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John C. Stennis Space Center
Electrical Safety Program

Approved by:

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Date

Document History Log

Status/Change/ Revision	Change Date	Originator/Phone	Description
Basic	May 19, 2009	Amy Rice 8-2972	Removed from SSP 8715-0001 Safety and Health Handbook and revised to include the guidance for electrical safety
Revision A	November 2, 2009	Amy Rice 8-2972	Added reference for Hazardous Classification SCWI
Revision B	January 18, 2011	Amy Rice 8-2972	Added Reference for Lock Out Tag Out SCWI, updated audit form number
Revision C	May 11, 2012	Amy Rice 8-2972	Updated 5.4 to reference NFPA 70E requirement. Updated extension cord section 6.1;
Revision D	August 2, 2012	Amy Rice 8-2972	Added reference for small appliance permits, updated forms section with the proper form numbers. Section 12.0.
Revision E	December 2, 2013	Delton Rodriguez 8-2499	Complete Revision
Revision F	June 24, 2014	Delton Rodriguez 8-2499	Clarifications to sections 5.0 and 6.0. Revised section 7.1.

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TABLES

1.0 PURPOSE

This Stennis Common Work Instruction (SCWI) establishes minimum standards to prevent personnel from hazardous electrical exposures and to ensure compliance with regulatory requirements applicable to electrical systems. This SCWI is designed to help ensure that energized electrical work at John C. Stennis Space Center (SSC) is performed safely by qualified electrical workers, who are trained and provided with the appropriate safe work procedures, protective equipment, and other controls. This SCWI is also intended to educate all employees about electrical shock, burns, and other potential electrical safety hazards.

2.0 APPLICABILITY

This procedure is applicable to office activities, industrial activities/operations, test operations, maintenance processes, and construction projects at SSC in which personnel may be exposed electrical hazards. This procedure applies to all NASA personnel, NASA on-site prime contractor personnel, and construction contractors.

3.0 REFERENCES

All references are assumed to be the latest version unless otherwise indicated.

a. 29 CFR 1910

b. 29 CFR 1910, Subpart S, Electrical

c. 29 CFR 1910.147, The Control of Hazardous Energy (Lockout/Tagout)

d. 29 CFR 1910.269, Electric Power Generation, Transmission, and Distribution

e. 29 CFR 1910.332, Training

f. 29 CFR 1926, Subpart K, Electrical

g. 29 CFR 1926.400 - 449, Electrical, Lockout and tagging of circuits

h. 29 CFR 1926.950-960, Power Transmission and Distribution

i. ANSI/AIAA G-095-2004, Guide to Safety of Hydrogen and Hydrogen Systems

j. ASTM F496-06, Standard Specifications for Service Care of Insulating Gloves and Sleeves

k. ASTM MNL 36, Safe Use of Oxygen and Oxygen Systems

l. ASTM 1506-10a, Standard Performance Specification for Flame Resistant and Arc Rated Textile Materials for Wearing Apparel for Use by Electrical Workers Exposed to Momentary Electric Arc and Related Thermal Hazards

m. ASTM F1959, Standard Test Method for Determining the Arc Rating of Materials for Clothing

n. Energized Electrical Work Permit

o. NEC Article 110.16, Flash Protection

p. NEC Article 400.8, Flexible Cords and Cables

q. NEC Article 590, Temporary Installations

r. NFPA 70, National Electrical Code®

s. NFPA 70B, Recommended Practices for Electrical Equipment Maintenance

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

u. NFPA 780, Standard for the Installation of Lightning Protection Systems

v. NPD 8710.5, NASA Safety Policy for Pressure Vessels and Pressurized Systems

w. SCWI-3410-0003, Training/Certification Plan and Schedule Report

x. SCWI-8715-0012, Work in Hazard Classification Areas

y. SCWI-8715-0013, SSC Control of Hazardous Energy Lockout/Tagout and Non-Service /Maintenance Hazardous Energy Isolation

z. SSP-8715-0001, Safety and Health Handbook

aa. SPR 8715.1, Safety and Health Program Requirements

bb. SPR 8730.4, SSC Metrology and Calibration Control Program

cc. SSP-1740-0018, Use of Small Electrical Appliances

dd. SSTD-8070-0081, ELEC, Facility Electrical Program

ee. SSTD-8070-0083, ELEC, Standard for the 13.8kV Distribution System

ff. NASA-STD-8719.17, NASA Requirements for Ground-Base Pressure Vessels and Pressurized Systems, appropriate OSHA

gg. UL 96, Lightning Protection Components

hh. UL 96A, UL Standard for Safety Installation Requirements for Lightning Protection Systems

4.0 RESPONSIBILITY

4.1 NASA Employees

All NASA employees shall:

a. Not work on or near energized electrical equipment above fifty (50) volts if not qualified to do so.

b. Maintain a safe workspace free of all electrical hazards and/or in violation of regulatory requirements.

c. Follow all applicable safe work practices listed in this SCWI.

d. Report unsafe electrical work conditions immediately to supervisor.

4.2 NASA SSC Directorates and Offices

NASA SSC Directorates and Offices shall:

a. Ensure all personnel are trained to recognize electrical hazards and understand the basic Occupational Safety and Health Administration (OSHA), National Electrical Code (NEC) and National Fire Protection Association (NFPA) 70E electrical safety standards applicable to their area.

b. Maintain a work environment free of all electrical safety hazards.

4.3 NASA Onsite Prime Contractors and Construction Contractors

NASA prime contractors and construction contractors shall:

a. Ensure personnel are trained to recognize electrical hazards and understand the basic OSHA and NEC electrical safety standards applicable to the area.

b. Develop detailed electrical safety procedures for their employees to address all work conducted in both high and low voltage areas.

c. Ensure employees are trained in the proper use, wear, inspection, and cleaning of proper Personal Protection Equipment (PPE) related to electrical work.

d. Develop and utilize electrical safety programs that meet or exceed all applicable guidelines of this SCWI.

e. Implement and document an overall electrical safety program that directs activity appropriate for the electrical hazards, voltage, energy levels and circuit conditions.

f. Review electrical safety procedures of their subcontractors when the task of the subcontractors involves electrical work.

g. Maintain electrical safety procedures as part of their overall safety plan. The procedures shall be made specific to SSC.

h. The electrical safety program and employee training shall be audited to verify the principles and procedures of the electrical safety program are in compliance with OSHA, NEC, and NFPA 70E.

i. Conduct fieldwork and document audits of employees, subcontractors, and construction contractors to verify the requirements contained in the procedures of the electrical safety program and federal regulations are being followed. When the auditing determines that the principles and procedures of the electrical safety program are not being followed, the appropriate revisions to the training program or revisions to the procedures shall be made.

j. Utilize Energized Electrical Work Permit Process for work on or near energized electrical equipment.

k. Recognize equipment adjustments in high voltage or any other highly hazardous locations as being “SAFETY CRITICAL.” The responsible organization safety representative shall approve “SAFETY CRITICAL” operations.

l. Maintain record keeping associated with the SCWI (e.g., documentation on electrical PPE, preventive maintenance, hot work permits, arc flash analysis and coordination reports and project arc flash analysis software files), per System Operations and Maintenance Responsibility Database (SOMRD).

4.4 Safety and Mission Assurance

The Safety and Mission Assurance (SMA) Office of NASA SSC and Onsite Prime contractors shall:

a. Be the Office of Primary Responsibility (OPR) for an electrical safety program work instruction that is up to date, and meets NASA, SSC, NFPA, and Occupational Safety Health Administration (OSHA) requirements.

b. Review all electrical safety plans for applicable content submitted by NASA direct construction contractors performing work at SSC. These plans shall be submitted as part of the construction contractor's health and safety plan.

c. Conduct field audits of employees, subcontractors, and construction contractors' electrical safety work to ensure compliance with federal regulations and compliance with this SCWI and shall be documented on NASA from SSC-869.

d. Evaluate work being performed and determine compliance with this SCWI.

e. Provide or assist in specific training for electrical work qualifications.

f. Provide or coordinate general training for employees on the content of this SCWI.

4.5 Facility Operating Support Contractor

The Facility Operating Support Contractor (FOSC) is the responsible organization for electrical (high and low voltage) work at SSC.

FOSC shall:

a. Correct electrical deficiencies reported through the Facility Manager Database in a timely manner.

b. Field arc flash stickers shall match the arc flash analysis report data. The method of calculating and data to support the information for the label shall be documented in an easily accessible central location for future system modifications and audits. Refer to Section 7.3 Equipment Labeling requirements.

c. Electrical equipment shall be maintained in accordance with manufacturers' instructions or industry consensus standards to reduce the risk of failure and the subsequent exposure of employees to electrical hazards. Maintenance, tests, and inspections shall be documented.

4.6 NASA Center Operations

NASA Center Operations shall:

a. Assure that a safe workplace is maintained through active coordination with and support to the designated facility managers.

b. The status of corrective actions shall be verified every thirty days.

5.0 SAFETY REQUIREMENTS AND QUALIFIED PERSONS

5.1 Qualified and Unqualified Personnel

Only qualified personnel will conduct any electrical related work. Qualified personnel include employees (and their supervisors) working on or near exposed electrical circuits or unlisted equipment posing a shock or arc flash hazard who have received work specific training, and demonstrate knowledge and skills needed to control the hazards associated with the electrical work. A worker may be qualified for one kind of electrical work, but not for another. Unqualified personnel are those personnel who have not received the full training specified in Section 9.1 and/or do not possess or have not proven the knowledge and proficiency necessary to safely and successfully complete the associated electrical work.

Refer to Section 9.0 and 9.2 for Training Requirements for Qualified and Unqualified persons.

5.2 Required Personnel

At a minimum, two (2) qualified persons must be in the immediate area at all times when work is being performed on exposed, energized electrical conductors, or circuit parts carrying 50V or more. Each qualified person must be able to see and hear the other. This ensures that the qualified person will be available to assist the other in case of an accident. Each qualified person will know the location of, have unobstructed access to, and know how to operate the power cutoff for the work area, and how to contact emergency personnel. When hazard levels are significant, a safety watch is required. Refer to NFPA 70E or OSHA for specific requirements.

5.3 Electrical Hazard Analysis

An electrical hazard analysis shall be conducted by qualified electrical supervisor/engineer where electrical work is conducted on facility electrical distribution systems or electrical

equipment or devices within the limited approach boundary of exposed, energized electrical conductors or circuit parts, and/or working within the arc flash boundary of electrical equipment, in accordance with NFPA 70E. This electrical hazard analysis consists of a Shock Hazard Analysis and Arc Flash Hazard Analysis.

5.4 Worksite Safety Briefing

Whenever work involves accessing energized parts, the qualified person in charge will conduct a job safety briefing with the personnel performing the work.

The job safety briefing will address, at a minimum:

1) Hazards associated with the work which also includes combustibles.
2) Procedures involved in the work.
3) Any special precautions required to maintain electrical safety.
4) Control of energy sources.
5) PPE and clothing required for the work.
6) Location of emergency and/or first aid equipment.
7) Emergency call number and procedures.
8) Voltage of circuits and equipment.
9) Shock hazard boundaries.
10) Arc flash energy.
11) Arc flash protection boundary.
12) Location and procedure for emergency power disconnect.

