Performing energized electrical work on systems greater than 600 volts requires a special review and the risk of performing such work must be evaluated by a team. Prior to initiation of the work a task-specific plan must be written, such as a Utility Distribution Services Electrical Switching Order. An *Energized Electrical Work Permit* must be completed prior to the initiation of work. Contact your supervisor if you believe a system greater than 600 volts must be worked on in an energized state.

In these instances, at least two Qualified Workers must be present whenever work is being performed on AC circuits of 600 volts or higher within the restricted approach boundary or on exposed energized parts. One of the two Workers will be designated as the primary Worker on the permit. The primary Worker exercise central responsibility for implementation and coordination of the work covered by the permit. The second person is responsible for observing and assisting the primary Qualified Worker as well as ensuring safe work practices is followed, conducted properly, and alerting the primary Qualified Worker of any unsafe conditions that develop. In addition, a Safety Watch may be assigned.

Personal Protective Equipment

A variety of PPE may have to be worn to protect employees from electric shock, burns and arc flash hazards. This includes safety glasses, hearing protection, insulated safety shoes, leather gloves, rubber gloves and sleeves, non-conductive hardhat, arc rated clothing and arc flash shield and hood. PPE will

be provided my managers or supervisor for use by employees working in areas where they could be exposed to electrical hazards.

For shock hazards, PPE such as voltage-rated gloves and hardhat must be worn when working within the Restricted Approach Boundary (shown in the table previously).

For arc flash hazards on electrical equipment for which an Arc Flash Risk Assessment has been performed, the labeling will identify the Arc Flash Boundary, the incident energy and the corresponding working distance needed to safely work on the equipment. In addition to the required arc flash hazard label, a color-coded sticker will also be placed on the equipment cover or door. This sticker will be either blue or red and have the following meanings.

- Blue: A blue sticker denotes an incident energy less than or equal to 8 cal/cm^2. Arc rated clothing of at least this level of protection, along with basic PPE, will be sufficient to safely operate and work on this type of gear.
- Red: A red sticker denotes an incident energy greater than 8 cal/cm^2. No work shall be conducted on this equipment without the development of a detailed Method of Procedure (MOP) and upstream de-energization. Required PPE will be evaluated on a case-by-case basis based upon the voltage class and hazards identified in the MOP.

For arc flash hazards on electrical equipment for which an Arc Flash Risk Assessment has not been performed, refer to *Attachment C* for arc flash hazard identification (whether PPE is required or not) and then *Attachment D* for the equipment-specific arc flash hazard PPE category. The specific PPE worn will be as defined in *Attachment E* for PPE categories.

PPE must be visually inspected prior to use and after any work performed that could damage the equipment. Any rubber protective equipment found to be defective (e.g., tears, holes, punctures, or cuts) must be removed from service and tagged “do not use - defective”. Rubber protective equipment must be kept clean and dry and stored in a manner that protects the rubber protective equipment from light, temperature extremes, excessive humidity, ozone, and other injurious substances and conditions. Rubber gloves should be stored cuff down in a bag, box, or container that is designed for rubber glove storage. Rubber gloves may be kept inside of leather protectors.

Rubber-insulated PPE must undergo periodic electrical testing in accordance with the requirements of applicable ANSI/ASTM standards. The intervals of retest for rubber goods issued for service must not be more than 6 months for gloves and 12 months for sleeves and blankets. Gloves and blankets must be marked with either the date tested or with the date the next test is due. Gloves or sleeves that have been electrically tested but not issued for service must not be placed into service unless they have been so retested within the previous 12 months.

Each employee who may be exposed to the hazards of an arc flash must not wear clothing (including undergarments) that, when exposed to flames or electrical arcs, could increase the extent of injury. The

following materials, either alone or in blends, are prohibited: acetate, nylon, polyester, polypropylene and spandex.

At a minimum, PPE with an arc rating of 8 cal/cm^2 will be required at all times by any individual (this applies to all Yale personnel and outside contractors / vendors) entering the labeled switchgear rooms. All electrical switchgear rooms within the power plants will be labeled with a sign, “Warning, Qualified Personnel Only”. Entry and exit to all switchgear rooms shall also be monitored by the operating shift on duty. All personnel performing work on the switchgear shall follow appropriate PPE as labeled on the gear.

Electrical Tools and Equipment

Equipment used while conducting electrical work includes insulated blankets, matting or isolation barriers, and electrically-insulated hand tools. Electrical tools must be specifically approved, rated, and tested for the voltages they may be used on. All equipment must be inspected before use by the Qualified Worker. If equipment is found with tears, holes, punctures, or cuts, remove them from service and tag “do not use, defective”. Electrical insulating equipment must be stored flat, undistorted, right side out, and unfolded. Blankets may be stored rolled provided the inner diameter of the roll is at least 2 inches.

