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Glenn Safety Manual – Chapter 8

Electrical Systems Safety

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Change Record

Rev.	Effective Date	Expiration Date	GRC25, Change Request #	Description
D	6/9/11	6/9/2016	121	Bi-annual Review/Revision
Change 1	4/23/14	6/9/2016	N/A	Administrative change to add front cover and change history log to comply with NPR 1400.1.
E	6/24/16	6/24/2021	15-018	70E requirements and GRC expectations to meet them, (5.7) Incorporate on-site knowledge requirements, (6.1) Incorporate NPR medical requirement statement, (6.2) Allow safety program grace period to respond to code changes, (6.5) Clarification, (6.7) New NFPA 70E requirements for "Buddies", (6.9.4) Closer reference to NFPA 70E requirements, (6.10) Clarify responsibility of classification determination, (6.11.2) Clarification, (6.11.3) Clarification of DSP responsibilities, (6.13.2) Remove redundant information already covered in System Manager Operating Instructions, (6.15.1) Update training requirements to coincide with NFPA 70E and IFO Audit Findings, (6.15.2) Meet NFPA 70E three year retraining requirement, one year on AED , CPR and release of victims.
Change 1	8/16/16	6/24/2021	N/A	Administrative change to add “In addition, at GRC, whenever the Restricted Arc Flash Boundary is crossed, by reach or tool,” and added “see Appendix D.”
Change 2	1/11/17	6/24/2021	N/A	Administrative change to revise title and audience of the training class within 6.15.1
Change 3	7/10/2017	6/24/2021	N/A	Administrative change to change Document Number from GLM-QS-1700.1 to GLP-QS-8715.1.
F	6/24/2021	6/24/2026	20-003	Bi-annual Review/Revision and added Hazardous Classification Committee and HCC Review Process.

***Include all information for each revision. Do not remove old revision data. Add new rows to table when space runs out by pressing the tab key in the last row, far right column.*

Contents

Chapter 8—Electrical Systems Safety

NOTE: *The current version of this chapter is maintained and approved by the Safety and Health Division (SHeD). The last revision date of this chapter was June 2021. The current version is located on the Glenn Research Center intranet within the Business Management Systems (BMS) Library. Approved by Chief of Safety and Health Division.*

1.0 PURPOSE

This chapter describes the minimum electrical safety guidelines and standards required for personnel engaged in electrical work at Glenn Research Center (GRC). It is not an instructional manual for untrained personnel nor is it a substitute for the detailed procedures necessary for completing electrical tasks safely. This chapter describes the responsibilities, regulations, and requirements to install, operate, maintain, or demolish electrical equipment and systems at GRC in order to ensure a safe working environment by minimizing hazards such as shock, arc flash, and arc blast.

2.0 APPLICABILITY

The provisions of this chapter are applicable to all NASA employees, support service contractors, and to all other agencies, organizations, and personnel who work within the confines of Lewis Field (LF) or Neil A. Armstrong Test Facility (GRC-ATF). In this chapter, all mandatory actions (i.e., requirements) are denoted by statements containing the term “shall.” The terms “may” or “can” denote discretionary privilege or permission, “should” denotes a good practice and is recommended but not required, “will” denotes expected outcome, and “are” or “is” denotes descriptive material.

3.0 BACKGROUND

3.1 The authority for this chapter comes from NASA Procedural Requirements (NPR) 8715.1, NASA General Safety Program Requirements, Chapter 3.6, Electrical Safety. The codes, standards, and regulations in this chapter are in place so that trained personnel take the proper precautions to safeguard against incidents and mishaps involving electricity.

3.2 The GRC has a number of different electrical systems, including, distribution, facility, and research equipment. This chapter describes the various electrical systems and the policies regarding them. It also describes the responsibilities of supervisors and personnel who work on these systems and the minimum training required.

4.0 POLICY

4.1 GRC Policy

The GRC policy is to design, install, operate, maintain, and demolish electrical systems in a manner that controls hazards likely to cause death, injuries, or system damage. This is

accomplished by following the Occupational Safety and Health Administration (OSHA) and industry-accepted standards and policies (see Section 6.0, Requirements).

4.2 Measurement and Verification

Compliance with the responsibilities and requirements of this chapter are measured and verified through the use of programmatic self-assessments, regulatory and agency audits, and internal field inspections and surveys.

5.0 RESPONSIBILITIES

Specific responsibilities of individuals and organizations tasked with establishing and following safety requirements for electrical systems utilized at GRC are as follows:

5.1 Authority Having Jurisdiction (AHJ)

5.1.1 The AHJ is responsible for implementing the fire safety provisions of NPR 8715.1, enforcing the electrical requirements of a code or standard, and approving equipment, materials, installation, and/or procedures.

5.1.2 The AHJ shall be permitted to render code interpretations in order to provide clarification to its requirements and approve variations/deviations to those requirements where it can be shown that alternative methods can still maintain an effective level of safety.

5.1.3 Technical documentation shall be submitted to the AHJ and the Safety and Health Division (SHeD) to demonstrate equivalency and that the system, method, or device is approved for the intended purpose.

5.2 Safety and Health Division (SHeD)

5.2.1 The SHeD, through the Operational Safety Branch, provides safety oversight and consultation that results in safe operations and practices of all programs, projects, and workers at GRC. This reduces the probability of injury to personnel and/or the prevention of damage to property.

5.2.2 The Chief of SHeD coordinates the appointment of area safety committee members and chairs.

5.3 Area Safety Committees

The area safety committees conduct third-party reviews of proposed installations, modifications, and operations in their assigned areas to ensure that electrical systems meet minimum design, operational, and safety standards. See Glenn Safety Manual Chapter 1, Safety Permit Process, for more information.

5.4 Electrical Applications Safety Committee (EASC)

a. Reviews tasks in all major electrical power systems, the associated distribution system, and high-voltage loads connected to the system.

b. Issues operating safety permits for the GRC high-voltage electric power distribution systems and for the high-voltage variable frequency electric power system in Building 23

c. Reviews and issues permits for any construction, maintenance, or repair activity that will modify a permitted system's one-line diagram or that will require a crew to work in the vicinity of high-voltage lines or equipment inside or outside of substations, power manholes, and tunnels on the GRC premises

> ***NOTE**: See Chapter 1 of the Glenn Safety Manual, Section 7.2.2, for a detailed description of EASC responsibilities.*

5.5 Process Systems Safety Committee (PSSC)

a. Ensures that the central process systems are designed, maintained, and operated safely

b. Conducts third-party reviews of all proposed installations, modifications, and operations that could affect systems specifically assigned to the PSSC and ensures that all electrical systems meet the requirements of this chapter

5.6 Hazardous Classification Committee (HCC)

a. Ensures proper engineering practices are applied and documented when designing or reclassifying test and storage facilities with respect to hazardous (classified) areas at GRC as required by national consensus codes and standards such as National Fire Protection Association (NFPA) 497 (Recommended Practice for the Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (classified) Locations for Electrical Installations in Chemical Process Areas), NFPA 70 Article 500, and Agency policies

b. Reviews proposed design requirements for test facilities where fire or explosion hazards may exist due to flammable gases, flammable liquid–produced vapors, combustible liquid–produced vapors, combustible dusts, or ignitable fibers/flyings

c. Assists area safety committees in reviewing proposed construction or changes to operating procedures within a hazardous (classified) area

5.7 Electrical Systems Managers

5.7.1 Electrical System Managers are members of the Facilities Infrastructure Division (FD) and are responsible to:

a. Ensure the system(s) and associated components are operated, maintained, and modified in a safe, effective, and efficient manner to support their intended use at the Center

b. Provide authoritative and expert information on technical issues while managing the planning and prioritization of work on their assigned system

c. Ensure a Facilities Change Request (GRC 29) and/or a GRC Safety Permit Request (initiated via the Safety Permit Web site, which may be accessed by typing "Safety Permit" in the Web Intranet at Glenn (WING) Transport box, is completed and approved prior to work being done on or near the systems they oversee.