For routine work, a brief discussion will meet the requirement if the employee, due to training and experience, can reasonably be expected to recognize and avoid the hazards involved in the job. Additional job briefings will occur if any one of the following conditions exists:

1) New and unfamiliar work.
2) Performed infrequently.
3) Outside of normal duties.
4) Performed differently than in a documented procedure.
5) Complicated work or incurs new electrical hazards.
6) Worker cannot be expected to recognize and avoid the hazards involved in the job (in particular, this may apply to newly assigned personnel).

5.5 Working On or Near Energized Electrical Equipment

Working <u>on</u> energized electrical equipment means actually touching energized parts. Working <u>near</u> energized electrical equipment means working close enough to energized parts to pose a risk even though work is on de-energized parts. Common tasks where there may be a need to work on or near live circuits include:

a. Taking voltage measurements, to include the verification of circuit elements and equipment

parts are de-energized after the application of Lockout/Tagout (LO/TO).

b. Opening and closing disconnects.

c. Prior to the start of work, conduct a job briefing and verify planning checklist. Refer to NFPA 70E Annex I for example.

d. Racking breakers in or out from the bus, or racking breakers out to a test position.

e. Removing panels and dead fronts.

f. Operation of high voltage switches or performing maintenance on high voltage switches and or sectionalizing cabinets.

5.5.1 Energized Electrical Work Permit (EEWP)

Working on equipment in a de-energized state is **required** unless de-energizing introduces an increased hazard or is not feasible.

a. If live parts (fifty (50) volts or more) are not placed in an electrically safe condition, work to be performed shall be considered energized electrical work and shall be performed by **written permit only.**

b. An example of an Energized Electrical Work Permit can be found in Annex J of NFPA 70E. The intent of this permit is to ensure that all appropriate safety precautions are taken prior to starting energized electrical work.

c. Work related to testing, troubleshooting, and voltage measuring may be completed without a permit provided appropriate safe work practices and PPE are used.

d. The permit shall be originated by the qualified electrical worker.

e. Energized Electrical Work Permits shall be submitted to the appropriate supervisor for each facility.

f. The permit shall be posted in an appropriate location where the energized work is taking place for the duration of the task.

g. Energized Electrical Work Permits shall be maintained for a period of one (1) year.

5.6 Approach Distances to Live Parts

The NFPA 70E defines three (3) approach distances for shock hazards and one (1) for arc flash. The approach boundaries specify minimum safe distances from exposed energized electrical circuits or circuit parts posing a shock hazard (limited, restricted, and prohibited approach) or an arc flash hazard (arc flash boundary).

a. Approach boundaries to energized electrical or circuit parts for shock prevention are defined in **Table 1 - Alternating Current (AC) Systems; and Table 2 - Direct Current (DC) Systems.**

b. The **limited approach** is a boundary to protect unqualified personnel (not performing work on exposed energized electric circuits above 50V and untrained in such work) from a shock hazard.

    1) Unqualified personnel may not approach energized exposed electrical parts or bring conductive objects within 10ft (3 m) or the distance as dictated by following Table 1. If approach within these distances is required, a qualified person will be notified to de-energize the parts or appropriate PPE or temporary insulating barriers will be utilized.
    2) Warning signs or temporary barriers will be installed in areas where energized electrical parts are exposed. A qualified person within this area will escort unqualified persons.
    3) In certain instances, the arc flash boundary might be a greater distance from the energized electrical conductors or circuit parts than the limited approach boundary. The shock protection boundaries and the arc flash boundary are independent of each other. Placement of barriers and use applicable of PPE should be adjusted to the greater hazard.
    4) Hearing protection shall be used whenever working within the arc flash boundary.

c. The **restricted approach boundary** is the closest distance to exposed live parts a qualified person can approach when using the applicable PPE. Due to its proximity to a shock hazard, the use of shock protection techniques and equipment are required. Inside this boundary, accidental movement can put a part of the body or conductive tools in contact with live parts or inside the prohibited approach boundary. To cross the restricted approach boundary, the qualified person must:

    1) Have an Energized Electrical Work Permit (EEWP) and an Electric Hazard Analysis that is approved by the responsible qualified supervisor.
    2) Use PPE suitable for working near exposed live parts and rated for the voltage and energy level involved.
    3) Be certain that no part of the body enters the prohibited approach boundary.

4) Minimize the risk from unintended movement by keeping as much of the body as possible out of the restricted space; body parts in the restricted space should be protected.
5) Hearing protection shall be used whenever working within the restricted approach boundary.

d. The **prohibited approach boundary** is the minimum approach distance to exposed live parts to prevent flashover or arcing. Approaching any closer is comparable to making direct contact with a live part. To cross the prohibited approach boundary, the qualified person must:

1) Have an EEWP with proper written work procedures justifying the need to work that close to exposed live parts and approved by the responsible qualified supervisor.
2) Have performed an Electric Hazard Analysis and approved by the responsible qualified supervisor.
3) Prior to the start of work, conduct a job briefing and verify planning checklist. Refer to NFPA 70E Annex I for example.
4) Have specified training to work on exposed live parts.
5) Use PPE appropriate for working near exposed live parts and rated for the voltage and energy level involved.
6) Hearing protection shall be used whenever working within the prohibited approach boundary.

e. The **Arc Flash Boundary** is the approach limit at a distance from exposed live parts within which a person could receive a second-degree burn if an electrical arc flash were to occur.

1) Arc-rated and other PPE shall be used by the employee based on either the Task Performed on Energized Equipment in **Table 3** or by performing an Electrical Hazard Analysis to determine the incident energy exposure and using **Table 6** to guide selection of arc-rated clothing and other PPE.
2) When working on de-energized parts and inside the flash protection boundary for nearby live exposed parts, use barriers such as insulated blankets to protect against accidental contact or wear proper PPE if the parts cannot be de-energized.
3) Have an EEWP that is approved by the responsible supervisor if the parts cannot be de-energized.
4) Prior to the start of work, conduct a job briefing [Safe Plan of Action (SPA)] and verify planning checklist. Refer to NFPA 70E Annex I for example.
5) Hearing protection shall be used whenever working within the arc flash boundary.

Table 1. Approach Boundaries to Live Parts for Shock Protection for Alternating Current (AC) Systems (All dimensions are the distance from live part to employee)

Nominal system voltage range, phase to phase[1]	**Exposed movable conductor[2]**	**Exposed fixed-circuit part**	**Restricted approach boundary[3] (allowing for accidental movement)**	**Prohibited approach boundary[3]**
	Limited approach boundary[3]			
Less than 50 volts	Not specified	Not specified	Not specified	Not specified
50 to 300 volts	10 ft. 0 in.	3 ft. 6 in.	Avoid contact	Avoid contact
301 to 750 volts	10 ft. 0 in.	3 ft. 6 in.	1 ft. 0 in.	0 ft. 1 in.
751 to 15 kV	10 ft. 0 in.	5 ft. 0 in.	2 ft. 2 in.	0 ft. 7 in.
15.1 kV to 36 kV	10 ft. 0 in.	6 ft. 0 in	2 ft. 7 in.	0 ft. 10 in.
36.1 kV to 46 kV	10 ft. 0 in.	8 ft. 0 in	2 ft 9 in.	1 ft. 5 in.
46.1 kV to 72.5 kV	10 ft. 0 in.	8 ft. 0 in.	3 ft 3 in.	2 ft. 2 in.
72.6 kV to 121 kV	10 ft. 8 in.	8 ft. 0 in.	3 ft. 4 in.	2 ft. 9 in.
138 kV to 145 kV	11 ft 0 in	10 ft. 0 in.	3 ft. 10 in	3 ft. 4 in.
161 kV to 169 kV	11 ft 8 in.	11 ft. 8 in.	4 ft. 3 in.	3 ft. 9 in.
230 kV to 242 kV	13 ft. 0 in.	13 ft. 0 in.	5 ft. 8 in.	5 ft. 2 in.
345 kV to 362 kV	15 ft. 4 in	15 ft. 4 in.	9 ft. 2 in.	8 ft. 8 in.
500 kV to 550 kV	19 ft. 0 in.	19 ft. 0 in.	11 ft. 10 in.	11 ft. 4 in.
765 kV to 800 kV	23 ft. 9 in.	23 ft. 9 in.	15 ft. 11 in.	15 ft. 5 in.

Source: NFPA 70E, Table 130.2 (C), Approach Boundaries to Live Parts for Shock Protection.

1. For single-phase systems, select the range that is equal to the system's maximum phase-to-ground voltage multiplied by 1.732.
2. A condition in which the distance between the conductor and a person is not under the control of the person. The term is normally applied to overhead line conductors supported by poles.
3. See definition in Article 100 and text in 130.2 (D)(2) and Annex C for elaboration.

Table 2. Approach Boundaries to Energized Electrical or Circuit Parts for Shock Prevention, Direct Current (DC) Systems

Nominal Potential Difference	Limited Approach Boundary		Restricted Approach Boundary; Includes Inadvertent Movement Adder	Prohibited Approach Boundary
	Exposed Movable Conductor[2]	Exposed Fixed Circuit		
<100 V	Not specified	Not specified	Not specified	Not specified
100 V–300 V	10 ft. 0 in.	3 ft. 6 in.	Avoid contact	Avoid contact
301 V–1 kV	10 ft. 0 in.	3 ft. 6 in.	1 ft. 0 in.	0 ft. 1 in.
1.1 kV–5 kV	10 ft. 0 in.	5 ft. 0 in.	1 ft. 5 in.	0 ft. 4 in.
5 kV–15 kV	10 ft. 0 in.	5 ft. 0 in.	2 ft. 2 in.	0 ft. 7 in.
15.1 kV–45 kV	10 ft. 0 in.	8 ft. 0 in.	2 ft. 9 in.	1 ft. 5 in.
45.1 kV– 75 kV	10 ft. 0 in.	8 ft. 0 in.	3 ft. 2 in.	2 ft. 1 in.
75.1 kV–150 kV	10 ft. 8 in.	10 ft. 0 in.	4 ft. 0 in.	3 ft. 2 in.
150.1 kV–250 kV	11 ft. 8 in.	11 ft. 8 in.	5 ft 3 in.	5 ft. 0 in.
250.1 kV–500 kV	20 ft. 0 in.	20 ft. 0 in.	11 ft. 6 in.	10 ft. 10 in.
500.1 kV–800 kV	26 ft. 0 in.	26 ft. 0 in.	16 ft. 5 in.	16 ft. 5 in.

Source: NFPA 70E, Table 130.2 (C), Approach Boundaries to Live Parts for Shock Protection.

1. All dimensions are distance from exposed energized electrical conductors or circuit parts to worker.
2. This terms describes a condition in which the distance between the conductor and a person is not under the control of the person. The term is normally applied to overhead line conductors supported by poles.

