LPR 1710.6 M-1

Effective Date: September 24, 2023

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Langley Research Center

ELECTRICAL SAFETY PROGRAM

National Aeronautics and Space Administration

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Change History Log

Revision	Date	Description of Change
M-1	9/24/23	1. Replace references to LF416 with NF 1921
M	9/24/23	1. Reorganized for ease of reading 2. Deleted duplicate requirements 3. Standardized terminology throughout the document 4. Added sections necessary for a documented Electrical Safety Program compliant with NFPA 70E 5. Added new forms for documenting qualifications, annual proficiency audits, and job planning 6. Added requirements for construction trailers Added Appendices for Temporary Wiring Approval, and Meggering of MV Motors

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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. In this document, use of the terms “shall” and “must” indicate mandatory requirements, and the terms “should”, “may”, and “will” indicate guidance requirements.

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 point” for LaRC is the 115kV utility connection at the B1233 main substation. The utility lines up to the “service point” are covered by ANSI/IEEE C2, National Electrical Safety Code (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.

d. In this directive, all mandatory actions (i.e., requirements) are denoted by statements containing the term “shall.” The terms “may” denotes a discretionary privilege or permission, “can” denotes statements of possibility or capability, “should” denotes a good practice and is recommended, but not required, “will” denotes expected outcome, and “are/is” denotes descriptive material.

e. In this directive, all document citations are assumed to be the latest version, unless otherwise noted.

P.3 AUTHORITY

a. The Control of Hazardous Energy, 29 Code of Federal Regulations (CFR) §1910.147.

b. Electric Power Generation, Transmission, and Distribution, 29 CFR §1910.269.

c. Electrical, 29 CFR pt. 1910, Subpart S.

d. Electrical, 29 CFR pt. 1926, Subpart K.

e. Electrical Power Transmission and Distribution, 29 CFR pt. 1926, Subpart V.

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

g. NASA Procedural Requirement (NPR) 8715.1, NASA Safety and Health Programs.

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

i. LAPD 1700.2, Safety Assignments and Responsibilities.

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

k. NFPA 70B, Recommended Practice for Electrical Equipment Maintenance.

l. NFPA 70E, Standard for Electrical Safety in the Workplace.

P.4 APPLICABLE DOCUMENTS AND FORMS

a. Powered Industrial Trucks, 29 CFR §1910.178.

b. Electric Power Generation, Transmission, and Distribution, 29 CFR §1910.269.

c. General, 29 CFR §1910.303.

d. Equipment, 29 CFR §1926.600.

e. NASA Procedural Requirement (NPR) 8715.1, NASA Safety and Health Programs.

f. Langley Procedural Requirement (LPR) 1710.10, Langley Research Center Energy Control Program (Lockout/Tagout).

g. LPR 1740.2, Langley General Safety Program Requirements.

h. LPR 1740.6, Personnel Safety Certification.

i. LPR 7123.2, Facility Configuration Management.

j. LPR 1800.1, LaRC Occupational Health Program.

k. LPR 8621.1, Langley Research Center Mishap Preparedness and Contingency Plan.

l. NASA Form (NF) 1896, Electrical Worker Qualifications Form.

m. NF 1897, Electrical Job Safety Planning and Job Briefing Worksheet.

n. NF 1898, Supervisor Electrical Safety Field Work Audit Form.

op. NF 1921, Energized Electrical Work Permit.

p. Langley Form (LF) 60, Confined Space Entry Permit.

q. LF 453, NASA Langley Safety Operators Permit.

r. LF 495, Energy Control Procedure.

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

t. ANSI/ISEA Z358.1, American National Standard for Emergency Eyewash and Shower Equipment.

u. Factory Mutual (FM) Data Sheet 5-23, Emergency and Standby Power Systems.

v. FM Data Sheet 7-39, Lift Trucks.

w. IEEE 95-2012, IEEE Recommended Practice for Insulation Testing of AC Electric Machinery (2300 V and Above) With High Direct Voltage.

x. IEEE 516, Guide for Maintenance Methods on Energized Power Lines.

y. International Code Council, International Fire Code (IFC).

z. National Fire Protection Association (NFPA) 1, Fire Code.

aa. NFPA 70, National Electrical Code (NEC).

ab. NFPA 70, National Electrical Code (NEC) Handbook.

ac. NFPA 70B, Recommended Practice for Electrical Equipment Maintenance.

ad. NFPA 70E, Standard for Electrical Safety in the Workplace.

ae. NFPA 505, Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Conversions, Maintenance, and Operations.

af. Underwriters Laboratories (UL) 1363, Relocatable Power Taps.

ag. UL 1449, Surge Protective Devices.

ah. UL 498A, Standard for Safety for Current Taps and Adapters.

ai. UL 962A, Furniture Power Distribution Units.

P.5 MEASUREMENT/VERIFICATION

Compliance with these requirements is ensured by the use of monthly facility safety inspections and periodic NASA Headquarters Institutional/Facility/Operational (IFO) Safety Audits.

P.6 CANCELLATION

LPR 1710.6 L-1, dated October 5, 2017

Original signed on file

Lisa Ziehman, Associate Director 09/24/2023
Title Date

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CHAPTER 1: QUALIFICATIONS AND TRAINING

1.1 WORKER QUALIFICATIONS

1.1.1 Personnel performing the following work shall be qualified in accordance with LPR 1740.6:

a. Qualified Electrical Persons who work on electrical equipment or systems rated 600 Volts or less.

b. Qualified Electrical Persons who work on electrical equipment or systems rated over 600 Volts.

c. Qualified Industrial Persons who may act as the second person under the two-person rule.

d. Electrical Safety Operators (600 Volts or less).

e. Electrical Safety Operators (over 600 Volts).

f. Mechanical Safety Operators performing electrical lockout/tagout (LOTO) for mechanical equipment operating 600 Volts or less.

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

1.1.3 Mechanical Safety Operators with an electrical designation of 600 Volts or less shall not be permitted to perform LOTO for electrical work or to use electrical test equipment to test for absence of voltage on exposed energized parts.

Note: Electrical work is work that has exposure to electrical conductors or circuit parts that pose a shock hazard when energized.

1.2 ELECTRICAL SAFETY TRAINING

1.2.1 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, Tables 130.4(E)(a) and 130.4(E)(b).

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

1.2.2 Electrical safety training shall be in accordance with the qualification requirements in LPR 1740.6 for each type of qualified person working on electrical equipment and systems.

1.3 AUDITING

1.3.1 The electrical safety program shall be audited to ensure compliance with the latest revision of NFPA 70E, at intervals not to exceed three years.

1.3.2 Supervisors shall conduct electrical safety field work audits of each Qualified Electrical Person to verify that the requirements contained in the electrical safety program are being followed, at intervals not to exceed 1 year.

1.4 DOCUMENTATION

1.4.1 Documentation of electrical worker qualifications and supervisor electrical safety field work audits shall be documented in accordance with Chapter 6 of this document.

CHAPTER 2: Electrical Hazard Control

2.1 ELECTRICALLY SAFE WORK CONDITION

2.1.1 Energized parts operating at voltages equal to or greater than 50 Volts, to which personnel might be exposed, shall be put into an electrically safe work condition and locked/tagged out before personnel work 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.

2.1.2 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.

2.1.3 All electrical circuits and equipment shall be considered energized until absence of voltage is verified by a Qualified Electrical Person and witnessed by a second qualified person if required by Table 3-1.

2.1.4 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. .

2.1.5 The application of LOTO devices shall be in accordance with LPR 1710.10.

2.2 JOB SAFETY PLANNING

2.2.1 Prior to performing work that involves potential exposure to electrical hazards, a job safety plan shall be completed in accordance with NFPA 70E, 110.1(I). The job safety plan shall include a description of the job, specific work procedures, and energy source controls.

2.2.2 Shock and arc flash risk assessments shall be conducted as part of the job safety planning to identify hazards and implement the appropriate hazard controls for each.

2.2.3 A job briefing shall be held to review the job safety plan with all personnel involved with the work being performed. The job safety plan shall be updated if the work scope changes or an unexpected condition is encountered.

2.2.4 Documentation of the job safety plan shall be in accordance with Chapter 6 of this document.

2.3 HAZARD CONTROL HIERARCHY

2.3.1 The hazard controls reviewed during the shock and arc flash risk assessments shall be implemented in accordance with the following hierarchy, listed in order of effectiveness:

a. Elimination.

b. Substitution.

c. Engineering controls.

d. Awareness.

e. Administrative controls.

f. PPE.

2.4 APPROACH BOUNDARIES TO EXPOSED ENERGIZED PARTS

2.4.1 Workers shall comply with the requirements of NFPA 70E, 130.4 (E), (F), and (G) for determining and working within the shock protection boundaries of exposed energized parts.

2.4.2 Workers shall comply with the requirements of NFPA 70E, 130.5 for determining and working within the Arc Flash Boundary when the likelihood of an arc flash exists.

2.4.3 The working distance (WD) for electrical tasks shall be 18 inches, unless specifically marked on the equipment.

2.5 ENERGIZED ELECTRICAL WORK PERMITS

2.5.1 No work, other than performing routine testing, troubleshooting, and voltage measurements, shall be performed on energized circuits of 50 Volts or greater without an approved NF 1921.

2.5.2 No work, other than opening of hinged switchgear panels or doors for inspection, data gathering, or infrared testing of the exposed energized circuit parts, shall be permitted on energized circuits over 600 Volts without an approved NF 1921.

2.5.3 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 an NF 1921.

2.5.4 The detailed procedure may be a separate document referenced by the NF 1921.

2.5.5 Only Qualified Electrical Persons shall perform work authorized by an approved NF 1921.

CHAPTER 3: ELECTRICAL SAFETY WORK PRACTICES

3.1 ADOPTION/COMPLIANCE WITH NFPA 70E

3.1.1 The Electrical Systems Committee (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.

3.1.2 LaRC shall adopt no editions of NFPA 70E earlier than those adopted for use in NPR 8715.1.

3.2 PPE SPECIFICS/REQUIREMENTS

3.2.1 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.