5.7.2 Electrical System Manager Positions include:

a. High-Voltage Systems Manager

b. Low-Voltage Systems Manager

c. Electrical Systems Manager (switchgear, motors, drives, emergency backup systems, etc.)

d. Control Systems Manager (central process distributed controls, process, and valve controls, life safety control and gaseous alarms, etc.)

e. Communication Systems Manager (communication distribution, network interface, security network, fiber distribution, telephone manholes, and ductbanks)

> ***NOTE**: In some areas, these Systems Managers have authored specific instructions to be adhered to when working on these systems.*

5.8 Neil A. Armstrong Test Facility Electrical Maintenance Specialist

a. Works with the GRC Electrical Systems Managers for concurrence and acceptance of electrical maintenance and construction projects

b. Provides design and task oversight, including high voltage isolation procedures, for work on or near the high voltage distribution system

5.9 Lewis Field Electrical Power Dispatcher (EPD)

a. Coordinates day-to-day central process systems high voltage activities

b. Operates the high voltage distribution system and directs all electrical switching activities within these areas

c. Prepares the electrical equipment switching orders used to govern the isolation and restoration of power to electrical systems or equipment

d. Provides concurrence to the Lewis Field Designated Safety Person (DSP) whenever energized metal-enclosed electric apparatus are opened

e. Coordinates with the Lewis Field DSP for entries and exits of personnel to electric supply stations and documents the purpose of the activities

5.10 Supervisors

5.10.1 Supervisors are responsible to:

a. Ensure that the requirements of this chapter are followed concerning their personnel's interaction with electrical systems

b. Ensure that employees are trained and meet the requirements of a "Qualified Person" (see Section 5.11) that pertain to their respective job assignments

c. Ensure that tasks are only assigned to qualified personnel

d. Maintain required records (e.g., training and licenses/certifications) to show each employee is qualified

e. Determine through regular supervision or through inspections conducted on at least an annual basis that each employee is complying with the required safety-related work practices

***NOTE**: GRC780A, Annual Safety Field Audit, can be used for documentation.*

5.10.2 If the supervision or annual inspections indicate that the employee is not complying with the required safety-related work practices, the employee shall be retrained or excused from continuing further work associated with interaction with electrical systems.

5.11 Qualified Person

5.11.1 A Qualified Person

a. Has demonstrated skills and knowledge related to the construction and operation of electrical equipment and installations

b. Has received and completed safety training to identify the hazards and reduce the associated risk

c. Is familiar with the proper use of special precautionary techniques; personal protective equipment (PPE), including arc flash insulating and shielding materials; and insulated tools and test equipment (see NFPA 70E, Standard for Electrical Safety in the Workplace, Article 110)

d. Is responsible for adhering to the requirements set forth in this chapter while working on his/her assigned tasks

5.11.2 The OSHA definition for a Qualified Person includes the phrase “has demonstrated skills.” To meet this requirement, the Supervisor or team lead shall document when and how an employee has actually demonstrated that he/she can perform the task.

***NOTE**: A person can be considered qualified with respect to certain equipment and methods but still be deemed unqualified for others.*

5.12 Certified Operator/Switchperson

A Certified Operator/Switch person is a Qualified Person (see Section 5.11) who has also received site-specific knowledge from their Supervisor of both the equipment and systems upon which they work. They shall also satisfy the training requirements in Section 6.16 of this chapter.

6.0 REQUIREMENTS

6.1 General

6.1.1 All personnel performing work on the various electrical systems at GRC shall have a working knowledge of the following documents, procedures, and policies and comply with the requirements therein.

6.1.2 If a conflict in procedure or policy arises between this chapter and local, state, or Federal regulations, the most stringent requirements shall apply.

6.1.3 Organizations involved in these tasks shall, upon request, provide support information and/or documentation (including training records if not available through the System for Administration, Training, and Education Resources for NASA (SATERN)) to the Operational Safety Branch to show compliance with these requirements.

6.1.4 Failure to observe the requirements of this section shall be reason for disciplinary action.

6.2 Codes, Standards, and Instructions

The following codes, standards, and instructions relate to the safe design, installation, construction, demolition, operation, and maintenance of electric power systems at GRC. The latest versions of these publications/documents shall be adhered to upon Agency acceptance.

6.2.1 National Electrical Code (NEC) (*NFPA 70*)

The NEC (NFPA 70) covers electrical conductors and equipment installed within or on public and private buildings and other premises. The purpose of the code is the practical safeguarding of persons and property from hazards arising from the use of electricity. This document also covers electrical requirements for Hazardous Classified locations where there is a potential for fire and explosion because of flammable gases or vapors, flammable liquids, combustible dust, or ignitable fibers/flyings.

6.2.2 National Electrical Safety Code (NESC) American National Standards institute (*ANSI)*/Electrical and Electronics Engineers (*IEEE) C2*

The NESC, or ANSI Standard C2, published by the (IEEE), is a standard of the safe installation, operation, and maintenance of electric power and communication utility systems, including power substations, power and communication overhead lines, and power and communication underground lines.

6.2.3 Standard for Electrical Safety in the Workplace and Arc Flash Protection (*NFPA 70E)*

This standard addresses electrical safety requirements for employee workplaces that are necessary for the practical safeguarding of employees during activities downstream of the electrical service point, such as the installation, operation, maintenance, and demolition of electric conductors, electric equipment, signaling and communications conductors and equipment, and raceways.

6.2.4 Occupational Safety and Health Act (OSHA) (*29 Code of Federal Regulations (CFR) 1910 and 1926*)

OSHA (Public Law 91-596) covers conditions, practices, and operations to ensure safe and healthful workplaces.

6.2.5 NASA Safety and Health Programs (*NPR 8715.1)*

This document is the central Agency document containing procedures and guidelines that define the NASA Safety Program.

6.2.6 Electric Power System Operating Instructions *(Low-Voltage Electrical Power System (LVEPS)-Operator Instructions (OI) xx and High-Voltage Electrical Power System (HVEPS)-OI xx)*

The GRC LVEPS and HVEPS managers have issued OIs applicable to their respective systems. OIs include policies governing the operation of the electrical power systems as well as policies involving safety considerations for people and equipment who/that interact with these systems and associated subsystems. Examples of OIs include policies associated with cable cutting, working in power manholes and electric cable tunnels, working on or near electrical equipment, and using specific emergency tie circuits. These are onsite instructions to be followed when working on a GRC facility. Current versions are available on the homepage of the FD web site, which can be accessed by typing "FD" in the WING transporter box.

6.2.6.1 Low Voltage Operating Instructions (OIs)

a. OI-001, Naming Convention on Low Voltage Panels and Low Voltage Apparatus

b. OI-002, Standard for Identification Plates for Low Voltage Equipment Enclosures

c. OI-003, Low Voltage Electrical Metering Standard

d. OI-004, Standards for Conduit Installation

e. OI-006, Occupancy Sensor Requirements

f. OI-007, The Use of Flat Conductor Cable

g. OI-008, Work On or Near Low Voltage Electrical Systems

h. OI-009, Low Voltage Electrical System Switching

i. OI-010, Procedures for Field Assembled/Repaired Cords

j. OI-011, Arc Flash Labeling Alternate Method of Compliance

6.2.6.2 High Voltage Operational Instructions (OIs)

a. OI-001, Procedures to Implement Technical Policies and Instructions

b. OI-004, Work in High Voltage Substations, Power Manholes, and Cable Tunnels

c. OI-006, Naming Conventions for Power Apparatus and Cables

d. OI-007, Place Name Tags on Power Apparatus and Cables

e. OI-008, Application of Arc Proofing on High Voltage Cables

f. OI-009, Procedure to Identify and Cut High Voltage Electric Cables

g. OI-011, Work On or Near High Voltage Electrical Systems

h. OI-012, GRC High Voltage Designated Safety Person

i. OI-013, New and Modified Electrical Systems

j. OI-015, Protective Relays in the HVEPS

k. OI-018, Operation and Maintenance Responsibilities for High Voltage Equipment

6.3.6.3 Temporary OI Deviance

Due to the complexity of GRC electrical power systems, unique circumstances may dictate that a temporary deviation from the written OIs is warranted. Requests for deviations will be initiated by submitting a written request by the responsible person (e.g., Project Manager, Contracting Officer (CO) or Contracting Officer's Technical Representative (COTR), Project Engineer, etc.) to the appropriate GRC Electrical Power System Manager. The request shall include a description of the unique circumstance, the rationale for the deviation, its duration, and the precautions and/or procedures to be implemented to mitigate any risk that may result from deviating from the OI.