5.7 Personal Protective Equipment

5.7.1 General Requirements

a. Employees working in areas where there are potential electrical hazards must be provided with and use PPE that is appropriate for the specific work to be performed. The electrical tools and protective equipment must be specifically approved, rated, and tested for the levels of voltage to which an employee may be exposed.

b. Employees shall wear nonconductive head protection whenever there is a danger of head injury from electric shock or burns due to contact with live parts or from flying objects resulting from an electrical explosion.

c. Employees shall wear protective eye equipment whenever there is a danger of injury from electric arcs, flashes, or flying objects resulting from an electrical explosion.

d. Employees shall wear rubber-insulating gloves where there is a danger of hand or arm contact with live parts or possible exposure to arc flash burn. The employer shall certify that each pair of glove is tested in accordance with American Society for Testing and Material (ASTM) F496-06 and industry standards. The certification shall identify the gloves has passed the test and the date it was tested. The employer shall have a system of documentation for tracking each pair of gloves with serial numbers, test results and test dates, which correspond to the issued gloves.

e. Where insulated footwear is used as protection against step and touch potential, dielectric overshoes shall be required. Insulated soles shall not be used as primary electrical protection.

f. Face shields without arc rating shall not be used for electrical work. Safety glasses or goggles must always be worn underneath face shields.

g. Additional illumination may be needed when using tinted face shields as protection during electrical work.

h. Electrical protective equipment must be selected to meet the criteria established by the ASTM and by the America National Standards Institute (ANSI).

i. Insulating equipment made of materials other than rubber shall provide electrical and mechanical protection at least equal to that of rubber equipment.

j. PPE must be maintained in a safe, reliable condition and be inspected for damage before each day's use and immediately following any incident that can reasonably be suspected of having caused damage.

k. Employees must use insulated tools and handling equipment that are rated for the voltages to be encountered when working near exposed energized conductors or circuit. Tools and handling equipment should be replaced if the insulating capability is decreased due to damage. Protective gloves must be used when employees are working with exposed electrical parts above fifty (50) volts.

l. Fiberglass reinforced plastic rod and tube used for live-line tools shall meet the requirements of applicable portions of electrical codes and standards dealing with electrical installation requirements.

m. Fuse handling equipment (insulated for circuit voltage) must be used to remove or install fuses when the fuse terminals are energized. Ropes and hand-lines used near exposed energized parts shall be nonconductive.

n. Protective shields, barriers, or insulating materials must be used to protect each employee from shock, burns, or other electrical injuries while that person is working near exposed energized parts that might be accidentally contacted or where dangerous electric heating or arcing might occur.

o. Documentation of electrical PPE testing and identified storage areas shall be maintained and made available for audit and review.

5.7.2 Arc Rated Apparel and Under-Layers

a. Arc Rated (AR) apparel shall be visually inspected before each use. AR apparel that is contaminated or damaged shall not be used. Protective items that become contaminated with grease, oil, flammable liquids, or combustible liquids shall not be used.

b. The garment manufacturer's instructions for care and maintenance of AR apparel shall be followed. AR apparel shall be stored in a manner that prevents physical damage; damage from moisture, dust, or other deteriorating agents; or contamination from flammable or combustible materials. When AR clothing is cleaned, manufacturer's instructions shall be followed to avoid loss of protection.

c. When AR apparel is worn to protect an employee, it shall cover all ignitable clothing and allow for movement and visibility.

d. AR apparel must cover potentially exposed areas as completely as possible. AR shirt sleeves must be fastened and AR shirts/jackets must be closed at the neck.

e. Non-melting, flammable garments (i.e., cotton, wool, rayon, silk, or blends of these materials) may be used as under-layers beneath AR apparel.

f. Meltable fibers such as acetate, nylon, polyester, polypropylene, and spandex shall not be permitted in fabric under-layers next to skin. (An incidental amount of elastic used on non-melting fabric underwear or socks shall be permitted.)

g. AR garments worn as outer layers over AR apparel (i.e., jackets or rainwear) must also be made from AR material.

h. Arc Flash suits must permit easy and rapid removal by the user. Location of flash suits shall be identified for documentation.

5.7.3 Rubber Insulating Equipment

i. Rubber insulating equipment includes protective devices such as gloves, sleeves, blankets, and matting.

j. Matting will be required when the type of work performed requires the qualified person to contact the floor in a kneeling or prone position.

k. Insulating equipment must be inspected for damage before each day's use and immediately following any incident that could have caused damage.

l. An air test must be performed on rubber insulating gloves before each use.

m. Insulating equipment found to have defects that might affect its insulating properties must be removed from service until testing indicates that it is acceptable for continued use.

n. Where the insulating capability of protective equipment is subject to damage during use, the insulating material shall be protected by an outer covering of leather or other appropriate materials.

o. Rubber insulating equipment and tools shall be tested according to the schedule supplied by the manufacturer.

p. Rubber insulating equipment must be stored in an area protected from light, temperature extremes, excessive humidity, ozone, and other substances and conditions that may cause damage.

q. Repairs to rubber insulating equipment are prohibited.

5.7.4 Insulated Tools and Materials

a. Only insulated tools and equipment shall be used within the Limited Approach Boundary of exposed energized parts.

b. Insulated tools and materials shall be rated for the voltages on which they are used.

c. Insulated tools and materials shall be inspected per NFPA 70E:

1) Visual - Safety and protective equipment and protective tools shall be visually inspected for damage and defects before initial, prior to each use and/or at intervals thereafter as service conditions require. In no case shall the interval exceed one (1) year.
2) Testing - The insulation of protective equipment and protective tools shall be verified by the appropriate test and visual inspection to ascertain that insulating capability has been retained before initial use, and at intervals thereafter as service conditions and applicable standards and instructions require. In no case shall the interval exceed three (3) years.

d. Insulated tools shall be designed and constructed for the environment to which they are exposed and the manner in which they are used.

e. 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.

f. Portable ladders used for electrical work shall have nonconductive side rails.

5.7.5 Access Limiting Equipment

a. Barricades/Red Barricade Tape shall be used in conjunction with safety signs to prevent or limit access to work areas containing live parts. Conductive barricades shall not be used where they might cause an electrical hazard. Barricades shall be placed no closer than the Limited Approach Boundary. In certain instances, the Arc Flash Boundary might be a greater distance from the energized electrical conductors or circuit parts than the Limited Approach Boundary. The shock protection boundaries and the arc flash boundary are independent of each other. Placement of barriers and use applicable of PPE should be adjusted to the greater hazard.

b. If signs and barricades do not provide sufficient protection, an attendant will be assigned to warn and protect pedestrians. The primary duty of the attendant shall be to keep an unqualified person out of the work area where an electrical hazard exists. The attendant shall remain in the area as long as there is a potential exposure to electrical hazards.

5.7.6 Hazard Risk Category Classifications for Determining PPE

a. Arc Flash Hazard Analysis shall be performed per NFPA 70E 130.5 when working within the Arc Flash Protection Boundary.

b. If the equipment is not listed, the voltage is not listed, or the Tasks are not listed in **Table 3**, an Arc Flash Hazard Analysis shall be performed. In order to use **Table 3**, qualified electrical personnel shall verify that the fault current and the overcurrent protection device (OCPD) tripping time are both equal to or lower than the values assumed for **Table 3**; otherwise, an Arc Flash Hazard Analysis shall be required prior to performing any electrical work activities. The verification of fault current and clearing times shall be documented for audits. **Table 6** can be used as guidance for the selection of Arc-Rated clothing and other personal protective equipment (PPE).

   Exception: If the contractor chooses not to verify the fault current and the overcurrent protective device (OCPD) tripping time are both equal to or lower than the values assumed for **Table 3**, the contractor can use **Table 3** to determine the tasks performed on energized equipment provided that the next higher Hazard/Risk Category for 0 or 1 (only) is used for determining the protective Clothing and Equipment, e.g. if the Hazard/Risk Category is a 1 then a Hazard/Risk Category 2 should be used. For troubleshooting 480V systems, a Category 2 will be acceptable, e.g. sewer lift stations.

c. Whenever work requires an Energized Electrical Work Permit, qualified electrical personnel shall perform an Electrical Hazard Analysis.

d. Prior to using **Table 4**, qualified electrical personnel shall determine the arcing current in kA. **Table 4** can be used if the arcing currents' kA values are within the acceptable ranges indicated in **Table 4**. If the arcing currents exceed the kA values or voltage values in **Table 4**, the 2012 NEC ANNEX D.8 equation Maximum Power Method shall be used to determine DC arc flash incident energy. This method applies to DC systems rated up to 1000Vdc.

e. Some DC systems under the 50V and 100V may require Direct-Current Arc Flash Calculation. Other DC systems that may require Direct-Current Arc Flash Calculation are DC systems with high available fault current, battery banks, and UPS systems. Hazard identification and risk assessment should take into account the unique characteristics of DC systems. If determined that an electrical hazard does exist, only those persons considered as qualified are permitted to perform tasks such as testing, troubleshooting, voltage measuring, or similar diagnostic work.

Table 3. Hazard Risk Category for Various Work Task

Task Performed on Energized Equipment	Hazard/Risk Category	V-rated Gloves	V-rated Tools
Panelboards or Other Equipment Rated 240 V and Below - Note 1			
Perform infrared thermography and other non-contact inspections outside the Restricted boundary approach	0	N	N
Circuit breaker (CB) or fused switch operation with covers on	0	N	N
CB or fused switch operation with covers off	1	Y	N
Work on energized electrical conductors and circuit parts, including voltage testing	1	Y	Y
Remove/install CBs or fused switches	1	Y	Y
Removal of bolted covers (to expose bare, energized parts)	1	N	N
Opening hinged covers (to expose bare, energized parts)	0	N	N
Worked on energized electrical conductors and circuit parts of utilization Equipment fed directly by a branch circuit of the panelboard	1	Y	Y
Panelboards or Switchboards Rated >240 V and up to 600 V (with molded case or insulated case circuit breakers) - Note 2			
Perform infrared thermography and other non-contact inspections outside the Restricted boundary approach	1	N	N
CB or fused switch operation with covers on	0	N	N
CB or fused switch operation with covers off	1	Y	N
Work on energized electrical conductors and circuit parts, including voltage testing	2	Y	Y
Worked on energized electrical conductors and circuit parts of utilization Equipment fed directly by a branch circuit of the panelboard or switchboard	2	Y	Y
600 V Class Motor Control Centers (MCCs) Note 3 (except as indicated)			
Perform infrared thermography and other non-contact inspections outside the Restricted boundary approach	1	N	N
CB or fused switch operation with enclosure doors closed	0	N	N
Reading a panel meter while operating a meter switch	0	N	N
CB or fused switch or starter operation with enclosure doors open	1	N	N
Work on energized electrical conductors and circuit parts, including voltage testing	2	Y	Y
Work on control circuits with energized parts 120 V or below, exposed	0	Y	Y
Work on control circuits with energized parts> 120 V, exposed	2	Y	Y
Insertion or removal of individual starter "buckets" from MCC – Note 4	4	Y	N
Application of safety grounds, after voltage test	2	Y	N
Removal of bolted covers (to expose bare, energized electrical conductors and parts) – Note 4	4	N	N
Opening hinged covers (to expose bare, energized electrical conductors and parts) – Note 4	1	N	N
Worked on energized electrical conductors and circuit parts of utilization Equipment fed directly by a branch circuit of the motor control center	2	Y	Y
600 V Class Switchgear (with power circuit breakers or fused switches) - Note 5			
Perform infrared thermography and other non-contact inspections outside the Restricted boundary approach	2	N	N
CB or fused switch operation with enclosure doors closed	0	N	N
Reading a panel meter while operating a meter switch	0	N	N
CB or fused switch operation with enclosure doors open	1	N	N
Work on energized electrical conductors and circuit parts, including voltage testing	2	Y	Y
Work on control circuits with energized parts 120 V or below, exposed	0	Y	Y
Work on control circuits with energized parts>120 V, exposed	2	Y	Y
Insertion or removal (racking) of CBs from cubicles, doors open or closed	4	N	N
Application of safety grounds, after voltage test	2	Y	N
Removal of bolted covers (to expose bare, energized electrical conductors and parts)	4	N	N
Opening hinged covers (to expose bare, energized electrical conductors and parts)	2	N	N
Other 600 V Class (277 V through 600 V, Nominal) Equipment – Note 6 (except as indicated)			
Lighting or small power transformers (600 V, maximum)	--	--	--