3.2.2 Conductive articles of jewelry and clothing (e.g., 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.

3.2.3 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 the IE value in cal/cm^2 indicated on the AFSH warning label.

3.2.4 If an Arc Flash risk assessment for a task on electrical equipment determines that an Arc Flash incident is likely to occur, Arc Flash PPE shall be used while within the Arc Flash Boundary as defined by NFPA 70E, 130.5(E) and selected in accordance with NFPA 70E, 130.5(F).

3.2.5 Arc flash PPE selection shall be based on the Arc Flash PPE Category indicated in the NFPA 70E Arc Flash Hazard PPE Category 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 Arc Flash PPE Category.

3.2.6 When working within the Restricted Approach Boundary or the Arc Flash Boundary of exposed electrical conductors or circuit parts, workers shall wear PPE in accordance with NFPA 70E, 130.7(C)(1).

3.3 RUBBER GLOVE USAGE

3.3.1 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.

3.3.2 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.

3.3.3 Gloves that do not meet the requirements of Section 3.3.2 shall be exchanged for compliant gloves prior to the start of work.

3.3.4 The test date on the gloves shall be allowed to exceed that required in Section 3.3.2 if the organization manages and documents issuance of gloves in accordance with NFPA 70E, Table 130.7(C)(7)(b), “Rubber Insulating Equipment, Minimum Test Intervals.”

3.3.5 Rubber gloves alone shall not be relied upon for protection from energized circuits of more than 3,500 Volts to ground.

3.4 STORAGE OF PROTECTIVE DEVICES

3.4.1 Protective equipment (e.g., arc flash suits, insulative blankets, sleeves, hot sticks) shall be maintained in a safe, reliable condition.

3.4.2 Protective equipment shall be visually inspected before each use.

3.4.3 Periodic testing of protective equipment shall comply with NFPA 70E, 130.7(C)(14) and 130.7(G).

3.5 HARD HAT AREA

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

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

3.6 LADDER USAGE

3.6.1 Portable ladders shall have nonconductive side rails if they are used where personnel or ladder could contact exposed live parts operating at 50 Volts or more or where an electrical hazard exists.

3.6.2 Only portable, nonconductive, ladders shall be used for entries into manholes. Existing fixed ladders have been determined to be structurally deficient and shall not be used.

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

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

3.7 TEST INSTRUMENTS AND TOOLS

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

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

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

3.8 TWO-PERSON RULE

3.8.1 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 in accordance with LPR 1740.6.

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.

3.8.2 Under the two-person rule, the second qualified person may 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.

3.8.3 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 may 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.

3.8.4 The two-person rule is mandatory whenever electrical work not requiring an NF 1921, 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 over 600 Volts.

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

3.8.6 For voltages 600 Volts or less, the second person may be a Qualified Electrical Person or a Qualified Industrial Person.

3.8.7 For voltages over 600 Volts, the second person shall be a Qualified Electrical Person.

3.8.8 A Mechanical 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 an active CPR/AED certification.

Note: Table 3-1 provides specific requirements for the second person under the two-person rule based on type of work and voltage.

3.9 SAFETY WATCH

3.9.1 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 in accordance with LPR 1740.6.

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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 to safely monitor the progress and methods of the qualified person doing the work.

e. Wear 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.

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

g. 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.

3.9.2 A Safety Watch is required for any electrical work that requires the use of an NF 1921.

3.9.3 For work in substations, depending upon the scope of work, if the requirements for a Safety Watch as required above align with the requirements for a Safety Supervisor as required in Section 3.33.6, the same Qualified Electrical Person can serve in both roles.

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

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Table 3-1. Requirements for Second Person under Two-Person Rule

	Voltage			
Type of Work	**Less than 50V**	**50 – 250V**	**251 – 600V**	**Greater than 600V**
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 + NF 1921	SW + NF 1921	SW + NF 1921 (3)

NR = Not Required

QEP = Qualified Electrical Person

QIP = Qualified Industrial Person

SW = Safety Watch

(1) Energized work is not permitted without an approved NF 1921

(2) QEP required for de-energized work in substations

(3) Applies to opening of hinged covers as described in Section 2.5.2

3.10 TESTING (OVER 600 VOLTS)

3.10.1 High-voltage testing shall be conducted by completing the following steps in order:

a. LOTO 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.

3.10.2 High-voltage insulation resistance testing of rotating machinery shall also comply with the precautions listed in IEEE 95-2012, 4.1.

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3.11 MINIMUM INSULATION RESISTANCE VALUES

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

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

3.11.3 A DC “Megger” (colloquially referred to as an instrument for measuring the insulation resistance of electrical equipment) appropriate to the circuit working voltage shall be used to obtain the measurements. Validation is mandatory prior to energizing after any repair that may have affected the equipment insulation system.

3.11.4 In general, power system equipment shall be tested for minimum values of 1 megohm or 1 megohm per 1,000 Volts of operating voltage, whichever is greater.

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

3.11.6 For medium voltage motors that have been idle, the frequency of insulation resistance testing shall comply with the testing requirements of the facility’s standard operating procedures, unless the facility complies with the recommendations in Appendix J.

3.12 INFRARED (IR) THERMOGRAPHY

3.12.1 Infrared thermography of electrical systems shall be performed only by a Qualified Electrical Person certified in performing infrared thermography.

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

3.12.3 Infrared thermography shall comply with section 3.8, “Two-Person Rule.”

3.13 PORTABLE EQUIPMENT GROUNDING

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

3.13.2 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.

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

3.14 PROTECTIVE GROUNDING

3.14.1 Equipment normally energized over 600 Volts shall always be considered energized unless protective grounds and/or other appropriate safety measures, in accordance with LPR 1710.10 are confirmed to be in place.

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3.14.2 Work shall not be conducted on de-energized lines and equipment having a nominal voltage rating over 600 Volts unless protective grounds have been applied, except as permitted in Section 3.14.5.

3.14.3 Protective grounding shall be applied to de-energized lines and equipment having a nominal voltage rating over 600 Volts if exposed current-carrying parts are to be contacted or approached within the Restricted Approach Boundary as delineated in NFPA 70E, Tables 130.4(E)(a) and 130.4(E)(b).

3.14.4 Other nearby exposed parts of any electrical equipment rated over 600 Volts, which are not associated with the work but may be approached within the Minimum Approach Distance during work activities, shall either be de-energized with protective grounds applied or suitably isolated to prevent contact in accordance with Appendix F.

3.14.5 If the installation of protective grounding is determined to be impracticable or would present a greater hazard to workers than working without grounds, the lines and equipment may be treated as safe to work on by exception, but not safetied, if all of the following are verified to be true and documented on the LF 495:

a. Electrically safe work condition is established including verification of the absence of voltage.

b. Verification there is no possibility of contact with another energized source.

c. The hazard of induced voltage is not present.

3.14.6 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 over 600 Volts.

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

3.14.8 When protective 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 and the location of protective grounds documented.

3.14.9 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.

3.14.10 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.

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

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

3.14.13 Protective grounding cables shall not be less than 2/0 AWG copper or equivalent.

3.15 PROTECTIVE GROUNDING: OVERHEAD LINES AND POLE WORK

3.15.1 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.

3.15.2 A multi-grounded common neutral of 4/0 AWG copper or equivalent is an acceptable ground for pole work.

3.15.3 Pole guy wires shall not be used as ground points.

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

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

3.15.6 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.

3.16 PROTECTIVE GROUNDING: TRANSFORMERS

3.16.1 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.

3.16.2 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.

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

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

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

3.17 PROTECTIVE GROUNDING: CURRENT AND POTENTIAL TRANSFORMERS

3.17.1 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.

3.17.2 Current transformer cases and secondaries shall be grounded.

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

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

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

3.18 PROTECTIVE GROUNDING - POWER CAPACITORS

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

3.18.2 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.

3.18.3 All individual power capacitor tanks shall be grounded.

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

3.19 PROTECTIVE GROUNDING - UNDERGROUND CABLES

3.19.1 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.

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

3.20 UNDERGROUND UTILITIES AND OPERATIONS - GENERAL REQUIREMENTS

3.20.1 Entries into electrical manholes, vaults, and confined spaces containing electrical cables and equipment shall require an approved LF 60 in accordance with LPR 1740.2.

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

3.20.3 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.

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

3.20.5 When practicable, manholes shall be entered or exited by means of a ladder in accordance with Section 3.6.2.

3.20.6 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.

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

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

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

Verify the correct version before use by checking the LMS website.

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

3.21 GAS AND FUMES IN UNDERGROUND LOCATIONS

3.21.1 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.

3.21.2 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. (

3.21.3 If gas or fumes are detected, no one shall enter the manhole or vault, except as provided for in Section 3.21.7, until thorough ventilation has been accomplished and tests made to ascertain that the gases or fumes have been eliminated.

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

3.21.5 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.

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

3.21.7 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.

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

3.22 ENERGIZED CABLES IN UNDERGROUND LOCATIONS

3.22.1 All cables in manholes shall be considered as sources of potential shock and arc flash and shall not be moved or manipulated while energized.

3.22.2 On cables with exposed conductive outer sheaths, tests shall be made to verify that there is no voltage between the outer sheaths and ground.

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

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

3.22.5 If barriers cannot be used to isolate energized cables from the work in the manhole, the cables shall be de-energized prior to starting the work and remain de-energized for the duration of the work.

3.22.6 Only qualified workers shall be permitted to work in electrical manholes or cable tunnels if energized cables are present.

3.22.6.1 Unqualified workers shall be allowed to assist in these operations if adequate supervision and safety guarding of the unqualified worker is provided.

Verify the correct version before use by checking the LMS website.

3.22.7 Arc Flash PPE is not required for manhole entries limited to performing non-contact visual inspections and no manipulation of energized cables.

3.23 CUTTING AND SPLICING CABLES

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

3.23.2 Before cutting into de-energized high voltage cables (over 600 Volts) for the purpose of making repairs or removing the cables from the raceway system, workers shall comply with the requirements covering clearing, tagging, testing, grounding, and cable identification.

