LPR 1710.6K

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Langley Research Center

ELECTRICAL SAFETY

National Aeronautics and Space Administration

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Responsible Office: Safety and Mission Assurance Office

PREFACE

P.1 PURPOSE

a. This Langley Research Center (LaRC) Procedural Requirement (LPR) sets forth minimum electrical safety requirements and standards within the framework of LaRC safety policies and constraints.

1) It shall be used by professionals routinely engaged in electrical work.

2) It shall not be used as an instruction manual for untrained personnel.

3) It shall not be used as a substitute for detailed procedures judged necessary for the safe conduct of a specific task by individuals and their supervisors.

b. These procedural requirements contain both guidance and requirements for the assurance of safe working environments for professionals routinely engaged in electrical work at LaRC.

P.2 APPLICABILITY

a. These procedural requirements apply to all persons performing work at LaRC, including civil servants, contractors, research associates, and others.

b. Non-compliance with this LPR will result in appropriate disciplinary action that may include termination for a civil servant employee or exclusion from the Center for a contractor employee.

c. LaRC is a multi-building industrial complex, whereby electrical power is obtained from the local electrical utility and distributed to the various buildings and facilities via a Center-owned and operated power distribution system composed of industrial substations, high-voltage cabling, and power distribution equipment. For the application of referenced codes, standards, and regulations in this document, the “service points” for buildings and facilities at LaRC are identified on Effort Code 300 Switching Diagrams, which are described in Section 3.3.1. The power distribution system up to the “service point” is covered by ANSI/IEEE C2- NESC, and electrical installations beyond the “service point” are covered by the NFPA 70, “National Electrical Code (NEC).” NFPA 70E is applicable for the same installations covered by the NEC.

P.3 AUTHORITY

a. National Fire Protection Association (NFPA) 70, National Electrical Code (NEC)

b. NFPA 70B, “Recommended Practice for Electrical Equipment Maintenance”

c. NFPA 70E, “Standard for Electrical Safety in the Workplace”

d. American National Standards Institute/Institute of Electrical and Electronic Engineers C2- National Electrical Safety Code (ANSI/IEEE C2-NESC)

e. Occupational Health and Safety Administration (OSHA) 29 Code of Federal Regulations (CFR) 1910.147 of Subpart J

f. OSHA 29 CFR 1910.269 of Subpart R

g. OSHA 29 CFR 1910, Subpart S

h. OSHA 29 CFR 1926, Subpart K – Electrical

i. OSHA 29 CFR 1926.550 of Subpart N – Cranes and Derricks

j. OSHA 29 CFR 1926, Subpart V – Power Transmission and Distribution

k. National Electrical Manufacturer's Association (NEMA)

l. Electronic Industries Association (EIA)

m. The Insulated Power Cable Engineers Association (IPCEA) and Association of Edison Illuminating Companies (AEIC)

n. Institute of Electrical and Electronic Engineers, Inc. (IEEE)

o. American National Standards Institute (ANSI)

p. Instrumentation, Systems, and Automation (ISA) Society

P.4 APPLICABLE DOCUMENTS AND FORMS

a. NASA Procedural Requirement (NPR) 8715.3, “NASA General Safety Program Requirements”

b. Langley Policy Directive (LAPD) 1150.2, “Councils, Boards, Panels, Committees, Teams, and Groups”

c. LAPD 1700.2, “Safety Assignments and Responsibilities”

d. LPR 1710.10, “Langley Research Center Energy Control Program (Lockout/Tagout)”

e. LPR 1740.2, “Facility Safety Requirements”

f. LPR 1740.4, “Facility System Safety Analysis and Configuration Management”

g. LPR 1740.6, “Personnel Safety Certification”

h. Langley Form (LF) 60, "Confined Space Entry Permit”

i. LF 416, “LaRC Energized Electrical Work Permit”

j. LF 453, “NASA Langley Safety Operators Permit”

k. LF 495, “Energy Control Procedure”

P.5 MEASUREMENT/VERIFICATION

None

P.6 CANCELLATION

LPR 1710.6, dated December 2, 2008, is rescinded and should be destroyed.

Original signed on file

David E. Bowles
Deputy Director

Distribution:

Approved for public release via the Langley Management System; distribution is unlimited.

1. WORK REQUIREMENTS

1.1 ELECTRICAL SAFETY PROGRAM PRINCIPLES

1.1.1 Implementation of the NEC and NFPA 70E

1.1.1.1 The NEC is updated on a 3-year cycle. The Chairperson for the LaRC Electrical Systems Committee (ESC) shall be responsible for the implementation of the revised edition of the NEC for use at LaRC.

1.1.1.2 The ESC Chairperson shall issue a memorandum establishing the date of implementation for all new editions of the NEC. (See LAPD 1150.2, “Councils, Boards, Panels, Committees, Teams and Groups.”)

1.1.1.3 Because there is no general provision in the NEC requiring NEC changes or updates to be retroactive, the upgrade of an electrical system merely to meet the changed NEC is not required.

1.1.1.4 The revised NEC requirements shall immediately be implemented if the implementation will improve the safeguarding of personnel or will protect LaRC equipment.

1.1.1.4.1 Such determinations shall be made in consultation with the Office of the Chief Counsel, the Center Operations Directorate, and the Safety and Mission Assurance Office.

1.1.1.5 The requirements of the latest adopted version of the NEC shall be used for all new electrical work unless more stringent requirements are imposed by LaRC policy.

1.1.1.6 If a facility is being constructed when the new NEC is adopted, the ESC shall evaluate the new NEC requirements and determine if there are reasons to incorporate any changes into the construction contract.

1.1.1.6.1 If so, the ESC shall issue a memorandum to the appropriate line organizations requesting that these changes be incorporated into the contracts.

1.1.1.7 Modified electrical equipment shall be brought up to the requirements of the latest version of the NEC unless the modifications to the equipment do not significantly change the function or design of the system.

1.1.1.8 Electrical wiring and equipment not included in the modification does not have to be updated.

Note: The NFPA 70E is updated on a 3-year cycle, but because it provides work safety requirements and not installation requirements, the most recent edition is typically not adopted for use.

1.1.1.9 The ESC Chairperson shall issue a memorandum establishing the edition of the NFPA 70E and date of adoption for use at LaRC, noting any amendments to the adopted edition applicable to LaRC.

1.1.1.10 LaRC shall adopt no editions of NFPA 70E earlier than those adopted for use in NPR 8715.3.

1.1.2 General Requirements

1.1.2.1 All electrical circuits and equipment shall be considered energized until properly tested by a qualified electrical person and witnessed by a second qualified person.

1.1.2.2 Equipment operating at or above 50 volts shall be de-energized and have lockout/tagout (LOTO) performed prior to performing work if there is a possibility that an employee may work within the restricted approach boundary or the arc flash boundary of exposed electrical conductors or circuit parts.

1.1.2.3 Energized parts that operate at less than 50 volts to ground need not be de-energized if there will be no increased exposure to electrical shock or other injuries resulting from direct or indirect electrical contact.

1.1.2.4 Before commencing work on any mechanical equipment or systems that have electrical connections or contain explosive, combustible, or other dangerous gases or fluids, the equipment or systems shall be properly grounded and/or made safe in accordance with other LaRC safety regulations concerning these materials.

1.1.2.5 Disconnecting means shall be legibly marked to indicate its source of power and purpose, unless located and arranged so the purpose is evident.

1.1.2.6 Up-to-date circuit directories shall be provided on all panelboards to clearly identify the purpose or load of each circuit.

1.1.2.6.1 Circuit identification shall be in sufficient detail to distinguish each circuit from all others.

1.1.2.7 Switchboards, panelboards, and motor control centers shall be clearly labeled to warn qualified persons of potential arc flash hazards when working on energized equipment.

1.1.2.7.1 Labeling shall meet the requirements of the NEC. See Section 4.1.6 for Arc Flash and Shock Hazard Labeling requirements.

1.1.2.8 Electrical wall outlets shall be labeled to indicate the source electrical panel number and circuit number.

1.1.2.9 Identification markings on building light and power distribution panels, circuits, and components shall not be relied on for establishing safe work conditions.

1.1.2.10 Ground wires or connections to frames or cases shall not be removed from any energized equipment.

1.1.2.11 Equipment grounding conductors shall not be used in the wiring of any power circuit.

1.1.2.12 Non-conductive fish tape shall be used when pulling wires through a conduit into energized equipment.

1.1.2.13 Commutating-type tools shall not be operated in close proximity to volatile materials.

1.1.2.14 Portable ladders shall have non-conductive side rails, if they are used where the employee or ladder could contact exposed live parts operating at 50 volts or more or where an electrical hazard exists.

1.1.2.14.1 Nonconductive ladders shall meet the requirements of ANSI standards for ladders in NFPA 70E, Table 130.7(F).

1.1.2.14.2 Metal ladders shall be marked with signs or decals reading "**CAUTION - DO NOT USE NEAR ELECTRICAL EQUIPMENT**."

1.1.2.15 When possible, one shall stand to the side away from the door/cover when operating (opening or closing) disconnect switches.

1.1.2.16 Only devices designed for voltage testing and rated for the nominal voltage of the circuit under test shall be used to make voltage checks.

1.1.2.16.1 Test voltage indicators shall be verified immediately before and after use by application to an energized circuit or by using an appropriate test unit.

1.1.3 Two-Person Rule/ Safety Watch

1.1.3.1 Certain electrical work requires the use of the two-person rule, which requires the presence of a second qualified person with the following qualifications and responsibilities:

a. Be a qualified electrical person or, if permitted by the task, a qualified industrial person.

b. Have a general knowledge of the work being performed.

c. Remain in visual and audible contact with the person performing the work and in no case be more than 50 feet from the work area.

d. Have a thorough knowledge of the location of disconnects and shutdown controls.

e. Be able to de-energize equipment and alert emergency rescue personnel.

f. Be trained and current in Cardiopulmonary Resuscitation / Automated External Defibrillator (CPR/AED).

1.1.3.2 Under the two-person rule, the second qualified person shall be allowed to work in a separate location from the electrical work provided that all the requirements above are satisfied and safety is not compromised.

1.1.3.3 If the second qualified person is also performing electrical work that requires the use of the two-person Rule, both qualified electrical persons working in separate locations shall be allowed to act as the second person for each other provided that all of the requirements above are satisfied for both workers and safety is not compromised.

1.1.3.4 Certain high hazard electrical work requires that the second person be a Safety Watch, which is a more stringent hazard control measure than the two-person rule. When a Safety Watch is required, the Safety Watch shall have the following qualifications and responsibilities:

a. Be a qualified electrical person.

b. Have no other duties that preclude continually observing, coaching, and monitoring for potential hazards and mistakes.

c. Have a thorough knowledge of the specific working procedures to be followed and the work to be done.

d. Be close enough to the work in progress to safely monitor the progress and methods of the qualified person doing the work and use clothing and PPE appropriate to the hazard and the distance from the work in progress. In no case shall the Safety Watch be more than 50 feet from the qualified person(s) performing the work.

e. Ensure only qualified persons are allowed within the Limited Approach Boundary.

f. Ensure Limited Approach Boundaries are properly barricaded and controlled. If signs and barricades do not provide sufficient warning and protections for the Limited Approach Boundary, an attendant (third person) shall be stationed to warn and prevent unqualified persons from entering.

1.1.3.5 The two-person rule is mandatory whenever electrical work not requiring an LF 416 (including measurements) is to be performed on exposed energized parts exceeding 250 volts to ground or is conducted in a high-risk area with exposed energized parts exceeding 600 volts.

1.1.3.5.1 For voltages up to 600 volts, the second person may be a qualified electrical person or a qualified industrial person.

1.1.3.5.2 For voltages exceeding 600 volts, the second person shall be a qualified electrical person.

1.1.3.6 A Safety Watch is required for any electrical work that requires the use of an LF 416.

1.1.3.7 Table 1.1 provides specific requirements for the second person under the two-person rule based on type of work and voltage.

	Voltage			
Type of Work	**Less than 50V**	**50 – 250 V**	**251 – 600 V**	**Greater than 600 v**
De-energized	NR	NR	NR	NR (2)
Racking	NR	NR	QEP or QIP	QEP
Verifying Absence of Voltage for LOTO	NR	NR	QEP or QIP	QEP
Diagnostics & Testing	NR	NR	QEP or QIP	QEP
Energized (1)	NR	SW + LF 416	SW + LF 416	SW + LF 416 (3)

Table 1.1 –Requirements for Second Person under Two-Person Rule

NR = Not Required
QEP = Qualified Electrical Person
QIP = Qualified Industrial Person
SW = Safety Watch

(1) Energized work is not permitted without an Approved LF 416, LaRC Energized Electrical Work Permit.
(2) QEP required for de-energized work in substations per Section 4.4.1.5
(3) Applies to removal of covers as described in Section 1.2.1.5

1.1.3.8 A non-electrical Safety Operator with an electrical designation of 600 Volts shall be considered a Qualified Industrial Person for the purpose of serving as the second person under the two-person rule only if they have had CPR/AED training.

1.1.3.9 For work in substations, depending upon the scope of work, if the requirements for Safety Watch as required above align with the requirements for a Safety Supervisor as required in Section 4.3-Work in Energized Substations, the same qualified electrical person can serve in both roles.

1.2 SPECIFIC REQUIREMENTS

1.2.1 Live Work Requirements

1.2.1.1 Live parts to which an employee might be exposed shall be put into an electrically safe work condition and locked/tagged out before an employee works on or

near them, unless the employer can demonstrate that de-energization introduces additional or increased hazards or is infeasible due to equipment design or operational limitations.

1.2.1.2 Equipment normally energized above 600 volts shall always be considered energized unless protective grounds and/or other appropriate safety measures, in accordance with LPR 1710.10, “Langley Research Center Energy Control Program (Lockout/Tagout),” are confirmed to be in place.

1.2.1.3 If de-energizing equipment introduces additional or increased hazards or is infeasible due to equipment design or operational limitations, a detailed procedure shall be developed for the energized work and documented on LF 416, “Energized Electrical Work Permit.”

1.2.1.3.1 The detailed procedure may be a separate document referenced by the Energized Electrical Work Permit.

1.2.1.3.2 Work authorized by the Energized Electrical Work Permit shall be performed only by electrically qualified personnel.

1.2.1.4 No work (other than performing routine testing, troubleshooting, and voltage measurements) shall be performed on energized power circuits of 600 volts or less without a LF 416.

1.2.1.5 Removal of switchgear panels or panel door barriers from energized circuits above 600 volts for inspection, data gathering, or infrared testing of the exposed energized bus shall not be performed without an LF 416.

1.2.1.6 Workers shall not work alone on equipment with exposed energized parts operating at greater than 250 volts to ground.

1.2.2 Personal Protection Equipment (PPE)

1.2.2.1 Personal Protective Equipment (PPE) shall be used to mitigate the hazards of shock and electrical burns from arc flash when work, including troubleshooting, voltage testing, and LOTO, is performed on or near energized electrical equipment. Arc Flash and Shock PPE shall not be required once the electrical equipment has been placed into an Electrically Safe Work Condition.