Maximum usage voltage phase-to-phase or phase-to-ground for insulating blankets, mats, covers, line-hose, sleeves, and gloves is as follows:

Class	Max Use Voltage (AC)
00	500
0	1,000
1	7,500
2	17,000

Requirements for Equipment Safety

Equipment installed must be listed or labeled by a Nationally Recognized Testing Laboratory (such as Underwriters Laboratories, Inc. (UL)). 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. 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.

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.

Isolation and Grounding

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

Clearances Around Electrical Equipment

Maintain clearance spaces 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. Clearances must be in accordance with OSHA, NEC, and the National Electrical Safety Code (NESC). These working clearances are not required if the equipment is unlikely 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 other items.

Clearances - Electrical Equipment Rated at 600 Volts or Less

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

Some buildings at Yale University, because of their age, have power and lighting circuit breaker panels that were installed prior to present working clearance codes and regulations. These installations may be acceptable, but must be evaluated to determine if additional safety measures are necessary. Contact your supervisor or electrical manager. If a reduction in clearance is granted, a sign stating “Caution - Inadequate Working Clearance” will be attached to the equipment.

Clearances - Electrical Equipment Rated at More Than 600 Volts

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

Medical Requirements

Employees working in close proximity or directly on electrical circuits are expected to be physically fit with no medical conditions that could be aggravated, or cause the employee harm. Employees with any questions about their health and electricity should contact their personal physician or the Employee Health Office at (203) 432-0071.

Program Review

Facilities Operations and Yale Environmental Health and Safety will periodically review the electrical safety program and procedures to ensuring procedures are being followed and requirements are met.

Contractors and Vendors (Outside Service Personnel)

Contractors, vendors, and other visitors are responsible for their own health and safety programs, including programs for any energized electrical work. Their programs must meet applicable and current OSHA Regulations, and the requirements of this Program, at the minimum. University contacts and liaisons with contractors and vendors are responsible for sharing information about known hazards related to the facility that may impact the contractor's work prior to the work. Yale will report observed contractor-related violations to the contractor. All contractors, vendors and their employees are expected to adhere to all PPE requirements for entry and work on electrical switchgear when marked. Failure to follow these requirements will be subject to any penalty clauses in contract documents.

The contractor will advise Yale of:

- Any unique hazard(s) presented by the contract work,
- Any unanticipated hazards found during the contract work that Yale did not mention, and
- Measure(s) the contractor took to correct any violations reported by Yale and to prevent such violation from recurring in the future.
- Justification for all proposed energized work.

Additional information for contractors and Yale employees who direct or interface with contractor activities may be found in the University's Contractor Health & Safety Guidelines.

Attachment A – Revision History

Date	Action
2011	Program drafted for Facilities Safety Manual
July & Aug 2013	Revised by FacOps and EHS
Aug 26, 2013	Issued final version
November 2013	Utilities Comments
January 2014	Final Utilities Comments
February 2014	Incorporating PP Comments, Final Version Issued
December 2014	Updated Facilities Comments
March 2016	Accepted edits/changes
September 2016	Outside consultant review
December 2016	Consultant review updates
February 2017	Updates based on input from Physical Plant and Working Group
March 2017	Updated based on input from Utilities
May 2017	Updates to task matrices (Attachment G)
August 2018	Formatting and updates to matrices (Attachment G)
April 2019	Aligning training / work practices with Attachment G. Changing Qualified Electrical Worker to Qualified Worker
May 2019	Elimination of Qualified Utilities Operators category
June 2019	Formatting
July 2019	Consultant review updates
August 2019	Formatting and updated permit

Attachment B –Energized Electrical Work Permit

Energized Electrical Work Permit

8/5/2019

1. General Information

Location/Worksite:	Work Area:	Work Order #:
Start Date:	Start Time:	Expected Duration:
Description of Circuit/Equipment:		
Scope of Work:		

Personnel Involved/Impacted (check all that apply):	☐Facilities Operations	☐Utilities	☐Engineering	☐Emergency Contractor
	☐Contractor(s)/Other(s) (list):			

Requestor Information

Name:	Title:
Signature:	Date of Request:

2. Justification for Request

Person Completing the Justification:
Detailed analysis on why the circuit/equipment cannot be de-energized or the work deferred to the next scheduled outage:

3. Shock Hazard Analysis

Person Completing the Analysis:		
Nominal Voltage:	Maximum Voltage:	Glove Voltage Rating:
Limited Approach Boundary (feet):	Restricted Approach Boundary (feet):	
Comments:		

4. Flash Hazard Analysis

Person Completing the Analysis:	
Flash Protection Boundary (feet):	Hazard Category:
Comments:	

5. Personal Protective Equipment (check all that apply)

☐Arc-Flash PPE Category:		☐Insulating sleeves	☐Balaclava sock hood	☐FR vest
☐Hardhat	☐EH safety shoes	☐Arc flash face shield	☐FR pants	☐FR hat liner
☐Ear plugs/muffs	☐Rated insulating gloves	☐Ear and neck wrap	☐FR long sleeve shirt	☐Other (list):
☐Safety glasses with side shields	☐Leather gloves Leather protectors	☐Arc flash suit hood	☐FR jacket	