3.23.3 Before being cut, cables shall be identified by tags, ducts, and duct records.

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

3.23.5 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.

3.23.6 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.

3.23.7 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.

3.24 RE-CLOSING CIRCUITS AFTER PROTECTIVE DEVICE OPERATION

3.24.1 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.

3.24.2 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.

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

3.24.4 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.

Verify the correct version before use by checking the LMS website.

3.24.5 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.

3.24.6 When a trip occurs on breakers over 600 Volts, the troubleshooting process shall verify the settings of all breakers between the fault and the tripped breaker.

3.25 SWITCH OPERATIONS (600 VOLTS OR LESS)

3.25.1 When possible, personnel shall stand to the side away from the door/cover when opening or closing disconnect switches.

3.26 SWITCH OPERATIONS (OVER 600 VOLTS)

3.26.1 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 1740.6.

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

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

a. Obtain concurrence from a Qualified Electrical Person 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 LOTO(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 over 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.

3.26.4 Medium voltage (MV) switches used to facilitate personnel entry into a wind tunnel or research test facility by establishing a visible air gap in conductors feeding MV control equipment and loads shall only be operated by Qualified Electrical Persons.

3.26.4.1 Exception 1: A qualified operator may remotely operate a MV switch if the following conditions are met:

a. The MV switch is electrically operated, and

b. The MV switch is interlocked with the MV control equipment to prevent operation of the MV switch under load.

3.26.4.2 Exception 2: A qualified operator may manually operate a MV switch if the following conditions are met:

a. The MV switch is located between the MV control equipment and the load, and

b. There is a positive means of verifying the absence of voltage on the line side terminals of the MV switch.

3.27 LIVE-LINE TOOLS

3.27.1 The clear live-line tool distance shall not be less than the values for phase-to-ground or phase-to-phase exposures, as applicable, in accordance with OSHA 29 CFR 1910.269, Tables R-6 and R-7.

3.27.2 The minimum length for disconnect poles is the combination of minimum clear live-line tool distance between the head and protective collar (or identifying mark) and the minimum handle length for the applicable voltage.

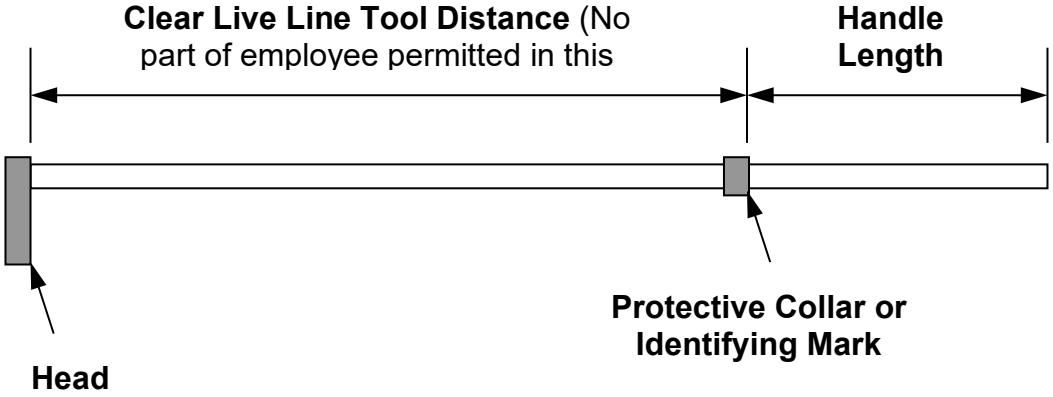

Figure 3-1. Lengths for Live-Line Tools

3.28 RACKING/REMOVAL OF CIRCUIT BREAKERS (600 VOLTS OR LESS)

3.28.1 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.

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

3.29 RACKING CIRCUIT BREAKERS (OVER 600 VOLTS)

3.29.1 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 1740.6.

3.29.2 The two-person rule shall be used during the racking of circuit breakers.

3.29.3 Racking of circuit breakers rated over 600 Volts 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.

Verify the correct version before use by checking the LMS website.

3.29.4 Attachment and detachment of a remote racking device is classified as a low-risk electrical task and does not require the use of Arc Flash PPE.

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

3.29.6 All unqualified personnel shall be cleared from the immediate and adjacent areas during racking operations, no closer than the Arc Flash Boundary defined by NFPA 70E, 130.5.

3.30 TESTING OF CIRCUIT BREAKERS AND PROTECTIVE RELAYS

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

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

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

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

3.30.5 All solid-state microprocessor type protective relays shall be checked and calibrated once every six years; unless monitored, then once every ten years.

3.30.6 Every reasonable effort shall be made to perform an end-to-end check of the relay circuitry when checking and calibrating protective relays.

3.31 WORK IN ENERGIZED SUBSTATIONS

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

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

3.31.3 Physical barriers shall be used whenever practicable.

3.31.4 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.

3.31.5 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.

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

3.31.7 After execution of a power outage by a LaRC certified Safety Operator as evidenced by receipt of the red tag stubs, the LOTO 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 personnel to work in the substations.

3.31.8 When work involves handling of lengths of conduit, bus, steel, or large equipment in substations with exposed energized bus, a Safety Watch shall be assigned to assure the safety of the work area.

3.32 SUBSTATION ACCESS

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

3.32.2 Keys for substation locks shall be assigned to qualified key holders who are Qualified Electrical Persons who have a need to enter the substations on a regular basis.

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

3.32.4 Temporary keys may be assigned to other Qualified Electrical Persons at the discretion of the power distribution system Facility Safety Head. the Facility Coordinator, the Electrical Standard Practice Engineer.

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

3.32.6 Qualified key holders shall escort anyone they permit into the substation.

3.32.7 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.

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

3.32.9 When the non-electrical work is performed around electrical hazards, the qualified key holder or another Qualified Electrical Person shall act as a Safety Watch.

3.32.10 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 Qualified Electrical Person present.

3.33 SUBSTATION REQUIREMENTS FOR CONTRACTORS

3.33.1 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 Sections 3.33.2 through 3.33.13 in addition to the requirements of Section 3.31.

Verify the correct version before use by checking the LMS website.

3.33.2 A work plan shall be submitted at least seven 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.

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

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

3.33.5 One or more individuals responsible for the electrical safety of each work team shall be designated by the contractor as a safety supervisor(s).

3.33.6 The safety supervisor(s) shall attend the LaRC Construction Safety Briefing in accordance with LPR 1740.2.

3.33.7 Before work begins, the contractor shall provide documentation to the Government establishing that the appointed safety supervisors are qualified and knowledgeable in OSHA and LaRC safety regulations and requirements.

3.33.8 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:

a. 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).

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

c. 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.

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

e. No entrance shall be made while work is being conducted unless the contractor safety supervisor has been first contacted to verify conditions are safe or that entries by other keyholders are coordinated with the contracted work.

3.34 CRANES AND LIFTING EQUIPMENT ADJACENT TO EXPOSED ENERGIZED PARTS

3.34.1 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.

3.34.2 If crane usage is required to support the work, a power outage shall be requested for the work area.

Verify the correct version before use by checking the LMS website.

3.34.3 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 accordance with OSHA 29 CFR 1926.600.

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

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

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

3.34.7 Exposed energized conductors of up to 115 kV 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 1926.600(a)(6):

Table 3-2. Minimum Clearances Between Power Lines and Cranes

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 1926.600(a)(6)(ii). See this standard for distance requirements for voltages other than those shown here.

Verify the correct version before use by checking the LMS website.

CHAPTER 4: ELECTRICAL INSTALLATIONS

4.1 ADOPTION/COMPLIANCE WITH NATIONAL ELECTRICAL CODE

4.1.1 The NEC is updated on a three-year cycle. The Chairperson for the LaRC ESC shall be responsible for the implementation of the revised edition of the NEC for use at LaRC.

4.1.2 The ESC Chairperson shall issue a memorandum establishing the date of implementation for all new editions of the NEC.

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

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

4.1.5 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.

4.1.6 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.

4.1.7 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.

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

4.1.9 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.

4.1.10 Electrical wiring and equipment that are not part of the modification do not have to be updated.

4.2 EQUIPMENT IDENTIFICATION

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

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

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

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

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

4.3 SHOCK AND ARC FLASH HAZARD LABELING

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

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

4.3.3 Generic labels shall be installed on electrical equipment required by the NEC that does not require a detailed label.

Note: See Appendix D for guidance on formatting of detailed and generic labels and installation location on equipment.

4.4 GROUNDING

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

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

4.5 WORKING SPACE

4.5.1 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.

4.5.2 Working space around electrical equipment shall provide sufficient clearance to avoid body contact with grounded parts while performing maintenance on energized equipment.

4.5.3 Minimum working space around equipment operating at 600 Volts or less and working space entrance requirements shall comply with NEC, 110.26.

4.5.4 The minimum working space around equipment operating over 600 Volts shall comply with NEC, 110.34.

4.5.5 Existing installations that do not comply with the minimum working space requirements of Sections 4.5.3 and 4.5.4 shall mitigate the non-compliance using the guidance provided in Appendix E.

4.6 TRANSFORMERS: INSTALLATION OR REPAIR

4.6.1 Whenever work is to be performed on connected transformers, protective grounds shall be applied as required by Section 3.16.

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

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

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

Verify the correct version before use by checking the LMS website.

4.6.5 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.

4.6.6 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.

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

4.6.8 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.

4.7 OBSOLETE EQUIPMENT REMOVAL

4.7.1 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) Cable and wiring shall be removed from conduit, duct banks, and raceways.

(3) Cable and wire that is 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 2,400 Volts and above may remain in place.

b. All exposed conduits shall be removed.

(1) Conduit that is direct buried or in duct banks may remain in place.

4.7.2 After the equipment has been removed, affected Configuration Controlled Information (CCI) shall be revised to document the change.

4.8 PROTECTIVE DEVICE COORDINATION

4.8.1 Protective relay settings to provide selective tripping shall be coordinated and approved by the Electrical Standard Practice Engineer or designee.

4.8.2 The required settings and the frequency of periodic testing of all protective relays in use shall be maintained by the responsible operations organization.