Removal of bolted covers (to expose bare, energized electrical conductors and parts)	2	N	N
Opening hinged covers (to expose bare, energized electrical conductors and parts)	1	N	N
Work on energized electrical conductors and circuit parts, including voltage testing	2	Y	Y
Application of safety grounds, after voltage test	2	Y	N
Revenue meters (kW-hour, at primary voltage and current) Insertion or removal	2	Y	N
Cable trough or tray cover removal or installation	1	N	N
Miscellaneous equipment cover removal or installation	1	N	N
Work on energized electrical conductors and circuit parts, including voltage testing	2	Y	Y
Application of safety grounds, after voltage test	2	Y	N
Insertion or removal of plug-in devices into or from busways	2	Y	N

Task (Assumes Equipment Is Energized, and Work Is Done Within the Flash Protection Boundary	**Hazard/Risk Category**	**V-rated Gloves**	**V-rated Tools**
NEMA E2 (fused contactor) Motor Starters, 2.3 kV through 7.2 k V Note 7			
Perform infrared thermography and other non-contact inspections outside the Restricted boundary approach	3	N	N
Contactor operation with enclosure doors closed	0	N	N
Reading a panel meter while operating a meter switch	0	N	N
Contactor operation with enclosure doors open	2	N	N
Work on energized electrical conductors and circuit parts, including voltage testing	4	Y	Y
Work on control circuits with energized parts 120 V or below, exposed	0	Y	Y
Work on control circuits with energized parts> 120 V, exposed	3	Y	Y
Insertion or removal (racking) of starters from cubicles, doors open or closed	4	N	N
Application of safety grounds, after voltage test	3	Y	N
Removal of bolted covers (to expose bare, energized parts	4	N	N
Opening hinged covers (to expose bare, energized electrical conductors and parts)	3	N	N
Insertion or removal (racking) of starters from cubicles of arc-resistant construction, tested in accordance with IEEE C37.20.7, doors closed only	0	N	N
Metal Clad Switchgear, 1 kV through 38 kV Note 7			
Perform infrared thermography and other non-contact inspections outside the Restricted boundary approach	3	N	N
CB or fused switch operation with enclosure doors closed	2	N	N
Reading a panel meter while operating a meter switch	0	N	N
CB or fused switch operation with enclosure doors open	4	N	N
Work on energized electrical conductors and circuit parts, including voltage testing	4	Y	Y
Work on control circuits with energized parts 120 V or below, exposed	2	Y	Y
Work on control circuits with energized parts >120 V, exposed	4	Y	Y
Insertion or removal (racking) of CBs from cubicles, doors open	4	N	N
Insertion or removal (racking) of CBs from cubicles, doors closed	2	N	N
Application of safety grounds, after voltage test	4	Y	N
Removal of bolted covers (to expose bare, energized electrical conductors and parts)	4	N	N
Opening hinged covers (to expose bare, energized electrical conductors and parts)	3	N	N
Opening voltage transformer or control power transformer compartments	4	N	N
Arc-Resistant Switchgear Type 1 or 2 (for clearing times of <0.5 sec with a perspective fault current not to exceed the arc resistant rating of the equipment) Note 7			
CB operation with enclosure door closed	0	N	N
Work on control circuits with energized electrical conductors and circuit parts 120 V or below, exposed	2	Y	Y
Insertion or removal (racking) of CBs from cubicles, doors open	4	N	N
Insertion or removal (racking) of CBs from cubicles, doors closed	0	N	N
Insertion or removal (racking) of ground and test device with door closed	0	N	N
Insertion or removal (racking) of voltage transformers on or of the bus door closed	0	N	N
Other Equipment 1 kV Through 38 kV Note 7			

Metal enclosed interrupter switches, fused or unfused	--	--	--
Switch operation of arc-resistant-type construction, tested in accordance with IEEE C37.20.7, doors closed only	0	N	N
Switch operation, doors closed	2	N	N
Work on energized electrical conductors and circuit parts, including voltage testing	4	Y	Y
Removal of bolted covers (to expose bare, energized electrical conductors and parts)	4	N	N
Opening hinged covers (to expose bare, energized electrical conductors and parts)	3	N	N
Outdoor disconnect switch operation (hookstick operated)	3	Y	Y
Outdoor disconnect switch operation (gang-operated, from grade)	2	N	N
Insulated cable examination, in manhole or other confined space	4	Y	N
Insulated cable examination, in open area	2	Y	N

Source: NFPA 70E, Table 130.7 (C)(15)(a)

General Notes (applicable to entire table):
(a) Rubber insulating gloves are gloves rated for the maximum line-to-line voltage upon which work will be done.
(b) Insulated and insulating hand tools are tools rated and tested for the maximum line-to-line voltage upon which work will be done, and are manufactured and tested in accordance with ASTM F1505, *Standard Specification for Insulated and Insulating Hand Tools*.
(c) Y = yes (required), N = no (not required).
(d) For systems rated less than 1000 V, the fault currents and upstream protective device clearing times are based on an 18 in. working distance.
(e) For systems rated 1 kV and greater, the Hazard/Risk Categories are based on a 36 in. working distance.
(f) For equipment protected by upstream current limiting fuses with arcing fault current in their current limiting range (1⁄2 cycle fault clearing time or less), the hazard/risk category required may be reduced by one number.

Specific Notes (as referenced in Table 3):
1. Maximum of 25 kA short circuit current available; maximum of 0.03 sec (2 cycle) fault clearing time; minimum 18 in. working distance. Potential arc flash boundary with exposed energized conductors or circuit parts using above parameters: 19 in.
2. Maximum of 25 kA short circuit current available; maximum of 0.03 sec (2 cycle) fault clearing time; minimum 18 in. working distance. Potential arc flash boundary with exposed energized conductors or circuit parts using above parameters: 30 in.
3. Maximum of 65 kA short circuit current available; maximum of 0.03 sec (2 cycle) fault clearing time; minimum 18 in. working distance. Potential arc flash boundary with exposed energized conductors or circuit parts using above parameters: 53 in.
4. Maximum of 42 kA short circuit current available; maximum of 0.33 sec (20 cycle) fault clearing time; minimum 18 in. working distance. Potential arc flash boundary with exposed energized conductors or circuit parts using above parameters: 165 in.
5. Maximum of 35 kA short circuit current available; maximum of up to 0.5 sec (30 cycle) fault clearing time; minimum 18 in. working distance. Potential arc flash boundary with exposed energized conductors or circuit parts using above parameters: 233 in.
6. Maximum of 65 kA short circuit current available; maximum of 0.03 sec (2cycle) fault clearing time; minimum 18 in. working distance (except as indicated). Potential arc flash boundary with exposed energized conductors or circuit parts using above parameters: 53 in.
7. Maximum of 35 kA short circuit current available; maximum of up to 0.2 sec (12 cycle) fault clearing time; minimum 36 in. working distance. Potential arc flash boundary with exposed energized conductors or circuit parts using above parameters: 422 in.

Table 4. Hazard/Risk Category Classifications and Use of Rubber Insulating Gloves and Insulating Hand Tools — Direct Current Equipment

Tasks Performed on Energized Equipment	Hazard / Risk Category	Rubber Insulating Gloves	Insulated and Insulating Hand Tools
Storage batteries, direct-current switchboards and other direct-current supply sources >100 V <250 V			
Parameters: Voltage: 250 V Maximum arc duration and working distance: 2 sec @ 18 in.			
Work on energized electrical conductors and circuit parts, including voltage testing where arcing current is ≥1 kA and <4 kA Potential arc flash boundary using above parameters at 4 kA: 36 in.	1	Y	Y
Work on energized electrical conductors and circuit parts, including voltage testing where arcing current is ≥4 kA and <7 kA Potential arc flash boundary using above parameters at 7 kA: 48 in.	2	Y	Y
Work on energized electrical conductors and circuit parts, including voltage testing where arcing current is ≥7 kA and <15 kA Potential arc flash boundary using above parameters at 15 kA: 72 in.	3	Y	Y
Storage batteries, direct-current switchboards and other direct-current supply sources ≥250 V ≤600 V Parameters: Voltage: 600 V Maximum arc duration and working distance: 2 sec @ 18 in.			
Work on energized electrical conductors and circuit parts, including voltage testing where arcing current is ≥1 kA and <1.5 kA Potential arc flash boundary using above parameters at 1.5 kA: 36 in.	1	Y	Y
Work on energized electrical conductors and circuit parts, including voltage testing where arcing current is ≥1.5 kA and <3 kA Potential arc flash boundary using above parameters at 3 kA: 48 in.	2	Y	Y
Work on energized electrical conductors and circuit parts, including voltage testing where arcing current is ≥3 kA and <7 kA Potential arc flash boundary using above parameters at 7 kA: 72 in.	3	Y	Y
Work on energized electrical conductors and circuit parts, including voltage testing where arcing current is ≥7 kA and <10 kA Potential arc flash boundary using above parameters at 10 kA: 96 in.	4	Y	Y

Source : NFPA 70E Table 130.7(C)(15)(b)

Y: Yes (required).
 If acid exposure is possible, the clothing is required to be protected from acid and arc rated to the hazard
according to ASTM F 1891 or equivalent and evaluated by ASTM F 1296 for acid protection.

 In clean rooms or other electrical installations, that do not permit leather protectors for arc flash exposure,
ASTM F 496 is required to be followed for use of rubber insulating gloves without leather protectors, and the rubber gloves chosen are required to be arc rated to the potential exposure level of the hazard/risk category.

Source: NFPA 70E, Table 130.7 (C) (15) (b)

Table 5. Protective Clothing and PPE Matrix

Hazard/Risk Category	Protective Clothing and Equipment	
Hazard/Risk Category 0		
Protective clothing, Non-melting (according to ASTM F 1506-00) or Untreated Natural Fiber with a Fabric Weight of at Least 4.5 oz/yd²		Shirt (long sleeve) Pants (long)
Protective Equipment		Safety glasses or safety goggles (SR) Hearing protection (ear canal inserts) Heavy Duty Leather gloves (AN) (Note 2)
Hazard/Risk Category 1		
Arc-Rated Clothing, Minimum Arc Rating of 4 (Note 1)		Arc-rated long sleeve shirt (Note 3) Arc-rated pants (Note 3) Arc-rated coverall (Note 4) Arc-rated face shield or arc flash suit hood (Note 7) Arc-rated jacket, parka, or rainwear, hard hat liner (AN)
Arc Rated Protective Equipment		Hard hat Safety glasses or safety goggles (SR) Hearing protection (ear canal inserts) Heavy duty Leather gloves (AN) (Note 2) Leather work shoes (AN)
Hazard/Risk Category 2		
Arc Rated Clothing, Minimum Arc Rating of 8 cal/cm² (Note 1)		Arc-rated long sleeve shirt (Note 5) Arc-rated pants (Note 5) Arc-rated coverall (Note 6) Arc-rated face shield or arc flash suit hood (Note 7) Arc-rated jacket, parka, or rainwear (AN)
Arc Rated Protective Equipment		Hard hat Safety glasses or safety goggles (SR) Hearing protection (ear canal inserts) Heavy DutyLeather gloves (Note 2) Leather work shoes
Hazard/Risk Category 3		
Arc Rated Clothing, Minimum Arc Rating of 25 cal/cm² (Note 1)		Arc-rated long sleeve shirt (AR) (Note 8) Arc-rated pants (AR) (Note 8) Arc-rated coverall (AR) (Note 8) Arc-rated arc flash suit jacket (AR) (Note 8) Arc-rated arc flash pants (AR) (Note 8) Arc-rated face shield or arc flash suit hood (Note 8) Arc-rated jacket, parka, or rainwear (AN)