6. Safe Work Practices (check all that apply)

☐Restricted access	☐Non-conductive lighting	☐Insulated tools	☐Communication method (list):
☐Warning signs/tags	☐Non-conductive fuse puller	☐Insulated mat	☐Tools for release/emergency equipment (list):
☐Barricades and shields	☐Non-conductive ladder	☐Insulated blanket	☐Other work practices:
☐Means to secure doors/panels	☐Protective grounding set	☐Test equipment	

7. Pre-Job Requirements (check all that apply)

☐Review diagrams, work orders, manuals	☐Remove conductive apparel/jewelry	☐Test equipment	☐Install protective barriers	☐Safety watch assignment

☐Notify affected personnel	☐Determine safe body positioning	☐Don PPE	☐Inspect PPE, insulating materials and tools	☐Other pre-job requirements:
☐Conduct job briefing	☐Install warning signs/tags	☐Utilities employees obtain authorization from the appropriate plant manager	☐Facilities Operations employees obtain authorization from the appropriate facilities manager	
☐Restricted access to unqualified personnel	☐Determine equipment, tools and PPE needed			
8. Post-Job Requirements (check all that apply)				
☐Visually inspect the work area	☐Label circuits and panels	☐Stow tools, PPE, and insulating materials	☐Tag hazardous, defective or damaged equipment	☐Notify affected personnel
☐Remove tools, jumpers and insulating barriers	☐Re-install covers/panels and guard doors	☐Remove signs and barriers	☐Clean up work area	☐Return closed permits to supervisor
☐Return interlocks to operable condition	☐Other post-job requirements:			
9. Personnel Involved				
Qualified Worker(s):				
Safety Watch:				
Comments:				
10. Approvals				
	Name	Title	Approve/Disapprove (check one)	Signature/Date/Time
Utilities or Facilities Manager (if applicable)			☐Approved[1] ☐Disapproved[2]	
Engineering (if applicable)			☐Approved[1] ☐Disapproved[2]	
Supervisor			☐Approved[1] ☐Disapproved[2]	
11. Permit Closure				
☐Job complete	☐Permit received by supervisor (retain for at least 2 years)		Supervisor Name:	

1. *Permit approved based on the information and requirements provided.*
2. *Permit denied and requires de-energized work.*

Attachment C – Arc Flash Hazard Identification

Table 130.5(C) Estimate of the Likelihood of Occurrence of an Arc Flash Incident for ac and dc Systems

Task	Equipment Condition	Likelihood of Occurrence*
Reading a panel meter while operating a meter switch. Performing infrared thermography and other non-contact inspections outside the restricted approach boundary. This activity does not include opening of doors or covers. Working on control circuits with exposed energized electrical conductors and circuit parts, nominal 125 volts ac or dc, or below without any other exposed energized equipment over nominal 125 volts ac or dc, including opening of hinged covers to gain access. Examination of insulated cable with no manipulation of cable. For dc systems, insertion or removal of individual cells or multi-cell units of a battery system in an open rack. For dc systems, maintenance on a single cell of a battery system or multi-cell units in an open rack.	Any	No
For ac systems, work on energized electrical conductors and circuit parts, including voltage testing. For dc systems, working on energized electrical conductors and circuit parts of series-connected battery cells, including voltage testing. Removal or installation of CBs or switches. Opening hinged door(s) or cover(s) or removal of bolted covers (to expose bare, energized electrical conductors and circuit parts). For dc systems, this includes bolted covers, such as battery terminal covers. Application of temporary protective grounding equipment, after voltage test. Working on control circuits with exposed energized electrical conductors and circuit parts, greater than 120 volts. Insertion or removal of individual starter buckets from motor control center (MCC). Insertion or removal (racking) of circuit breakers (CBs) or starters from cubicles, doors open or closed. Insertion or removal of plug-in devices into or from busways. Examination of insulated cable with manipulation of cable. Working on exposed energized electrical conductors and circuit parts of equipment directly supplied by a panelboard or motor control center. Insertion or removal of revenue meters (kW-hour, at primary voltage and current). Removal of battery conductive intercell connector covers. For dc systems, working on exposed energized electrical conductors and circuit parts of utilization equipment directly supplied by a dc source. Opening voltage transformer or control power transformer compartments. Operation of outdoor disconnect switch (hookstick operated) at 1 kV through 15 kV. Operation of outdoor disconnect switch (gang-operated, from grade) at 1 kV through 15 kV.	Any	Yes
Operation of a CB, switch, contactor, or starter. Voltage testing on individual battery cells or individual multi-cell units. Removal or installation of covers for equipment such as wireways, junction boxes, and cable trays that does not expose bare, energized electrical conductors and circuit parts. Opening a panelboard hinged door or cover to access dead front overcurrent devices. Removal of battery nonconductive intercell connector covers.	Normal	No
Maintenance and testing on individual battery cells or individual multi-cell units in an open rack Insertion or removal of individual cells or multi-cell units of a battery system in an open rack. Arc-resistant switchgear Type 1 or 2 (for clearing times of less than 0.5 sec with a prospective fault current not to exceed the arc-resistant rating of the equipment) and metal enclosed interrupter switchgear, fused or unfused of arc resistant type construction, 1 kV through 15 kV. Insertion or removal (racking) of CBs from cubicles; Insertion or removal (racking) of ground and test device; or Insertion or removal (racking) of voltage transformers on or off the bus.	Abnormal	Yes