4.8.3 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.

4.8.4 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 that may affect the short circuit duty of the circuit breakers on the LaRC power distribution system.

4.9 CONNECTION TO GOVERNMENT ELECTRICAL SUPPLIES

4.9.1 Prior to connection by the contractor 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.

4.10 INITIAL ENERGIZATION OF ELECTRICAL EQUIPMENT

4.10.1 Prior to initial energization of supply feeders and new electrical equipment, all protective devices shall be adjusted and verified to match the settings of an approved protective device coordination report.

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

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

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

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

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

4.10.7 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.

4.11 TEMPORARY WIRING

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

4.11.2 Temporary wiring shall be permitted during tests, experiments, and developmental work lasting no longer than 90 days.

4.11.3 For tests, experiments, and developmental work lasting more than 90 days, permanent wiring methods shall be used unless temporary wiring is approved by the LaRC Safety Manager or designee for the required time period exceeding 90 days.

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

Verify the correct version before use by checking the LMS website.

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

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

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

4.11.8 Temporary wiring shall comply with the temporary wiring requirements of the NEC.

4.11.9 Temporary wiring shall be approved by the Electrical Standard Practice Engineer or designee in a memo documenting the temporary wiring configuration and posted at the point of connection to the government's electrical supply for the duration of use.

Note: An example of a temporary power approval memo is provided in Appendix H.

4.12 CONSTRUCTION TRAILERS

4.12.1 Temporary power to construction trailers shall be permitted under the guidelines provided in Appendix I.

4.12.2 In addition, a protective device coordination report shall be generated and approved to validate existing, or recommend new, protective device settings at the point of connection to the government's electrical supply.

4.13 EXTENSION CORDS

4.13.1 Extension cords may be used for temporary applications only and shall not be used for more than 90 consecutive days without LaRC Safety Manager or designee approval.

4.13.2 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.

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

a. Be protected from damage should the door or window slam shut.

b. Be removed immediately when no longer in use.

c. Not pose a trip hazard.

4.13.4 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 Sections 4.13.5 and 4.13.6.

4.13.5 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 Persons only using listed cord types SO, ST, or SJ in continuous lengths and UL listed plugs and receptacles.

4.13.6 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 Persons only after justification for fabrication of the extension cords.

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

4.13.8 High-current equipment (e.g., microwave ovens, space heaters, and coffee pots) shall be plugged directly into wall receptacles to prevent the use of extension cords in lieu of branch circuit permanent wiring methods.

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

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

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

4.13.12 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.

4.13.13 Extension cords shall not be daisy-chained (i.e., one extension cord plugged into another extension cord) except that a Ground Fault Circuit Interrupter (GFCI) cord set, three feet in length or less, may be connected between a wall receptacle and an extension cord to provide shock protection.

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

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

4.14 GFCI

4.14.1 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 GFCIs for shock protection.

4.14.2 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.

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4.15 POWER STRIPS

4.15.1 A power strip is an electrical enclosure having multiple receptacle outlets and having a power supply cord and attachment plug for direct connection to a permanently installed branch circuit outlet.

4.15.2 Power strips shall be UL listed for use.

4.15.3 A Relocatable Power Tap (RPT) is a power strip listed in accordance with UL 1363 that is not intended to be permanently mounted (i.e., removable without the use of a tool) to any facility or work surface or equipment enclosure; however, RPTs shall be allowed to hang from screws or hooks if the RPT is manufactured with slots or keyholes for that purpose.

4.15.4 A Furniture Power Distribution Unit (FPDU) is a power strip listed in accordance with UL 962A and is intended to be permanently mounted.

4.15.5 Power strips shall not be daisy-chained to other power strips, multi-plug adapters, or extension cords.

4.15.6 Power strips shall not be used to power high current equipment (e.g., microwave ovens, space heaters, and coffee pots).

4.15.7 A surge protector is a power strip 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, monitors, scanners, and printers.

4.15.8 Surge protectors shall be UL listed in accordance with UL 1449 as Surge Protective Devices (SPDs).

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

4.15.10 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.

4.15.11 Surge protectors shall have a minimum energy suppression rating of 1,200 joules.

4.16 MULTI-PLUG ADAPTERS

4.16.1 A multi-plug adapter is a male and female contact device that plugs directly into a permanently installed branch circuit outlet to provide multiple receptacle outlets.

4.16.2 Multi-plug adapters shall be UL listed in accordance with UL 498A.

4.16.3 Multi-plug adapters shall not be daisy-chained to other multi-plug adapters, power strips, or extension cords.

4.16.4 Multi-plug adapters shall not be used to power high current equipment (e.g., microwave ovens, space heaters, and coffee pots).

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CHAPTER 5: SPECIAL EQUIPMENT HANDLING PROCEDURES

5.1 BATTERIES

5.1.1 Stationary 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 systems:

a. Face shields and goggles, rubber gloves, and protective rubber aprons shall be worn whenever batteries or cells are being handled, filled, or charged per LPR 1800.1.

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

c. Ensure all ventilation caps and cell cover caps are in place, operational, and not damaged.

d. No smoking, hot work, open flame, or spark producing operations shall be permitted in the area where batteries are handled, filled, or charged.

e. Do not place or store metallic objects on battery cells.

f. Battery maintenance shall only be performed by qualified personnel.

g. Battery charging shall comply with all manufacturer recommendations.

h. 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/ISEA Z358.1.

i. Battery room(s) shall comply with NFPA 1, Chapter 52; IFC, Section 608*;* NEC, Article 480; NFPA 70E, Article 320; and Factory Mutual (FM) Data Sheet 5-23*.* Where conflicts arise between various requirements, the requirement which affords the highest degree of safety shall be applied.

j. Battery systems shall only be installed in a well-ventilated area to prevent hydrogen gas from exceeding 1% concentration. Where ventilation is to be provided solely by mechanical means, mechanical ventilation must operate continuously **OR** be tied to both a thermometer and hydrogen leak detector such that each works as a switch to cycle fan on/off as required. Mechanical ventilation shall be monitored by the fire alarm system. If thermostat or hydrogen detector calls for exhaust fan to come on and air flow meter does not confirm its operation, condition shall be communicated to the fire alarm system and battery charger power automatically shut down. Ventilation fans serving battery charging areas shall be fed by emergency power.

k. Battery rooms shall have fire/smoke detection as deemed appropriate by the NASA Fire Chief for any given condition.

l. Valve Regulated Lead Acid (VRLA) batteries require listed devices or equipment to provide for thermal runaway management. Thermal runaway management shall be interlocked with battery charger such that upon detection of thermal

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runaway, power to battery charger is shut off and condition reported via the fire alarm system.

m. If not already provided, fire sprinkler protection may be required depending on the quantity of the electrolyte of the battery system.

n. Battery rooms shall be separated from the remainder of the facility by barriers (e.g., walls, floors, ceilings) having a minimum 1-hr. fire resistance rating.

o. Electrolyte spill control is mandated for flooded lead-acid battery systems.

p. Doors from rooms or spaces containing battery systems shall swing in the direction of egress travel and be equipped with listed panic hardware where latching of doors is provided.

q. All proposed battery rooms or battery systems shall be approved by the NASA Fire Chief prior to the procurement of equipment or commencement of work.

r. The environment of rooms containing battery systems shall be maintained such that temperatures are kept within safe operating range as determined by battery manufacturer.

s. Doors into rooms housing battery systems shall be posted with signs stating "*Room Contains Stationary Storage Battery System."*

t. Battery chargers shall be provided with both undercharge and overcharge protection.

u. Rooms containing battery systems shall be provided with emergency lighting with self-testing, self-diagnostic features as well as an audible local alarm.

5.1.2 Lithium ion/polymer batteries and battery cells are subject to overcharging or too-rapid charging and physical damage that may result in high temperature, high velocity gas discharges and venting with flame. The following requirements are for research battery packs/cells:

a. Contact the LaRC Fire Chief for proper fire suppression equipment before receipt and placing the battery(s) into service or before initial charging operations.

b. Battery charging/discharging shall comply with all manufacturer recommendations.

c. Battery charging/discharging shall be accomplished with a manufacturer approved charger. Battery(s) shall not be left unattended during charging operations.

d. No manual charging or discharging equipment is permitted.

e. All battery charging equipment shall contain overcharging and over-discharging protection. Thermal monitoring may be required by the manufacturer during charge/discharge operations.

f. All battery charging equipment shall be properly grounded.

g. Batteries shall be charged/discharged in a fire-resistant container or pouch and on a non-flammable surface.

h. Batteries shall be stored and transported in a protective enclosure to prevent physical damage.

i. Contact the LaRC Fire Department by dialing 911 from any Center telephone or 757-864-2222 from a cellular telephone if a battery begins to distort its shape, swell up, emit smoke/gases, or becomes extremely hot. In the event of physical damage, remove the battery from service for observation and place in an approved storage container by itself or in an open area away from combustible material as it may take more than two hours for a reaction to occur.

j. Do not store a battery in temperatures greater than manufacturer's recommendation.

k. No intentional destruction or physical damage to batteries is permitted.

l. Modifications to manufacturers' cell configurations shall be approved by the LaRC Fire Chief and shall be performed by qualified personnel.

m. Batteries shall only be disposed of in specially marked Lithium Ion/Polymer battery buckets.

5.1.3 Use of powered industrial truck batteries shall be in accordance with the following procedural requirements:

a. Follow all handling and safety precautions in Section 5.1.1 of this document.

b. Ensure battery installations are in compliance with OSHA 29 CFR 1910.178(g).

c. Only charge batteries with a manufacturer's approved charging unit.

d. Comply with NFPA 505, Section 9.3, "Changing and Charging Storage Batteries."

e. Comply with Factory Mutual FM Data Sheet 7-39, "Lift Trucks.

5.1.3.1 Facility Safety Heads and Facility Coordinators shall be responsible for ensuring that each battery installation and battery usage is in compliance with these procedural requirements.