1.2.2.2 Arc Flash PPE selection shall be based on the Incident Energy (IE) value in cal/cm^2 and PPE requirements indicated on the Arc Flash and Shock Hazard (AFSH) warning label. The Arc Flash PPE shall have an Arc Thermal Protection Value (ATPV) greater than or equal to IE value in cal/cm^2 indicated on the AFSH warning label.

1.2.2.3 Arc Flash PPE shall be based on the Hazard/Risk Category (HRC) indicated in the Hazard/Risk Category Classification Task Tables for equipment that has a generic AFSH warning label or has no AFSH warning label. The Arc Flash PPE shall have an ATPV greater than or equal to the minimum arc rating in cal/cm^2 corresponding to the PPE HRC Category.

1.2.2.4 When working within the restricted approach boundary or the arc flash boundary of exposed electrical conductors or circuit parts or while in the process of achieving or returning from an Electrically Safe Work Condition, the minimum required Arc Flash PPE shall not be less than work clothing equivalent to HRC 0 PPE.

1.2.2.5 See Appendix D for additional guidance for selecting and using PPE based on AFSH warning labels.

1.2.2.6 Rubber insulating gloves with leather protectors shall be worn together and shall have an insulation class greater than or equal to the voltage to which they are exposed.

1.2.2.7 Prior to each use, rubber insulating gloves shall be verified:

a. To be free from damage.

b. To be free of air leaks.

c. To ensure the date of use does not exceed six months past the test date marked on the glove.

1.2.2.8 Gloves that do not meet the requirements of 1.2.2.7 shall be exchanged prior to start of work.

1.2.2.9 The test date on the glove shall be allowed to exceed that required in Section 1.2.2.7 if the organization manages and documents issuance of gloves in accordance with the Maximum Test Intervals for Rubber Insulating Equipment noted in NFPA 70E.

1.2.2.10 Conductive articles of jewelry and clothing (such as watchbands, bracelets, rings, key chains, necklaces, metallized aprons, cloth with conductive thread, metal headgear, or metal-framed glasses) shall not be worn without appropriate PPE where they present an electrical contact hazard with exposed live parts.

1.2.2.11 Rubber gloves alone shall not be relied upon for protection from energized circuits of more than 3500 volts to ground.

1.2.3 Storage of Protective Devices

1.2.3.1 Protective equipment shall be maintained in a safe, reliable condition.

1.2.3.2 The protective equipment shall be visually inspected before each use.

1.2.3.3 Periodic testing of electrical equipment shall meet the requirements of NFPA 70E, Art. 130.7(C)(8).

1.2.4 Hard Hat Area

1.2.4.1 Electrical substations with exposed bus shall be designated as hard hat areas.

1.2.4.2 Personnel within the confines of electrical substations shall wear Class E, Type 1, or Type 2 hard hats.

1.2.5 Welding

1.2.5.1 Welding or burning shall not be permitted in the immediate vicinity of electrical equipment, except that associated with the splicing or termination of lead-sheathed cable.

1.2.5.2 Any deviations to Section 1.2.5.1 shall require the concurrence of the Facility Coordinator and the Electrical Standard Practice Engineer.

1.2.6 Lockout/Tagout

1.2.6.1 The application of lockout/tagout devices shall be in accordance with LPR 1710.10, “Langley Research Center Energy Control Program (Lockout/Tagout).”

1.2.7 Confined Space Entry

1.2.7.1 Entries into electrical manholes, vaults, cable tunnels, and confined spaces containing electrical cables and equipment shall comply with LPR 1740.2, “Facility Safety Requirements.”

1.2.8 Portable Equipment Grounding

1.2.8.1 The cases of all portable electrical motor-driven hand tools shall be grounded by use of standard three-prong plugs and receptacles.

1.2.8.2 All other electrical equipment supplied with 50 volts or above shall have cases or frames connected to ground, except:

a. Devices operated solely from self-contained batteries.

b. Devices that have cases and all exposed parts protected by insulating material.

c. Double-insulated tools.

1.2.9 Temporary Wiring

1.2.9.1 Temporary wiring shall be permitted during periods of construction, remodeling, maintenance, repair, emergencies, and demolition of buildings, structures, equipment, or similar activities.

1.2.9.2 Temporary wiring shall be permitted during tests, experiments, and developmental work lasting no longer than 90 days. For tests, experiments, and developmental work lasting more than 90 days, permanent wiring methods must be used unless temporary wiring is approved by the LaRC Safety Manager for the required time period exceeding 90 days.

1.2.9.3 Temporary wiring shall be installed with the same level of safety and quality as required for permanent wiring methods.

1.2.9.4 Temporary wiring shall be removed immediately upon completion of construction or purpose for which the wiring was installed.

1.2.9.5 Temporary wiring shall not be run directly on ungrounded conductive surfaces but shall be supported by suitable wood or other insulating materials.

1.2.9.6 Temporary wiring shall be kept out of water at all times unless listed for that purpose.

1.2.9.7 Temporary wiring shall conform to the requirements of NFPA 70 - NEC.

1.2.10 Extension Cords

1.2.10.1 Extension cords usage shall abide by the restrictions for temporary wiring as delineated in Section 1.2.9 of this document.

1.2.10.2 Extension cords may be used for temporary applications only and shall not be used for more than 90 consecutive days without LaRC Safety Manager Approval.

1.2.10.3 Where extension cords are used, they shall not be:

a. Used as a substitute for the fixed wiring of a structure.

b. Routed through holes in walls, ceiling, or floors.

c. Concealed behind building walls, ceilings, or floors.

d. Attached to building surfaces.

e. Run through doorways, windows, hinged door openings in enclosures, or similar openings.

1) If it is absolutely necessary to run an extension cord through a doorway or open window for short-term use, the extension cord:

a) Shall be protected from damage should the door or window slam shut.
b) Shall be removed immediately when no longer in use.
c) Shall not pose a trip hazard.

1.2.10.4 Unmodified, commercially manufactured extension cords rated “Heavy Duty” or “Extra-Heavy Duty” in continuous lengths without splices, and Underwriter’s Laboratory (UL) listed shall be used for 120 Vac single-phase service, except as permitted in Section 1.2.10.5.

1.2.10.5 Extension cords for special applications, such as 120 Vac single-phase in lengths longer than those commercially available, and 208 Vac or 480 Vac three-phase

service, may be fabricated as required by qualified electrical personnel only using cords classified as SO, ST, or SJ in continuous lengths and UL listed plugs and receptacles.

1.2.10.5.1 At the time of fabrication, extension cords shall be tested by a qualified electrical person for proper wiring and grounding and a blue tamper-proof padlock inspection seal installed on the plug and receptacle to indicate the cord is properly constructed and to prevent unauthorized modification. The blue tamper-proof inspection seals can be obtained from the LaRC Safety Manager by qualified electrical personnel only after justification for fabrication of the extension cords.

1.2.10.6 Extension cords shall have adequate current carrying capacity to handle the maximum current draw of the connected electrical device.

1.2.10.7 Extension cords shall be sized in accordance with NFPA 70B, Table 20-5, based on cord length and load current.

1.2.10.8 Extension cords shall not be used to power high-current equipment.

1.2.10.8.1 High-current equipment (i.e. Microwave ovens, space heaters, and coffee pots) shall be plugged directly into wall receptacles.

1.2.10.9 Extension cords shall be of the three-pronged grounded type, and suitable for the conditions of use and location.

1.2.10.9.1 Two-conductor extension cords shall not be used, even if the device it serves uses a two-prong plug.

1.2.10.10 In outdoor or wet locations, and in areas where a person may come in contact with a solidly grounded conductive object, such as building structural steel or pressure vessel, extension cords shall use integral or separate Ground Fault Circuit Interrupters (GFCIs) for shock protection.

1.2.10.11 Extension cords used to supply temporary power to equipment used during construction, remodeling, maintenance, repair, or demolition of buildings, structures, or equipment shall have GFCI protection for personnel.

1.2.10.12 Extension cords shall not be daisy-chained (one extension cord plugged into another extension cord) except that a GFCI cord set, 3 feet in length or less, may be connected between a wall receptacle and an extension cord to provide shock protection.

1.2.10.12.1 A GFCI cord set longer than 3 feet is considered to be an extension cord with integral GFCI protection and shall not be daisy-chained with other extension cords.

1.2.10.13 Extension cords with molded multiple receptacles are permitted provided that the total connected load does not exceed the cord ampacity.

1.2.10.14 Extension cords that are frayed, cut, or damaged such that inner conductors are visible, or that have outer sheaths that have pulled away from their molded plugs, shall not be used and shall be removed from service.

1.2.10.15 Examples of acceptable and unacceptable extension cord configurations are shown in Appendix C.

1.2.11 Relocatable Power Taps (RPT) or Power Strips

1.2.11.1 A Relocatable Power Tap (RPT), commonly referred to as a power strip, is a variation of an extension cord, where the cord terminates in a row or grouping of receptacles. RPTs are commonly used in offices to provide multiple receptacles to office equipment. Because an RPT is a variation of an extension cord, in addition to the requirements for RPT usage delineated in this section, RPT usage shall comply with the requirements for extension cords as delineated in Section 1.2.10.

1.2.11.2 Only Underwriters Laboratories (UL) approved RPTs shall be permitted for use.

1.2.11.3 Except as permitted in Section 1.2.11.4, RPTs shall not be permanently mounted to any facility surface; however, RPTs shall be allowed to hang from screws or hooks if the RPT is manufactured with slots or keyholes for that purpose.

1.2.11.4 RPTs specifically designed for installation in equipment racks is a permissible method for supplying utility power to rack-mounted equipment.

1.2.11.5 A surge protector power strip is an RPT intended to protect sensitive electronic equipment from transient over-voltages. Surge protectors shall be permitted to supply power only to sensitive electronic equipment, such as computers, printers, monitors, scanners, and printers.

1.2.11.5.1 Only UL-approved surge protectors listed as “Transient Voltage Surge Suppressors” shall be used in surge protector applications.

1.2.11.6 Surge protectors shall have an internal circuit breaker to protect the unit from being overloaded and to prevent overheating and fire.

1.2.11.7 Surge protectors shall not be located in moist or damp locations, or in areas where the unit may be covered by carpet, furniture, or any other item that will limit or prevent air circulation.

1.2.11.8 Surge protectors shall have a minimum energy suppression rating of 1200 joules.

1.2.11.9 Extension cords or additional RPTs shall not be plugged into an RPT because this is considered daisy chaining, which is a prohibited application of extension cords.

1.2.11.10 RPTs shall not be used to power high current equipment.

1.2.11.10.1 High-current equipment (i.e. microwave ovens, space heaters, and coffee pots) shall be plugged directly into wall receptacles.

1.3 ABOVE 600 VOLTS (HIGH VOLTAGE)

1.3.1 Protective Grounding - General

1.3.1.1 Protective grounds are temporary grounding and short circuiting conductors, which are placed on de-energized electrical equipment for personnel protection. These grounds are a temporary protective measure and should not be confused with the fixed ground system required by NEC. Protective grounds are normally used to prevent accidental energizing of equipment and systems and shall be applied to any equipment when, in the opinion of the worker, the worker's supervisor, or the safety supervisor, the application is required.

1.3.1.1.1 If protective grounds are determined to be necessary, they shall be applied before beginning work on systems or equipment, which may bring personnel into contact with parts that are normally energized above 600 volts.

1.3.1.2 The Safety Operator shall be responsible for testing the system to ensure that no voltage is present prior to providing safety clearance.

1.3.1.2.1 When grounds are determined to be necessary, it shall be the responsibility of the Safety Operator to ensure that adequate grounds are placed for the protection of the workers.

1.3.1.3 Before attaching protective grounds, the equipment or circuit to be protected shall be:

a. De-energized.

b. Tested to verify the absence of voltage.

c. Locked and tagged as required by LPR 1710.10.

1.3.1.3.1 All conductors, static wires, circuit neutrals, and cable sheaths shall be connected in a manner that will ground all conductive portions of the circuit to a common point.

1.3.1.3.2 The protective grounds shall not be removed until all workers are clear of the circuit or equipment.

1.3.1.3.3 The ground end of the protective grounding cable shall always be connected first and disconnected last.

1.3.1.3.4 Protective grounding cables shall not be less than 2/0 AWG copper or equivalent. Special requirements for some specific configurations are addressed in Sections 1.3.2 through 1.3.6.

1.3.2 Protective Grounding - Overhead Lines and Pole Work

1.3.2.1 All protective grounding cables shall be connected to an approved ground point, which may be a grounded metal structure, a substation ground point, an anchor rod, or a driven or screw-type ground rod.

1.3.2.1.1 A multi-grounded common neutral of 2/0 AWG copper or equivalent is an acceptable ground for pole work.

1.3.2.1.2 Pole guy wires shall not be acceptable ground points.

1.3.2.2 Circuit conductors shall be grounded by attaching the grounded cables to the conductors, progressing upward and outward from the work point.

1.3.2.2.1 Personnel shall remain as far below the conductors as possible, keeping clear of the grounded cables and clamps.

1.3.2.2.2 At the completion of work, grounding cables shall be removed in reverse order from installation, keeping clear of the cables and clamps until all conductors have been ungrounded.

1.3.3 Protective Grounding - Transformers

1.3.3.1 Before working on transformers, the following shall be performed:

a. Open the transformer primary disconnect switch.

b. Remove the secondary fuses or open the secondary breaker.

c. Check the system to verify that the voltage is zero.

d. Install protective grounds.

e. Install insulated barriers or boards to isolate energized studs.

1.3.3.2 Where connected transformers are in the zone between protective grounds, the primary side of the transformer shall be disconnected by either removing the line taps or opening the fuse cutouts.

1.3.3.2.1 Where primary line work is to be performed on the transformer, the secondary wires shall also be disconnected or protective grounds applied.

1.3.3.2.2 The secondary neutral, if established as grounded, shall be considered as an adequate ground.

1.3.3.2.3 On distribution transformers, the secondary neutral shall be considered an adequate ground for protective grounding, if the permanent ground is interconnected with the secondary neutral, the transformer case and a ground electrode.

1.3.4 Protective Grounding - Current and Potential Transformers

1.3.4.1 Before working on an instrument or other device in a current transformer secondary circuit, the transformer secondary circuit shall be shorted together or bridged in such a manner as to prevent opening the secondary circuit.

1.3.4.2 Current transformer cases and secondaries shall be grounded.

1.3.4.3 When more than one set of current transformer secondaries are electrically connected, a ground point shall be selected that provides grounding for the network.

1.3.4.4 When the primary circuit is energized, secondaries of current transformers shall not be opened.

1.3.4.5 The case and one wire on the low-voltage side of a potential transformer shall always be grounded before energizing the transformer.

1.3.5 Protective Grounding - Power Capacitors

1.3.5.1 A period of at least five minutes shall elapse after de-energizing power capacitor units or banks before protective grounds are installed.

1.3.5.1.1 All capacitor units in the working area, and any other capacitor units adjacent to the working area that could be contacted, shall be short circuited and grounded.

1.3.5.2 All individual power capacitor tanks shall be grounded.

1.3.5.2.1 In the case of capacitors installed in banks on insulated conductive mounting racks, the racks shall also be grounded before working on the bank.