6.3 Electrostatic Shock

6.4.1. The familiar phenomenon of a static shock—more specifically, an electrostatic discharge (spark)—is caused by electrons flowing between objects at different electric potentials coming close to or in contact with one another. Sparks can cause fires and explosions. Many semiconductor devices used in electronics are very sensitive to the presence of static electricity and can be damaged by a static discharge. Personnel working with this type of equipment shall be knowledgeable of this phenomenon and the precautions to be taken.

6.4.2 Good grounding of all parts of the equipment and precautions against charge buildups on equipment and personnel through common conductive paths (i.e., conductive wristbands, tables, and floors) shall be used as prevention measures. See Electrostatic Discharge (ESD) Association TR20.20, Handbook for the Development of an ESD Control Program for the Protection of Electronic Parts, Assemblies, and Equipment.

6.4 Electrical Apparatus/System Interaction *(NFPA 70E*)

6.5.1 All electrical systems and equipment shall be considered energized until verified to be de-energized and grounded (as required) prior to beginning hands-on work.

6.5.2 Verification that an electrical apparatus is de-energized shall be made using a suitable voltage detector and using the hot-dead-hot technique. Subsequent verification may be made by observing the open position of isolating breakers, switches, and links in sectionalizing boxes or by observing the personnel safety grounds installed at the worksite.

6.5.3 Only qualified persons shall be permitted to perform such verification.

6.5.4 Where new work is incrementally energized during the checkout process or is energized at any time during the construction phase prior to placing the new system into service, temporary warning tags shall be placed on the energized new work.

> ***NOTE**: A suitable tag to use is GRC946, CAUTION DO NOT OPERATE, Stock Number 7530-01-LNO-1281, stating in the remarks section why the tag is being placed. This tag merely indicates the status the system has been left in or system/equipment configuration.*

6.5 Energized Systems

6.6.1 As a rule, GRC does not allow work on energized electrical systems. Exceptions are provided for specific tasks allowed in NFPA 70E, Article 130.2 (B) (3), Exemptions to Work Permit. A GRC System Manager and/or GRC Safety Committee Chair may concur with other exceptions to this policy after careful review of the situation and hazards involved. Such decisions shall be documented using an Energized Electrical Work Permit (GRC780).

6.6.2 After permission is granted to work on energized equipment only tools and voltage testing devices designed and rated for the voltage level of the system voltage shall be used by qualified persons.

6.6.3 Before opening an energized enclosed electric supply apparatus, personnel shall contact the EPD at Lewis Field or the Electrical Maintenance Specialist at Armstrong Test Facility. See Figure C3 in Appendix C for sample arc flash label. The EPD or Electric Maintenance Specialist will then refer to the arc flash database and inform personnel of the arc flash boundary and incident energy of the apparatus.

6.6.4 Whenever energized enclosed electric supply apparatus are opened (including but not limited to high- or low-voltage, metal-enclosed switchgear, unit substations, motor control centers, transfer switches, motor starters, transformer primary and secondary disconnect switches, variable frequency drives (VFDs), panelboards, and switchboards that normally isolate the public from exposed electrically energized components), special precautions shall be taken, including the following:

a. Both approach and arc flash boundaries shall be established and properly barricaded.

b. No one without proper PPE shall cross these boundaries at any time.

c. If the qualified person who opened the electrical supply apparatus must leave the area, the opened enclosures shall be closed and secured.

6.6.5 Removal or replacement of bolted covers larger than 4 feet diagonally on panels greater than 240 Voltage (to expose bare, energized electrical conductors or parts) with a PPE category of 1 or greater shall require the panel to be de-energized or submittal and approval of an Energized Electrical Work Permit. Once removed, the panel may be re-energized until time to replace the cover. This requirement is to prevent accidental contact with energized parts while removing large and cumbersome conductive covers.

6.6 De-energized (Isolated) Systems

6.7.1 Isolation of a low-voltage electrical power apparatus at GRC requires a minimum of one electrical open.

6.7.2 To isolate high-voltage apparatus, GRC requires two opens (or two independent actions). If that cannot be achieved, one electrical open with grounds in place shall suffice. These grounds do not replace the need for working (safety) grounds being placed by the personnel performing the high-voltage tasks.

6.7.3 When isolation or lockout/tagout causes a disruption in service, an Area Clearance form (GRC978) is required prior to beginning work. The Area Clearance Procedure can be found in Glenn Safety Manual Chapter 9, Lockout/Tagout, Appendix D.

6.7.4 When a written lockout/tagout plan is required, an Electrical Equipment Switching Order shall

a. Govern all scheduled switching, isolation, locking out, tagging out, or grounding of any part of the GRC electrical power systems

b. Govern the restoration of power to isolated systems or equipment

6.7.5 Such orders shall be prepared by the EPD at LF or the responsible engineer at GRC-ATF.

6.7.6 Particular effort shall be made to ensure that all potential power sources, including potential transformers (PTs), are disconnected to preclude back feed of power to the isolated site.

6.7.7 All switching procedures shall comply with the NESC (ANSI/IEEE C2), Part 4.

6.7.8 Each switch person shall

a. Be a Certified (Qualified) Operator/Switchperson (see Section 5.12) for the specific electrical power system and equipment involved

b. Have a copy of the written switching procedure

c. Initial the written switching procedure attesting to completion of each step of the procedure as it is completed

6.7 Lockout/Tagout Procedures (*29 Code of Federal Regulations (CFR) 1910.147 and Glenn Safety Manual Chapter 9*)

6.8.1 Lockout/tagout procedures shall be followed whenever work is being performed on a system or piece of equipment where isolation and/or control of hazardous energy is required to prevent injury to personnel. (Refer to the Glenn Safety Manual, Chapter 9, for details on lockout/tagout procedures.)

6.8.2 Isolation shall only be accomplished using a Certified (Qualified) Operator/Switchperson.

6.8.3 Lockout/tagout shall only be performed by the individual(s) being protected by those isolation devices.

6.8 Buddy System (*NPR 8715.1B, Section 13.8.3.4, Test/Operations Safety*)

6.9.1 Whenever the restricted approach or arc flash boundaries (see Appendix E for more information) are crossed, by reach or tool, one person, the “Buddy,” trained to recognize electrical hazards, shall be delegated to watch the movements of other personnel working with energized electrical equipment operating at 50 V or more. This is because data from the U.S. Bureau of Labor Statistics indicates that approximately 40 percent of electrical incidents involved energized systems of 250 volts or less.

6.9.2 Removal of bolted panelboard covers exposing energized parts shall also require the presence of a Buddy.

6.9.3 Once an electrically safe work condition (ESWC) is established, a Buddy is no longer required. Establishing an ESWC is the only work procedure that ensures that an electrical injury cannot occur. Until the ESWC is established (including verification of the loss of potential), an unacceptable risk of injury from exposed energized electrical conductors or circuit parts exists and the Buddy is required.

6.9.4 NFPA 70E requires that employees exposed to shock hazards and those employees responsible for taking action in case of emergency (the Buddy) shall be trained annually in methods of release of victims from contact with exposed energized electrical conductors or circuit parts since they become exposed to a shock hazard when trying to free the victim.

6.9.5 These employees shall also receive annual instruction in methods of first aid and emergency procedures, such as approved methods of resuscitation and AED use (if the employer's emergency response plan includes it). See Section 6.16 for training course details.

6.9 Work in a Confined Space (*29 CFR 1910.146, 29 CFR 1910.269, and ANSI Z117.1*)

6.10.1 Many electrical systems are contained within confined spaces. Entry into confined spaces is governed by procedures detailed in the Glenn Safety Manual, Chapter 16, Regulatory Permit Requirements.

6.10.2 If high-voltage cables or equipment are contained within the space, the HVEP Systems Manager or Chair of the EASC shall be notified. Depending on the nature and location of the work, a Safety Permit may be needed as well.