(continues)

Table 130.5(C) *Continued*

Task	Equipment Condition	Likelihood of Occurrence*
Equipment condition considered to be "normal" if all of the following circumstances apply: (1) The equipment is properly installed in accordance with the manufacturer's recommendations and applicable industry codes and standards. (2) The equipment is properly maintained in accordance with the manufacturer's recommendations and applicable industry codes and standards. (3) The equipment is used in accordance with instructions included in the listing and labeling and in accordance with manufacturer's instructions. (4) Equipment doors are closed and secured. (5) Equipment covers are in place and secured. (6) There is no evidence of impending failure such as arcing, overheating, loose or bound equipment parts, visible damage, or deterioration.		

*As defined in this standard, the two components of risk are the likelihood of occurrence of injury or damage to health and the severity of injury or damage to health that results from a hazard. Risk assessment is an overall process that involves estimating both the likelihood of occurrence and severity to determine if additional protective measures are required. The estimate of the likelihood of occurrence contained in this table does not cover every possible condition or situation, nor does it address severity of injury or damage to health. Where this table identifies "No" as an estimate of likelihood of occurrence, it means that an arc flash incident is not likely to occur. Where this table identifies "Yes" as an estimate of likelihood of occurrence, it means that additional protective measures are required to be selected and implemented according to the hierarchy of risk control identified in 110.1(H).

Informational Note No. 1: An example of a standard that provides information for arc-resistant switchgear referred to in Table 130.5(C) is IEEE C37.20.7, *Guide for Testing Metal-Enclosed Switchgear Rated Up to 38 kV for Internal Arcing Faults.*

Informational Note No. 2: Improper or inadequate maintenance can result in increased fault clearing time of the overcurrent protective device, thus increasing the incident energy. Where equipment is not properly installed or maintained, PPE selection based on incident energy analysis or the PPE category method might not provide adequate protection from arc flash hazards.

Informational Note No. 3: Both larger and smaller available fault currents could result in higher incident energy. If the available fault current increases without a decrease in the fault clearing time of the overcurrent protective device, the incident energy will increase. If the available fault current decreases, resulting in a longer fault clearing time for the overcurrent protective device, incident energy could also increase.

Informational Note No. 4: The occurrence of an arcing fault inside an enclosure produces a variety of physical phenomena very different from a bolted fault. For example, the arc energy resulting from an arc developed in the air will cause a sudden pressure increase and localized overheating. Equipment and design practices are available to minimize the energy levels and the number of procedures that could expose an employee to high levels of incident energy. Proven designs such as arc-resistant switchgear, remote racking (insertion or removal), remote opening and closing of switching devices, high-resistance grounding of low-voltage and 5000-volt (nominal) systems, current limitation, and specification of covered bus or covered conductors within equipment are available to reduce the risk associated with an arc flash incident. See Informative O for safety-related design requirements.

Informational Note No. 5: For additional direction for performing maintenance on overcurrent protective devices, see Chapter 2, Safety-Related Maintenance Requirements.

Informational Note No. 6: See IEEE 1584, *Guide for Performing Arc Flash Calculations*, for more information regarding incident energy and the arc flash boundary for three-phase systems.

Attachment D – Arc Flash Hazard PPE Categories (AC)

Table 130.7(C)(15)(a) Arc-Flash PPE Categories for Alternating Current (ac) Systems

Equipment	Arc-Flash PPE Category	Arc-Flash Boundary
Panelboards or other equipment rated 240 volts and below Parameters: Maximum of 25 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	1	485 mm (19 in.)
Panelboards or other equipment rated greater than 240 volts and up to 600 volts Parameters: Maximum of 25 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	2	900 mm (3 ft)
600-volt class motor control centers (MCCs) Parameters: Maximum of 65 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	2	1.5 m (5 ft)
600-volt class motor control centers (MCCs) Parameters: Maximum of 42 kA available fault current; maximum of 0.33 sec (20 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	4	4.3 m (14 ft)
600-volt class switchgear (with power circuit breakers or fused switches) and 600-volt class switchboards Parameters: Maximum of 35 kA available fault current; maximum of up to 0.5 sec (30 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	4	6 m (20 ft)
Other 600-volt class (277 volts through 600 volts, nominal) equipment Parameters: Maximum of 65 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	2	1.5 m (5 ft)
NEMA E2 (fused contactor) motor starters, 2.3 kV through 7.2 kV Parameters: Maximum of 35 kA available fault current; maximum of up to 0.24 sec (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.)	4	12 m (40 ft)
Metal-clad switchgear, 1 kV through 15 kV Parameters: Maximum of 35 kA available fault current; maximum of up to 0.24 sec (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.)	4	12 m (40 ft)
Arc-resistant switchgear 1 kV through 15 kV [for clearing times of less than 0.5 sec (30 cycles) with an available fault current not to exceed the arc-resistant rating of the equipment], and metal-enclosed interrupter switchgear, fused or unfused of arc-resistant-type construction, 1 kV through 15 kV Parameters: Maximum of 35 kA available fault current; maximum of up to 0.24 sec (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.)	N/A (doors closed) 4 (doors open)	N/A (doors closed) 12 m (40 ft)
Other equipment 1 kV through 15 kV Parameters: Maximum of 35 kA available fault current; maximum of up to 0.24 sec (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.)	4	12 m (40 ft)