1.3.6 Protective Grounding - Underground Cables

1.3.6.1 Protective grounding of conductors in underground cables cannot always be performed at the point of work. Protective grounds shall be attached at the nearest location where the conductors can be reached.

1.3.6.2 Conductive sheathing or shielding tape shall have a protective ground applied on both sides of the work point.

1.3.7 Underground Utilities and Operations - General Requirements

1.3.7.1 A LaRC-approved LF 60, “Confined Space Entry Permit,” shall be required before entry into any manhole or vault as required in Section 1.2.7.1 of this document. For specific requirements related to confined space entry, see LPR 1740.2.

1.3.7.2 Manhole cover hooks, cover lifters, or recessed handles shall be used for removing or replacing manhole covers.

1.3.7.3 Open manholes, hand holes, or vault gratings shall be protected by suitable barriers or guards and adequate lighting shall be provided during hours of darkness.

1.3.7.3.1 Safety cones and warning flags shall be used to direct vehicular and pedestrian traffic around such openings.

1.3.7.4 When practicable, manholes shall be entered or exited by means of a ladder.

1.3.7.5 When working in manholes, hand holes, or vaults, one person shall be stationed on the surface, to be readily available to those working below the surface.

1.3.7.6 Tools and materials shall be raised or lowered in manholes by means of a suitable bucket, toolbox, or rope.

1.3.7.7 Manhole covers and gratings shall be properly seated when replaced.

1.3.7.8 Approved lighting units shall be used when working underground, or below grade.

1.3.7.9 Air-driven tools used around energized cables shall be grounded.

1.3.7.10 Digging permits shall be required for excavations of 6 inches or deeper in accordance with LPR 1740.2.

1.3.8 Gas and Fumes

1.3.8.1 No one shall smoke, strike matches, or permit any other type of open flame in or close to a manhole or vault being ventilated until tests have determined that it is safe from gases or fumes.

1.3.8.2 Before entering a manhole or vault, forced ventilation shall be provided or appropriate gas detection tests (approved by the LaRC Safety Manager) shall be performed.

1.3.8.3 If gas or fumes are detected, no one shall enter the manhole or vault (except as provided for in Section 1.3.8.6) until thorough ventilation has been accomplished and tests made to ascertain that the gases or fumes have been eliminated.

1.3.8.4 When ventilating a manhole or vault to eliminate gases or fumes, the manholes on either side shall be opened when practicable.

1.3.8.5 Except where forced ventilation is provided, gas tests shall be made at regular intervals when underground work is in progress in manholes, hand holes, and vaults.

1.3.8.5.1 If gases or fumes are detected, the manhole or vault shall be vacated promptly, ventilation started, and the condition reported to the supervisor.

1.3.8.6 If it should become necessary to perform work in a manhole or vault containing gases or fumes, no one shall enter except under direct authorization of the LaRC Safety Manager.

1.3.8.6.1 The LaRC Safety Manager's representative shall be present and responsible for seeing that approved respiratory protective equipment and ventilation equipment are used.

1.3.9 Energized Cables in Manholes

1.3.9.1 All cables in manholes shall be considered as sources of potential shock and arc flash.

1.3.9.2 Tests shall be made to verify that there is no voltage between the outer sheaths and grounds.

1.3.9.3 Even though cables are shown to have no potential between their outer sheath and ground, contact shall be avoided unless necessary to complete some specific item of work.

1.3.9.4 High voltage gloves shall be worn unless the cable has been de-energized.

1.3.9.5 When working around energized cables in manholes, a physical barrier shall be provided to prevent contact of new cables, equipment or personnel with the existing energized cables.

1.3.9.6 If energized cables cannot be physically isolated so barriers can be installed to prevent potential arc flash hazards created by inadvertent contact with the energized cables, appropriate arc flash PPE shall be used.

1.3.9.7 Only qualified workers shall be permitted to work in electrical manholes or cable tunnels if energized cables are present. Unqualified workers shall be allowed to assist in these operations if adequate supervision and safety guarding of the unqualified worker is provided.

1.3.9.8 The conductive sheathing or shielding tape of all energized cables adjacent to the underground work area shall be verified to be grounded prior to commencing work.

1.3.9.8.1 If ground verification is not feasible, then barriers shall be installed to prevent workers from making contact with energized cables or equipment.

1.3.9.8.2 If neither barrier erection nor ground verification is feasible, all cables adjacent to the work area shall be de-energized.

1.3.10 Cutting and Splicing Power Cables

1.3.10.1 Splicing or taping of energized power cables shall not be permitted.

1.3.10.2 Before cutting into de-energized high voltage cables (above 600 volts) for the purpose of making repairs or removing the cables from the raceway system, workers shall also comply with the instructions elsewhere in these procedural requirements covering clearing, tagging, testing, grounding, and short circuiting, and shall also comply with the Section 1.3.10.3.

1.3.10.3 Before being cut, cables shall be identified by tags, ducts, and/or duct records.

1.3.10.3.1 Tags and ducts associated with the cables shall be checked against records.

1.3.10.3.2 Physical checks shall be made on either side of the location where the work is to be performed.

1.3.10.3.3 When the ends of the high voltage power cable are accessible and can be "open circuited," a pulsating test current shall be applied to the conductor and a current measuring instrument shall be used to positively identify the cable.

1.3.10.3.4 After the cable has been identified, the cable shall be cut using a remotely actuated grounded cutting device, as follows:

a. The cutting device shall have a grounded cutting head to provide a spiking function during cutting.

b. The cutting device shall be installed on the cable using rubber gloves or an insulated stick.

c. The cutting device shall be remotely actuated by a hydraulically actuated or other mechanically actuated device.

d. The cutting device shall provide at least 25 feet of separation between the cutting head and the remote actuator.

e. For cables in a manhole, workers shall be outside the manhole during remote cutting of cables.

1.3.11 Racking Circuit Breakers Rated Over 600V

1.3.11.1 Racking of circuit breakers rated over 600V for clearance to work on electrical circuits or during facility operations shall be performed by personnel who have been certified as Safety Operators for the specific equipment in accordance with LPR 1710.10.

1.3.11.2 The two-person rule shall be used during the "rack in" or "rack out" of a circuit breaker.

1.3.11.3 Racking of circuit breakers rated over 600V from an energized bus shall be performed only with a remote racking device that provides at least 25 feet of distance between the racking device and the remote actuator.

1.3.11.4 Attachment and detachment of a remote racking device is classified as a low-risk electrical task and shall require only the use of HRC 0 PPE.

1.3.11.5 Circuit breakers shall not be racked into operating position with the closing springs charged or fully compressed.

1.3.11.6 All unqualified personnel shall be cleared from the immediate and adjacent areas during racking operations, a minimum distance no less than the “Flash Protection Boundary” for flash protection defined by NFPA 70E, Art. 130.3(A) and Section 4.1.5 of this document.

1.3.12 High Voltage Switching

1.3.12.1 All electrical switching required for clearance to work on electrical circuits shall be performed by personnel who have been certified as Safety Operators for the specific equipment in accordance with LPR 1710.10.

1.3.12.2 Appropriate PPE shall be used when operating high-voltage disconnecting switches.

1.3.12.2.1 The minimum clear insulating length for disconnect poles shall be in accordance with OSHA 29 CFR 1926.950, Table V-1 and as indicated in Figure 1.1.

1.3.12.3 The minimum length for disconnect poles is the combination of minimum clear insulating length between the head and protective collar (or identifying mark) and the minimum handle length for the applicable voltage range.

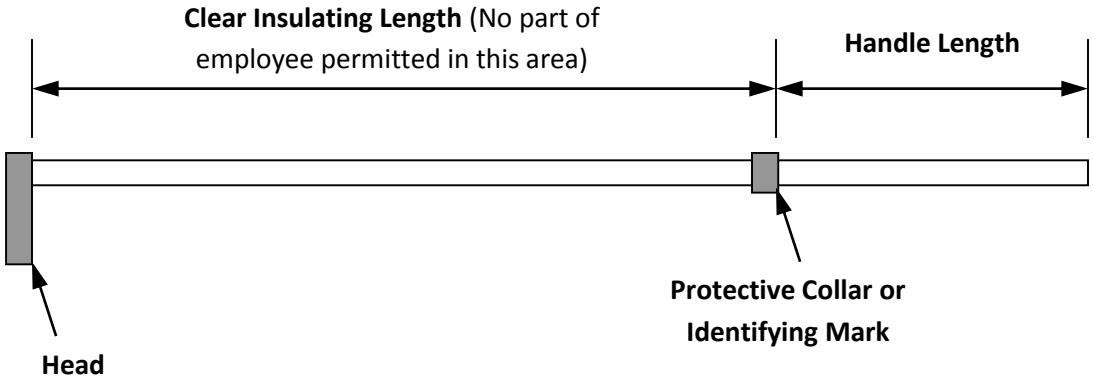


Figure 1.1 – Lengths for Disconnect Poles

	Minimum Disconnect Pole Lengths		
Voltage Range (Phase to Phase)	**Minimum Clear Insulating Length**	**Minimum Handle Length**	**Minimum Pole Length**
601 to 2,000	2 feet	1 feet	3 feet
2,100 to 15,000	2 feet	1 feet 8 inches	3 feet 8 inches
15,100 to 35,000	2 feet 4 inches	2 feet	4 feet 4 inches
35,100 to 46,000	2 feet 6 inches	2 feet	4 feet 6 inches
72,600 to 121,000	3 feet 4 inches	2 feet 2 inches	5 feet 6 inches

Table 1.2 – Minimum Disconnect Pole Lengths

1.3.12.4 When work is to be performed on secondary circuits or equipment, which are disconnected from sources of power only by switches with non-visible contacts, the following procedures shall be incorporated into the LF 495, “Safety Operator Clearances Procedure,” associated with each switch being locked and tagged:

a. Obtain concurrence from qualified electrical technician and the Facility Coordinator.

b. De-energize the switch.

c. Perform tests to verify that there is no voltage on the secondary circuits where the work is to be performed. Tests shall measure voltage from phase to phase and from each phase to ground.

d. Apply lockout/tagout(s). Indicate on the red tag(s) that no work shall be performed on the high-voltage (primary) side of the equipment.

e. Apply protective grounding as close as physically possible to the secondary circuit power source.

f. Before operating any switch used for maintenance or for isolating circuits above 600 volts, the switch operator is to be accompanied by a second electrically qualified person, who is to stand at a safe distance and be prepared to respond in the event of an emergency.

2. TRAINING REQUIREMENTS

2.1 TECHNICAL TRAINING

2.1.1 Qualified workers shall be technically trained and experienced in the work methods required by their electrical work assignments and shall have safety training on the operation of the equipment and the use of safe work practices.

2.1.2 Technical training commensurate with the assignments of the qualified electrical person shall be documented and shall meet the requirements of the person's job description.

2.1.3 Refresher technical training shall be taken as required by the qualified electrical person's job assignments and certification requirements.

2.1.4 An individual who is undergoing on-the-job electrical technical training and who has demonstrated competence in performing work safely shall be considered qualified if the individual is under the direct supervision of a qualified electrical person.

2.1.5 The qualified individual shall have completed safety training on the hazards involved prior to performing the work.

2.2 SAFETY TRAINING

2.2.1 The direct supervisor of any person who works with electrical equipment shall ensure the person has completed the minimum electrical safety training defined below.

2.2.2 The level of electrical safety training shall be based on the level of electrical risk and hazard to which the person will be exposed.

Type	Length (minimum)	Frequency	Unqualified	Non-Electrical SO w/ Elect. LOTO	QEP and QIP, 600V & below	QEP, over 600 V
Electrical Safety Awareness	Web-based or 1-hour instructor-led	Annually	Yes			
NFPA 70E	8-hour instructor-led	Every 3 years		Yes	Yes	Yes
High Voltage/ 1910.269	2-hour instructor-led (can be combined with NFPA 70E training)	Every 3 years				Yes
CPR/AED	2-hour instructor-led	At frequency of certifying organization			Yes	Yes

Table 2.1 - Electrical Safety Training

2.2.3 Safety training for qualified persons shall include as a minimum:

a. Training in the skills and techniques to distinguish exposed energized parts from other parts of the electrical equipment.

b. Training in the skills and techniques necessary to determine the nominal system voltage of the exposed energized part.

c. Training to determine the minimum approach distances to exposed energized parts as specified in NFPA 70E, Table 130.2(C) and Sections 4.1.4 and 4.1.5 of this document.

d. Training to determine the degree and extent of an electrical hazard and in the proper use of PPE required to perform the task safely.

2.3 SAFETY OPERATORS

2.3.1 Electrical Safety Operators shall meet the training and qualification requirements for Safety Operator Certification as required by LPR 1710.10, Section 2.9

2.3.2 Non-Electrical Safety Operators performing electrical lockout/tagout for mechanical equipment operating at less than 600 volts shall complete the safety training for qualified electrical persons as defined in Section 2.2.

2.3.3 Non-electrical Safety Operators with an electrical designation of 600 volts shall be permitted to operate switches, disconnects, and circuit breakers (not including racking) to isolate electrically driven equipment during LOTO for non-electrical maintenance.

2.3.4 Non-electrical Safety Operators with an electrical designation of 600 volts shall not be permitted to perform LOTO for electrical work (electrical work is work that has

exposure to electrical conductors or circuit parts that pose a shock hazard when energized) or to use electrical test equipment to test for absence of voltage on exposed energized parts.

3. ELECTRICAL SYSTEM DOCUMENTATION REQUIREMENTS

3.1 AREA OF RESPONSIBILITY

3.1.1 It shall be the responsibility of the person or group preparing design drawings to initiate action to document changes to the electrical drawings described in the following paragraphs.

3.1.1.1 In the event that changes are made to the electrical system and drawings are not produced prior to the changes, the personnel performing the work shall be responsible for preparing drawings of such detail that the information can be entered onto the record drawings.

3.2 CONFIGURATION MANAGEMENT

3.2.1 LPR 1740.4, “Facility System Safety Analysis and Configuration Management,” defines the Configuration Management (CM) Program. It also identifies the facilities under CM and defines the minimum electrical drawings required for these facilities.

3.2.1.1 All changes to these drawings or equipment shall conform to the requirements of LPR 1740.4.

3.2.1.2 It is the intent for all drawings and diagrams included in the CM program to be updated to the “as-built” configuration. It is recognized that this is a difficult and expensive process. The updating of the drawings is currently a requirement of the Center Maintenance Operation and Engineering (CMOE) contract. The schedule for updating the drawings will be based on the approved drawing update schedule in accordance with the requirements of the CMOE contract.

3.3 TYPE OF DRAWINGS

3.3.1 Switching and Metering One Line Diagrams (Effort Code 300)

3.3.1.1 Switching and metering one line diagrams shall be maintained in LaRC’s Configuration Management On-Line (CMOL) system under Effort Code 300.

3.3.1.1.1 Switching and metering one line diagrams shall be kept in an “as-built” condition as defined by LPR 1740.4.

3.3.1.2 The list of disconnect devices (switches, circuit breakers, etc.) shall be included in Effort Code 300 as a device list.