> ***NOTE**: See HVEPS-OI-004 for specific requirements for confined spaces containing high-voltage electric supply equipment or cables.*

6.10 General Electrical Considerations

This section presents general GRC policies for work done on or near electrical power systems. The appropriate Systems Manager shall approve exceptions to these policies.

6.10.1 Configuration Control

All electrical systems, including control and protective systems, are under configuration control at GRC. When work on these systems involves a change to one-lines, legends, names, or functions, a Facilities Change Request (GRC29) shall be submitted and approved.

6.10.2 Validation of Operating Equipment (*LVEP and HVEP OIs*)

6.11.2.1 New electrical equipment, repaired electrical equipment where the repair involves the insulation system, and equipment that has not been energized for an extended period of time (3 months for outdoor equipment and 6 months for indoor equipment) shall be tested to ensure that the equipment's dielectric strength is at a safe level before energizing.

6.11.2.2 The appropriate Systems Manager shall be consulted for specific testing requirements for a particular piece of equipment.

6.11.2.3 Energizing of new or repaired power system equipment requires approval, via email, by the appropriate power Systems Manager. The EPD Office shall receive email authorization from the appropriate Systems Manager prior to energizing new or repaired electrical equipment.

6.10.3 Separately Derived Electric Power Systems (*NFPA 70 and 70E*)

6.11.3.1 Separately derived electric power systems, whether derived from generators, transformers, converter windings, photovoltaics, or batteries, present unusual safety considerations. Design, installation, operation, and maintenance of such systems shall conform to NFPA 70 and NFPA 70E.

6.11.3.2 Designs for such systems shall be reviewed and approved by the appropriate GRC Electrical Systems Manager.

6.10.4 Battery Systems (*NFPA 70 Article 480, and NFPA 1, Chapter 52*)

6.11.4.1 Design and installation of all stationary installations of storage batteries is governed by NFPA 70, Article 480. There are several IEEE standards to follow regarding batteries as well.

6.11.4.2 Ventilation systems (see NFPA 1, Uniform Fire Code, Chapter 52, Energy Storage Systems), forced or natural, shall be examined and maintained to prevent buildup of explosive mixtures. This shall include a functional test of any associated detection and alarm system as battery charging could generate significant quantities of hydrogen and other flammable gases. See NFPA 70E, Article 240.

6.11.4.3 The nature of batteries is such that they cannot be shut off; therefore, special care and handling is required to perform installation, maintenance, or testing. Working with batteries exposes an employee to both potential shock and arc flash hazards. An energized electrical work permit is required to interact with energized batteries.

6.11.4.4 In addition to the electrical hazards, batteries expose an employee to hazards associated with the chemical electrolyte used in the battery. When selecting work practices and PPE, the employee shall be trained to consider exposure to these hazards as well.

6.11.4.5 If battery electrolyte should come into contact with skin or clothing, immediately treat skin or clothing with water or a weak neutralizing solution. Electrolyte in the eyes, however, is a very dangerous situation; immediately flush the eyes with profuse amounts of water, then seek medical attention. See NFPA 70E, Article 320 for more information.

6.10.5 Instrument Transformers (*NFPA 70, Article 250.170*)

The following precautions shall be observed in handling instrument transformers**:**

a. Current transformer cases and secondaries shall be grounded.

b. Where more than one set of current transformers are connected electrically, a ground point shall be selected that provides grounding for the network.

c. Secondaries of current transformers (CTs) shall never be opened while the primary circuit has current flow.

> ***NOTE**: If current is passing through the primary of a CT, and the secondary circuit is not connected to the current coil, a very high and dangerous voltage will be present. The CT becomes a voltage step-up transformer under this condition. Therefore, it is important to always short the X1 and X2 terminals to each other before breaking the circuit under load. Shorting bars or shorting terminal strips are permanently installed on most CTs or CT circuits for this purpose.*

d. Always ensure PTs fuse are removed from circuits to be worked on.

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

6.10.6 Capacitors (*NFPA 70 Article 460, NFPA 70E Article 360*).

Design and installation of all capacitors, except surge capacitors or capacitors furnished as a component part of other apparatus, are governed by NFPA 70, Article 460. The following steps shall be taken before employees work on capacitors:

a. The capacitors shall be disconnected from the energizing source.

b. Residual charge shall be bled off through a suitable current limiting resister.

c. The capacitor(s) shall be grounded.

d. Capacitors shall be isolated, and the absence of the stored voltage verified utilizing proper PPE as required in NFPA 70E, Article 120.

e. Since capacitor units may be connected in series-parallel configurations, after residual charge is bled off, each unit shall be shorted between all insulated terminals and the capacitor tank before handling.

f. Racks for capacitors shall be grounded.

g. Any internal resistor shall not be depended upon to discharge capacitors. Also, see Section 6.12 for special requirements for high-voltage capacitor banks used as part of experimental equipment.

6.10.7 Fuses (Removal and/or Replacement) (*NFPA 70E*)

Removal and/or replacement of fuses may be accomplished once the fuse is disconnected from all sources of electrical energy. The following requirements apply:

a. Removal and/or replacement of fuses from an energized circuit shall require an Energized Electrical Work Permit (GRC780).

> ***NOTE**: Exception: An Energized Electrical Work Permit is not required for control power, instrumentation, and PT secondary fuses being removed or replaced with the*

circuit energized, as long as the transformer the systems are connected to is rated less than 240 V and 20 kVA or smaller.

b. Fuses shall not be removed on energized circuits above 34.5 kV.

c. Fuses are not to be replaced under load.

d. Fuse or fuse holder handling equipment, insulated for the circuit voltage, shall be used to remove or install a fuse if the fuse terminals are energized.

6.11 Hazardous (Classified) Locations (*NFPA 70, Articles 500 through 516)*

6.12.1 Some LF and GRC-ATF facilities and test rigs employ or store flammable gases or vapors, flammable liquids, combustible dust, or ignitable fibers or flyings. These areas are classified as hazardous locations and require proper design to address these hazards. The HCC shall approve the classification of these areas before construction and/or the areas becoming operational. Guidance for classifying areas is contained in various NFPA publications, including NFPA 497 and NFPA 496, Standard for Purged and Pressurized Enclosures. Requirements for electrical and electronic equipment and wiring for all voltages in such classified locations are covered in NFPA 70, Articles 500 through 516. The following process was created to ensure designs meet one of the protection techniques defined in NFPA 70, Article 500.7, and/or the recommended practices of NFPA 497.

6.12.2 HCC Review Process

6.12.2.1 The requestor shall provide the following information to the HCC for review:

a. Hazardous area classification drawing, to include

(1) Building location and outline

(2) Plan view of major equipment and piping systems containing flammable liquids and gases along with material storage location

(3) Appropriate cross hatching of proposed hazardous areas dimensioned to show extent of classification

(4) Side views as necessary to show vertical extent of classification and to indicate ventilation airflow path

(5) Process system vents and show any structural openings or obstructions to airflow (indoor and/or outdoor)

(6) Legend for cross hatching, shading, etc., designating Classification Division and Group

b. System information, to include

(1) Description of flammable materials

(2) Quantity, description of storage containers, flow rates into process area

(3) Physical state (liquid (L) or gas (G))

(4) Safety Data Sheet (SDSs) with the following minimum data: molecular weight or vapor density, normal and maximum temperature and pressure, flash point, explosive range, composition if a mixture, and auto ignition temperature

(5) Ventilation information for indoor systems (physically verify if unsure and classification depends on adequate ventilation): fan location or air pickup points, makeup air inlet locations, path of airflow, and airflow rates

(6) Specific equipment used for a proposed protection technique

> ***NOTE**: If space permits, this system information should be included in a table on the classification drawing.*

6.12.2.2 The HCC will determine the suitability of the proposed design in meeting the requirements of NFPA 70, Article 500, and NFPA 497 and will provide a response to the requester.