Note: For equipment rated 600 volts and below and protected by upstream current-limiting fuses or current-limiting circuit breakers sized at 200 amperes or less, the arc flash PPE category can be reduced by one number but not below arc flash PPE category 1.

Informational Note to Table 130.7(C)(15)(a): The following are typical fault clearing times of overcurrent protective devices:

(1) 0.5 cycle fault clearing time is typical for current limiting fuses when the fault current is within the current limiting range.

(2) 1.5 cycle fault clearing time is typical for molded case circuit breakers rated less than 1000 volts with an instantaneous integral trip.

(3) 3.0 cycle fault clearing time is typical for insulated case circuit breakers rated less than 1000 volts with an instantaneous integral trip or relay operated trip.

(4) 5.0 cycle fault clearing time is typical for relay operated circuit breakers rated 1 kV to 35 kV when the relay operates in the instantaneous range (i.e., "no intentional delay").

(5) 20 cycle fault clearing time is typical for low-voltage power and insulated case circuit breakers with a short time fault clearing delay for motor inrush.

(6) 30 cycle fault clearing time is typical for low-voltage power and insulated case circuit breakers with a short time fault clearing delay without instantaneous trip.

Informational Note No. 1: See Table 1 of IEEE 1584TM, *Guide for Performing Arc Flash Hazard Calculations*, for further information regarding Notes b through d.

Informational Note No. 2: An example of a standard that provides information for arc-resistant switchgear referred to in Table 130.7(C)(15)(a) is IEEE C37.20.7, *Guide for Testing Metal-Enclosed Switchgear Rated Up to 38 kV for Internal Arcing Faults.*

Table 130.7(C)(15)(b) Arc-Flash PPE Categories for Direct Current (dc) Systems

Equipment	Arc-Flash PPE Category	Arc-Flash Boundary
Storage batteries, dc switchboards, and other dc supply sources Parameters: Greater than or equal to 100 V and less than or equal to 250 V Maximum arc duration and minimum working distance: 2 sec @ 455 mm (18 in.)		
Available fault current less than 4 kA	2	900 mm (3 ft)
Available fault current greater than or equal to 4 kA and less than 7 kA	2	1.2 m (4 ft)
Available fault current greater than or equal to 7 kA and less than 15 kA	3	1.8 m (6 ft)
Storage batteries, dc switchboards, and other dc supply sources Parameters: Greater than 250 V and less than or equal to 600 V Maximum arc duration and minimum working distance: 2 sec @ 455 mm (18 in.)		
Available fault current less than 1.5 kA	2	900 mm (3 ft)
Available fault current greater than or equal to 1.5 kA and less than 3 kA	2	1.2 m (4 ft)
Available fault current greater than or equal to 3 kA and less than 7 kA	3	1.8 m (6 ft.)
Available fault current greater than or equal to 7 kA and less than 10 kA	4	2.5 m (8 ft)

Notes

(1) Apparel that can be expected to be exposed to electrolyte must meet both of the following conditions:

(a) Be evaluated for electrolyte protection

Informational Note: ASTM F1296, *Standard Guide for Evaluating Chemical Protective Clothing*, contains information on evaluating apparel for protection from electrolyte.

(b) Be arc-rated

Informational Note: ASTM F1891, *Standard Specifications for Arc Rated and Flame Resistant Rainwear*, contains information on evaluating arc-rated apparel.

(2) A two-second arc duration is assumed if there is no overcurrent protective device (OCPD) or if the fault clearing time is not known. If the fault clearing time is known and is less than 2 seconds, an incident energy analysis could provide a more representative result.

Informational Note No. 1: When determining available fault current, the effects of cables and any other impedances in the circuit should be included. Power system modeling is the best method to determine the available short-circuit current at the point of the arc. Battery cell short-circuit current can be obtained from the battery manufacturer. See Informative Annex D.5 for the basis for table values and alternative methods to determine dc incident energy. Methods should be used with good engineering judgment.