3.3.1.3 The following cable and switch legend applies to the switching diagrams:

Series Number	Voltage Level
1000	115 kV
2000	22 kV
3000	6.6 kV and 6.9 kV
4000	2.4 kV
5000	125 VDC and 115 VAC
6000	120/208 V
7000	277/480 V
8000	4.16 kV and 4.6 kV (Variable Frequency)
9000	13.8 kV
9500	34.5 kV

Table 3.1 – Cable and Switch Legend

3.3.2 Manhole Drawings (Effort Code 301)

3.3.2.1 Manhole drawings shall be maintained in LaRC's CMOL system under Effort Code 301.

3.3.3 Manhole drawings shall be kept in an "as-built" condition as defined by LPR 1740.4.Building Drawings - Low Voltage One Line Diagrams (Effort Code 302)

3.3.3.1 Building drawings (low voltage one line diagrams) shall be maintained in LaRC's CMOL system under Effort Code 302.

3.3.3.1.1 As a minimum, building drawings shall include single line diagrams of the 208 volt and 480 volt power distribution system and floor plans showing the location of the power distribution equipment (transformers, panelboards, switching centers, motor controls centers, etc.).

3.3.3.1.2 The single line diagrams shall reference the applicable high voltage switching diagram maintained in CMOL under Effort Code 300.

3.3.3.1.3 Building drawings shall be kept in an "as-built" condition as defined by LPR 1740.4.

3.3.4 Major Electrical Substation Drawings (Effort Code 303)

3.3.4.1 Major electrical substation drawings shall be maintained in LaRC's CMOL system under Effort Code 303.

3.3.4.2 Major electrical substation drawings shall be kept in an “as-built” condition as defined by LPR 1740.4. Major electrical substations are delineated in the Stratton Substation Facility Resume under Appendix 3.

3.3.5 System Design Drawings

3.3.5.1 Drawings for facilities not under the CM Program may not be up-to-date and shall be field verified for accuracy prior to designing or implementing any changes.

3.3.5.2 The following “as-built” documentation shall be provided for each system/building which is not included in the CM Program:

a. A control criteria document that includes sign off by the design engineers for each discipline involved and which identifies the basic interlock logic needed to assure safe and practical control for each process system.

b. An overall system functional or block diagram clearly describing the engineering design intent for each system giving the function of each major component.

c. System schematics and/or elementary wiring diagrams, including one-line distribution diagrams for building power systems including the building unit substation, secondary breakers, panelboards, and motor control centers.

d. Individual equipment wiring diagrams and interconnection drawings showing each terminal strip connection, excluding building light and power panels.

e. Panel schedules for building light and power.

f. Facility location or plot plans showing all basic equipment, panelboards, motor control centers, main distribution panels, unit substations, and major facility equipment.

3.3.6 On-Site Drawings

3.3.6.1 Except as defined for facilities in the LaRC CMOL system, the respective Facility Coordinator shall determine the type and location of drawings to be kept on-site.

3.4 DRAWING DISTRIBUTION

3.4.1 Copies of Effort Code 300 switching diagrams for the high-voltage power distribution system (over 600 volts) shall be distributed to personnel on a list approved by the Chairperson of the ESC.

3.4.1.1 The Chairperson shall assure that corrected copies of drawings affected by modifications are promptly provided to holders of switching diagram sets.

3.4.1.2 Electronic copies of these diagrams are included in the LaRC CMOL system and are accessible for viewing and making copies (but not revising) by LaRC employees who have been assigned an appropriate computer access password.

3.4.1.3 The Center Operations Directorate shall be responsible for initiating Change Notification Sheets (CNS) for updating the electronic copies on CMOL.

3.4.2 Copies of other drawings will be distributed to personnel as defined in LPR 1740.4 and/or as determined by the Chairperson of the ESC.

4. OPERATIONS AND MAINTENANCE REQUIREMENTS

4.1 GENERAL

4.1.1 Color Coding – Indicating Lights

4.1.1.1 The color of indicating lights designating the condition or position of the contacts on circuit breakers or switches for new or modified systems shall conform to the following:

a. Contacts closed – red

b. Contacts open – green

c. Contact automatically tripped open – amber

Note: The above color-coding of indicator lights is specific to switchgear as referenced in IEEE C37.11 and C37.100.

4.1.1.2 The color of indicating lights designating the position of valves that allow flow or block flow shall conform to the following:

a. Allows flow – green

b. Blocks flow – red

4.1.1.3 The required designation as indicated here may be waived by the LaRC Safety Manager if, for reason of prior usage in a facility, it is deemed safer to use other designations. This special ruling shall require written notification and approval from the LaRC Safety Manager.

4.1.1.4 The color coding of indicating lights (and pushbuttons) for industrial control systems is not consistent throughout industry, nor is it consistent for facility control systems at LaRC. The color coding of indicating lights (and pushbuttons) for control systems within a facility shall be consistent.

4.1.1.4.1 Existing control systems are not required to be updated to meet this requirement unless they are being modified or upgraded, at which time they shall use the prevailing color scheme for control systems within the facility. Guidance for color coding or indicator lights (and pushbuttons) may be found in NFPA 79, IEC 60204-1, and IEC 60073.

4.1.2 Control Voltages for Devices

4.1.2.1 All controls subject to “routine” operational adjustments of exposed electrical components or controls that are not packaged in a manner to preclude casual or

random entry by unauthorized individuals shall conform to the NEC Art. 725 for Low Energy Power and/or Low Voltage Power Circuits.

4.1.3 Working Space Around Equipment

4.1.3.1 Sufficient access and working space shall be provided and maintained around all electrical equipment to permit ready and safe operation and maintenance of such equipment.

4.1.3.2 Working space around electrical equipment shall be based on providing sufficient clearance to avoid body contact with grounded parts while performing maintenance on energized equipment.

4.1.3.3 Minimum working space around equipment operating at 600 volts or less and working space entrance requirements shall meet the requirement of NEC, Art. 110.26.

4.1.3.4 Except for substations, the minimum working space around equipment operating over 600 volts shall meet the requirement of NEC, Art. 110.34.

4.1.3.4.1 For substation locations, the minimum working space shall meet the requirement of ANSI/IEEE C2-NESC, Rule 125.B.

4.1.3.5 Existing installations that fail to meet the minimum working space requirements of Sections 4.1.3.3 and 4.1.3.4 shall mitigate the non-compliance using the guidance provided in Appendix E.

4.1.4 Approach Distances to Exposed Energized Parts – Shock Protection

4.1.4.1 NFPA 70E defines three shock protection boundaries (Limited Approach Boundary, Restricted Approach Boundary, and Prohibited Approach Boundary) for workers approaching exposed energized parts.

4.1.4.1.1 The distances for these boundaries, (based on system voltage) are listed in NFPA 70E, Table 130.2(C).

4.1.4.1.2 The requirements for crossing the shock protection boundaries by qualified and unqualified persons are defined in NFPA 70E, Art. 130.2, summarized in Table 4.1, and illustrated in Figure 4.1.4.1.

	Boundary Crossing Requirement Based on Worker Qualifications	
Shock Protection Boundary	**Unqualified Worker**	**Qualified Worker**
Limited Approach Boundary	Prohibited from crossing unless escorted by qualified worker	Permitted to cross
Restricted Approach Boundary	Prohibited from crossing	Prohibited from crossing except as permitted by NFPA 70E, Art. 130.2 (C) and Section 4.1.4.2, below
Prohibited Approach Boundary	Prohibited from crossing	Crossing this distance treated the same as making contact with energized parts

Table 4.1 – Boundary Crossing Requirements

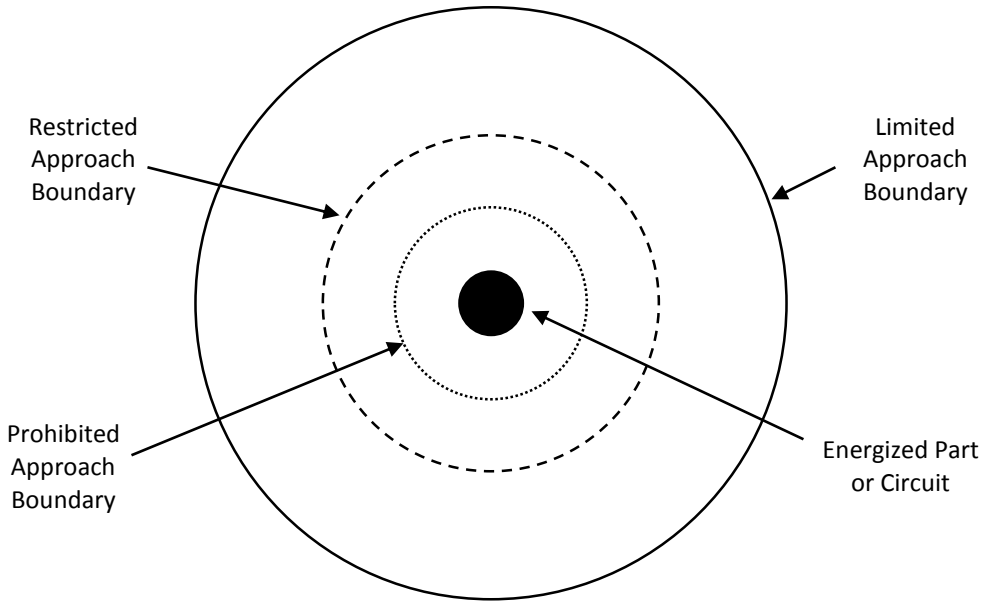


Figure 4.1 – Boundaries for Shock Hazard Protection Based on System Voltage Levels

4.1.4.2 Qualified persons shall neither approach nor take any conductive object closer to exposed energized parts than the “Restricted Approach Boundary” defined in NFPA 70E, Table 130.2(C) and listed below, for any reason unless such parts are adequately

guarded as required by NFPA 70E, Art. 130.2(C). Voltage ranges shown are those applicable to systems at LaRC.

Nominal System Voltage Range - Phase-to-Phase	Distance from Energized Parts to Restricted Approach Boundary
50 – 300 volts	Avoid contact
301 - 750 volts	1 feet
751 - 15,000 volts	2 feet 2 inches
15,100 – 36,000 volts	2 feet 7 inches
36,100 – 46,000 volts	2 feet 9 inches
72,600 – 121,000 volts	3 feet 3 inches

Table 4.2 – Restricted Approach Boundary

4.1.5 Approach Distances to Exposed Energized Parts – Arc Flash Protection

4.1.5.1 If work on or near exposed energized parts is required, as permitted by Section 1.2.1.1, flash protection PPE shall be utilized as required by NFPA 70E, Art. 130.3(B).

The need for and level of flash protection PPE is determined by whether or not the worker is closer than the Flash Protection Boundary (FPB) and what the available Incident Energy (IE) level is at the Working Distance (WD) from the exposed energized part resulting from an arc flash. FPB and WD are illustrated in Figure 4.2.

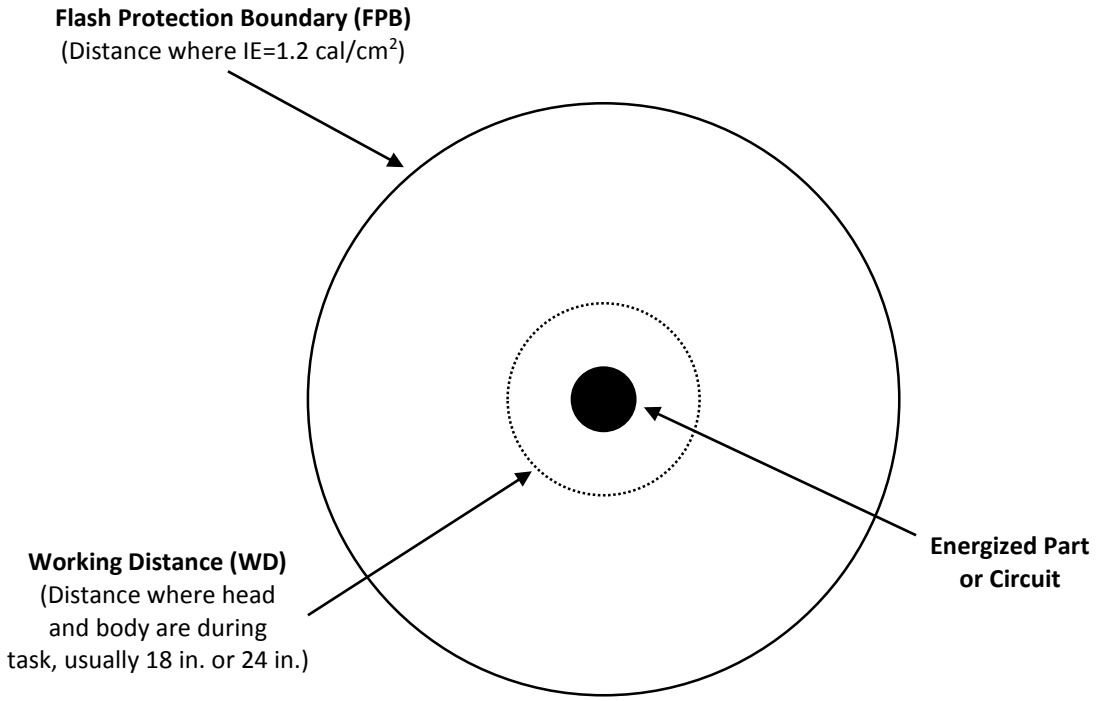


Figure 4.2 – Boundaries for Arc Flash Protection Based on Arc Flash Incident Energy Levels

Note: The FPB is the distance that the incident energy is no greater than 1.2 cal/cm^2, which is the energy that will result in a second-degree burn when not using arc flash PPE.

4.1.5.1.1 The FPB shall be 4 feet for systems that are 600 volts or less (assuming a maximum available bolted fault current of 50 kA and a 6 cycle clearing time), unless marked on the equipment by an arc flash hazard label.

4.1.5.1.2 Alternatively, and for equipment operating above 600 volts, NFPA 70E, Art. 130.3(A), shall be used to calculate the FPB or the Electrical Standard Practice Engineer shall be contacted to obtain this distance.

Note: The WD is the distance between the worker's head or body and the exposed energized part for the specific task.

4.1.5.2 The WD for electrical tasks shall be 18 inches, unless specifically marked on the equipment as 24 inches.

4.1.5.3 Incident energy levels for the selection of PPE shall be based on the calculated energy level at the working distance for the task.

4.1.5.3.1 If not marked on the equipment by an arc flash hazard label, the incident energy level shall be obtained from the Electrical Standard Practice Engineer.

4.1.5.3.2 The Hazard/Risk categories based on incident energy levels are listed in NFPA 70E, Table 130.7(C)(11). Alternatively, NFPA 70E, Table 130.7(C)(9) shall be used to select PPE for various electrical tasks in lieu of calculating incident energy levels at the WD.

> *Note: Flash Protection PPE does not prevent injury resulting from an arc flash. It is designed only to limit the injury resulting from an arc flash to a second-degree burn, which has been determined to be a survivable burn*.

4.1.6 Arc Flash and Shock Hazard Warning Labels

4.1.6.1 Detailed labels shall be installed on all electrical equipment required to be analyzed for arc flash hazards as required by NFPA 70E.