Arc Rated Protective Equipment		Hard hat FR hard hat liner (AR) Safety glasses or safety goggles (SR) Hearing protection (ear canal inserts) Arc-rated gloves (Note 2) Leather work shoes
Hazard/Risk Category 4		
Arc Rated Clothing, Minimum Arc Rating of 40 cal/cm² (Note 1)		Arc-rated long sleeve shirt (AR) (Note 9) Arc-rated pants (AR) (Note 9) Arc-rated coverall (AR) (Note 9) Arc-rated arc flash suit jacket (AR) (Note 9) Arc-rated arc flash pants (AR) (Note 9) Arc-rated face shield or arc flash suit hood (Note 9) Arc-rated jacket, parka, or rainwear (AN)
Arc Rated Protective Equipment		Hard hat FR hard hat liner (AR) Safety glasses or safety goggles (SR) Hearing protection (ear canal inserts) Arc-rated gloves (Note 2) Leather work shoes

Source: NFPA 70E, Table 130.7(C)(10))

(AN) = As needed (optional)
(AR) = As required
(SR) = Selection required

Notes:
1. See Table 130.7(C)(11). Arc rating for a garment or system of garments is expressed in cal/cm^2.
2. If rubber-insulating gloves with leather protectors are required by Table 130.7(C)(9), additional leather or arc-rated gloves are not required. The combination of rubber insulating gloves with leather protectors satisfies the arc flash protection requirement.
3. The Arc Rated shirt and pants used for Hazard/ Risk Category 1 shall have a minimum arc rating of 4 cal/cm².
4. Alternate is to use Arc Rated coveralls (minimum arc rating of 4) instead of Arc Rated shirt and Arc Rated pants.
5. Arc Rated shirt and Arc Rated pants used for Hazard/ Risk Category 2 shall have a minimum arc rating of 8 cal/cm².
6. Alternate is to use Arc Rated coveralls (minimum arc rating of 8) instead of Arc Rated shirt and Arc Rated pants.
7. A face shield with a minimum arc rating of 4 cal/cm² for Hazard/Risk Category 1 or a minimum arc rating of 8 cal/cm² for Hazard/Risk Category 2, with wrap-around guarding to protect not only the face, but also the forehead, ears, and neck (or, alternatively, an arc-rated arc flash suit hood), is required.
8. An alternate is to use a total Arc Rated clothing system and hood, which shall have a minimum arc rating of 25 cal/cm² for Hazard/Risk Category 3.
9. The total clothing system consisting of Arc Rated shirt and pants and/or AR coveralls and/or arc flash coat and pants and hood shall have a minimum arc rating of 40 cal/cm² for Hazard/Risk Category 4.
10. Alternate is to use a face shield with a minimum arc rating of 8 cal/cm² and a balaclava (sock hood) with a minimum arc rating of 8 cal/cm².and which covers the face, head and neck except for the eye and nose areas.

Table 6. Guidance on Selection of Arc-Rated Clothing and Other Personal Protective Equipment (PPE) for Use When Incident Exposure is Determined by a Hazard Analysis

Incident Energy Exposure	Protective Clothing and PPE
Less than or Equal to 1.2 cal/cm2	
Protective clothing, nonmelting (in accordance with ASTM F 1506-08) or untreated natural fiber	Shirt (long sleeve) and pants (long) or coverall
Other personal protective equipment	Face shield for projectile protection (AN) Safety glasses or safety goggles (SR) Hearing protection Heavy-duty leather gloves or rubber insulating gloves with leather protectors (AN)
Greater than 1.2 to 12 cal/cm2	
Arc-rated clothing and equipment with an arc rating equal to or greater than the incident energy determined in a hazard analysis (See Note 3.)	Arc-rated long-sleeve shirt and arc-rated pants or arc-rated coverall or arc flash suit (SR) (See Note 3.) Arc-rated face shield and arc-rated balaclava or arc flash suit hood (SR) (See Note 1.) Arc-rated jacket, parka, or rainwear (AN)
Other personal protective equipment	Hard hat Arc-rated hard hat liner (AN) Safety glasses or safety goggles (SR) Hearing protection Heavy-duty leather gloves or rubber insulating gloves with leather protectors (SR) (See Note 4.) Leather work shoes
Greater than 12 cal/cm2	
Arc-rated clothing and equipment with an arc rating equal to or greater than the incident energy determined in a hazard analysis (See Note 3.)	Arc-rated long-sleeve shirt and arc-rated pants or arc-rated coverall and/or arc flash suit (SR) Arc-rated arc flash suit hood Arc-rated gloves Arc-rated jacket, parka, or rainwear (AN)
Other personal protective equipment	Hard hat Arc-rated hard hat liner (AN) Safety glasses or safety goggles (SR) Hearing protection
	Arc-rated gloves or rubber insulating gloves with leather protectors (SR) (See Note 4.) Leather work shoes

AN: As needed [in addition to the protective clothing and PPE required by 130.5(B)(1)].

SR: Selection of one in-group is required by 130.5(B)(1).

Notes:

(1) Face shields with a wrap-around guarding to protect the face, chin, forehead, ears, and neck area are required by 130.8(C)(10)(c). For full head and neck protection, use a balaclava or an arc flash hood.

(2) All items not designated "AN" are required by 130.7(C).

(3) Arc ratings can be for a single layer, such as an arc-rated shirt and pants or a coverall, or for an arc flash suit or a multi-layer system consisting of a combination of arc-rated shirt and pants, coverall, and arc flash suit.

(4) Rubber insulating gloves with leather protectors provide arc flash protection in addition to shock protection. Higher class rubber insulating gloves with leather protectors, due to their increased material thickness, provide increased arc flash protection

Source: NFPA 70E, Annex H Table H.3(b)

5.8 Working Space about Electrical Equipment

5.8.1 Spaces Around Electrical Equipment

a. **Sufficient Access and Working Space -** Per 5.8.1b shall be provided and maintained around all electric equipment to permit ready and safe operating and maintenance of such equipment. Floor marking of areas is a best practice but not required.

b. **Working Space -** Working space for equipment operating at 600 volts, nominal, or less to ground and likely to require examination, adjustment, services, or maintenance while energized shall comply with the dimensions of Table 7 or as required or permitted elsewhere in NFPA 70E.

c. **Depth of Working Space -** The depth of the working space in the direction of live parts shall be not less than that indicated in Table 7. Distances shall be measured from the exposed live parts or from the enclosure or opening if the live parts are enclosed.

Table 7. NFPA 70 110.26(A)(1) Working Spaces

Nominal Voltage to Ground	Minimum Clear Distance		
	Condition 1	**Condition 2**	**Condition 3**
0-150	914 mm (3 feet)	914 mm (3 feet)	914 mm (3 feet)
151-600	914 mm (3 feet)	1.07 m (3½ feet)	1.22 m (4 feet)

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

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

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

d. **Dead-front Assemblies -** Working space shall not be required in the back or sides of assemblies, such as dead-front switchboards or motor control centers, where all connections and all renewable or adjustable parts, such as fuses or switches, are accessible from locations other than the back or sides. Where rear access is required to work on non-electrical parts on the back of enclosed equipment, a minimum horizontal working space of 762 mm (30 inches) shall be provided.

e. **Low Voltage -** Smaller working spaces can be permitted where all uninsulated parts operate at not greater than 30 volts rms, 42 volts peak, or 60 volts Direct Current (DC).

f. **Existing Buildings -** In existing buildings were electric equipment is being replaced, Condition 2 working clearance shall be permitted between dead-front switch boards, panel boards, or motor control centers located across the aisle from each other where conditions of maintenance and supervision ensure that written procedures have been adopted to prohibit equipment on both sides of the aisle from being open at the same time. Qualified electrical workers who are authorized will service the installation.

g. **Width of Working Space -** The width of the working space in front of the electrical equipment shall be the width of the equipment or 762 mm (30 inches), whichever is greater. In all cases, the work space shall permit at least a 90-degree opening of equipment doors or hinged panels.

h. **Height of Working Space -** The workspace shall be clear and extend from the grade, floor, or platform to the height of 2.0m (6'-6") or the height of the equipment, whichever is greater per NEC 110.26(A)(3). Within the height requirements of this section, other equipment that is associated with the electrical installation and is located above or below the electrical equipment shall be permitted to extend not more than 150 mm (6 inches) beyond the front of the electrical equipment.

i. **Clear Spaces -** Working space required by NFPA 70E shall not be used for storage. When normally enclosed live parts operating at fifty (50) volts or more are exposed for inspection or service, the working space, if in a passageway or a general open space shall be suitably guarded.

j. **Storage** - Storage of any materials is prohibited in mechanical and electrical rooms.

5.8.2 Other Working Space Requirements

Entrance to and egress from working spaces, illumination, headroom, and dedicated equipment space shall be maintained in accordance with NEC Article 110.26C**.**

5.9 Vehicular or Mechanical Equipment

a. When work must be performed near overhead lines, the lines shall be de-energized and grounded, or other protective measures shall be provided before work is started.

b. If the lines are to be de-energized, arrangements shall be made with the person or organization that operates or controls the electric circuits involved to de-energize and ground the lines.

c. If protective measures, such as guarding, isolating, or insulating are provided, these precautions shall prevent employees from contacting such lines directly with any parts of their bodies or indirectly through conductive materials, tools, or equipment.

5.9.1 Elevated Equipment

Where any vehicle or mechanical equipment structure will be elevated near energized overhead lines, they shall be operated to maintain the Limited Approach Boundary distance indicated in NFPA 70E Table 130.2(C), column 2. However, under any of the following conditions, the clearances shall be permitted to be reduced:

a. If the vehicle is in transit with its structure lowered, the Limited Approach Boundary distance to the overhead lines as indicated in NFPA 70E Table 130.2 (C), column 2, shall be permitted to be reduced by six (6) feet. If insulated barriers rated for the voltages involved are installed and they are not part of an attachment to the vehicle, the clearance shall be permitted to be reduced to the design working dimensions of the insulating barrier.

b. If the equipment is an aerial lift insulated for the voltage involved, and if the work is performed by a qualified person, the clearance (between the non-insulated portion of the aerial lift and the power line) shall be permitted to be reduced to the Restricted Approach Boundary given in NFPA 70E Table 130.2 (C), column 4.

5.9.2 Equipment Contact

Employees standing on the ground shall not contact the vehicle or mechanical equipment or any of its attachments unless either of the following conditions applies:

a. The employee is using protective equipment rated for the voltage.

b. The equipment is located so that no non-insulated part of the structure (that portion of the structure that provides a conductive path to employees on the ground) can come closer to the line than permitted in NFPA 70E 130.8 (F)(1).

5.9.3 Equipment Grounding

a. If any vehicle or mechanical equipment capable of having parts of its structure elevated near energized overhead lines is intentionally grounded, employees working near the point of grounding shall not stand at the grounding location whenever there is a possibility of overhead line contact.

b. Additional precautions, such as the use of barricades or insulation, shall be taken to protect employees from hazardous ground potentials (step and touch potential) that can develop within a few feet or more outward from the ground point.