Informational Note No. 2: The methods for estimating the dc arc-flash incident energy that were used to determine the categories for this table are based on open-air incident energy calculations. Open-air calculations were used because many battery systems and other dc process systems are in open areas or rooms. If the specific task is within an enclosure, it would be prudent to consider additional PPE protection beyond the value shown in this table. Research with ac arc flash has shown a multiplier of as much as 3× for arc-in-a-box [508 mm (20 in.) cube] versus open air. Engineering judgment is necessary when reviewing the specific conditions of the equipment and task to be performed, including the dimensions of the enclosure and the working distance involved.

Attachment E – Personal Protective Equipment by Category

Table 130.7(C)(15)(c) Personal Protective Equipment (PPE)

Arc-Flash PPE Category	PPE
1	**Arc-Rated Clothing, Minimum Arc Rating of 4 cal/cm² (16.75 J/cm²)[a]** Arc-rated long-sleeve shirt and pants or arc-rated coverall Arc-rated face shield[b] or arc flash suit hood Arc-rated jacket, parka, rainwear, or hard hat liner (AN) **Protective Equipment** Hard hat Safety glasses or safety goggles (SR) Hearing protection (ear canal inserts)[c] Heavy-duty leather gloves[d] Leather footwear (AN)
2	**Arc-Rated Clothing, Minimum Arc Rating of 8 cal/cm² (33.5 J/cm²)[a]** Arc-rated long-sleeve shirt and pants or arc-rated coverall Arc-rated flash suit hood or arc-rated face shield[b] and arc-rated balaclava Arc-rated jacket, parka, rainwear, or hard hat liner (AN) **Protective Equipment** Hard hat Safety glasses or safety goggles (SR) Hearing protection (ear canal inserts)[c] Heavy-duty leather gloves[d] Leather footwear
3	**Arc-Rated Clothing Selected so That the System Arc Rating Meets the Required Minimum Arc Rating of 25 cal/cm² (104.7 J/cm²)[a]** Arc-rated long-sleeve shirt (AR) Arc-rated pants (AR) Arc-rated coverall (AR) Arc-rated arc flash suit jacket (AR) Arc-rated arc flash suit pants (AR) Arc-rated arc flash suit hood Arc-rated gloves[d] Arc-rated jacket, parka, rainwear, or hard hat liner (AN) **Protective Equipment** Hard hat Safety glasses or safety goggles (SR) Hearing protection (ear canal inserts)[c] Leather footwear
4	**Arc-Rated Clothing Selected so That the System Arc Rating Meets the Required Minimum Arc Rating of 40 cal/cm² (167.5 J/cm²)[a]** Arc-rated long-sleeve shirt (AR) Arc-rated pants (AR) Arc-rated coverall (AR) Arc-rated arc flash suit jacket (AR) Arc-rated arc flash suit pants (AR) Arc-rated arc flash suit hood Arc-rated gloves[d] Arc-rated jacket, parka, rainwear, or hard hat liner (AN) **Protective Equipment** Hard hat Safety glasses or safety goggles (SR) Hearing protection (ear canal inserts)[c] Leather footwear

AN: As needed (optional). AR: As required. SR: Selection required.

[a]*Arc rating* is defined in Article 100.