4.1.6.2 Generic labels shall be installed on electrical equipment required by NFPA 70 that does not require a detailed label.

4.1.6.3 See Appendix D. For guidance on formatting of detailed and generic labels and installing location on equipment.

4.1.7 High-Voltage Verification Test Conditions

4.1.7.1 High-voltage testing shall be preceded by the following actions:

a. Red tag the applicable circuits

b. Check for absence of voltage

c. Install temporary grounds/bump ground circuits

d. Secure the area

e. Remove temporary grounds

f. Perform high voltage testing

g. Perform grounding procedures

4.1.7.2 During these tests all safety precautions listed in Section 6, Paragraph 6.9 of ANSI/IEEE 95-1977 shall be followed.

4.1.7.3 Operational electrical equipment shall be periodically validated to determine that the dielectric strength has not fallen below safe levels.

4.1.7.3.1 The responsible operations group shall maintain procedures specifying the method and frequency of the tests.

4.1.7.3.2 A DC “Megger” (instrument for measuring the insulation resistance of electrical devices) appropriate to the circuit working voltage shall be used to obtain the readings. Validation is mandatory prior to energizing after any repair, which may have affected the equipment insulation system.

4.1.7.3.3 In general, power system equipment shall be tested for minimum values of 1 megohm or 1 megohm per 1000 volts of operating voltage, whichever is greater.

4.1.7.3.4 If lesser values are obtained, an appraisal shall be made by the responsible engineering organization before the equipment is energized.

4.1.8 Cranes and Lifting Equipment Adjacent to Exposed Electrical Energized Parts

4.1.8.1 Where cranes or other lifting equipment are used in or around high-voltage substations, overhead lines, or exposed energized parts, the operations and equipment shall be in conformance with OSHA 29 CFR 1926.550. See Section 4.3.1.6 for additional requirements on crane usage.

4.1.8.2 All lifting equipment shall be effectively grounded when being moved or operated in close proximity to energized lines or equipment.

4.1.8.2.1 Consideration shall be given to grounding the load, particularly if insulated lifting straps are in use.

4.1.8.3 Lifting equipment shall be operated with a dedicated observer to warn the equipment operator of potentially hazardous situations and/or movements.

4.1.8.4 Exposed energized conductors of up to 115kV are in use in high-voltage substations at LaRC. The following clearances shall be maintained between cranes and lifting equipment and exposed energized conductors as required by OSHA 29 CFR 1926.550(a)(15):

Conductor Voltage	Minimum distance between conductors and equipment
50 kV and below	10 ft
115 kV	12 ft, 2 in (Note 1)

Note 1: Distance calculated for 115 kV based on requirements from OSHA 29 CFR 1926.550(a)(15). See this standard for distance requirements for voltages other than those shown here.

4.2 FACILITIES AND EQUIPMENT

4.2.1 Installation or Major Repair – General

4.2.1.1 Prior to selecting and installing any new electrical equipment or systems, the design engineer shall consult and coordinate the work with the Facility Safety Head.

4.2.1.2 The Facility Safety Head shall be responsible for the overview of safety aspects for the repair or overhaul of major research equipment that requires partially or totally disabling a facility's research operations.

4.2.2 Installation or Repair of Transformers

4.2.2.1 Whenever work is to be performed on connected transformers, protective grounds shall be applied as required by Section 1.3.3 of this document.

4.2.2.2 When transformers are installed or replaced, the secondaries shall be checked for correct voltage and phase rotation.

4.2.2.3 When transformers are installed and before they are energized, the ground connection shall be made to the case, and where applicable, to the neutral.

4.2.2.4 Transformer covers or handhole plates shall not be removed from energized transformers.

4.2.2.5 All transformers shall be considered energized at full voltage unless they are disconnected from the primary and secondary power source, or unless they are disconnected from the primary power source and protective grounds have been applied to the transformer secondary.

4.2.2.5.1 The opening of a fused primary cutout or switch shall not be considered a primary disconnection unless the de-energized side of the cutout or switch is grounded.

4.2.2.6 When removing transformers, the case and neutral ground shall be disconnected last.

4.2.2.7 Because it is possible to have up to full phase-to-ground voltage on the transformer neutral, transformer neutrals shall always be treated as phase conductors, unless established as grounded.

4.2.3 Removal of Obsolete Equipment

4.2.3.1 When equipment is removed, the electrical wiring, conduit, and control boxes shall be removed from the equipment to the power source in accordance with the following procedures:

a. The power source shall be de-energized and disconnected prior to disconnecting the load or cutting the cables or wiring.

1) Overhead power lines shall be removed.

2) All cable and wiring shall be removed from conduit, ductbanks, etc.

3) Cable and wire that are direct buried do not have to be removed and may remain below ground.

4) The ends of the direct buried cable or wire shall be buried below ground and the location(s) identified on the Underground Utility Drawings. In unique situations and at the discretion of LaRC's Electrical Standard Practice Engineer, cables rated 2400 volts and above may remain in place.

b. All exposed conduits shall be removed.

1) Conduit that is direct buried or in ductbanks may remain in place.

4.2.3.2 After the equipment has been removed, the controlled electrical wiring diagrams, schematics, and so forth, shall be revised to show this change. See Section 3 for documentation update requirements.

4.2.4 Control Systems

4.2.4.1 Whenever control systems are dependent on electrical power for safe operation, provisions shall be made to have the control systems operate to the failsafe position in the event of an electrical power failure.

4.2.5 Standby Electrical Power

4.2.5.1 A minimum of two 60 kW or larger diesel electric or equivalent portable power plants shall be available for emergency use.

4.2.5.1.1 Portable power plant shall be provided at a voltage rating of 480 volts and/or 208 volts, three-phase, 60 Hertz that will permit connections to the bus on the secondary side of building unit substations.

4.2.6 Contractor Connections into Government Electrical Utilities

4.2.6.1 Prior to permitting the contractor to make connection into any part of the government electrical power distribution system, the contractor shall:

a. Make written application to the government contracting officer stating the date, time, location, and the service desired.

b. Make the necessary checks of the contractor's system and the government's supply jointly with the government representative to ensure their compatibility and safety.

4.2.7 Initial Energization of Electrical Systems Above 600 Volts

4.2.7.1 Initial energizing of all new electrical equipment shall be performed in the presence of the appropriate government representative.

4.2.7.2 All power feeder circuit breakers shall be checked for adjustment and operation in accordance with the manufacturer's instructions.

4.2.7.3 All protective relays and other such devices shall be tested to verify their capability of operating in the range required.

4.2.7.3.1 Where possible, tests shall include “loading in” at the current transformer secondaries to validate the circuitry as well as the device.

4.2.7.4 All wiring shall be field verified for conformity to the design, fabrication, and functional requirements.

4.2.7.5 All electrical equipment shall be tested in accordance with industry standards at voltage levels approved for the specific type of equipment by the LaRC cognizant engineering group or approved designee.

4.2.7.5.1 The minimum acceptable insulation resistance for electrical equipment shall be the greater of 1 megohm or 1 megohm per 1000 volts of operating voltage.

4.2.8 Protective Relay Settings

4.2.8.1 Protective relay settings shall be coordinated and concurred with by the Electrical Standard Practice Engineer to provide selective tripping.

4.2.8.1.1 The responsible electrical engineering organization shall review and approve the coordination.

4.2.8.1.2 The responsible operations organization shall maintain a listing of the required settings and the frequency of periodic testing of all protective relays in use.

4.2.8.2 All electromechanical relays for 22 kV and 115 kV circuits on the LaRC power system shall be checked and calibrated once every 2 years.

4.2.8.2.1 All electromechanical protective relays for circuits less than 22 kV shall be checked and calibrated once every 4 years.

4.2.8.2.2 All sold-state microprocessor type protective relays shall be checked and calibrated once every 6 years; unless monitored, then once every 10 years.

4.2.8.2.3 Every reasonable effort shall be made to perform an end-to-end check of the relay circuitry in the process of this check.

4.2.9 Circuit Interruption Devices

4.2.9.1 All circuit interruption devices shall be rated to interrupt the maximum short circuit current of the power system at the point of application of the device.

4.2.9.2 Short circuit system studies shall be made by the responsible electrical engineering organization and concurred with by the Electrical Standard Practice Engineer to obtain data on short circuit interrupting duty requirements whenever large loads are added, or major system changes are made which may affect the short circuit duty of the circuit breakers on the LaRC power distribution system.

4.2.9.3 Re-closing Circuits After Protective Device Operation - After a circuit is de-energized by a circuit protective device, the circuit shall not be manually re-energized until it has been determined that the equipment and circuit can be safely energized.

4.2.9.4 Molded-case circuit breakers or fuses shall be reset if it can be determined that the trip was due to an overload condition and not a fault.

4.2.9.4.1 Otherwise, the circuit shall be checked to determine that it is safe to energize.

4.2.9.4.2 Circuit breakers can be reset, however repetitive re-closing is prohibited. The problem shall be traced to the root cause if a circuit breaker trips twice in succession.

4.2.9.5 Circuit breakers shall be immediately inspected and checked to assure suitability for reuse after any operation in which the circuit breaker opens under short circuit or fault conditions.

4.2.9.5.1 When a trip occurs on breakers above 600 volts, the troubleshooting process shall verify the settings of all breakers between the fault and the tripped breaker.

4.2.9.6 All 115 kV circuit breakers shall be operated at least once every 24 months to assure satisfactory mechanical operation.

4.2.9.7 All 22 kV circuit breakers shall be operated at least once every 48 months to assure satisfactory mechanical operation.

4.2.10 Removal of Circuit Breakers Rated 600V and below

4.2.10.1 Removal of bolt-on/plug-on circuit breakers, motor starters, or other non-racking devices from energized bus in panelboards, switchboards or motor control centers shall not be permitted.

4.2.10.2 Racking of circuit breakers rated 600 volts and below shall be done only using the appropriately rated PPE.

4.2.10.3 See Section 1.3.11 for racking of Circuit Breakers rated over 600 volts.

4.2.11 Infrared (IR) Thermography

4.2.11.1 Infrared Thermography of electrical systems shall be performed only by a qualified electrical person certified in performing infrared thermography.

4.2.11.2 Thermographers performing infrared thermography shall comply with the approach distance specified in NFPA 70E for qualified persons.

4.2.11.3 Infrared Thermography shall comply with Section 1.1.3, Two-Person Rule/Safety Watch.

4.3 WORK IN ENERGIZED SUBSTATIONS

4.3.1 General Requirements

4.3.1.1 In addition to the other industry electrical safety codes, rules, and regulations specified elsewhere in this document, work in energized substations shall comply with the requirements of ANSI/IEEE C2-NESC, all applicable OSHA standards for substations, and Section 1.3 of this document.

4.3.1.2 Work areas shall be clearly defined by the installation of barriers and rope guards.

4.3.1.2.1 Barriers and rope guards shall be sufficient to restrain workers from inadvertently moving out of the work area.

4.3.1.3 Physical barriers shall be used whenever practicable.

4.3.1.3.1 When adequate barriers cannot be installed around all energized parts adjacent to the work area, action shall be taken to provide the continuous safeguarding of each worker.

4.3.1.4 A safe zone area shall be established between the work area and the energized parts based on the Minimum Approach Distances provided in Appendix F. The need to schedule an outage to facilitate the work in a substation shall be based on the guidelines provided in Appendix F.

4.3.1.5 Electric power outages required to execute work in the substation shall be requested at least seven days in advance of the need.

4.3.1.6 Cranes shall not be used while in or near an energized substation with exposed conductors where movement of the crane might cause objects to fall into or strike energized parts of the substation.

4.3.1.7 If crane usage is required to support the work, a power outage shall be requested for the work area. See Section 4.1.8 for clearance requirements for cranes working around exposed energized conductors.

4.3.1.8 When work involves handling of lengths of conduit, bus, steel, or large equipment in substations with exposed energized bus, a full-time employee knowledgeable of the safety required and without other duties shall be assigned to assure the safety of the work area.

4.3.1.9 After execution of a power outage by a LaRC certified Safety Operator as evidenced by receipt of the red tag stubs, the lockout/tagout responsible person shall check to:

a. Ensure the designated circuits have been de-energized.

b. Ensure the designated circuits are properly grounded.

c. Verify that the immediate work area and a zone beyond the work area have been made safe before permitting employees to work in the substations.

4.3.1.10 Additional safety supervisors shall be assigned as needed for the protection of the workers when the work is so divided and extensive that one safety supervisor cannot effectively maintain safety surveillance over the workers and their operations.

4.3.2 Contractor Personnel Other Than SpecializedContractors

4.3.2.1 Except for specialized contractors that provide on-site operational and maintenance support for electrical systems at LaRC, contractor personnel who are required to enter and/or work in energized substations shall comply with Section 4.3.2.2 through 4.3.2.6 in addition to the requirements of Section 4.3.1.

4.3.2.2 A work plan shall be submitted at least 7 days prior to initiating work in the substation, outlining the work to be done and identifying the circuits required to be de-energized to safely conduct operations.

4.3.2.2.1 The work plan shall include a detailed step-by-step work procedure for each phase of the work.

4.3.2.2.2 All changes to this work plan shall be reviewed with the responsible LaRC personnel prior to initiation.

4.3.2.3 An individual responsible for the electrical safety of each work team shall be appointed by the contractor.

4.3.2.3.1 The safety supervisor(s) shall attend the Construction Safety Briefing.

4.3.2.3.2 Before the work begins, the responsible individual shall provide a document to the government establishing that the appointed safety supervisor(s) is (are) qualified and knowledgeable in OSHA and LaRC safety regulations and requirements.

4.3.2.4 The government representative shall be contacted at the beginning of work each day for admittance to the substation unless the contractor has been granted permission to utilize contractor-owned substation locks to control access as follows:

4.3.2.4.1 Contractor substation locks, applied in series with government substation locks to permit authorized contractor access during substation construction projects, shall be conspicuously identified, marked, or tagged with the contractor’s name, contract number, and the name of authorized keyholder(s).

4.3.2.4.2 Contractor substation locks shall be uniquely keyed and shall not be used for any other purpose or keyed the same as other jobsite locks.

4.3.2.4.3 Contractor substation locks found to be unlocked and uncontrolled shall be removed and may result in temporary or permanent forfeiture of contractor substation access privileges.

4.3.2.4.4 Surveillance of the substation gates shall be maintained to permit only authorized personnel to enter.

4.3.2.4.5 No entrance shall be made while work is being conducted unless the contractor safety supervisor has been first contacted to verify conditions are safe.

4.4 SUBSTATION ACCESS

4.4.1 Standard Substation Access Procedures

4.4.1.1 Doors and gates that control access to high voltage substations shall be secured with locks.

4.4.1.1.1 Keys for these locks shall be assigned to qualified key holders who are electrically qualified personnel who have a need to enter the substations on a regular basis.

4.4.1.2 The issuance of substation keys shall be approved by the power distribution system Facility Safety Head and Facility Coordinator, and the Electrical Standard Practice Engineer.

4.4.1.3 Temporary keys may be assigned to other electrically qualified personnel at the discretion of the power distribution system Facility Safety Head and Facility Coordinator, and the Electrical Standard Practice Engineer.