6.12.3 **Equivalency Review** (*Glenn Work Instruction-Q-8700.3, Safety and Mission Assurance Engineering Review Board (SERB), Section 8.4*)

If the design does not meet one of the prescribed protection techniques of Article 500 and NFPA 497 and the requester would like further consideration, the requester will provide the following, together with the HCC Review Process information listed above, to the SHeD Chief:

c. Detailed description of the proposed alternate protection technique

d. Rationale and engineering judgment as to why the proposed protection technique is equivalent to a prescribed technique

e. A supporting hazards analysis, including all mitigations

f. A supporting risk assessment identifying risk after mitigation in accordance with Glenn Safety Manual Chapter 1. Use GRC923A, Safety Permit Hazard Analysis Worksheet, or equivalent and then submit either (1) or (2):

(1) If it is an equivalency with no additional risk, and SHeD is in concurrence, submit a Safety and Mission Assurance (SMA) Management Board/SMA Engineering Review Board (SERB) Request (GRC941).

(2) If it is not an equivalency, or SHeD does not concur, submit a Safety and Health Requirement Relief Request (GRC83).

6.12.4 Responsible personnel shall involve the Operational Safety Branch early in evaluations of use of hazardous materials and the need for classified electrical equipment during design and prior to the installation/operation of such equipment.

> ***NOTE:** NFPA 70 paragraph 500.5(A) Fine Print Note (FPN) states "Through the exercise of ingenuity in the layout of electrical installations for hazardous (classified) locations, it is frequently possible to locate much of the equipment in a reduced level of classification or in an unclassified location and, thus, to reduce the amount of special equipment required."*

6.12.5 No construction or change to operating procedures shall be allowed within a hazardous (classified) area without a review conducted by the applicable safety committee and the HCC that documents the rationale leading to approval of the construction or change to operating procedures.

6.12.6 All hazardous (classified) locations shall have suitable and prominent warning signs clearly posted to identify the area as a classified location. (National Electric Manufacturers Association (NEMA) Z535.4 contains information on warning signs.) The following shall be included:

a. The NEC Class, Division, and Group

b. The organization responsible for the area

c. A statement stating that no changes may be made to the facility without an approved Facilities Change Request (GRC29).

6.12.7 The organizational element responsible for a hazardous (classified) area shall maintain a file relating to the area. Such files shall contain the document(s) identifying area classifications as well as supporting documents such as calculations, preliminary and final hazard analyses, and related meeting minutes.

6.12 Personal Protective Equipment

***NOTE**: For additional information on PPE, see Chapter 15 of the Glenn Safety Manual.*

6.12.1 Hard Hats *(29 CFR 1910.135 and ANSI Z89.1)*

All personnel entering any high-voltage substation, power manhole, and/or cable tunnel shall wear a Type I, Class E hard hat conforming to 29 CFR 1910.135 and ANSI Z89.1, Standard for Industrial Head Protection.

6.12.2 Eye Protection *(ANSI Z87.1 and American Society for Testing and Materials (ASTM) F2178)*

6.13.2.1 Safety glasses, goggles, or face shields shall be worn by an individual in any area or during any work where there is a reasonable probability of eye injury.

6.13.2.2 Eye and face protection shall meet or exceed ANSI Z87.1, Standard for Occupational and Educational Personal Eye and Face Protection Devices, and ASTM F2178, Standard Test Method for Determining the Arc Rating and Standard Specification for Eye or Face Protective Products.

6.12.3 Safety Shoes *(ASTM F2412 and F2413)*

All personnel entering any high-voltage substation, power manhole, and/or cable tunnel shall wear safety shoes meeting the requirements of ASTM F2412, Standard Test Methods for Foot Protection, and F2413, Standard Specification for Performance Requirements for Protective (Safety) Toe Cap Footwear.

6.12.4 Rubber Insulating Gloves *(ASTM D120 and ASTM F496)*

6.13.4.1 Rubber gloves used for protection against electrical shock shall meet the requirements of ASTM D120, Standard Specification for Rubber Insulating Gloves, and be tested in accordance with ASTM F496, Standard Specification for Rubber Insulating Gloves in Service Care. In addition, ASTM F1236, Standard Guide for Visual Inspection of Electrical Protective Rubber Products, provides suggested methods of pre-use inspections to ensure glove integrity.

6.13.4.2 All qualified switch persons shall have two pairs of personal rubber insulating gloves, protective leather gloves, and a glove bag.

6.13.4.3 Protective leather gloves shall always be worn over lineman-type rubber gloves and will be in accordance with ASTM F696, Standard Specification for Leather Protectors for Rubber Insulating Gloves.

6.13.4.4 Preferable glove construction shall be in contrasting two-color combinations. The contrast between the thin outer color against the inner color makes inspecting for cuts and tears easier when the glove is inflated or stretched.

6.13.4.5 Whenever the inner rubber color is visible, the pair of gloves shall be discarded.

6.12.5 Hot Sticks *(ANSI/IEEE Standard 516 and 29 CFR 1910.269(j))*

6.13.5.1 All hot sticks (live-line tools) shall

a. Be made of fiberglass

b. Meet the requirements of 29 CFR 1910.269(j)

c. Be removed from service for examination, cleaning, repair, and testing every 2 years and whenever required under paragraph 29 CFR 1910.269 (j)(2)(ii)

6.13.5.2 Field care, handling, and storage of hot sticks shall be per ANSI/IEEE Standard 516, Section 4.

6.12.6 Protective Clothing *(NFPA 70E)*

6.13.6.1 Personnel shall wear protective clothing as required by NFPA 70E Table 130.7(C)(15)(c) when performing energized work, whether or not an Energized Electrical Work Permit (GRC780) is required.

6.13.6.2 NFPA 70E Table 130.7(C)(15)(c) lists the requirements for protective clothing and other protective equipment based on Arc Flash PPE Category 1 through 4. This clothing and equipment shall be used when working within the arc flash protection boundary.

> ***NOTE**: For more information, refer to NFPA 70E Informative Annex H, Guidance on Selection of Protective Clothing and Other Personal Protective Equipment; ASTM F1506, Standard Performance Specification for Flame Resistant and Electric Arc Rated Protective Clothing Worn by Workers Exposed to Flames and Electric Arcs; and ASTM F1959, Standard Test Method for Determining the Arc Rating of Materials for Clothing.*

6.13 Equipment Safety Tests and Checks (*ANSI/IEEE or NETA (International Electric Testing Association*)

6.13.1 Tests Required Prior to Initial Energization

6.14.1.1 Initial energization of all new electrical equipment shall be done only in the presence of the appropriate Government representative.

6.14.1.2 Before the initial energization, feeder circuit breakers shall be checked for proper adjustments in accordance with the manufacturer's instructions. (Molded-case circuit breakers without solid-state trip devices are excluded from this requirement.)

6.14.1.3 All protective relays and other such devices shall be tested to ensure they can operate in the range required. Where possible, tests shall include loading in at the current transformer secondaries to validate the circuitry as well as the device.

6.14.1.4 All wiring shall be checked for conformity to the design and to functional requirements.

6.14.1.5 All motors, cables, and switchgear shall be tested in accordance with industry standards and manufacturer's recommendations at voltage levels approved by the appropriate Systems Manager for the specific type of equipment. The industry standards shown in Table I shall apply.

TABLE I.—TESTING STANDARDS

Equipment	Standard[a]
Motors	ANSI/IEEE /NETA
Cables – all insulation types	ICEA/ANSI/NETA
Switches/Switchgear/Breakers	ANSI/IEEE /NETA
Transformers	ANSI/IEEE /NETA

[a]See appropriate Systems Manager to determine preferred standards and methods.

6.13.2 Circuit-Interrupting Devices

6.14.2.1 All circuit-interrupting devices shall be rated to interrupt the maximum short-circuit current that can be supplied by the power system at the point of application of the device.

6.14.2.2 Whenever a proposal is made to add circuit-interrupting devices to the system and whenever large loads are added or major system changes are made, the responsible engineering organization shall make system short-circuit studies to establish the circuit-interrupting duty requirements.

6.14.2.3 All such studies shall be reviewed and approved by the responsible FD Systems Manager.

6.14.2.4 After any operation in which a circuit breaker opens under short circuit or fault conditions, the circuit breaker shall be inspected, relay targets reviewed, and an assessment made to determine why the breaker operation occurred. Only after this assessment is completed and the cause for the tripping is isolated/removed can the circuit breaker be reclosed and the circuit re-energized.

6.14.2.5 The inspection and assessment shall be reviewed by a qualified operator with support from the responsible FD System Manager.