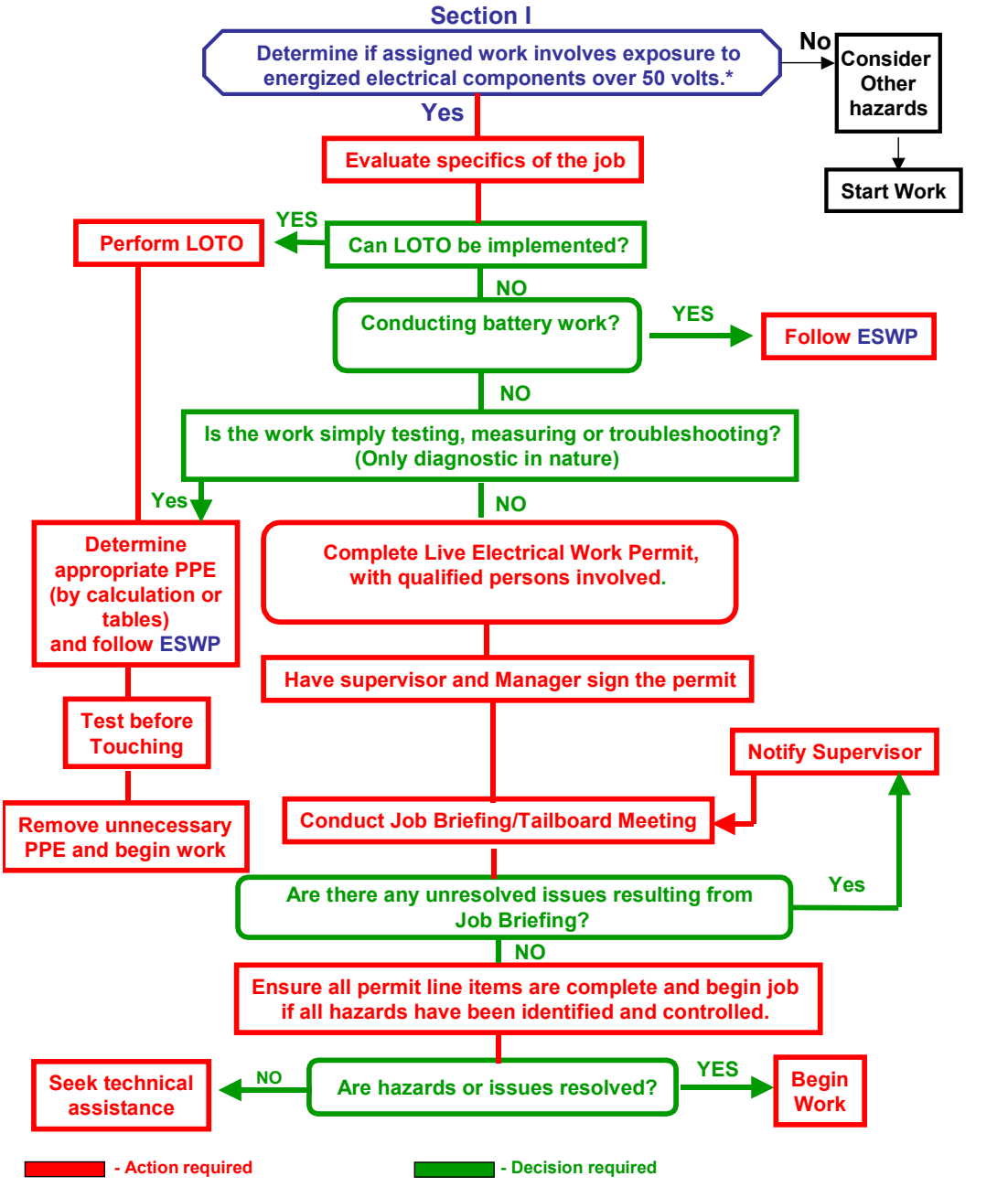
[b]Face shields are to have wrap-around guarding to protect not only the face but also the forehead, ears, and neck, or, alternatively, an arc-rated arc flash suit hood is required to be worn.

[c]Other types of hearing protection are permitted to be used in lieu of or in addition to ear canal inserts provided they are worn under an arc-rated arc flash suit hood.

[d]If rubber insulating gloves with leather protectors are used, additional leather or arc-rated gloves are not required. The combination of rubber insulating gloves with leather protectors satisfies the arc flash protection requirement.

Attachment F – Electrical Hazard Risk Evaluation

STEP-BY-STEP ELECTRICAL HAZARD/RISK EVALUATION



ESWP=Electrical Safe Work Practices
*LOTO electrically safe work condition verification step is considered work on energized parts

Attachment G – Electrical Task Matrix

Facilities Operations Electrical Task Matrix

Item No.	Job Task / Function	*Qualified Worker*							*Unqualified Worker*
		Facilities Electrician	Equipment, Refrigeration, Oil Burner Mechanic	General Building Mechanic	Fire Mechanics	Controls Mechanic	Electrical-Supervisor (emergency only)	Equipment/ Control Supervisors (emergency only)	Plumbers Millworkers Carpenters Locksmith Masons Glaziers Painters Structural Trade - Supervisors Plumbing - Supervisors
1	Open/Close 110V/208V Breakers & Disconnects	Yes					Yes		
2	Open/Close 480V Breakers & Disconnects	Yes					Yes		
3	Reset tripped breakers 110V; 15 and 20 amp	Yes	Yes (once and report)	Yes (once and report)			Yes		
4	Reset tripped breakers 110V; 30 amp or larger	Yes					Yes		
	Reset tripped breakers 110V/ 208V above 20 amps	Yes					Yes		
5	Reset tripped breakers 480V & Disconnects	Yes					Yes		
6	Reset tripped breakers/disconnects 5KV & 15KV	Yes							
7	Operate / Manipulate Synch Panel	Yes							
8	LO/TO 600V and less	Yes	Yes	Yes	Yes	Yes	Yes		
9	LO/TO 5kV and Higher	Yes							
10	Electrical Installation, Repairs / Preventative Maintenance (the need to open / access energized and/or de-energized sections of gear) with authorized permit	Yes (2 QW when energized)							
11	Electrical Installation, Repairs / Preventative Maintenance (the need to open / access energized and/or de-energized sections of VFD's, Controllers, PLC's)	Yes	Yes			Yes	Yes	Yes	
12	Troubleshooting - Visual	Yes	Yes		Yes	Yes	Yes	Yes	
13	Troubleshooting - Use of electrical testing instruments / access energized	Yes	Yes		Yes	Yes	Yes	Yes	