4.4.1.4 Personnel who require access to the substations but are not qualified key holders shall contact a qualified key holder.

4.4.1.4.1 The qualified key holder shall escort anyone they permit into the substation.

4.4.1.5 Substation entries shall adhere to the following general requirements:

a. At least two people shall be involved in all entries into the substation when work is to be performed.

b. Entry gates/doors shall be closed but shall remain unlocked while personnel are working in the substations.

c. Entry gates/doors shall be locked when the last person exits the substation.

4.4.2 Substation Access for Non-Electrical Work

4.4.2.1 Unqualified personnel performing non-electrical work such as grounds keeping and painting in energized substations shall obtain substation access from a qualified key holder.

4.4.2.2 When the non-electrical work is performed around electrical hazards, the qualified key holder or another electrically qualified person shall act as a safety watch.

4.4.2.2.1 If the electrical hazard can be eliminated by de-energizing circuits or securing access to circuits by padlocks or barriers then the work shall be allowed to be performed with no electrically qualified person present.

5. SPECIAL EQUIPMENT HANDLING PROCEDURES

5.1 BATTERIES

5.1.1 Vented batteries and battery cells, regardless of electrode type, contain dangerous electrolytes that are subject to spillage. Overcharging or too-rapid charging can cause electrolyte boiling and spewing and the production of explosive gases. The following requirements shall be followed for these devices:

a. Face shields and goggles, rubber gloves, and protective rubber aprons shall be worn whenever batteries or cells are being handled, filled, or charged.

b. Ample neutralizing agent shall be present to fully neutralize any electrolyte spill that may occur in battery operations.

c. Battery charging shall take place in a well-ventilated area.

d. No smoking shall be permitted in the area where batteries are handled, filled, or charged.

e. Battery charging shall comply with all manufacturer recommendations.

f. An eyewash station shall be in an accessible location that requires no more than 10 seconds to reach. This eyewash station can be in each facility or on the battery technician's truck. Eyewash devices shall comply with ANSI Z358.1-2004.

5.2 FUSES

5.2.1 Fuses shall not be removed on energized circuits above 23,000 volts.

5.2.1.1 Fuses shall not be removed from loaded energized circuits with voltage ranges from 50 volts to 23,000 volts.

5.2.1.2 In addition to the PPE requirements of NFPA 70E when removing or replacing fuses on unloaded energized circuits, the following shall be required:

a. Rated 50 to 600 volts, insulated fuse tongs, extractors, or other approved methods shall be used.

b. Rated 601 to 1000 volts, lineman's type rubber gloves in addition to either insulated fuse tongs or extractors shall be used.

c. Rated 1001 to 23,000 volts, lineman's type rubber gloves in addition to insulated high-voltage sticks or tongs shall be used.

5.3 EXPERIMENTAL EQUIPMENT – GENERAL

5.3.1.1 Experimental electrical equipment that is under development, and therefore subject to frequent modifications, presents a particular hazard to personnel. Operating and emergency procedures may change from day to day. The following minimum safety requirements shall be followed while using experimental electrical equipment:

5.3.1.2 A responsible member of the research team shall be designated to establish correct working procedures as well as proper emergency procedures for review and approval by the Electrical Safety Engineer.

5.3.1.2.1 Particular emphasis shall be placed on emergency de-energizing of the equipment.

5.3.1.3 Areas where high energy sources are present shall be marked and physical barriers used where practicable.

5.3.1.3.1 Electrical and mechanical safety interlocks shall be used where practicable.

5.3.1.4 Personnel shall not work alone on high energy equipment unless the electrical equipment has been de-energized and secured in an electrically safe work condition.

5.3.1.5 Before working on high voltage/high energy equipment that has been energized and then de-energized after lockout/tagout has been implemented, the equipment shall be grounded to ensure no residual voltage remains as a potential shock hazard.

5.3.1.6 Use of high-voltage capacitor banks on experimental equipment shall comply with the requirements of Section 5.4 of this document.

5.3.1.7 Fail safe circuits shall be used, where practicable, to minimize possible hazards to personnel and equipment.

5.3.1.8 Temporary wiring shall meet the requirements of the NEC and Sections 1.2.9 and 1.2.10 of this document.

5.3.1.9 Indiscriminate use of extension cords and portable cables shall be avoided.

5.3.1.10 Any equipment that has frayed cords or three-wire cord ends that have had the grounding prong removed shall not be used.

5.3.1.11 Faulty equipment and tools shall be repaired by qualified personnel.

5.3.1.12 The general and specific work requirements under Sections 1.1 and 1.2 of this document shall apply to work under this paragraph

5.3.1.13 Use of knockout boxes to house receptacles for an on-site extension cord shall not be permitted.

5.4 EXPERIMENTAL EQUIPMENT – HIGH VOLTAGE CAPACITOR BANKS

5.4.1 Test personnel conducting experiments in which capacitor banks with voltages above 600 volts are employed shall have total knowledge of the experiment and the circuit and component layout. Personnel shall be fully trained in the operating and safety procedures to be used at that facility, including procedures to be used in the event of equipment failure.

5.4.2 The high-voltage test area shall be enclosed and protected through the use of gates and interlocks on the test controls.

5.4.2.1 Capacitors and related high-voltage component faults are a possible source of hazardous shrapnel. These components shall be isolated in a manner that precludes personnel injury or facility related hazards, such as fire.

5.4.3 High-voltage warning signs shall be displayed in a conspicuous location.

5.4.4 Flashing warning lights shall be used to indicate that tests are in progress.

5.4.5 A shorting switch or grounding device that normally discharges the capacitor bank shall be clearly visible to the test operator.

5.4.6 A voltmeter (VM) connected across the capacitor bank shall be clearly visible to the test operator at all times.

5.4.6.1 A redundant VM shall be installed at the capacitor banks.

5.4.7 Prior to touching a high-voltage component within the test area, a grounding wand approved by the LaRC Safety Manager for the particular installation shall be used to verify that the capacitor bank is fully discharged.

5.4.8 Extreme caution shall be used on capacitor banks operated by DC voltages, because a DC capacitor bank will maintain a residual voltage for extended periods.

5.4.9 Capacitors connected in a series to form a bank shall be treated with great care, and prior to making any changes to a test bank or circuit, each capacitor in a series string shall be properly discharged.

5.5 POLYCHLORINATED BIPHENYLS (PCB) HAZARDS

5.5.1 Electrical equipment, such as transformers, capacitors, and so forth, may contain a highly toxic, noncombustible, synthetic, electrical insulating liquid known generically as polychlorinated biphenyls (PCB). PCB has been sold under various trade names, including “Askeral,” “Inerteen,” “Chlorexol,” “Noflamal,” and “Pryranol.” All leaks of fluid containing PCB shall be reported immediately to the LaRC Environmental Manager.

APPENDIX A – DEFINITIONS

A.1 Buddy System: See Two-Person Rule/Safety Watch.

A.2 Cardiopulmonary Resuscitation (CPR): A procedure designed to restore normal breathing after cardiac arrest that includes the clearance of air passages to the lungs and heart massage by the exertion of pressure on the chest.

A.3 De-energized: Free from any electrical connection to a source of potential difference and from electrical charge; not having a potential different from that of the earth. (NFPA 70E)

A.4 Electrically Safe Work Condition: Energized at less than 50 volts or de-energized, locked and tagged, tested to ensure the absence of voltage, and grounded if deemed necessary. (NFPA 70E)

A.5 Energized: Electrically connected to a source of potential difference.

A.6 Energized Electrical Work Permit: A management-approved written permit required by NFPA 70E to work on energized equipment that cannot be placed in an electrically safe work condition.

A.7 Exposed (as applied to energized parts): Capable of being inadvertently touched or approached nearer than a safe distance by a person, especially parts that are not suitably guarded, isolated, or insulated. (NFPA 70E)

A.8 Fail-Safe: The capability to go to a predetermined safe state (i.e. minimum energy or minimized hazard condition) in the event of a specific malfunction.

A.9 Field Verified (as applied to electrical configuration controlled drawings): Verification that the drawing accurately depicts the configuration of installed systems or equipment by visual comparison and by point-to-point wire checks prior to placing the system into service. Point-to-point wire checks require ringing out or talking down the wiring between points of termination and are usually done during installation.

A.10 Functionally Verified (as applied to electrical configuration controlled drawings): Verification that the drawing accurately depicts the configuration of a functional system or equipment by visual comparison.

A.11 Grounded: Connected to earth or to some conducting body that serves in place of the earth. (NFPA 70E)

A.12 Guarded: Covered, shielded, fenced, enclosed, or otherwise protected by means of suitable covers, casings, barriers, rails, screens, mats, or platforms to remove the likelihood of approach or contact by persons or objects to a point of danger. (NFPA 70E)

A.13 High-Voltage: Voltage class designation for electric power systems and equipment operating above 600 volts.

A.14 Live Part: Energized conductive component. (NFPA 70E)

A.15 Lockout/Tagout (LOTO): The full procedure of determining what is required to make a system safe; the action of making the system safe; and the placing of locks, locking devices, and red tags to preclude changing from the safe condition.

A.16 Low Voltage: Voltage class designation for electric power systems and equipment operating at 600 volts or less.

A.17 Qualified Electrical Person: One who has been trained in and demonstrates adequate knowledge of the installation, construction, and operation of electrical equipment and has received electrical safety training on the hazards involved. One who is undergoing on-the-job training and, in the course of such training, has demonstrated an ability to perform duties safely at that level of training, and who, under the direct supervision of a qualified electrical person, is considered to be a qualified electrical person for the performance of those duties.

A.18 Qualified Industrial Person: One who has been trained in and demonstrates adequate knowledge of the installation, construction, and operation of industrial equipment and has received safety training on the hazards involved; has received electrical safety training; is a non-electrical Safety Operator with an electrical designation of 600 volts; and has CPR/AED Training.

A.19 Safety Operator (SO): Individual who has been qualified and certified to perform Red Tag Lockout/Tagout on electrical systems for which the Red Tag LOTO is requested and possesses a current NASA Langley Form 453, “NASA Langley Safety Operators Permit.” LaRC SOs are the only persons authorized to hang or remove red locks, red tags, and associated locking hardware.

A.20 Service Point: The point of connection between the facilities of the serving utility and the premises wiring. (NEC) Service points for the facilities at LaRC are identified on Effort Code (EC) 300 Switching Diagrams.

A.21 Two-Person Rule/ Safety Watch: The practice of employing a second qualified person to directly observe the electrical work of a qualified electrical person working on or near unguarded electrical equipment. System voltage and work location will determine the qualifications of the second person.

A.22 Unqualified Person: A person who is not qualified. (NFPA 70E)

A.23 Voltage (of a circuit): The greatest root-mean-square (rms) (effective) difference of electrical potential between any two conductors of the circuit concerned. (NFPA 70E)