5.2 FUSES

5.2.1 Fuses shall not be removed on energized circuits rated over 23,000 Volts.

5.2.2 Fuses shall not be removed from loaded energized circuits rated 50 Volts to 23,000 Volts.

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

a. On circuits rated 50 to 600 Volts, insulated fuse tongs, extractors, or other approved methods shall be used.

b. On circuits rated 601 to 1,000 Volts, lineman's type rubber gloves in addition to either insulated fuse tongs or extractors shall be used.

c. On circuits rated 1,001 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

5.3.1 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.

5.3.2 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.

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

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

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

5.3.6 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.

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

5.3.8 Use of high-voltage capacitor banks on experimental equipment shall be in accordance with Section 5.4.

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

5.3.10 Temporary wiring shall be in accordance with Section 4.11.

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

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

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

5.3.14 Use of knockout boxes to house receptacles for an onsite extension cord shall not be permitted.

5.4 HIGH VOLTAGE CAPACITORS

5.4.1 Test personnel conducting experiments in which capacitor banks with voltages over 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.

5.4.3 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.

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

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

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

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

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

5.4.9 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.

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

5.4.11 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.

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CHAPTER 6: DOCUMENTATION

6.1 CONFIGURATION MANAGEMENT

6.1.1 LPR 7123.2 defines the Configuration Management (CM) Program. It also identifies the facilities under CM and defines the minimum electrical drawings required for these facilities.

6.1.2 All changes to these drawings or equipment shall comply with the requirements of LPR 7123.2.

6.1.3 New electrical drawings that are to be entered into the CM program shall be Field Verified and shall reflect the as-built configuration of the system when it was placed into service.

6.1.4 Electrical drawings that depict an existing functional system or equipment and are to be entered into the CM program or are already in the CM program shall be Functionally Verified to reflect the system configuration in its current operational condition.

6.2 SWITCHING AND METERING ONE LINE DIAGRAMS (EFFORT CODE 300)

6.2.1 Switching and metering one line diagrams shall be maintained in accordance with LPR 7123.2 under Effort Code 300.

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

6.2.3 The following cable and switch legend listed in Table 6-1 applies to the switching diagrams.

Table 6-1. Cable and Switch Legend

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

6.3 MANHOLE DRAWINGS (EFFORT CODE 301)

6.3.1 Manhole drawings shall be maintained in accordance with LPR 7123.2 under Effort Code 301.

6.4 FACILITY LOW VOLTAGE ONE-LINE DIAGRAMS (EFFORT CODE 302)

6.4.1 Low voltage one line diagrams shall be maintained in accordance with LPR 7123.2 under Effort Code 302.

6.4.2 Low voltage one line diagrams shall reflect the 208 Volt and 480 Volt power distribution system of the facility.

6.4.3 The EC 302 one-line diagrams shall include the secondary unit substations (SUS) that supply low voltage power to the facility and the primary connection to the medium voltage source of power referencing applicable Effort Code 300 switching diagram.

6.5 MAJOR ELECTRICAL SUBSTATION DRAWINGS (EFFORT CODE 303)

6.5.1 Major electrical substation drawings shall be maintained in accordance with LPR 7123.2 under Effort Code 303.

Note: Major electrical substations are delineated in Appendix 3 of the Stratton Substation Facility Resume.

6.6 INCIDENT REPORTING

6.6.1 LPR 8621.1 defines the policy and procedural requirements for reporting, investigating, and documenting electrical mishaps and close calls.

6.7 REQUIRED PERMITS

6.7.1 An NF 1921must be submitted and approved prior to performing any non-exempt energized electrical work as defined in Section 2.5.

6.8 DOCUMENTATION OF WORKER QUALIFICATIONS

6.8.1 Worker qualifications defined in Section 1.1.1 shall be documented on an NF 1896 or equivalent and retained for the duration of the worker’s employment.

6.9 DOCUMENTATION OF SUPERVISOR ELECTRICAL SAFETY FIELD WORK AUDIT

6.9.1 Supervisor Electrical Safety Field Work Audits required in Section 1.4.1 shall be documented on an NF 1898 or equivalent and retained for a period of one year.

6.10 DOCUMENTATION OF ELECTRICAL JOB SAFETY PLANNING

6.10.1 Electrical job safety planning defined in Section 2.2 shall be documented on an NF 1897 or equivalent and retained for a period of 30 days following the completion of the job.

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APPENDIX A. DEFINITIONS

Arc Flash Boundary: When an arc flash hazard exists, an approach limit from an arc source at which incident energy equals 1.2 cal/cm^2 (5 J/cm^2) (NFPA 70E).

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

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.

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).

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).

Energized: Electrically connected to a source of potential difference.

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. At LaRC, this is an NF 1921.

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).

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.

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.

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.

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

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).

High-Voltage: Voltage class designation for electric power systems and equipment operating over 600 Volts.

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Limited Approach Boundary: An approach limit at a distance from an exposed energized electrical conductor or circuit part within which a shock hazard exists (NFPA 70E).

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

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.

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

Minimum Approach Distance: The closest distance a qualified employee is permitted to approach either an energized or a grounded object, as applicable for the work method being used.

Qualified Electrical Person (QEP): 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. In addition, 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.

Qualified Industrial Person (QIP): 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.

Racking: The process of inserting a circuit breaker to, or removing it from, its connected position on the electrical bus of a switchgear by manual or motorized operation of the circuit breaker racking mechanism.

Restricted Approach Boundary: An approach limit at a distance from an exposed energized electrical conductor or circuit part within which there is an increased likelihood of electric shock, due to electrical arc-over combined with inadvertent movement (NFPA 70E).

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 LF 453. LaRC SOs are the only persons authorized to hang or remove red locks, red tags, and associated locking hardware.

Service Point: The point of connection between the facilities of the serving utility and the premises wiring (NEC).

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.

Unqualified Person: A person who is not qualified in accordance with NFPA 70E.

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).

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APPENDIX B. ACRONYMS

AEIC	Association of Edison Illuminating Companies
AFSH	Arc Flash and Shock Hazard
AED	Automated External Defibrillator
ANSI	American National Standards Institute
ATPV	Arc Thermal Protection Value
AWG	American Wire Gauge
CCI	Configuration Controlled Information
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
FPDU	Furniture Power Distribution Unit
FUED	Facility Utilities Electronic Database
GFCI	Ground Fault Circuit Interrupter
HRC	Hazard Risk Category
IE	Incident Energy
IEEE	Institute of Electrical and Electronic Engineers
IFO	Institutional Facility/Operational
IPCEA	Insulated Power Cable Engineers Association
IR	Infrared; Insulation Resistance
ISA	Instrumentation, Systems, and Automation
kV	Kilovolts
kW	Kilowatts
LaRC	Langley Research Center

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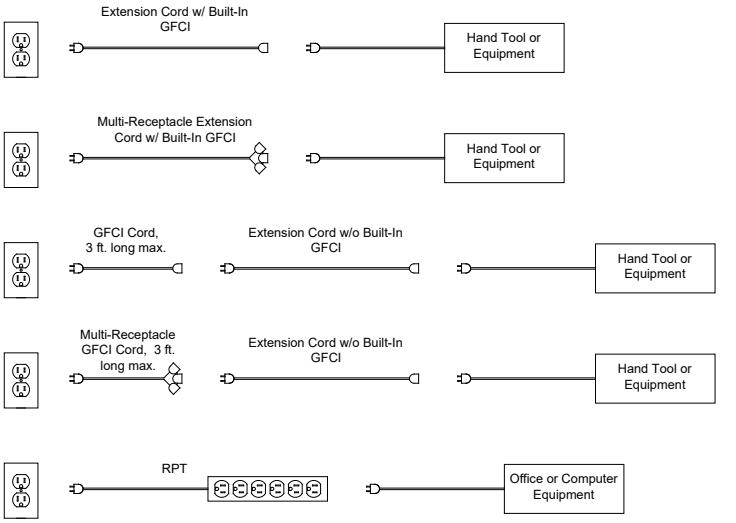
LF	Langley Form
LOTO	Lockout/Tagout
LPR	Langley Research Center Procedural Requirement
LV	Low Voltage
MAD	Minimum Approach Distance
MCC	Motor Control Center
MV	Medium Voltage
NBR	No Buddy Required
NEC	National Electrical Code
NEMA	National Electrical Manufacturer's Association
NESC	National Electrical 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
RNC	Rigid Nonmetallic Conduit
RPT	Relocatable Power Taps
SFAB	Safety and Facility Assurance Branch
SO	Safety Operator
SOP	Standard Operating Procedure
SPD	Surge Protective Devices
SUS	Secondary Unit Substations
Swgr	Switchgear
UL	Underwriters Laboratories
V	Volts
VM	Voltmeter
VPI	Vacuum pressure impregnated
VRLA	Valve Regulated Lead Acid
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

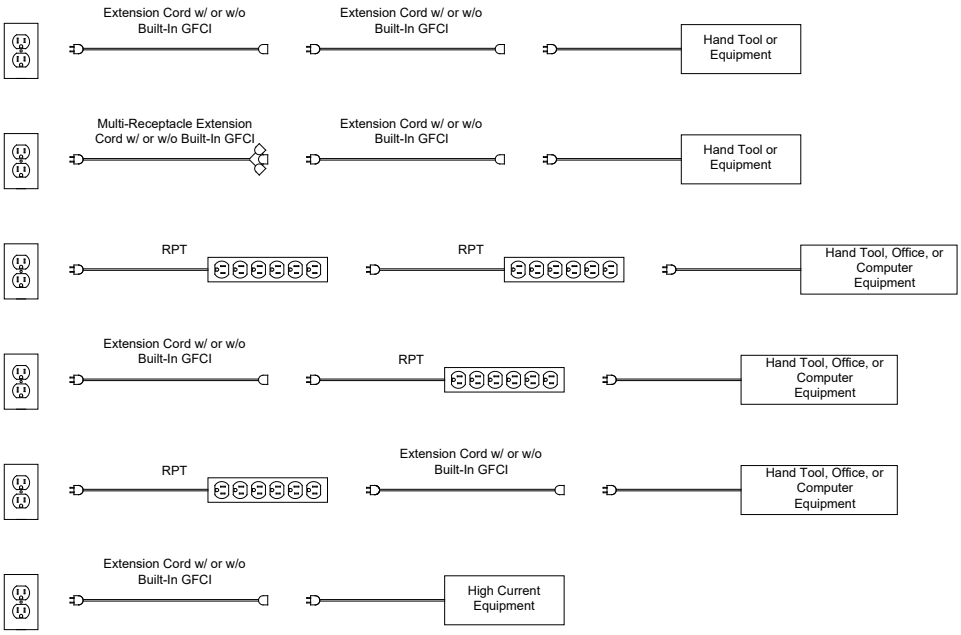


Figure C-1. Extension Cord Configurations

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APPENDIX D. ARC FLASH AND SHOCK HAZARD LABEL USAGE

D.1 Label Requirements

D.1.1 The 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 detailed label and a generic label.