6.14.2.6 Since fuses do not have associated relaying (targets) to provide information as to their opening the circuit, unless the reason for the operation occurring is evident (e.g., a known overload situation), replacement of the fuse and restoration of the circuit may be done only after proper lockout/tagout has occurred, minimum testing (insulation resistance) has been accomplished, and the fault situation has been isolated/removed.

6.13.3 Protective System Checks

6.14.3.1 Protective relay settings shall be coordinated to provide selective tripping.

6.14.3.2 The appropriate Electrical Systems Manager shall maintain a listing of the required settings and the frequency of periodic testing of all protective relays in use.

6.14.3.3 All HVEPS protective relays shall be checked and calibrated on a triennial basis.

6.13.4 High-Voltage Insulation Testing

6.14.4.1 High-voltage test levels and procedures for all operating equipment shall be verified with the HVEPS Manager to ensure that the test voltage selected and/or procedure used is based on evaluations of the type and condition of insulation, age, damage, equipment history, and desired service, as recommended per manufacturer requirements and industry standards from IEEE, ANSI, and NETA.

6.14.4.2 High-voltage dielectric testing shall be performed in the presence of the DSP. Isolation, tagging, area securing, and grounding procedures as required shall precede testing.

6.14.4.3 During testing, all safety precautions listed in the respective standard/specification shall be followed.

6.14 Experimental Equipment

6.14.1 Safety Responsibility

6.15.1.1 The Project Manager is responsible for the safety of personnel and equipment associated with the development of experimental apparatus. Experimental electrical or electromechanical equipment that is under development, and therefore subject to frequent modifications, can present a particular hazard to personnel. A periodic assessment of project/equipment hazards using, as a minimum, a Safety Permit Hazard Analysis Worksheet, GRC923A, shall be performed. See Chapter 1 of the Glenn Safety Manual for more information on safety permits.

6.15.1.2 These assessments shall be used to establish correct working procedures, to identify need and use of appropriate PPE, and to establish proper emergency procedures. Particular emphasis shall be placed on de-energization of the equipment.

6.14.2 Experimental, Developmental, or Special Electrical/Electronic Equipment (*NFPA 70E, Article 350*)

Following are additional guidelines for working on or near energized electrical experimental, developmental, or flight-level electrical/electronic equipment:

a. A member of the research and development team, such as the Project Engineer, shall establish correct working procedures as well as proper precautions, warnings, emergency procedures, and approved operators lists.

b. Safety should be a recurring topic of discussion during project team meetings. Emphasis should be placed on establishing and familiarizing project personnel with emergency procedures to de-energize the equipment.

c. New project personnel shall be apprised of unusual shock hazards associated with the equipment.

d. All work shall be in accordance with NFPA 70E.

e. As a minimum, guards shall be provided around exposed connections energized above 50 V rms per NFPA 70.

f. After de-energizing (per GRC Lockout/Tagout Program), a required minimum discharge time should be observed and/or grounding probe(s) should be utilized to discharge circuits prior to physical contact or circuit modifications to ensure that no residual or hazardous voltages remain.

g. Where reasonable and possible, fail safe and/or current limiting circuits should be incorporated in equipment to minimize effects of personnel exposure to hazardous electric shock energy.

h. Temporary wiring utilized shall

(1) Be rated for the environment and use

(2) Be routed in a reasonably neat manner

(3) Not pose unreasonable additional hazards

(4) Meet the requirements of NFPA 70 unless justified in writing by the GRC Fire Protection AHJ

i. Periodic hazard assessment of project/equipment hazards and identification of appropriate PPE shall be conducted using the GRC Job Hazard Analysis form (GRC239) or an equivalent hazard analysis process.

j. Faulty equipment, frayed cords, or faulty grounding conditions shall be repaired (per LVEPS-OI-10) or eliminated.

6.14.3 Experimental Equipment Utilizing High-Voltage Capacitor Banks

6.14.3.1 Test personnel conducting experiments in which capacitor banks with voltages above 600 V are employed shall have total knowledge of the experiment, the circuit, and the component layout.

6.14.3.2 Safety Permit Requestors shall ensure all personnel tasked to the project are 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. These personnel should be listed on a Qualified Operators List (GRC580) within the GRC Electronic Safety Permit System. General guidance for use of capacitors on power circuits is contained in NFPA 70, Article 460 and paragraph 8.8.16.

6.14.3.3 Additional precautions and procedures are as follows:

a. Each high-voltage test area shall be enclosed and protected by using gates and interlocks on the test controls.

b. Since capacitors and related high-voltage component faults are a source of hazardous shrapnel, these components shall be isolated in a manner that precludes personnel injury or facility-related hazards such as fire.

c. High voltage warning signs shall be displayed in conspicuous locations.

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

e. Shorting switches and grounding devices that normally discharge the capacitor bank shall be clearly visible to the test operator.

f. These devices shall be fail-safe and shall function to a safe configuration with no electrical power.

g. A voltmeter connected across the capacitor bank shall be clearly visible to the test operator at all times and a redundant voltmeter shall be installed at the capacitor bank.

h. Prior to touching a high-voltage component within the test area, personnel shall determine, by using a grounding wand approved by the Safety Manager for the installation, that the capacitor bank is fully discharged to a building ground.

i. Extreme caution shall be used on capacitor banks that are operated by DC voltages, since a DC capacitor bank will maintain a residual voltage for extended periods.

j. Each capacitor terminal in a series/parallel string shall be properly shorted to ground prior to making any changes to a test bank or circuit.

6.15 Training (*NPR 8715.1B and NFPA 70E*)

Employees exposed to shock hazards shall

a. Be trained, per NFPA 70E, in methods of release of victims from contact with exposed energized electrical conductors or circuit parts.

b. Be regularly instructed (at least once every 2 years) in methods of first aid and emergency procedures such as approved methods of resuscitation (cardiopulmonary resuscitation (CPR), automated external defibrillator (AED), etc.) (see Appendix D, Correlation of Current in Amperes and Reaction With the Human Body).

6.15.1 Electrical Certification Training

6.15.1.1 There are two types of Electrical Certified Operators at GRC: Low Voltage and High Voltage. The proficiencies required for each are summarized in Table II.

TABLE II.—ELECTRICAL CERTIFIED OPERATOR PROFICIENCES

Proficiency	Low Voltage	High Voltage
Supervisor verification	X	X
Be task qualified	X	X
Complete Low Voltage Safety course and pass exam	X	X
Complete Safe Release of an Electrical Shock Victim course	X	X
Complete Lockout/Tagout Training	X	X
Complete High Voltage Safety course and pass exam		X

6.15.1.2 Qualified Electrical Low Voltage Employees shall complete the following training:

a. The GRC Low Voltage Safety, SATERN Course GRC-4R1690. This instructor-led course provides information on this chapter, site-specific LVEPS-OIs, and an overview of Glenn Safety Manual Chapter 9 and NFPA 70E.

b. The GRC Low Voltage Safety Exam, SATERN Course GRC-4R1693. This is the online test for the course listed above. A passing test score (80 percent) shall provide the onsite certification requirement needed for Qualified Employees to perform switching and operating low-voltage equipment. Tests can be scheduled to be taken offline if personnel do not have access to SATERN.

c. Safe Release of an Electrical Shock Victim, SATERN online course GRC-111-15

d. Lockout/Tagout Training, Instructor-led SATERN course GRC-4R1508

6.15.1.3 Qualified Electrical High Voltage Employees shall complete the above training classes in addition to the following training:

a. GRC High Voltage Safety, SATERN Course GRC-4R1840. This instructor-led course provides information from this chapter, the site-specific HVEPS-OIs, and information on OSHA, NFPA 70E, and IEEE C2.

b. GRC High Voltage Safety Exam, SATERN Course GRC-4R1841. This is the online test for the course listed above. A passing test score (80 percent) shall provide the onsite certification requirement needed for Qualified Employees to perform switching and operating high-voltage

equipment. Tests can be scheduled to be taken offline if personnel do not have access to SATERN.