5.10 Working on De-Energized Equipment

a. The most important principle of electrical safety is to **assume all electric circuits are energized unless each involved worker ensures they are not.** Every circuit and conductor must be tested every time work is done. Proper PPE must be selected in accordance with Section 5.7.6.

b. PPE shall always be worn until the equipment is proven to be de-energized.

c. NFPA 70E lists six (6) steps to ensure conditions for electrically safe work:

1) Identify all sources of power to the equipment. Check applicable up-to-date drawings, diagrams, and identification tags.
2) Remove the load current, and then open the disconnecting devices for each power source.
3) Where possible, visually verify that blades of disconnecting devices are fully open or that drawout-type circuit breakers are fully withdrawn.
4) Apply LO/TO devices in accordance with SCWI-8715-0013, SSC Control of Hazardous Energy Lockout/Tagout and Non-Service/Maintenance Hazardous Energy Isolation
5) Test each phase conductor or circuit part with an adequately rated voltage detector to verify that the equipment is de-energized. Test each phase conductor or circuit part, both phase-to-phase and phase-to-ground using a calibrated meter per *SPR 8730.4, SSC Metrology and Calibration Control Program.* Check the voltage detector before and after each test to be sure it is working.
6) Properly ground all possible sources of induced voltage and stored electric energy (such as capacitors) before touching. If conductors or circuit parts that are being de-energized could contact other exposed conductors or circuit parts, apply ground-connecting devices rated for the available fault current.

d. **The process of de-energizing is "live" work and can result in an arc flash** due to equipment failure. When de-energizing, follow the procedures described in Section 5.1.

6.0 GENERAL ELECTRICAL SAFETY REQUIREMENTS

This section applies to all employees regardless of qualification.

6.1 Inspections and Audits of Panel Boards

Only qualified personnel will open or close electrical panel and or box doors or touch any circuit breaker for inspections or audits of electrical dead front panel boards. A Hazard/Risk Category 0 for PPE shall be used for the inspection of dead front panel board schedules. Hearing protection shall be used whenever inspecting or auditing electrical dead front panel boards. Inspectors and auditors are required to take the FOSC Electrical Utilization Class prior to performing inspections or audits of electrical dead front panel boards.

6.2 Extension Cords

a. NEC Article 400.7 and 400.8, "Flexible Cords and Cables," and Article 590, "Temporary Installations," do not permit flexible cords and cables to be used as a substitute for permanent building wiring.

b. Flexible Cords and cables used for temporary purposes shall not be in use for more than ninety (90) days unless otherwise approved by NASA Safety and Mission Assurance (SMA).

c. Use of extension cords and re-locatable multiple-outlet power strips are to be used in a manner compatible with their Nationally Recognized Testing Laboratory (NRTL; e.g., UL, FM) rating and listing. They shall not be used as a substitute for the installation of permanent building branch circuits.

d. Extension cords intended for hazardous locations shall comply with *SCWI-8715-0012, Work in Hazard Classification Locations.*

e. Job-made extension cords shall comply with the following:

   1) Be constructed using NRTL (e.g., UL, FM) approved parts.
   2) Be assembled by qualified electrician knowledgeable in wiring methods as required by the NEC for electrical equipment and maintain a documented log of the personnel performing the wiring.
   3) Be constructed with cable conductor sized appropriately for the voltage and amperage (amp) rating required for the intended use.
   4) Be tested and verified for correct phasing of the cord, hot-to-hot, neutral-to-neutral, and ground-to-ground, by the qualified electrical personnel constructing the extension cord during assembly.

f. Damaged extension cords ends may be replaced as needed (no jacket repairs or splicing are authorized). The damaged portion of the extension cord may be removed and be replaced with a cord connector or attachment plug. Shrink-wrapping of cords only applies to hard service cords (types S, SO, ST, and STO) as designated on the cord by the manufacturer.

g. Extension cords and multiple-outlet power strips shall not be connected in series (daisy-chained) and are to be plugged directly into a wall receptacle.

h. Extension cords and multiple-outlet power strips may be used as needed to support office-type equipment in an office environment when used in a manner compatible with their NRTL rating and listing.

i. Extension cords and multiple-outlet power strips shall not exceed 15 feet in length when used in the office environment.

j. Extension cords and multiple-outlet power strips shall have conductors correctly sized and rated, have an outer jacket rated for their intended use, and be used according to the manufacturer's recommended instructions.

k. Extension cords and multiple-outlet power strips are to be inspected before use for defects such as exposed wiring, loose connections, cracked insulation, and loose strain reliefs.

l. Pre-Use: Portable cord-and-plug-connected equipment and extension cords must be visually inspected before each use on any shift for external defects such as loose parts, deformed and missing pins, or damage to outer jacket or insulation, and for possible internal damage such as pinched or crushed outer jacket. Any defective cord or cord-and-plug-connected equipment must be removed from service and no person may use it until it is repaired and tested to ensure its safety in accordance with 6.2.f. All NASA Onsite Prime Contractors and Construction Contractors shall follow the Assured Equipment Grounding Conductor Program (AEGCP) or use Ground Fault Circuit Interrupter Protection as outlined in Section 7.1.

m. Extension cords or power strips must be kept clear of walkways where they can become a tripping hazard or be damaged. Protect cords by placing them along a perimeter wall or under protective covers.

n. Extension cords shall be protected from damage. Sharp corners shall be avoided. Flexible cords shall not be run through windows or doors unless protected from damage and precautions have been taken to protect personnel, and then only on a temporary basis. Flexible cords shall not be run above ceilings or inside or through walls, ceilings, or floors, and may not be fastened with staples or otherwise hung in such a fashion as would damage the outer jacket or insulation.

o. Attachment plugs and receptacles may not be connected or altered in any way that would interrupt the continuity of the equipment grounding conductor. Additionally, these devices may not be altered to allow the grounding pole to be inserted into current connector slots.

p. Clipping the grounding prong from an electrical plug or using an electrical cord with the ground prong missing is prohibited.

q. In general, all equipment and tools connected by cord and plug must be grounded. Listed or labeled double-insulated tools and appliances need not be grounded.

r. Extension cords must be of the three (3) wire type. Extension cords and flexible cords must be designed for hard or extra-hard usage (e.g., types S, ST, and SO). The rating or approval must be visible.

s. Because of the nature of SSC environment, Ground-Fault Circuit Interrupters (GFCI) shall be used with all extension cords when work is performed outdoors and indoors when there is the potential for damp or wet environments. Portable type GFICs shall be tested each time before use with the test and reset buttons.

t. Portable equipment must be handled in a manner that will not cause damage. Flexible electric cords connected to equipment may not be used for raising or lowering the equipment.

u. Work in *wet* or *damp locations* (i.e., areas surrounded or near water or other liquids) should not be performed unless it is absolutely critical. Electrical work should be postponed until the liquid can be cleaned up.

v. In the event that working in wet or damp locations cannot be avoided, the following special precautions must be incorporated:

    1) All portable electric equipment and flexible cords used in highly conductive work locations must be approved for those locations.
    2) Only electrical cords equipped with or connected to a GFCI shall be used.
    3) All GFCIs shall be plugged in at the power source, not at the working end of the cord. Cord-connected portable tools likely to be used in wet and conductive locations shall be protected by Underwriters Laboratories (UL) approved weather proof GFCI. The GFCI shall be rated for the load of the equipment being used.
    4) A dry barrier shall be placed over any wet or damp work surface.
    5) All electrical cords shall be kept away from standing water.

w. Employees' hands must be dry when plugging and unplugging flexible cords and cord-and-plug connected equipment if energized equipment is involved.

x. If the connection could provide a conducting path to employees' hands (e.g., if a cord connector is wet from being immersed in water), the energized plug and receptacle connections must be handled only with insulating protective equipment.

y. Locking-type connectors must be properly locked into the connector.

6.3 Temporary Wiring

This section applies to temporary wiring typically found in a construction environment where voltages are less than 600 volts.

a. Feeders must originate in an approved distribution center, such as a panel board, that is rated for the voltages and currents the system is expected to carry. Over current protection and cables (type), shall comply with NEC Article 590.4(B).

b. All branch circuits shall originate in an approved power outlet, switchgear, switchboard or panel board, motor control center, or fused switch enclosure.

c. Neither bare conductors nor earth returns may be used for the wiring of any temporary circuit.

d. Receptacles must be of the grounding type. Unless installed in a complete metallic raceway, each branch circuit must contain a separate equipment-grounding conductor and all receptacles must be electrically connected to the grounding conductor.

e. Flexible cords and cables must be of an approved type and suitable for the location and intended use. They may be used only for pendants, wiring of fixtures, and connection of portable lamps or appliances, elevators, hoists, connection of stationary equipment where frequently interchanged, prevention of transmission of noise or vibration, data processing cables, or where needed to permit maintenance or repair.

f. Suitable disconnecting switches or plug connects shall be installed to permit the disconnection of all ungrounded conductors of each temporary circuit.

6.4 Small Appliance Permit for Personal Use

a. All appliances for personal use in the workplace such as coffee pots, heaters, microwaves, and toasters will be listed and shall exhibit the label of an NRTL.

b. SSC Form 222, Permit for Use of Small Appliance, is issued only by the SSC Fire Department and shall accompany small electric appliances per SSP-1740-0018.

c. The permit shall be obtained prior to initial usage of the appliances at NASA SSC.

d. Electric heaters for office use shall not be permitted without written authorization from the Authority Having Jurisdiction for fire safety.

6.5 Portable Electric Tools and Electrical Apparatus

a. Area Supervisors shall ensure that periodic inspections are performed of portable electric tools and apparatus, and that employees using such tools have been properly trained.

b. Prior to use, employees shall inspect portable electric tools, hand lamps, and extension cords to ensure proper configuration, safe operation, and tag out of defective tools/equipment for return to the tool crib for repair/replacement.

c. Electric tools, hand lamps, extension cords, and similar hand-held electric equipment shall be approved by an NRTL for its intended purpose.

d. Pneumatic tools, portable electrical tools, intrinsically safe instruments or approved equipment shall meet the standards/requirements for use in any area that meets a NFPA Class I/Division I and Class I/Division II classification per SCWI-8715-0012.

e. All portable electric tools shall be equipped with a ground wire unless they are double insulated. Portable electric tools equipped with the double-insulation system are normally identified by a two-conductor cord and plug attached to the portable electric tool.

f. Low-voltage transformers, insulating platforms, rubber mats, or rubber gloves are to be used when using tools in damp locations.

g. Low-voltage transformers shall be used whenever electrical work is performed in wet locations.

h. The operating control on handheld power tools shall have a switch that requires constant pressure to operate and be located as to minimize the possibility of inadvertent actuation. Vendor-delivered tools with trigger locks installed shall not be engaged at SSC.

i. Hand-held circular saws with a blade diameter of more than two (2) inches and electric chain saws without positive accessory holding means shall be equipped with a switch that requires constant pressure to operate.

j. Handheld powered drills, horizontal/vertical/angle grinders with wheels greater than two (2) inches in diameter, disc sanders with discs greater than two (2) inches in diameter, belt sanders, and reciprocating/saber/scroll/jig saws with blade shanks greater than a nominal 0.25 inches (+0.05 inch) shall be equipped with a switch that requires constant pressure to operate (dead man switch).