APPENDIX B - ACRONOYMS

AEIC Association of Edison Illuminating Companies

AFSH Arc Flash and Shock Hazard

AED Automated External Defibrillator

ANSI American National Standards Institute

AWG American Wire Gauge

CFR Code of Federal Regulations

CM Configuration Management

CMOE Center Maintenance, Operation, and Engineering

CMOL Configuration Management On-Line

CNS Change Notification Sheets

CPR Cardiopulmonary Resuscitation

DC Direct Current

EIA Electronic Industries Association

ESC Electrical Systems Committee

ESWC Electrically Safe Work Condition

FPB Flash Protection Boundary

FUED Facility Utilities Electronic Database

GFCI Ground Fault Circuit Interrupter

HRC Hazard Risk Category

IE Incident Energy

IEEE Institute of Electrical and Electronic Engineers

IPCEA Insulated Power Cable Engineers Association

IR Infrared

ISA Instrumentation, Systems, and Automation

kV Kilovolts

kW Kilowatts

LaRC Langley Research Center

LF Langley Form

LOTO Lockout/Tagout

LPR Langley Research Center Procedural Requirement

LV Low Voltage

MCC Motor Control Center

NBR No Buddy Required

NEC National Electrical Code

NEMA National Electrical Manufacturer's Association

NESC National Electrical Safety Code

NFPA National Fire Protection Association

NPS Non-Personal Service

OSHA Occupational Health and Safety Administration

PCB Polychlorinated Biphenyls

PPE Personal Protection Equipment

QEP Qualified Electrical Person

QIP Qualified Industrial Person

RPT Relocatable Power Taps

SO Safety Operator

Swgr Switchgear

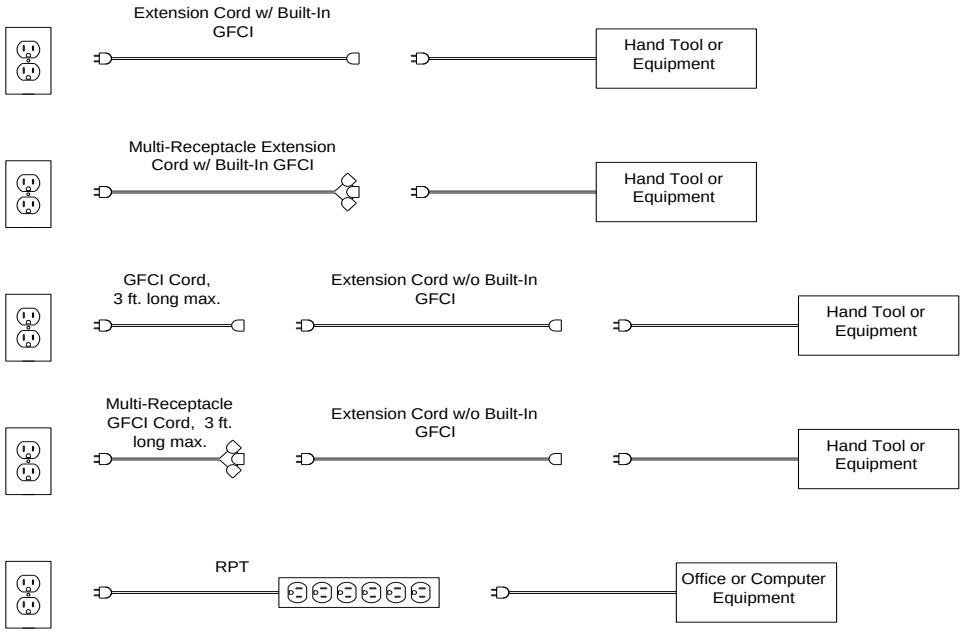
UL Underwriters Laboratories

V Volts

WD Working Distance

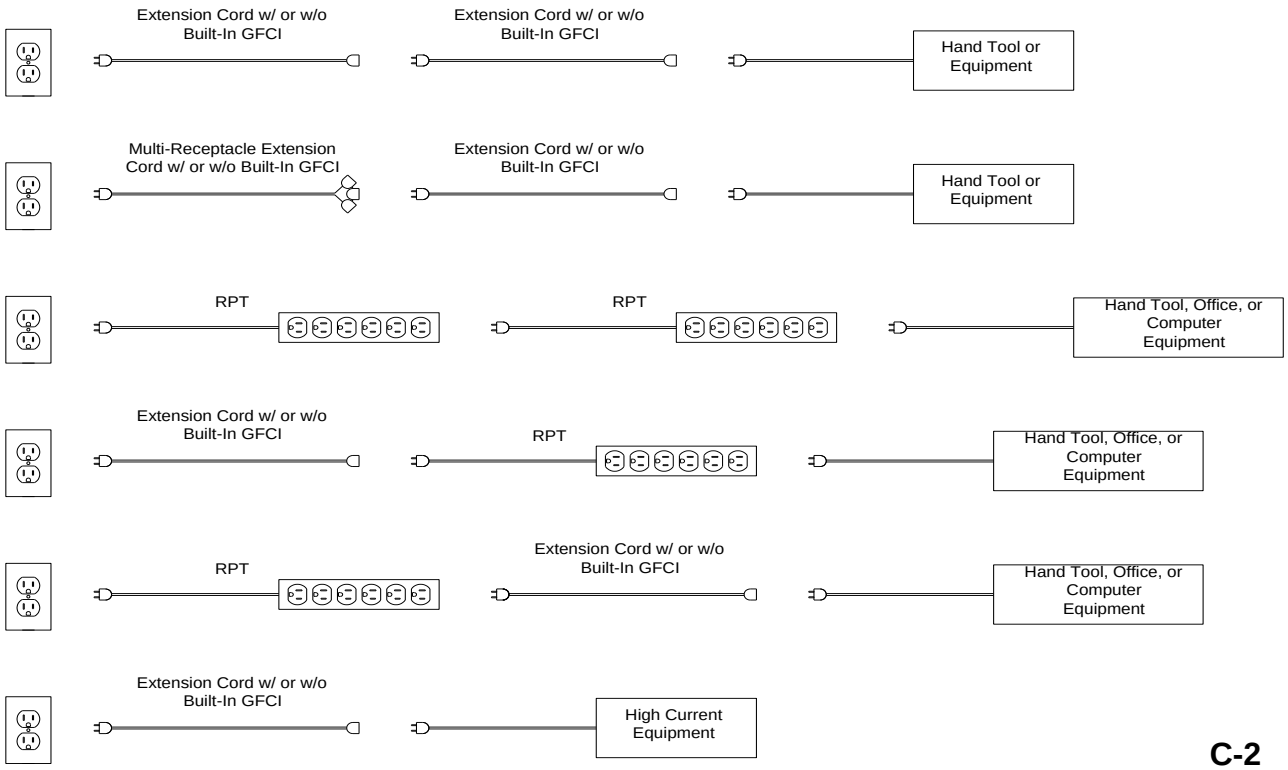
APPENDIX C – EXTENSION CORD CONFIGURATIONS

Acceptable combinations of extension cords and RTP's (Note 1)



Note 1. Extension cords used to supply temporary power to equipment used during construction, remodeling, maintenance, repair, or demolition of buildings, structures, or equipment, in damp or wet locations, in outdoor locations, or when direct contact with grounded conductive objects is possible, shall have GFCI protection for personnel.

Unacceptable (Daisy chain) combinations of extension cords and RTP's



APPENDIX D – ARC FLASH AND SHOCK HAZARD LABEL USAGE

D.1 Label Requirements

D.1.1 NFPA 70, National Electrical Code (NEC), and NFPA 70E require the use of AFSH Labels on electrical equipment to warn of arc flash and shock hazards while working on and operating certain types of electrical equipment.

D.2 Label Types and Locations

D.2.1 Two types of AFSH Labels are in use at LaRC; a generic label and a detailed label.

D.2.2 Install a detailed AFSH label on the following types of electrical equipment included in an arc flash hazard analysis:

1. Low Voltage (LV) Switchgear (Swgr).
2. Switchboards.
3. Panelboards.
4. Large Dry-type Transformers.
5. Motor Control Centers (MCC).
6. Disconnect Switches or other branch circuit loads directly fed from a branch circuit breaker having a rating 100 amps or greater.

D.2.3 Install a generic AFSH label on the following types of electrical equipment and not usually included in an arc flash hazard analysis:

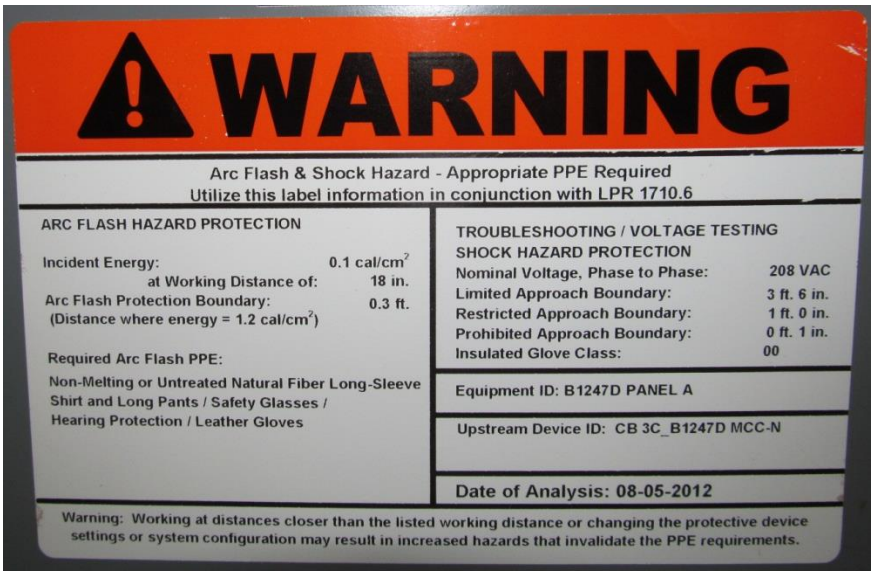
1. Branch circuit fed Disconnect Switches and Starters feeding small motors.
2. Disconnect Switches or other branch circuit loads directly fed from a branch circuit breaker having a rating less than 100 amps.
3. LV Swgr and Motor Control Center (MCC) cubicle buckets.

D.2.4 Detailed AFSH Labels will be located on electrical equipment as follows:

1. Generally, the new detailed labels will replace the generic labels with some minor exceptions.
2. On LV Swgr and MCCs:
    a. One detailed label on the main breaker based on line side fault.
    b. One detailed label at the top of the Swgr or MCC, applicable to all cubicle buckets, based on load side bus fault.
    c. One detailed label on each cubicle bucket in the same vertical section as the main breaker.
    d. Leave existing generic labels on each bucket for general warning but use detailed bus label for PPE selection.

D.3 AFSH Label Format

D.3.1 The format and required information for Detailed AFSH Labels at LaRC is shown below:



D.3.2 The format and required information for Generic AFSH Labels at LaRC is shown below:

D.4 Use of Detailed AFSH Label for PPE Selection

D.4.1 Once equipment has received a detailed AFSH label, PPE selection shall be based on the IE value of the detailed label and not the NFPA 70E task tables.

D.4.2 The IE value shown on the label is the worst case value that can be seen at the equipment.

D.4.3 In some cases, the upstream device that clears the arc fault may not be the first upstream protective device. For that reason, devices that have an incoming main protective device are analyzed on both the line side and load side of the main to determine worst case IE level.

D.4.4 The available arc fault current at a branch circuit load will usually be lower than that available at the panelboard from which it is fed due to attenuation.

D.4.5 Even though the arc fault current is lower than at the panelboard, the branch circuit load may have a higher IE than the panelboard. This is because a lower arc fault current may be sufficient to trip the breaker in the long term part of the trip curve and not the instantaneous part of the trip curve.

D.4.6 A longer trip time results in higher IE, even though the arc fault current may be lower.

D.4.7 It is incorrect to assume that a downstream device, such as a disconnect switch, will have a lower IE level than the panelboard it is fed from.

D.4.8 So if a device has a generic label, use the NFPA 70E task tables – do not use the detailed label of the upstream breaker to determine the required PPE.

D.4.9 Devices with generic labels can be evaluated on a case-by-case basis to validate or adjust the required PPE level dictated by the NFPA 70E task tables.

D.5 LaRC's Simplified Arc Flash PPE Selection Criteria

D.5.1 LaRC has adopted a Simplified Arc Flash PPE Selection Criteria to minimize the need to purchase and maintain multiple levels of Arc Flash PPE.

IE from AF Label	***Required PPE***		***HRC from NFPA 70E Task Table***	*****Required PPE***
ESWC	*Not required*		*ESWC*	*Not required*
< 1.2 cal/cm^2	******* *Nat. fiber or non-melting*		*HRC 0*	*HRC 0*
1.2 to 40 cal/cm^2	*PPE rated >= IE and as described on label*	***-or-***	*HRC 1*	*HRC 2*
			HRC 2	
			HRC 3	*HRC 4*
			HRC 4	
> 40 cal/cm^2	*Do not work energized*		*N/A*	*Do not work energized*

Table D.1- Simplified Arc Flash PPE Selection Criteria

ESWC - Electrically Safe Work Condition
HRC – Hazard Risk Category

******* *Equivalent to HRC 0 PPE*
**** **** *Does not preclude the use of HRC 1 or HRC 3 arc flash PPE if available and adequate for the HRC level*

D.6 Comparison of IE Values and HRC

D.6.1 IE levels do not directly correlate to the HRC levels in the NFPA 70E task tables.

D.6.2 HRC levels were developed by the NFPA 70E Technical Committee based upon the perceived risk due to the severity of hazard from IE exposure and probability of exposure based on the task performed.

D.6.3 PPE selection based on IE from the labels does not include any element of risk analysis based on the type of task being performed.

D.6.4 Methods for evaluating risks associated with electrical tasks are under development; however, no industry standard methodology has been adopted.

APPENDIX E – WORKING SPACE ABOUT ELECTRICAL EQUIPMENT

E.1 Routine safety audits often cite “inadequate clearance in front of electrical equipment” as an audit finding; however the basis for the finding is often in dispute and required actions to mitigate the finding are unclear. Requirements for working space about electrical equipment, 600 volts, nominal, or less are found in 29 CFR 1910. 303(g)(1)[1] and the National Electrical Code (NEC) 110.26. Similarly, requirements for working space about electrical equipment, over 600 volts, nominal, are found in 29 CFR 1910. 303(h)(3)[2] and the NEC 110.34. These require “sufficient access and working space be provided and maintained about all electrical equipment to permit ready and safe operation and maintenance of such equipment.” This is the basis for determining the adequacy of working space about electrical equipment. The following provides guidance on correct application of the working space requirements for existing electrical equipment and resolution of audit findings.

E.2 The key to understanding working space requirements is realizing that minimum dimensions to meet the “sufficient access and working space” requirements may not be explicitly specified and may need to be deduced or, if provided, may only be applicable for specific conditions. Applicability of the requirements may be triggered by the type of work or maintenance expected to be performed on the electrical equipment.

E.3 NEC 100-Definitions, defines “Accessible (as applied to equipment). Admitting close approach; not guarded by locked doors, elevation, or other effective means.” NEC 110.26(A)-Working Space requires minimum working space dimensions for “equipment likely to require examination, adjustment, servicing, or maintenance while energized.” [3] The text in NEC 110.34 for over 600 volts, nominal, is similar. From the explanatory section of the NEC Handbook, “Minimum working clearances are not required if the equipment is such that it is not likely to require examination, adjustment, servicing, or maintenance while energized. However, “sufficient” access and working space is still required.

E.4 Because the phrase “equipment likely to require examination, adjustment, servicing, or maintenance while energized” is subject to interpretation, the Electrical Systems Committee has determined that all electrical equipment that “can be

[1] 29 CFR 1910. 303(g)(1) are OSHA regulations.
[2] 29 CFR 1910. 303(h)(3) are OSHA regulations.
[3] While it is LaRC policy to establish an Electrically Safe Work Condition prior to working on electrical equipment, voltage testing and troubleshooting are examples of work on energized equipment that requires code mandated minimum working space.

opened with a tool or key to expose energized electrical conductors or circuit parts" meets the above criteria and is required to comply with the working space requirements for energized equipment. This includes electrical equipment such as panelboards, MCCs, fusible and non-fused disconnect switches, motor starters, and industrial control panels.

E.5 For existing electrical equipment meeting the above definition and cited as not compliant with minimum working space requirements, the following corrective actions should be taken:

a. Correct all access and working space non-compliances around existing electrical equipment that do not require extensive rework or that is not cost prohibitive.

b. For any remaining cited non-compliances, a warning sign with the following text shall be applied to the equipment to prohibit examination, adjustment, servicing, or maintenance of the equipment while energized:

> Note: "Working space about *(name of equipment)* does not meet the requirements of 29 CFR 1910.303(g)(1) (*or 29 CFR 1910.303(h)(3)*). Apply LOTO to upstream *(name of upstream disconnecting means)* to establish an Electrically Safe Work Condition before performing examination, adjustment, servicing or maintenance of this equipment."

E.6 Figure E.1 is an example of a warning sign installed on equipment without adequate working space. Warning signs can be obtained from the Safety and Facility Assurance Branch (SFAB).

Figure E.1 – Example Warning Sign

E.7 Alternative corrective actions proposed to mitigate exposure to electrical hazards when performing examination, adjustments, servicing or maintenance shall be approved by the Electrical Systems Committee in the rare instance that a cited working space non-compliance on exiting electrical equipment cannot be mitigated by the corrective actions noted above.

E.8 For all new installations, electrical equipment shall meet the working space requirements of NEC 110.26(A) and 110.34.

APPENDIX F – SUBSTATION MINIMUM APPROACH DISTANCES

F.1 This provides the guidelines for selecting minimum approach distances (MADs) for shock protection applicable to activities in outdoor substations at LaRC that have exposed energized circuit parts and conductors.

F.2 29 CFR 1910.269, IEEE 516, and the National Electrical Safety Code (NESC), provide minimum approach distances applicable to work on electric power generation, transmission, and distribution systems. Substations and equipment on the upstream side of the service point, usually operated by a utility or part of an industrial complex like at LaRC, are covered by these requirements. Work methods permitted for qualified workers include work on de-energized circuits and work on exposed energized circuits using insulated gloves (rubber glove method), using insulated tools and covers (insulated tool method), and by insulating the worker (barehand method). The energized work methods are permitted because utilities generally do not have the flexibility to schedule outages on equipment without major impact to customers and critical loads and qualified workers have specialize training for these work methods. Minimum approach distances are based on work being done by qualified workers trained in these work methods. Unlike a utility, LaRC has the flexibility to coordinate outages to eliminate the need to work on exposed energized circuit parts and conductors. As a matter of policy, only work on de-energized circuits is permitted at LaRC.

F.3 The NESC assumes that all work in substations and the electrical power distribution system will be done by qualified workers and currently minimum approach boundaries are not included for unqualified persons. There are routine instances when an unqualified person needs access to an outdoor substation with exposed energized circuit parts and conductors. Minimum approach distances for unqualified workers have been proposed during the last few update cycles of the NESC to address this issue; however, to date minimum approach distances for unqualified workers are not included. Currently only NFPA 70E – Standard for Electrical Safety in the Workplace, applicable to work inside of the facilities, includes minimum approach boundaries for unqualified workers. The minimum approach boundary for unqualified worker is the Limited Approach Boundary. The NESC working group has proposed using the same Limited Approach Boundary definition and distances as found in NFPA 70E.