D.2.2 A detailed AFSH label is used on the following types of electrical equipment, for which an arc flash hazard analysis has been completed:

a. Low Voltage (LV) Switchgear (Swgr).

b. Switchboards.

c. Panelboards.

d. Large dry-type transformers.

e. Motor Control Centers (MCCs).

f. Disconnect switches or other branch circuit loads directly fed from a branch circuit breaker having a rating 100 amps or greater.

D.2.3 A generic AFSH label is used on the following types of electrical equipment, which are not usually included in an arc flash hazard analysis:

a. Branch-circuit fed disconnect switches and starters feeding small motors.

b. Disconnect switches or other branch circuit loads directly fed from a branch circuit breaker having a rating less than 100 amps.

c. LV Swgr and MCC cubicle buckets.

D.2.4 Detailed AFSH labels are located on electrical equipment as follows:

a. Generally, detailed labels will be located on the front door or panel of the equipment.

b. On LV Swgr and MCCs:

(1) One detailed label on the main breaker based on line side fault.

(2) One detailed label at the top of the Swgr or MCC, applicable to all cubicle buckets, based on load side bus fault.

(3) One detailed label on each cubicle bucket in the same vertical section as the main breaker.

(4) Generic labels on each bucket for general warning with the detailed bus label for PPE selection.

D.3 AFSH Label Format

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

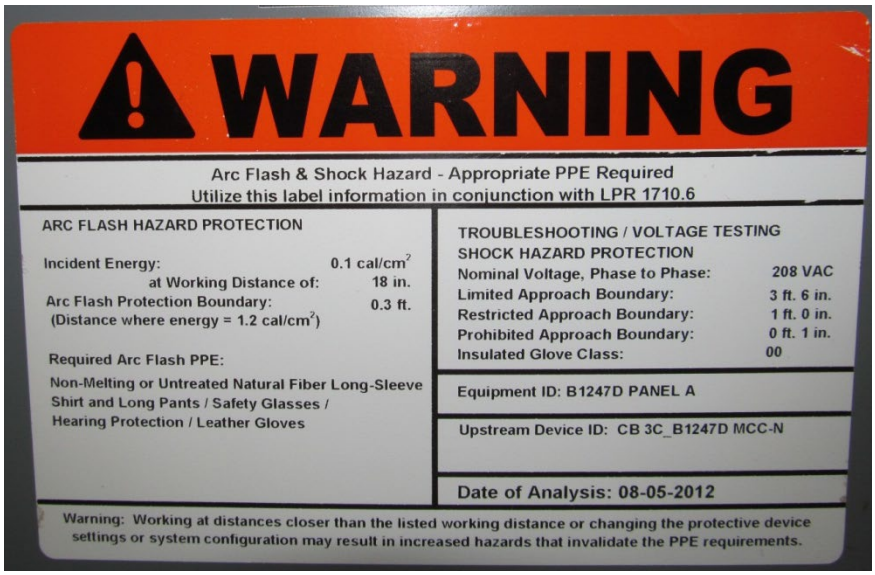

Figure D-1. Detailed Arc Flash Label Format

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

Figure D-2. Generic Arc Flash Label Format

D.4 Use of Detailed AFSH Labels for PPE Selection

D.4.1 For equipment having a detailed AFSH label, if an arc flash risk assessment indicates the need to use arc flash PPE, PPE selection shall be based on the IE value indicated on the detailed label and not by the NFPA 70E Arc Flash PPE Categories method.

D.4.2 The IE value shown on the label is the worst case value that can be experienced during an arc flash event 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

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protective device are analyzed on both the line side and the 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 Because of the short time and long time trip characteristics of circuit breakers, an attenuated arc fault current may take longer to trip the circuit breaker than a bolted short circuit fault current.

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 from which it is fed.

D.4.8 If a device has a generic label, use the Arc Flash PPE Categories method to determine the required PPE; 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 Process

D.5.1 LaRC has adopted a Simplified Arc Flash PPE Selection Process to minimize the need to purchase and maintain multiple levels of arc flash PPE, shown below in Table D-1.

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Table D-1. Simplified Arc Flash PPE Selection Process

IE from AF Label	*Required PPE*		*AF PPE Categories*	*Required PPE***
ESWC	*Not required*		*ESWC*	*Not required*
< 1.2 cal/cm^2	*Clothing and PPE as described on the label**		*-*	*-*
1.2 to 40 cal/cm^2	*AF PPE rated >= IE and as described on label*	***or***	*1*	*AF PPE Cat 2*
			2	
			3	*AF PPE Cat 4*
			4	
> 40 cal/cm^2	*Do not work energized*		*N/A*	*Do not work energized*

ESWC = Electrically Safe Work Condition

**As recommended in NFPA 70E, Tables H.3 for IE >=1.2 cal/cm^2*

***Does not preclude the use of Cat 1 or Cat 3 Arc Flash PPE if available and adequate for the assessed arc flash hazard*

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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 OSHA 29 CFR 1910.303(g)(1) and NEC 110.26. Similarly, requirements for working space about electrical equipment, over 600 Volts, nominal, are found in OSHA 29 CFR 1910.303(h)(3) 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 defines “Accessible (as applied to equipment). Admitting close approach; not guarded by locked doors, elevation, or other effective means.” NEC 110.26(A) requires minimum working space dimensions for “equipment likely to require examination, adjustment, servicing, or maintenance while energized.”[1] The text in NEC 110.34 for over 600 Volts, nominal, is similar. From 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 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.

[1] 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.

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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:

"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.

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APPENDIX F. SUBSTATION MINIMUM APPROACH DISTANCES

F.1 This appendix 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 (i.e., rubber glove method), using insulated tools and covers (i.e., insulated tool method), and by insulating the worker (i.e., 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 specialized 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 Distances 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, applicable to work downstream of the service point, includes Minimum Approach Distances for unqualified workers. The Minimum Approach Distance for unqualified worker is the Limited Approach Boundary.

F.4 Because LaRC substation equipment is located downstream of the service point, NFPA 70E shock approach boundaries are applicable. 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 are essentially the same as the Restricted Approach Boundary found in NFPA 70E.

F.5 The Minimum Approach Distance for unqualified persons is the Limited Approach Boundary. The Minimum Approach Distance for qualified workers is the Restricted Approach Boundary; however, because of the increased hazard of working around exposed energized parts in a substation, the Restricted Approach 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. Figure F-1 and Figure F-2, below, illustrate the Limited and Restricted Approach Boundaries for substations and provide the distances for the

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voltage ranges applicable to LaRC. Distances shown are from the exposed energized part to the person.

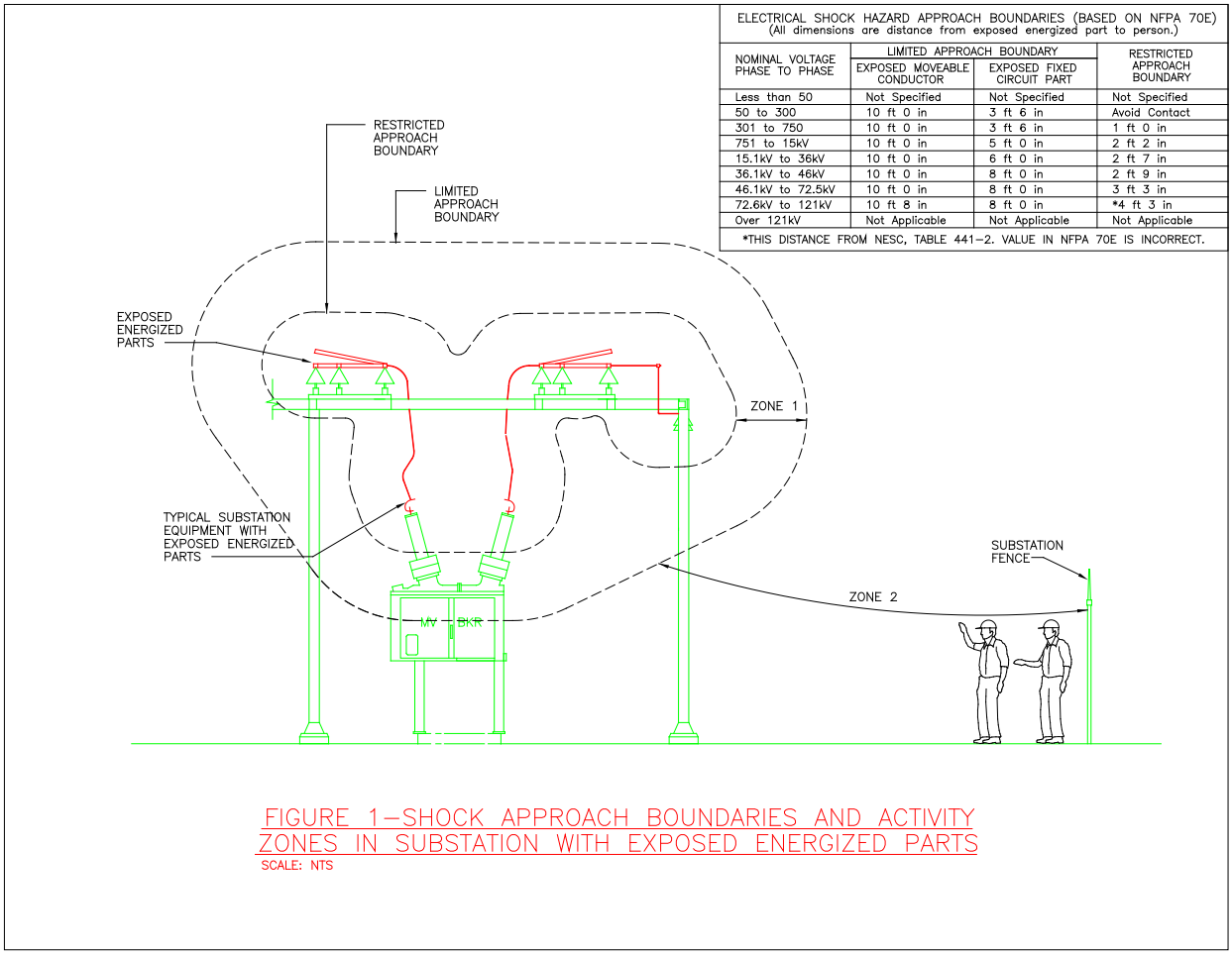

Figure F-1. Shock Approach Boundaries and Activity Zones in Substation with Exposed Energized Parts