6.15.1.4 Unqualified Employees working in machine shops, equipment rooms, test cells, etc., (Engineers, Tradespersons, and Janitorial Crews that are not trained to work on electrical equipment but are exposed to electrical circuits/equipment/machinery during the performance of their work) shall complete LC GRC-4R1343, Electrical Safety: Shock Proof—Unqualified. This video shall also be viewed as part of new employee orientation.

> ***NOTE**: The video does not qualify an employee. See Section 5.11 of this chapter on how an employee becomes qualified.*

6.15.1.5 All other Employees (onsite civil servant and contractor) shall complete SATERN Course GRC-111-11, Electrical Safety: What Everyone Should Know. This short video provides a basic explanation on how electricity works, what it can do to the human body, and how to use electricity safely. This video shall also be viewed as part of new employee orientation.

6.15.2 Employee Retraining

6.15.2.1 For all of the Electrical Certification training requirements, retraining of employees shall be accomplished at least once every 3 years, per NFPA 70E.

6.15.2.2 Retraining shall also be provided for any employee when the employer has reason to believe that the employee's knowledge or use of the requirements set forth in this chapter is inadequate.

6.15.3 Emergency Response Training

6.15.3.1 In addition to other training requirements, those responsible for responding to medical emergencies shall be trained in methods of first aid and emergency procedures, such as approved methods of resuscitation.

6.15.3.2 Training shall occur at a frequency that satisfies the requirements of the certifying body.

6.15.3.3 The employer shall annually certify that the employee's emergency response training is current.

> ***NOTE**: Heartsaver/AED Training Course GRC-4R1402 is available through SATERN.*

7.0 RECORDS

a. Facilities Change Request (FCR) (GRC29).—Maintained by Code FD.

b. Safety and Health Requirement Relief Request (GRC83).—Maintained by SHeD.

c. Job Hazard Analysis Form (GRC239).—Maintained by Organization or Contractor conducting task.

d. Qualified Operators List (GRC580).—Maintained by Code QSS Safety Permit Program.

e. GRC Annual Electrical Safety Field Audit (GRC780).— Maintained by Organization or Contractor conducting task.

f. GRC Annual Electrical Safety Field Audit (GRC780A).—Maintained by SHeD.

g. Safety Permit Hazard Analysis Worksheet (GRC923A).—Maintained by Code QSS Safety Permit Program.

h. Safety and Mission Assurance (SMA) Management Board/SMA Engineering Review Board (SERB) Request (GRC941).—Maintained by SHeD.

i. Area Clearance Form, NASA GRC-978.— maintained for one year by designated person.

j. Training records for civil servants.—Maintained by Office of Procurement (CH) within CerTrak.

k. Training records for contractors.—Maintained by Code CH or Onsite Contractor.

8.0 REFERENCES

Document Number	Document Name
29 CFR 1910 and 1926	Public Law 91-596, Occupational Safety and Health Act (OSHA),
NPR 8715.1B	NASA General Safety Program Requirements
GLP-QS-8715.1	NASA Glenn Safety Manual, BMS Document
GLP-FB-8820.1	Configuration Management of Facilities and Institutional Systems
GLWI-Q-8700.3	Safety and Mission Assurance Engineering Review Board (SERB)
ANSI/IEEE C2	National Electrical Safety Code
ANSI/IEEE 516	Guide for Maintenance Methods on Energized Power Lines
ANSI Z87.1	Standard for Occupational and Educational Personal Eye and Face Protection Devices
ANSI Z89.1	Standard for Industrial Head Protection
ASTM D120	Standard Specification for Rubber Insulating Gloves
ASTM F496	Standard Specification for In-Service Care of Insulating Gloves and Sleeves
ASTM F696	Standard Specification for Leather Protectors for Rubber Insulating Gloves and Mittens
ASTM F1236	Standard Guide for Visual Inspection of Electrical Protective Rubber Products
ASTM F1506	Standard Performance Specification for Flame Resistant and Electric Arc Rated Protective Clothing Worn by Workers Exposed to Flames and Electric Arcs

ASTM F1959	Standard Test Method for Determining the Arc Rating of Materials for Clothing
ASTM F2178	Standard Test Method for Determining the Arc Rating and Standard Specification for Eye or Face Protective Products
ASTM F2412	Standard Test Methods for Foot Protection
ASTM F2413	Standard Specification for Performance Requirements for Protective (Safety) Toe Cap Footwear
ANSI/NETA ATS	Standard for Acceptance Testing Specifications for Electrical Power Equipment and Systems
ANSI/NETA MTS	Standard for Maintenance Testing Specifications for Electrical Power Equipment and Systems
ESD TR20.20	Handbook for the Development of an Electrostatic Discharge Control Program for the Protection of Electronic Parts, Assemblies, and Equipment
HVEPS-OI-xx	High-Voltage Electric Power System Operating Instructions. Various dates
LVEPS-OI-xx	Low-Voltage Electrical Power System Operating Instructions. Various dates
NEMA Z535.4	Product Safety Signs and Labels
NFPA 1, Chapter 52	Uniform Fire Code, Energy Storage Systems
NFPA 70	National Electrical Code
NFPA 70E	Standard for Electrical Safety in the Workplace
NFPA 496	Standard for Purged and Pressurized Enclosures
NFPA 497	Recommended Practice for the Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (classified) Locations for Electrical Installations in Chemical Process Areas

APPENDIX A.—DEFINITIONS

Following are some key definitions related to electrical safety. Many additional related definitions are contained within referenced documents such as the National Electrical Code (NEC) (NFPA 70) and the National Electrical Safety Code (NESC) (ANSI/IEEE C2).

Arc Flash (Flash Hazard).—A dangerous condition associated with the release of energy caused by an electric arc.

Area Clearance Process.—Documented way of communicating a disruption in service. Primarily used to notify Affected Employees when performing lockout/tagout impacts their ability to perform their assigned tasks.

Authority Having Jurisdiction.—The organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, an installation, or a procedure.

Automated External Defibrillator.—A portable electronic device that automatically diagnoses the potentially life-threatening cardiac arrhythmias of ventricular defibrillation and ventricular tachycardia in a patient and is able to treat them through defibrillation.

Cardiopulmonary Resuscitation.—An emergency procedure in which the heart and lungs are made to work by manually compressing the chest overlying the heart and forcing air into the lungs. CPR is used to maintain circulation when the heart stops pumping.

Electrically Safe Work Condition.—A state in which the conductor or circuit to be worked on or near has been disconnected from energized parts, locked/tagged in accordance with established standards, tested to ensure absence of voltage, and grounded if deemed necessary.

Electric Supply Equipment.—Equipment that produces, modifies, regulates, controls, or safeguards a supply of electric energy.

Electric Supply Station.—Any building, room, or separate space within which electric supply equipment is located and the interior of which is accessible, as a rule, only to qualified persons. This includes substation, transformer, storage battery, and switchgear rooms or enclosures but does not include facilities such as pad-mounted equipment and installations in manholes and vaults.

Enclosure.—The case or housing of apparatus, or the fence or walls surrounding an installation to prevent personnel from accidentally contacting energized parts or to protect the equipment from physical damage.

Fine Print Note.—A note that is not a requirement and is for information purposes only.

Lockout/Tagout.—Method of controlling hazardous energy sources.

Personal Protective Equipment.—Equipment designed to protect employees from serious workplace injuries or illnesses resulting from contact with chemical, radiological, physical, electrical, mechanical, or other workplace hazards.

Potential Transformer.—A special type of transformer that allows meters to take readings from electrical service connections with higher voltage (potential) than the meter is normally capable of handling.

Qualified Operator (Switch person).—A person who has (1) received site-specific knowledge of both the equipment being operated and the system(s) it may impact; (2) been trained on the maintenance and safe operation of particular equipment, including specific voltages and the proper PPE; and (3) received instruction on lockout and/or tagout through the GRC Lockout/Tagout Program.

Qualified Person.—One who has skills and knowledge related to the construction and operation of electrical equipment and installations and has received safety training on the hazards involved. See NFPA 70E, Standard for Electrical Safety in the Workplace, Article 110.6.

Shock Hazard.—A dangerous condition associated with the possible release of energy caused by contact or approach to live parts.

Voltage (of a circuit).—The greatest root-mean-square (effective) difference of potential between any two conductors of the circuit concerned.