6.6 Portable Hand Lamps/Temporary Lighting

a. Only explosion-proof lamps shall be used in areas classified by NFPA 70 to contain flammable gas/dust atmospheres.

b. The guard and globe holder shall be made of nonferrous metal.

c. Lamps shall be equipped with polarized/grounded attachment plugs, a handle made of molded composition or other insulating material, and include a guard attached to the handle/lamp holder. Metal shell and paper-lined lamp holders are not permitted for use.

d. Bulbs of all overhead/temporary lighting shall be enclosed by guards to prevent damage to bulbs and injury to personnel by electric shock or broken glass.

e. Lamps for general illumination must be protected from breakage, and metal shell sockets must be grounded.

f. Temporary lights must not be suspended by their cords unless they have been designed for this purpose.

g. Portable lighting used in wet or conductive locations, such as tanks or boilers, must be operated at no more than twelve (12) volts or must be protected by GFCIs.

6.7 Test Instruments and Equipment

a. Only qualified persons shall perform tasks such as testing, troubleshooting, and voltage measuring within the limited approach boundary of energized electrical conductors or circuit parts operating at fifty (50) volts or more or where an electrical hazard exists.

b. Test instruments, equipment, and their accessories shall be rated for circuits and equipment to which they will be connected.

c. Test instruments, equipment, and their accessories shall be designed for the environment to which they will be exposed and for the manner in which they will be used.

d. Test instruments and equipment and all associated test leads, cables, power cords, probes, and connectors shall be visually inspected for external defects and damage before each use. If there is a defect or evidence of damage that might expose an employee to injury, the defective or damaged item shall be removed from service, and no employee shall use it until repairs and tests necessary to render the equipment safe have been made.

e. When test instruments are used for testing the absence of voltage on conductors or circuit parts operating at fifty (50) volts or more, the operation of the test instrument shall be verified before and after an absence of voltage test is performed.

6.8 Emergency Lighting

a. All windowless buildings shall be provided with emergency lighting.

b. Emergency lighting shall be provided for all occupied facilities per STTD-8070-0081-ELEC Facility Electrical Standard.

7.0 SPECIAL REQUIREMENTS FOR ELECTRICAL SAFETY

7.1 Assured Equipment Grounding Conductor Program (AEGCP) and Ground Fault Circuit Interrupter (GFCI) Protection

a. Employees who are exposed to electrical hazards at the work location shall use either Ground Fault Circuit Interrupter Protection or an Assured Equipment Grounding Conductor Program.

b. The Assured Equipment Grounding Conductor Program (AEGCP) and the Ground Fault Circuit Interrupter Protection applies to NASA Onsite Prime Contractors and Construction Contractors.

7.1.1 Assured Equipment Grounding Conductor Program (AEGCP)

a. The AEGCP is a scheduled system for testing construction site electrical tools and extension cords to assure their proper grounding, polarity and resistance.

b. The AEGCP shall cover all cord sets, receptacles not part of the permanent wiring of a structure, and equipment connected by a cord and plug on all maintenance and construction sites.

c. A written description of the program shall be maintained, which outlines the implementation and required procedures, equipment inspections, tests, and test schedule for inspection and copying by OSHA and any affected employee upon demand.

d. The contractor shall designate one or more competent persons (as defined in OSHA 1926.32(f)) to implement the program.

e. Daily Visual Inspections (Pre-Use) – Each cord set, attachment cap, plug and receptacle of cord sets, and any equipment connected by cord and plug, except cord sets and receptacles which are fixed and not exposed to damage, shall be visually inspected before each day's use for external defects, such as deformed or missing pins or insulation damage, and for indications of possible internal damage such as pinched or crushed outer jacket. Any defective cord or cord-and-plug connected equipment shall be removed from service. Cords/Equipment found damaged or defective shall not be used until repaired.

f. Removing Cords/Equipment – All cords or cord-and-plug connected equipment found damaged or defective, or which fails any of the prescribed inspections or tests, may not be used until repaired or replaced. All defective or failed equipment must be tagged with a Red Tag “Do Not Operate” until repaired and tested or rendered unusable and discarded. Equipment that has not been tested within 3 months shall not be used.

g. The following tests shall be performed on all cord sets, receptacles which are not a part of the permanent wiring of the building or structure, and cord- and plug-connected equipment required to be grounded:

1) All equipment grounding conductors shall be tested for continuity and shall be electrically continuous.
2) Each receptacle and attachment cap or plug shall be tested for correct attachment of the equipment grounding conductor.
3) The equipment grounding conductor shall be connected to its proper terminal.

h. All required tests shall be performed as follows:

1) Before first use on site
2) Before equipment is returned to service following any repairs
3) Before equipment is used after any incident in which it was reasonable to suspect it became damaged (for example, a cord set is run over)
4) At intervals not exceeding 3 months, except for cord sets and receptacles which are fixed and not exposed to damage which should be tested at intervals not to exceed 6 months
5) The tests required in items 1) – 4). shall be recorded
6) Tester shall use a either a continuity tester, ohmmeter, and/or a receptacle tester for testing continuity and equipment grounding conductor/terminals

i. The NASA Onsite Prime Contractors and Construction Contractors shall maintain a written record of the required tests, identifying all equipment that passed the test and the last date it was tested (or the testing interval). This record shall be kept by means of logs and color coding (see **Table 8**), or other effective means and shall be maintained until replaced by a more current record. These records will be available for inspection by OSHA and the affected persons upon demand.

Table 8. Assured Equipment Grounding Conductor Program – Color Coding Scheme

Quarter	Month	Monthly Color
1st	January	White
1st	February	White
1st	March	White
2nd	April	Red
2nd	May	Red
2nd	June	Red
3rd	July	Green
3rd	August	Green
3rd	September	Green
4th	October	Blue
4th	November	Blue
4th	December	Blue
	Repair Color	Brown

Note: Be sure that the last quarter's color tape is removed before the new quarter's tape is applied.

7.1.2 Ground Fault Circuit Interrupter (GFCI) Protection

a. GFCI protection shall be provided when an employee is outdoors and operating or using cord- and plug-connected equipment supplied by 125-volt, 15-, 20-, or 30-ampere circuits. For additional GFCI protection requirements, refer to section 6.2 Extensions Cords lines s. and v.

b. Portable electrical devices used inside/on conductive surfaces shall be equipped with a GFCI. Due to the complexity of a GFCI, it is necessary to test the device on a regular basis. For permanently wired devices, a monthly test is required per the listing and labeling requirements of the device. Refer to NFPA 70 (NEC), Section 110.3(B) and CFR 1910.303 (b) (2) for requirements.

c. All electrical equipment using over twenty-four (24) volts in a confined space shall be protected by a GFCI.

d. A GFCI line cord must be connected on the line side of the extension cord. Refer to Figure 1.

Figure 1. Example of a Line Cord GFCI

e. Temporary protective grounding equipment shall be placed at such locations (overhead lines, switchgear, busbar) and arranged in such a manner as to prevent each employee from being exposed to hazardous differences in electrical potential.

f. Temporary protective grounding equipment shall be capable of conducting the maximum fault current that could flow at the point of grounding for the time necessary to clear the fault.

g. Temporary protective grounding equipment shall meet the requirements of ASTM F 855, Standard Specification for Temporary Protective Grounds to be used on De-energized Electric Power Lines and Equipment.

7.2 Fundamental Safety Rules and Procedures - Electrostatic Discharge Control

This instruction provides the general safety requirements for the development of appropriate control measures to provide protection against personal injury, property damage, and/or mission degradation due to the Electrostatic Discharge of Energy (ESD) and subsequent initiation of solid propellants, igniter components, explosives, or flammable/combustible materials. These instructions establish mandatory electrostatic discharge control requirements for NASA and for NASA contractors at SSC who engage in the receiving, distributing, assembling, disassembling, handling, testing, repairing, or storing of explosive ordinance, flammable/combustible materials, or propellants. Electrostatic discharge control general requirements are listed below.

a. **Grounding Systems:** Grounding systems shall be tested and retested for electrical resistance and continuity in the following conditions:

1) When initial installation is completed to establish a baseline.
2) Before equipment is returned to service following any repairs.
3) Before equipment is used after an incident that is suspected to have caused damage to power (electrical) systems in the equipment or system.
4) Explosive operations/facilities shall be visually inspected semiannually and shall be tested once each year for electrical continuity and adequacy of grounding.

b. **Ground Tests:** Ground tests will be recorded, identifying the item/system, the date of test, the test equipment used, and the test equipment's calibration date.

c. **Ground System Inspection:** The ground system shall be visually inspected and grounds shall be tested by maintenance prior to activation and reactivation of the system if the equipment has been inactive for more than one (1) year. For explosive operations, the ground system shall be visually inspected by maintenance prior to activation and reactivation of the system if the equipment has been inactive for more than one (1) month. If the system has been inactive for more than six (6) months, it shall be visually inspected by maintenance and tested prior to activation and reactivation.

d. **Maximum Resistance to Ground:** The maximum resistance to ground permitted for different types of equipment/systems for hazardous locations and non-hazardous locations shall be designed and tested per SSTD-8070-0081-ELEC SSC Facility Electrical Standard and per NASA-STD-8719.12 Safety Standard for Explosives, Propellants, and Pyrotechnics.

e. **Electrostatic Charging Control:** Controls required for preventing electrostatic charging are dependent on many factors, including the materials being processed, contacting materials, the process or operation being performed, hardware and equipment design, and materials of construction. The control measures may include the use of anti-static spray to minimize charge build-up, static dissipation, and conductive plastics, metals, electrical bonding and grounding; process delays permitting charge relaxation from materials of low conductivity, and the use of leg or wrist-straps by operating personnel. The specific measures must be defined for each operation or process determined to be a significant electrostatic charge generator. Control measures shall be specified in individual operating procedures.

f. **Process Procedures:** Material electrical properties are primary contributors to the magnitude of the electrostatic charge build-up and rate dissipation. Process procedures shall define the materials to be permitted to contact live propellants, energetic materials, and loaded solid rocket motors. Nonconductive materials are not to be used unless specified within a procedure.

g. **ESD Measures for Combustibles:** ESD measures/controls for working with flammable/combustible liquids:

- Paint Spraying - Paint spray gun nozzles and pressure feed pots shall be grounded. Care must be taken to ensure ground connections remain free of paint coatings.

h. **ESD Measures for Hydrogen :** ESD measures/controls for working with liquid/gaseous hydrogen shall follow : NPD 8710.5, NASA Safety Policy for Pressure Vessels and Pressurized Systems, NASA-STD-8719.17, NASA Requirements for Ground-Based Pressure Vessels and Pressurized Systems, appropriate Occupational Safety and Health

Administration (OSHA), National Fire Protection Association (NFPA), American Society for Testing and Materials (ASTM) (ASTM MNL 36, Safe Use of Oxygen and Oxygen Systems), and American National Standards Institute (ANSI) (ANSI/AIAA G-095-2004, Guide to Safety of Hydrogen and Hydrogen Systems).