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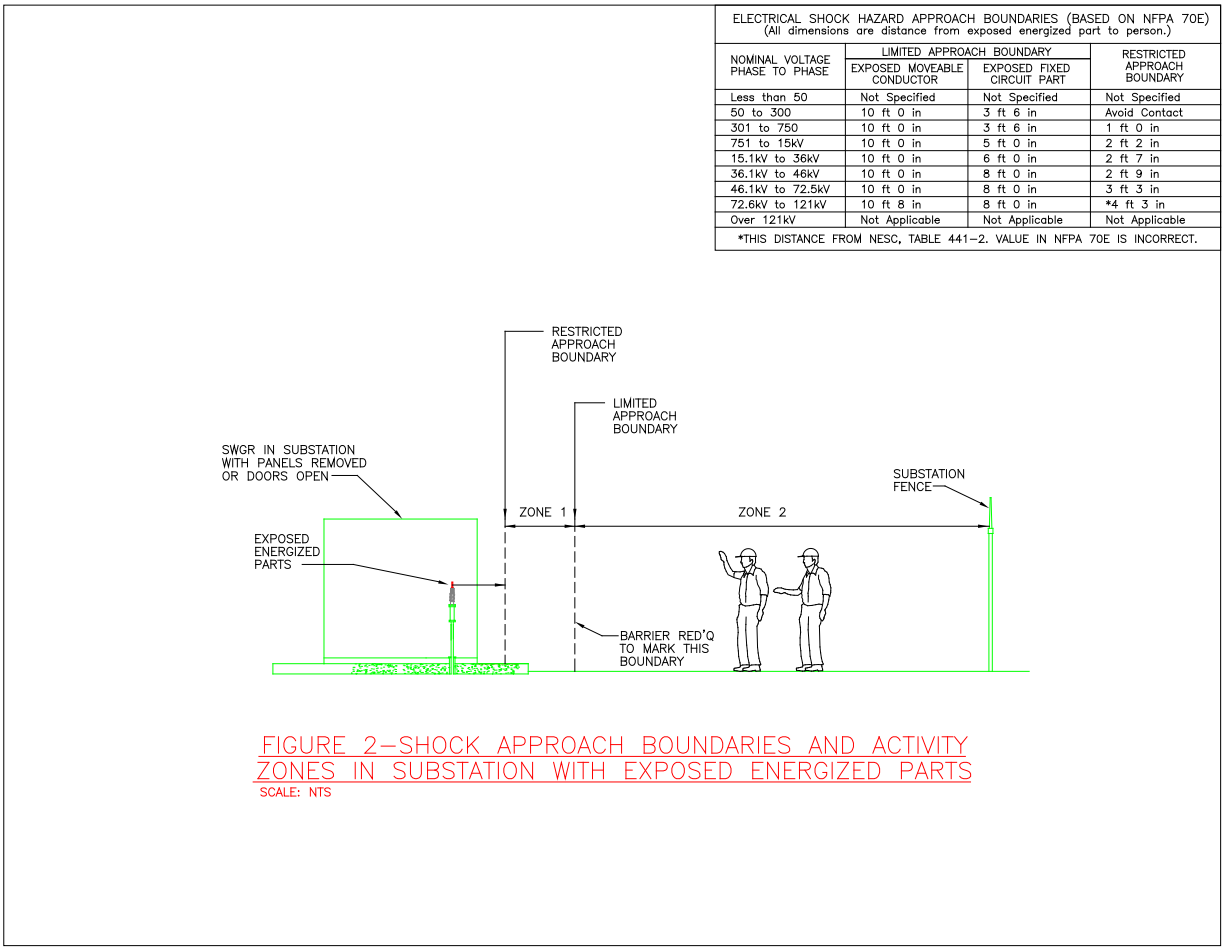

ELECTRICAL SHOCK HAZARD APPROACH BOUNDARIES (BASED ON NFPA 70E)
(All dimensions are distance from exposed energized part to person.)

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

Figure F-2. Shock Approach Boundaries and Activity Zones in Substation with Exposed Energized Parts.

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 (i.e., 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.

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APPENDIX G. HAZARDS OF ELECTRIC ARCS

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 (i.e., radiated heat energy) can exceed 40 cal/cm^2. An incident energy level of 1.2 cal/cm^2 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/cm . Requirements for arc flash hazard mitigation are found in the latest edition of the NEC and NFPA 70E, Article 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 (i.e., 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

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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 three 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 human are listed in Figure G-1 as follows:

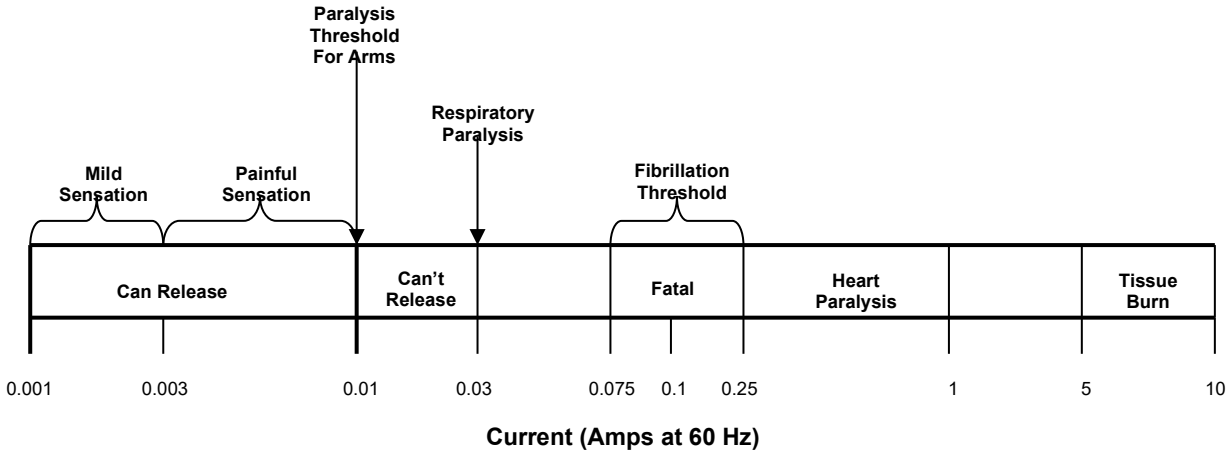

Figure G-1. Effects of Current on Average Human

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 2,300 Volts) 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 (e.g., 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 Table G-1.

Table G-1. Typical Body Current Paths

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

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Ear to Ear	1.1 A

APPENDIX H. TEMPORARY WIRING APPROVAL MEMO (Example)

Temporary power for induction heater to support coupling replacement

The electrical installation described below is approved for providing temporary electrical power to an induction heater in the motor nacelle of B648 to support replacement of a coupling in accordance with NFPA 70, Article 590 and Table 400.5(A)(1), “Ampacity for Flexible Cords and Flexible Cables.”

During a scheduled outage, install a 200 amp, 480 Volt, 3 pole, fusible disconnect switch, fused at 150 amps, on the left side of the MCC. Tap the MCC bus in vertical section #1 with a section of heavy duty flexible cord and feed the disconnect switch. Supply a longer section of heavy duty flexible cord from the disconnect switch to the area of the coupling and terminate in a NEMA cord receptacle, appropriately configured and rated to connect to the plug of the induction heater. Secure flexible cord to protect from damage.

Heavy duty flexible cord shall be 3/C, #1 AWG with #1 AWG ground, Type W.

This approval is in effect for the duration of the use of the induction heater, which is expected to not exceed 90 days in duration. Upon completion of the coupling replacement, the temporary flexible cord, receptacle, and disconnect switch shall be removed and penetrations at the MCC sealed.

If use of the temporary flexible cord is required after 90 days from the date of initial installation, the installation shall be inspected and approved for use for up to an additional 90 days as noted on the back of this sheet. Any deterioration of the temporary flexible cord or receptacle shall be corrected as a condition of continued use and noted.

Contact me if you have any questions regarding this installation.

Name

(Signature)

Standard Practice Engineer-Electrical

Original In-Service Date	Inspector Signature

Sleeve and post this approval at temporary power supply point

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Complete below if use for up to an additional 90 days is required:

Extension Date (if needed) LaRC Safety Manager (or designee)

Indicate repairs (if any):

TABLE 400.5(A)(2) Ampacity of Cable Types SC, SCE, SCT, PPE, G, G-GC, and W
[Based on Ambient Temperature of 30°C (86°F). See Table 400.4.]