F.4 Until minimum approach distances for unqualified workers are included in the NESC and other substation codes, LaRC will utilize the Limited Approach

Boundaries found in NFPA 70E to define the MAD for unqualified persons in the substation. The MADs for qualified workers found in the NESC is essentially the same as the Restricted Approach Boundary found in NFPA 70E, except that there is an error in the NFPA 70E distance for 72.6 to 121kV. Instead of being 3 feet, 4 inches, as shown, it should be 4 feet, 3 inches, which is the correct conversion of 1.29 meters. This correction aligns the NFPA 70E Restricted Approach Boundaries with the minimum approach boundaries found in the NESC and OSHA.

F.5 The minimum approach boundary for unqualified persons is the Limited Approach Boundary. The minimum approach boundary for qualified workers is the Restricted Approach Boundary; however, at LaRC this boundary will be used only by exception and only under an approved electrically energized work permit as required by NFPA 70E. For routine work in the substation, the minimum approach distance for qualified workers is the Limited Approach Boundary, the same as for unqualified persons. Figures 1 and 2, below, illustrate the Limited and Restricted Approach Boundaries for substations and provide the distances for the voltage ranges applicable to LaRC. Distances shown are from the exposed energized part to the person.

ELECTRICAL SHOCK HAZARD APPROACH BOUNDARIES (BASED ON NFPA 70E)
(All dimensions are distance from exposed energized part to person.)

NOMINAL VOLTAGE PHASE TO PHASE	LIMITED APPROACH BOUNDARY		RESTRICTED APPROACH BOUNDARY
	EXPOSED MOVEABLE CONDUCTOR	EXPOSED FIXED CIRCUIT PART	
Less than 50	Not Specified	Not Specified	Not Specified
50 to 300	10 ft 0 in	3 ft 6 in	Avoid Contact
301 to 750	10 ft 0 in	3 ft 6 in	1 ft 0 in
751 to 15kV	10 ft 0 in	5 ft 0 in	2 ft 2 in
15.1kV to 36kV	10 ft 0 in	6 ft 0 in	2 ft 7 in
36.1kV to 46kV	10 ft 0 in	8 ft 0 in	2 ft 9 in
46.1kV to 72.5kV	10 ft 0 in	8 ft 0 in	3 ft 3 in
72.6kV to 121kV	10 ft 8 in	8 ft 0 in	*4 ft 3 in
Over 121kV	Not Applicable	Not Applicable	Not Applicable

*THIS DISTANCE FROM NESC, TABLE 441-2. VALUE IN NFPA 70E IS INCORRECT.

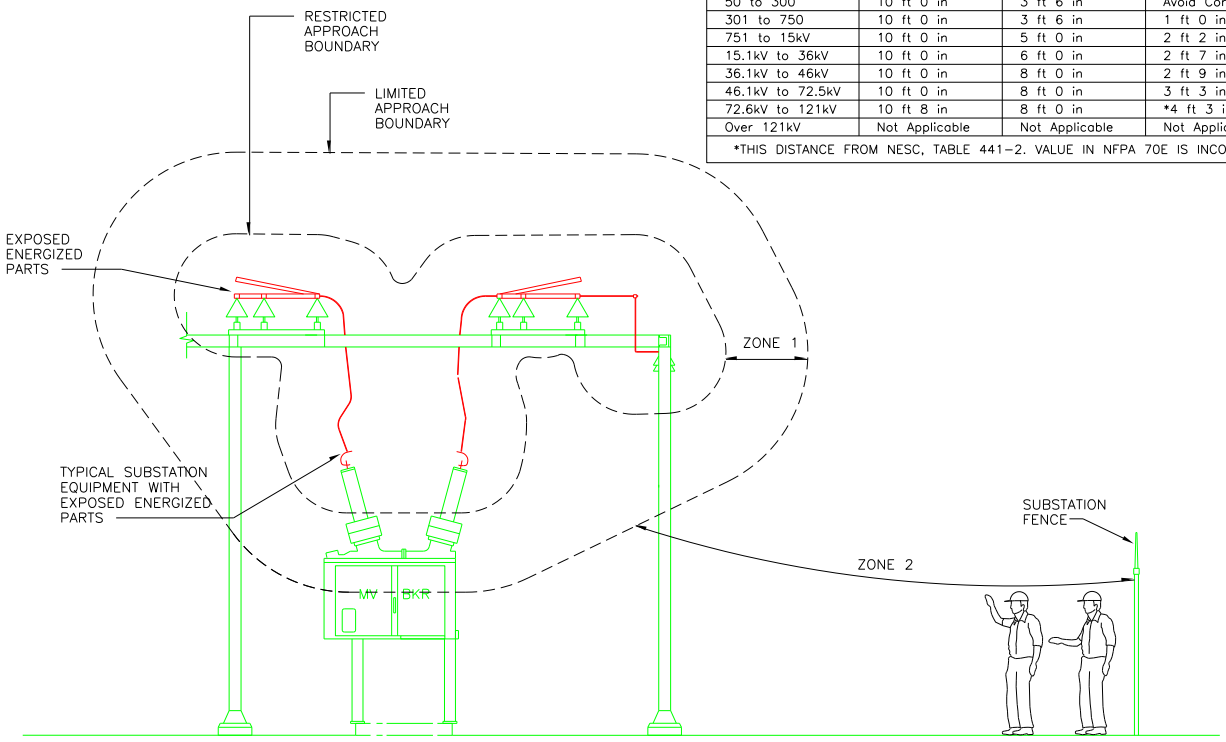


FIGURE 1—SHOCK APPROACH BOUNDARIES AND ACTIVITY ZONES IN SUBSTATION WITH EXPOSED ENERGIZED PARTS

SCALE: NTS

ELECTRICAL SHOCK HAZARD APPROACH BOUNDARIES (BASED ON NFPA 70E)
(All dimensions are distance from exposed energized part to person.)

NOMINAL VOLTAGE PHASE TO PHASE	LIMITED APPROACH BOUNDARY		RESTRICTED APPROACH BOUNDARY
	EXPOSED MOVEABLE CONDUCTOR	EXPOSED FIXED CIRCUIT PART	
Less than 50	Not Specified	Not Specified	Not Specified
50 to 300	10 ft 0 in	3 ft 6 in	Avoid Contact
301 to 750	10 ft 0 in	3 ft 6 in	1 ft 0 in
751 to 15kV	10 ft 0 in	5 ft 0 in	2 ft 2 in
15.1kV to 36kV	10 ft 0 in	6 ft 0 in	2 ft 7 in
36.1kV to 46kV	10 ft 0 in	8 ft 0 in	2 ft 9 in
46.1kV to 72.5kV	10 ft 0 in	8 ft 0 in	3 ft 3 in
72.6kV to 121kV	10 ft 8 in	8 ft 0 in	*4 ft 3 in
Over 121kV	Not Applicable	Not Applicable	Not Applicable

*THIS DISTANCE FROM NESC, TABLE 441-2. VALUE IN NFPA 70E IS INCORRECT.

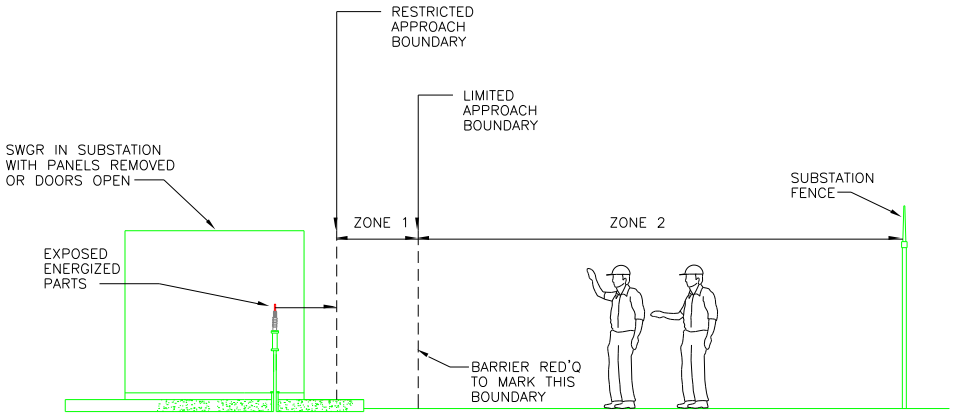


FIGURE 2–SHOCK APPROACH BOUNDARIES AND ACTIVITY ZONES IN SUBSTATION WITH EXPOSED ENERGIZED PARTS
SCALE: NTS

F.6 In rare circumstances, LaRC may choose to permit work in the substation by a qualified worker up to the Restricted Approach Boundary, depending upon the circumstances and qualifications and experience of the worker. In the substation, this is classified as Zone 1 type work. As noted above, work in this area can be done only under an approved electrically energized work permit. Because of the increased hazards of working in the substation, exemptions to the electrically energized work permit noted in NFPA 70E (testing, troubleshooting, and voltage measurements) are not permitted. Any work done outside of the Limited Approach Boundary is Zone 2 type work and requires no permit. Use of a voltage tester on the end of a live-line tool, where the qualified worker remains outside of the Limited Approach Boundary, is an example of work that requires no permit.

F.7 Achieving the Limited Approach Boundaries to energized parts shall be the basis for establishing the scope of required outages and LOTO to facilitate work in the substation.

APPENDIX G - HAZARDS OF ELECTRICITY

G.1 HAZARDS OF ELECTRIC ARCS

G.1.1 Arc Flash

G.1.1.1 While the phenomena of electric arcs and their destructive forces is nothing new, their threat to the safety of exposed electrical workers has only recently come under close scrutiny. Because of the availability of high-fault current levels in industrial systems, arcs from electric faults are more powerful and dangerous. An uncontrolled electric arc results in arc flash and arc blast. The severity of the hazard to the worker is determined by the amount of available energy at the fault and proximity of the worker to the fault. A dropped tool, deteriorating insulation on aging conductors, or animals are examples of factors that can create electric arc faults.

G.1.1.2 During a fault, conductive plasma is created that produces an arc flash at temperatures up to 35,000°F. The resulting radiated heat energy can create fatal burns or burns severe enough to result in long lost time recovery periods. Depending on the available short-circuit current at the fault and the duration of the fault, the resulting incident energy (radiated heat energy) can exceed 40 cal/cm2. An incident energy level of 1.2 cal/cm2 will create a second-degree burn, causing painful blistering of the skin. A third-degree burn results in complete destruction of the skin, cooking of the deeper tissues, and permanent damage and disfigurement.

G.1.1.3 Working on de-energized equipment will eliminate the arc hazard. If this is not possible, exposure to high incident energy levels while working on energized equipment can be mitigated by the use of flash-rated PPE and increasing exposure distance. Flash protective PPE is designed to limit incident energy levels during an arc flash to 1.2 cal/cm2. Requirements for arc flash hazard mitigation are found in the latest edition of the NEC and NFPA 70E, Art. 130.

G.1.2 Arc Blast

G.1.2.1 Arc blast is a second consequence of electric arcs. The arc blast is produced by the rapid expansion of super-heated air surrounding the arc and vaporization of conductive metal by the arc, resulting in an explosive air pressure wave. The blast energy or pressure resulting from an electric arc blast can be significant enough to cause falls or impact injuries that are more severe than burn injuries. Water turning into steam expands to 1,670 times its original volume. By comparison, when copper vaporizes, it expands to 67,000 times its original volume. This is the same expansion rate produced when dynamite explodes. Protective clothing will not protect against impact forces resulting from this blast pressure.

G.2 HAZARDS OF ELECTRIC SHOCKS

G.2.1 Effects of Electric Shocks

G.2.1.1 Some individuals who handle electrical equipment mistakenly believe their tolerance to electric shock is related to their ability to withstand the pain of the shock. Actually, the lethal incidence is a function of current passage (duration and level) through the heart region. Additionally, the onset of possibly lethal currents is only marginally higher than those ranked just painful and well within the range of industrial low-voltage power systems. While asphyxiation is the physiological result of the first zone of over-painful shock, the second zone results in heart ventricular fibrillation, or heart dysfunction. Not only is the latter not self-curing upon cessation of the current, but it is generally lethal within about 3 minutes. Just as it is current, not voltage, that heats a wire, it is current that causes the physiological damage.

G.2.1.2 The values of 60 Hz current and its typical effects on an average man are listed in Figure 6.2.1.2 as follows:

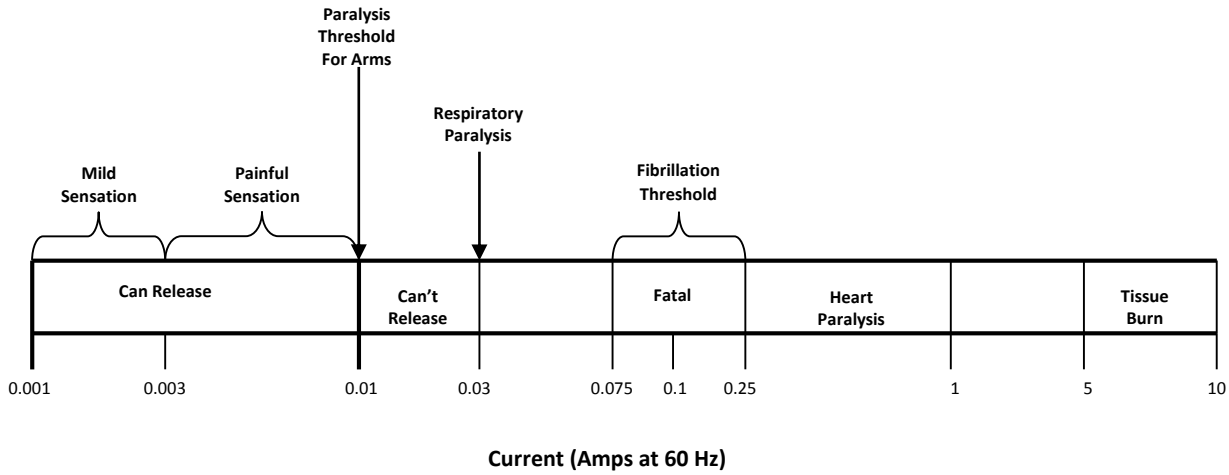


Figure G.1 – Effects of Current on Average Human

NOTE: Most GFCIs operate at 0.005 Amps

G.2.1.3 Note that as shock current values are increased they are statistically more dangerous from burn-type damage than heart failure. This is most likely because of the shorter exposure times. When very high voltages (above 2300 V) are involved, burns may not be severe as the victim initiates an arc that retracts (by reflex) the victim's attempted grasp. In summary, humans are affected in major proportion by the duration, as well as the level, of shock. When contact is made in such a manner as to retract the contracting part (such as a light finger touch when the strong muscular contractions of the arm pull the fingers away) the shock is much less dangerous than one of the same current level incurred by "freezing" to the contact with a full-hand grasp.

G.2.2 Body Current Levels at 120 Volts AC

G.2.2.1 Typical body current paths are listed in the table below.

Path	Current
Dry Skin	Less than 1 mA
Wet Skin	110 mA
Hand to Foot	220 mA
Ear to Ear	1.1 A

Table G.1 Typical Body Current Paths