Voltage (nominal).—A value assigned to a circuit or system for the purpose of conveniently designating its voltage class (e.g., 208Y/120 V, 2,400 V, or 34,500 V). The operating voltage of the system may vary above or below this value within a range that permits satisfactory operation of equipment.

Voltage, Low.—Electric system and equipment operating at 600 V nominal or less.

Voltage, High.—Electric system and equipment operating above 600 V nominal.

APPENDIX B.—ACRONYMS

AED	Automated External Defibrillator
AHJ	Authority Having Jurisdiction
ANSI	American National Standards Institute
ASTM	American Society of Testing and Materials (now ASTM International)
BMS	Business Management Systems
CFR	Code of Federal Regulations
CO	Contracting Officer
COTR	Contracting Officer's Representative
CPR	Cardiopulmonary Resuscitation
CT	Current Transformer
DSP	Designated High Voltage Safety Person
EASC	Electrical Applications Safety Committee
EPD	Electrical Power Dispatcher
ESD	Electrostatic Discharge Association
ESWC	Electrically Safe Work Condition
FD	Facilities Infrastructure Division
FPN	Fine Print Note
GLP	Glenn Procedure
GLWI	Glenn Work Instruction
GRC	Glenn Research Center
GRC-ATF	Glenn Research Center-Neil A. Armstrong Test Facilities
HCC	Hazardous Classification Committee
HVEPS	High-Voltage Electrical Power System
ICEA	Insulated Cable Engineers Association
IEEE	Institute of Electrical and Electronics Engineers
LF	Lewis Field
LVEPS	Low-Voltage Electrical Power System
MTS	Maintenance Testing Specification
NEC	National Electrical Code

NEMA	National Electric Manufacturers Association
NESC	National Electric Safety Code
NETA	International Electrical Testing Association
NFPA	National Fire Protection Association
NPR	NASA Procedural Requirements
OI	Operating Instruction
OSHA	Occupational Safety and Health Administration
PPE	Personal Protective Equipment
PSSC	Process Systems Safety Committee
PT	Potential Transformer
SATERN	System for Administration, Training, and Education Resources for NASA
SDS	Safety Data Sheet
SERB	Safety Engineering Review Board
SHeD	Safety and Health Division
SMA	Safety and Mission Assurance
VFD	Variable Frequency Drive
WING	Web Intranet at Glenn

APPENDIX C.—EXAMPLES OF SIGNS AND LABELS

WARNING

HAZARDOUS AREA

BUILDING: 44

THE ELECTRICAL INSTALLATION IN THE AREA IS RATED FOR:

CLASS 1, DIVISION 2, GROUP D

IN COMPLIANCE WITH NFPA 70

NO SYSTEM OR FACILITY MODIFICATIONS MAY BE MADE TO THIS AREA WITHOUT AN APPROVED FACILITIES CHANGE REQUEST (FCR) GRC29

THE GLENN OPERATING ORGANIZATION RESPONSIBLE FOR THIS AREA IS: FACILITIES INFRASTRUCTURE DIVISION

To update this sign contact Glenn Operational Safety Branch at GRC-SHeD@mail.nasa.gov

Figure C.1.—Hazardous Area Warning Sign.

Figure C.2.—Supply Station Entry Sign.

Figure C.3.—Arc Flash Label.

Building 85

Device Name	Bus V	Arc Flash Boundary (in)	Working Distance (in)	Incident Energy (cal/cm2)
BLDG 85 - F01	480	27	18	2.32
BLDG 85 - F01	480	27	18	2.32
BLDG 85 - F01	480	27	18	2.32
BLDG 85 - F01	480	27	18	2.32
BLDG 85 - F01	480	50	18	6.02
BLDG 85 - F01 (BLDG 85 - F01M LineSide)	480	27	18	2.32
BLDG 85 - F01 (BLDG 85 - F01M LineSide)	480	138	18	31.0
BLDG 85 - F0101	480	19	18	1.31
BLDG 85 - F0101 (BLDG 85 - F0101M LineSide)	480	19	18	1.31
BLDG 85 - F0102	480	9	18	0.37
BLDG 85 - F0201	480	27	18	2.30
BLDG 85 - F0201	480	49	18	5.97
BLDG 85 - F0202	480	19	18	1.30
BLDG 85 - F0301	480	11	18	0.58
BLDG 85 - F0302	480	9	18	0.41
BLDG 85 - FMCC01	480	19	18	1.27

Figure C.4.—Sample Arc Flash Database.

APPENDIX D.—CORRELATION OF CURRENT IN AMPERES AND REACTION OF THE HUMAN BODY

D.1 Reaction of Human Body to Electric Current

Table D.1 correlates current in amperes and reactions of the human body.

TABLE D.1—FROM NFPA, ELECTRICAL SAFETY PROGRAM (TABLE 7.1)

Reaction of human body to electric current	Current in amperes (small body–large body)
Perception threshold (tingling sensation)	0.0007–0.0010
Slight shock—not painful (no loss of muscle control)	0.0012–0.0018
Shock—painful (no loss of muscle control)	0.0060–0.0090
Severe shock (muscle control loss & difficulty breathing)	0.0150–0.0230
Possible ventricular fibrillation (3-sec shock)	0.1000–0.1000
Possible ventricular fibrillation (1-sec shock)	0.2000–0.2000
Heart muscle activity ceases	0.5000–0.5000
Tissue and organs burn	1.5000–1.5000

D.2 Example: Utilizing Ohm's Law

(Hand contact + internal + foot contact = Total resistance)

500 ohms + 100 ohms + 500 ohms = 1100 ohms

120 volts/1100 ohms = 0.1091 amps

D.3 Contact Resistance

Some persons who handle electrical equipment mistakenly believe that their tolerance to electric shock is related to their ability to withstand the pain of the shock. The lethal occurrence is a function of the amount and duration of current passing through the chest. Furthermore, a lethal current may only be marginally higher than one ranked just painful. It is current, not voltage, that causes physiological damage to humans. As the magnitude of the current increases, statistically the current is more dangerous as a cause of burns than as a cause of heart failure. Although resistance varies with many factors, the accepted value for the internal resistance of the human body is 100 ohms, and 500 ohms is used as a reasonable expectation for contact (touch) resistance. Several factors can impact contact resistance such as coarseness of the skin, area of contact, contact pressure, and degree of wetness of the surface. These factors can lower the overall resistance and allow increased current to flow.

APPENDIX E.—SAMPLE RESTRICTED APPROACH BOUNDARY

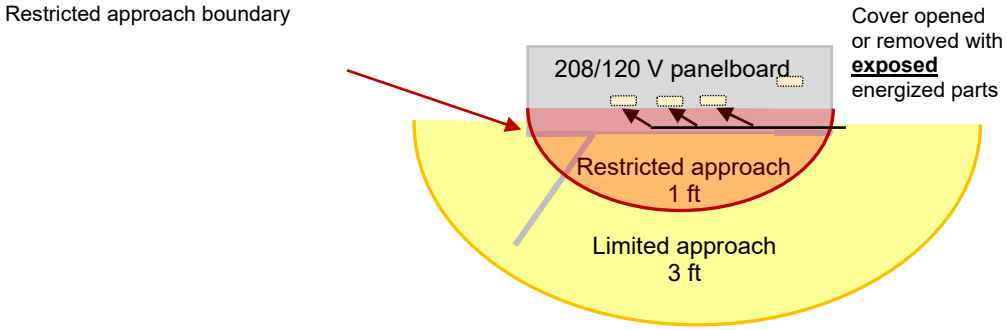

Figure E.1.—Shock Protection Approach Boundaries shown for 50 to 750 V. Boundary increases for voltages above 750 VAC
(see Table 130.4(E)(a) in NFPA 70E).

E.1 Restricted Approach Boundary

The restricted approach boundary is an approach limit at a distance from exposed energized electrical conductors or circuit parts within which there is an increased likelihood of electric shock for personnel. Only “qualified” employees may cross this boundary.

E.2 Limited Approach Boundary

The limited approach boundary is accessible to unqualified employees when escorted by a qualified employee. Figure E.1 represents boundary values when exposed to voltages of 50 to 750 VAC. Note that arc flash PPE may already have been required when the limited approach boundary was crossed.