Item No.	Job Task / Function	***Qualified Worker***							***Unqualified Worker***
		Facilities Electrician	Equipment, Refrigeration, Oil Burner Mechanic	General Building Mechanic	Fire Mechanics	Controls Mechanic	Electrical-Supervisor (emergency only)	Equipment/ Control Supervisors (emergency only)	Plumbers Millworkers Carpenters Locksmith Masons Glaziers Painters Structural Trade - Supervisors Plumbing - Supervisors
	sections of electrical equipment								
14	Troubleshooting - Use of electrical testing instruments / access energized sections of VFD's, Controllers, PLC's	Yes	Yes			Yes	Yes	Yes	
15	Clear Protective Relay alarms/lockouts	Yes					Yes		
16	Download / Access protective relay information (DPU's, etc.)	Yes					Yes		
17	Communicate with UI	Yes					Yes		
18	Racking Breakers In/Out - 600V or less	Yes							
19	Controls / Low Voltage Maintenance (less than 50V), Testing, Calibration	Yes	Yes		Yes	Yes	Yes	Yes	
20	Attendant - Safety Watch (600V and less)	Yes	Yes (associated with specific equipment)			Yes (associated with specific equipment	Yes		
21	Non-invasive maintenance of electrical equipment (i.e., changing filters, changing lamps, etc.)	Yes	Yes		Yes	Yes	Yes		

Utilities Operations Electrical Task Matrix

Item No.	Job Task	*Qualified Worker*						*Unqualified Worker*
		Facilities Electrician	Maintenance Controls	Operator	Distribution	Plant Management	Maintenance - Mechanical	Engineering Staff
		Utilities Electrician, HV Electrician	Controls Mechanic	Watch Engineer, Day Watch Engineer, Oiler, UPOT, UBIM	UPOT, Mechanic	Plant Manager, Assistant Plant Manager, Distribution Manager, Plant Engineer	Mechanic	Engineer
1	Open/Close 110V/208V Breakers & Disconnects	Yes	Yes	Yes	Yes	Yes	Yes	
2	Open/Close 600V and less Breakers & Disconnects	Yes	Yes	Yes	Yes	Yes	Yes	
3	Open/Close 5KV Breakers & Disconnects (Local/Remote)	Local (2 people) / Remote		Remote (DCS)		Remote via DCS (preferred) or Local (2 people)		
4	Open/Close 15KV Breakers & Disconnects (Local/Remote)	Local (2 People) / Remote		Remote (DCS)		Remote via DCS (preferred) or Local (2 people)		
5	Reset tripped breakers 110V/208V	Yes	Yes	Yes	Yes	Yes		
6	Reset tripped breakers 600V and less & Disconnects	Yes		Yes	Yes	Yes		
7	Reset tripped breakers/disconnects 5KV & 15KV	Yes				Yes		
8	Operate / Manipulate Synch Panel	Yes		Yes		Yes		
9	LO/TO 600V and less	Yes	Yes (single lock LOTO)	Yes	Yes	Yes	Yes (single lock LOTO)	
10	LO/TO 5kV and Higher	Yes				Yes		
11	Electrical Installation, Repairs / Preventative Maintenance (the need to open / access energized and/or de-energized sections of gear)	Yes						
12	Electrical Installation, Repairs / Preventative Maintenance (the need to open / access energized and/or de-energized	Yes	Yes	Yes (UBIM only)			Yes	

Item No.	Job Task	***Qualified Worker***						***Unqualified Worker***
		Facilities Electrician	Maintenance Controls	Operator	Distribution	Plant Management	Maintenance - Mechanical	Engineering Staff
		Utilities Electrician, HV Electrician	Controls Mechanic	Watch Engineer, Day Watch Engineer, Oiler, UPOT, UBIM	UPOT, Mechanic	Plant Manager, Assistant Plant Manager, Distribution Manager, Plant Engineer	Mechanic	Engineer
	sections of VFD's, Controllers, PLC's)							
13	Troubleshooting - Visual	Yes	Yes	Yes	Yes	Yes	Yes	Yes
14	Troubleshooting - Use of electrical testing gear / access energized sections of gear	Yes						
15	Troubleshooting - Use of electrical testing gear / access energized sections of VFD's, Controllers, PLC's	Yes	Yes	Yes (UBIM only)				
16	Clear Protective Relay alarms/lockouts	Yes		Yes	Yes	Yes		Yes
17	Download / Access protective relay information (DPU's, etc.)	Yes				Yes		Yes
18	Communicate with UI			Yes		Yes		Yes
19	Racking Breakers In/Out - all Voltage Levels	Yes						
20	Controls / Low Voltage Maintenance (less than 50V), Testing, Calibration	Yes	Yes					
21	DCS Programming		Yes			Yes		
22	Attendant - Safety Watch (600V and less)	Yes	Yes	Yes	Yes	Yes	Yes	
23	Attendant - Safety Watch (5kV and higher)	Yes				Yes		
24	Non-invasive maintenance of electrical equipment (i.e., greasing motors)	Yes	Yes	Yes	Yes		Yes	