Copper Conductor Size (AWG or kcmil)	Temperature Rating of Cable								
	60°C (140°F)			75°C (167°F)			90°C (194°F)		
	D[1]	E[2]	F[3]	D[1]	E[2]	F[3]	D[1]	E[2]	F[3]
12	—	31	26	—	37	31	—	42	35
10	—	44	37	—	52	43	—	59	49
8	60	55	48	70	65	57	80	74	65
6	80	72	63	95	88	77	105	99	87
4	105	96	84	125	115	101	140	130	114
3	120	113	99	145	135	118	165	152	133
2	140	128	112	170	152	133	190	174	152
1	165	150	131	195	178	156	220	202	177
1/0	195	173	151	230	207	181	260	234	205
2/0	225	199	174	265	238	208	300	271	237
3/0	260	230	201	310	275	241	350	313	274
4/0	300	265	232	360	317	277	405	361	316
250	340	296	259	405	354	310	455	402	352
300	375	330	289	445	395	346	505	449	393
350	420	363	318	505	435	381	570	495	433
400	455	392	343	545	469	410	615	535	468
500	515	448	392	620	537	470	700	613	536
600	575	—	—	690	—	—	780	—	—
700	630	—	—	755	—	—	855	—	—
750	655	—	—	785	—	—	885	—	—
800	680	—	—	815	—	—	920	—	—
900	730	—	—	870	—	—	985	—	—
1000	780	—	—	935	—	—	1055	—	—

[1]The ampacities under subheading D shall be permitted for single-conductor Types SC, SCE, SCT, PPE, and W cable only where the individual conductors are not installed in raceways and are not in physical contact with each other except in lengths not to exceed 600 mm (24 in.) where passing through the wall of an enclosure.

[2]The ampacities under subheading E apply to two-conductor cables and other multiconductor cables connected to utilization equipment so that only two conductors are current-carrying.

[3]The ampacities under subheading F apply to three-conductor cables and other multiconductor cables connected to utilization equipment so that only three conductors are current-carrying.

Sleeve and post this approval at temporary power supply point

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APPENDIX I. TEMPORARY WIRING FOR CONSTRUCTION TRAILERS

I.1 Temporary trailers are routinely installed at LaRC to support construction projects. When power is to be supplied to the trailer, permanent and temporary wiring methods may be utilized. Power to new construction trailers is to be installed below grade in Rigid Nonmetallic Conduit (RNC) direct buried not less than 18 inches below grade. The conduit installation depth may be decreased to no less than 6 inches below grade only if the conduit is removed when power is disconnected from the trailer and the trailer is removed from site.

I.2 When direct burial is not possible because of existing underground congestion or because existing concrete or pavement cannot be disturbed, temporary wiring methods may be approved on a case-by-case basis. When utilized, temporary wiring methods are to comply with the requirements of NEC, Article 225 and Article 590. A few of the pertinent guidelines are listed below along with an LaRC specific exception.

a. Temporary feeders to the trailers are to originate from an approved distribution center. Feeder conductors are permitted within cable assemblies or within multi-conductor cords or cables identified for hard or extra-hard use.

b. Flexible cords and cables are to be protected from accidental damage and be supported in place at intervals that ensure that they will be protected from physical damage. Supports are to be in the form of staples, cable ties, straps, or similar type fittings installed so as not to cause damage. Vegetation is not to be used for support of overhead spans of branch circuits or feeders.

c. Overhead spans are to meet the “clearance from ground” requirements of NEC 225.18.

d. Temporary electrical power and lighting installations are permitted during the period of construction, remodeling, maintenance, repair, or demolition of buildings, structures, equipment, or similar activities. Temporary electrical power wiring to construction trailers is not bound by the 90-day time limit for temporary electrical installations associated with holiday displays.

e. Temporary wiring is to be removed immediately upon completion of construction or purpose for which the wiring was installed.

I.3 Exception (specific to LaRC construction trailers):

a. Temporary wiring to construction trailers is not required to be removed at the completion of the construction contract if the construction trailer will be used for additional construction contracts at the same location, by the same contractor, and the start date of the new contract overlaps or is within 30 days of the completion date of the prior construction contract. The temporary wiring, however, is to be inspected for damage or deterioration by a LaRC construction inspector within seven days of the start date of each new construction contract. Replace temporary wiring when damage or deterioration is found by the inspector. For interpreting these code requirements, a construction contract is any contract that provides construction, remodeling, maintenance, repair, or demolition of buildings, structures, equipment or similar activities regardless of

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the funding source. The construction period is defined as the period of time between the start date and completion date of a construction contract.

b. Power installations to existing construction trailers not complying with these requirements may be exempt if the existing method is deemed safe by the LaRC construction inspector.

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APPENDIX J. MEGGERING GUIDELINES FOR MEDIUM VOLTAGE MOTORS THAT HAVE BEEN IDLE FOR EXTENDED PERIODS OF TIME

J.1 This appendix provides guidelines for revising the meggering requirements of MV motors[2] that have been idle for extended periods of time from those currently required by the facility's Standard Operating Procedures (SOPs). These guidelines do not modify any meggering requirements that may be required as part of periodic preventative and annual maintenance or troubleshooting activities for these motors.

J.2 MV motors and other large rotating equipment, are critical assets in the facilities where they operate. At LaRC, a significant number of these motors are over 40 years old, are unique in design, and difficult to repair or replace without significant cost or downtime to the facility. It is important to maintain the health of these motors to support research operations at these facilities. One important factor in the health of a large motor is the adequacy of the insulation system of the motor windings. The insulation system must achieve a minimum insulation resistance value to tolerate the applied motor voltage during operation. If the insulation resistance falls below accepted industry minimum values, windings may not be able to tolerate the applied voltage and can damage the motor due to failure of the insulation.

J.3 Unless the motor is of the fully encapsulated thermosetting-resin type, the motor insulation will be hygroscopic and will readily absorb moisture from the air. Moisture in the motor insulation will negatively impact the insulation system's ability to achieve and maintain industry recommended minimum insulation resistance (IR) values. Most of the large MV motors at LaRC installed since 1990 utilize vacuum pressure impregnated (VPI) resin type insulation systems that meet the definition of fully encapsulated. Prior to 1990, the motors are likely to have insulation systems that are hygroscopic.

J.4 As previously mentioned, keeping the motor insulation dry is of primary concern. When the older MV motors are in use, the absorption of moisture is not a problem because the temperature of the motor insulation is sufficiently above the dew point and condensation or absorption of moisture will not occur. The dew point is the temperature the air needs to be cooled to (at constant pressure) in order to achieve a relative humidity of 100%. However, when the motors are idle, the motors must be kept dry, which is typically done by the use of heaters. If the motor winding temperature is allowed to fall below the dew point, there is a likelihood that the insulation will absorb moisture and the IR value will fall below minimum accepted values. This is evidenced by obtaining low IR readings, colloquially referred to as "megger" readings when the motor has been idle for extended periods of time. When low megger readings are measured, the motor must not be energized until the motor is sufficiently dried out and megger readings above accepted minimums are obtained. A wet winding can typically be dried out by applying external heat (usually tenting and heat lamps) or by circulating low level DC current in the windings. The motor is sufficiently dry when IR values are above

[2] The term motor is used generically to refer to all rotating machines including motors, generators, synchronous condensers, and the like that have insulation systems for which this guidance on insulation resistance testing is applicable.

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industry minimum accepted values. The references at the end of this document provide guidance for testing motors with wet windings.

J.5 Prevention of condensation and moisture absorption can easily be accomplished by keeping the internal temperature of the motor sufficiently warm. Experience has shown that keeping the internal temperature at least 10 °F warmer than the dew point is enough to keep moisture from condensing on the motor frame and windings. Data from the National Weather Service in Wakefield, VA, indicates that the maximum dew point at LaRC for the past 30 years was 86 °F. To account for the possibility of large swings in ambient temperatures common for the Virginia Peninsula and recent trends in rising ambient temperatures, some margin should be provided above the 10 °F delta to guarantee the motor temperature always remains above the dew point. A 20 °F delta above the maximum dew point provides a good idle motor internal temperature of 106 °F ± 5 °F.

J.6 The most widely used and least expensive motor warming method is the use of electric-strip heaters attached to the motor frame near the underside of the motors. Guidance for the selection and operation of the electric-strip heaters can be found in Section 3.3 of the “Facilities Instructions, Standard, and Techniques” by the U.S. Department of the Interior (full reference below). The resultant internal motor temperature must be checked to ensure that the electric-strip heaters provide the recommended temperature margin above the maximum dew point. The number of heaters, location, and operating voltage can be adjusted if the measured temperature is too high or too low.

J.7 The recommendations above provide sufficient protection against condensation on the motor frame and absorption of moisture in the windings. This is the case, as long as the electric-strip heaters are functional. It is not uncommon during maintenance activities or during pre-operational checks, for maintenance personnel to find many, if not all, of the electric-strip heaters to be non-functional, resulting in poor megger readings and the need to dry out the motor windings prior to resumption of operations. This situation is the rationale behind the time-based meggering requirements for motors found in the facility’s SOPs.

J.8 The need for the time-based meggering requirements of the MV motors can be eliminated provided the following steps are taken:

1) Provide for external warming of the motor (electric-strip heaters) when the motor is idle.
2) Ensure that the rating and configuration of the electric-strip heaters is sufficient to provide an internal motor temperature of 106 °F ± 5 °F.
3) Provide for a method to measure and trend internal motor temperature continuously so that internal motor temperature can be verified to never fall below 106 °F ± 5 °F.
4) Alternatively to 3), once the heaters have been confirmed to provide the correct idle motor internal temperature, provide for a method to monitor and trend correct operation of the electric-strip heaters when the motor is idle (the installation and

monitoring of current switches on the heater circuit is one way to accomplish this requirement).

J.9 If the above steps are taken, the SOPs requiring time-based meggering of the MV motors can be eliminated by referencing compliance with these recommendations.

J.10 Additional information on megger testing can be found in the following:

a. Facilities Instructions, Standard, and Techniques (FIST), Vol 3-4, “Keeping Motor Windings Dry”, Nov 1991, U.S Dept. of the Interior.

b. IEEE 43 (R2013) Recommended Practice for Testing Insulation Resistance of Electric Machinery.

c. IEEE 56 (2016) Guide for Insulation Maintenance of Electric Machines.

d. Megger (2006), A Stitch in Time: The Complete Guide to Electrical Insulation Testing.