7.3 Equipment Labeling

a. NEC Article 110.16 and NFPA 70E 130.5(C) requires switchboards, switchgear, panel boards, industrial control panels, motor controls centers and are likely to require examination adjustment, servicing or maintenance while energized to be field marked to warn workers of potential electric arc flash hazards.

b. The term Industrial Control Panel covers every enclosure that may contain exposed energized conductors or components.

c. Marking is intended to reduce the occurrence of serious injury or death due to arcing faults to employees working on or near energized electrical equipment.

d. Markings (labels) shall be located so they are visible to the personnel before examination, adjustment, servicing, or maintenance of the equipment and markings shall meet NEC 110.21(B) requirements.

e. Labels shall be either of the two (2) shown in Figure 2.

f. The Figure 2 - The "Danger" header identifies those situations of extreme danger. The red "Danger" header shall be used when the voltage is over 600 volts or when the incident energy is over 40cal/cm². If the incident energy is less than that of the threshold, an orange "Warning" header shall be used. It is imperative that consistency shall be maintained on all labels throughout the facility.

g. The Danger and Warning Label shown in Figure 2 shall be used when a qualified electrical engineer determines the values of the Arc Flash Boundary, Incident energy, Category, Voltage, Glove Class, Limited Approach Boundary, Restricted Approach Boundary, Prohibited Approach Boundary, Location of the Equipment/Device or Bus, Company, Job # denotes Report #, Date, Engineer's Name, and Warning Description with Building #, Substation #, and Arc Flash Revision Date if applicable.

h. When arc flash and shock data are available for industrial control panels, labels shall include information on flash hazard boundary, the hazard category, required PPE, minimum arc rating, limited approach distances, restricted approach distances, and prohibited approach distances.

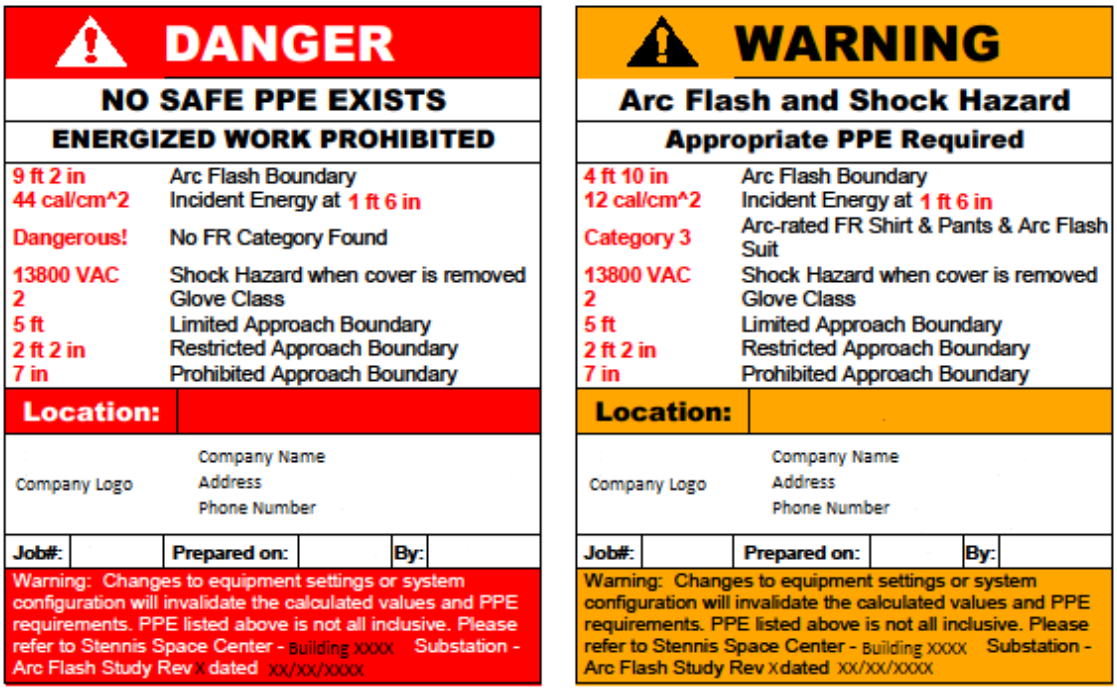

Figure 2. Electric Arc Flash Hazard - Danger and Warning Labels.

The "Danger" and "Warning" headers in Figure 2 are an example of labels to be affixed to industrial control panels after arc flash hazard analysis has been completed.

Note:
The labels, design and formatting shall conform to ANSI Z535 and Series of Standards for Safety Signs and Tags. All Arc Flash Labels shall withstand their usage and shall be VV rated. The print shall not fade and the adhesive shall be aggressive enough to avoid peeling. When necessary, a protective laminate should be applied to the print surface to protect from harsh chemicals, and exposure to sunlight.
Labels applied prior to September 30, 2011, are acceptable if they contain the available incident energy or required level of PPE. The method of calculating and data to support the information for the label shall be documented.

8.0 AUDIT PROCESS

The electrical safety program will be audited every twelve (12) months using SSC Form 869, Electrical Safety Audit Form.

9.0 TRAINING REQUIREMENTS

9.1 Training Requirements for Qualified Persons

a. The training requirements in this SCWI apply to personnel who are required to work within the limited approach boundary on, near, or in close proximity to exposed energized-electrical conductors or circuit parts operating at 50 volts or more and who face a risk of exposure to electrical hazards that have not been reduced to a safe level.

b. The employees shall receive training in accordance with NFPA 70E Article 110.2 and 110.3 and with 29 CFR Part 1910.332 and 333 and shall be able to demonstrate the following:

1) Universal electrical safety procedures
2) Skills and techniques necessary to distinguish exposed live parts from other parts of electric equipment
3) Perform on-the-job training with a qualified electrical worker
4) Skills and techniques necessary to determine the nominal voltage of exposed live parts
5) The approach distances specified in Table 130.2(C) and the corresponding voltages to which the qualified electrical worker will be exposed
6) Selection and use of proper work practices, PPE, tools, and insulating and shielding materials and equipment for working on or near energized parts

c. Qualified Persons must also be trained in recognizing signs and symptoms of electric shock, heart fibrillation, electric burns, and proper first aid protocols for these conditions. They must have the following training:

1) Basic Cardiopulmonary Resuscitation
2) Automatic External Defibrillator
3) Contacting emergency personnel and basic first aid

Note: Per OSHA interpretation letter dated 1/16/2007, "If an employee is trained in first aid and identified by the employer as responsible for rendering medical assistance as part of his/her job duties, that employee is covered by the bloodborne pathogens standard." This standard requires that a hepatitis B vaccination be made available to employees.

d. Training shall be documented. This documentation shall contain the content of the training, each employee's name, and the dates of training.

e. Training for NASA employees shall be conducted by trained and competent Facility Operating Services Contract (FOSC) persons.

f. Training and Refresher training will be performed in accordance with the frequency described in *SCWI-3410-0003, Training Certification and Schedule Report*.

g. Employees shall receive initial training through the New Employee Safety and Health Orientation (NESHO) program. The employer shall determine, through regular supervision or through inspections conducted on at least an annual basis that each employee is complying with the safety-related work practices required by this standard.

9.2 Training Requirements for Unqualified Persons

a. The training requirements in this section of the SCWI apply to personnel who are considered unqualified persons.

b. The employees shall receive training in accordance with NFPA 70E Article 110.2(b) and 29 CFR Part 1910.332 and 333.

c. Training shall be documented.

d. Training for NASA employees shall be conducted by trained and competent FOSC persons.

e. Employees shall receive initial training through the New Employee Safety and Health Orientation (NESHO) program and a refresher training every three (3) years.

10.0 OTHER ELECTRICAL PROCEDURES

SSTD-8070-0081-ELEC, Facility Electrical Standard, contains the basic engineering guidance, policy, criteria, and standards for the design and construction of electrical systems at SSC. SSTD-8070-0083-ELEC, Standard for the 13.8kV Distribution System contains the basic engineering guidance, policy, criteria, and standards for the design and construction of 13.8kV Distribution Systems at SSC.

11.0 RECORDS AND FORMS

All records and forms are assumed to be the latest version unless otherwise indicated. Quality Records are identified in the SSC Master Records Index.

a. NASA form SSC-222, Permit for Use of Small Appliance

b. NASA form SSC-869, Electrical Safety Audit

c. Energized Electrical Work Permit

12.0 APPENDIX A - ACRONYMS

AC	Alternating Current
AEGCP	Assured Equipment Grounding Conductor Program
amp	Amperage
ANSI	American National Standard Institute
AR	Arc Rated
ASTM	American Society for Testing and Material
CB	Circuit Breaker
CFR	Code of Federal Regulations
DC	Direct Current
EEWP	Energized Electrical Work Permit
ESD	Electrostatic Discharge of Energy
FOSC	Facility Operating Service Contractor
GFCI	Ground-Fault Circuit Interrupter
LO/TO	Lockout/Tagout
NASA	National Aeronautics and Space Administration
NESHO	New Employee Safety and Health Orientation
NEC	National Electrical Code
NFPA	National Fire Protection Association
NRTL	Nationally Recognized Testing Laboratory
OPR	Office of Primary Responsibility
OSHA	Occupational Safety and Health Administration
PPE	Personal Protective Equipment
SCWI	Stennis Common Work Instruction
SMA	Safety and Mission Assurance Directorate
SOMRD	System Operations and Maintenance Responsibility Database
SPA	Safe Plan of Action
SSC	John C. Stennis Space Center
UL	Underwriters Laboratories

13.0 APPENDIX B - DEFINITIONS

Arc Blast – A pressure wave resulting from arcing.

Arc Flash – An electrical short circuit through air when insulation or isolation between electrified conductors is breached or can no longer withstand the applied voltage. Temperatures can reach up to 35,000 ºF.

Arc Flash Boundary – The Arc Flash Boundary for systems of 50 volts and greater shall be a distance at which the incident energy equals 1.2cal/cm².

Arc Flash Hazard Analysis - The arc flash hazard analysis will determine the arc flash energy measured in calories/square centimeters (cal/cm²); establish the arc flash boundary (established at 1.2cal/cm², which is the onset of a second-degree burn); and determine the appropriate arc rated clothing and PPE against arc flash hazards.

Authorized Employee – A trained and qualified employee who locks out and tags the equipment or system to perform service or maintenance on the equipment or system.

Buddy System – While one (1) person works on the equipment, another person that is trained and able to recognize electrical hazards serves as an attendant. The attendant watches the movements of the person performing the work and warns or alerts the person if he/she gets dangerously close to exposed electrical hazards or live conductors, or performs an unsafe act. The attendant also assists the employee in the event of an accident.

Cardiopulmonary Resuscitation – 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.

Circuit – A conductor or system of conductors through which electric current is intended to flow.

Complex Equipment/Systems – Equipment/systems that operate at more than 120 volts, have a hazard category rating of two (2) or higher, have more than one (1) source of energy that are required to be de-energized to place the equipment in a safe-working condition, or have a specific sequence of steps required to safely shut-down or start-up.

Conductor – A material, usually in the form of a wire, cable, or bus bar, suitable for carrying electric current.

De-energized (as related to current-carrying parts) – Free from any electrical connection to a source of potential difference and from electric charge; not having a potential difference from that of the Earth.

Effectively Grounded – Intentionally connected to earth through a ground connection or connections of sufficiently low impedance and having sufficient current-carrying capacity to prevent the buildup of voltages that may result in undue hazards to connected equipment or to persons.

Electrical Equipment – Wiring, circuits, switches, switch gear, fuses, breakers, distribution systems, and any other equipment or systems capable of containing electrical energy.

Electrical Hazard – A dangerous condition where contact with energized parts or equipment/systems failure can result in electric shock, arc-flash burn, thermal burn, or blast.

Electrically Safe-Work Condition – A state in which the conductor or circuit part to be worked on or near has been disconnected from energized parts, and the equipment/systems have been locked/tagged in accordance with established standards (29 CFR 1910.147, The Control of Hazardous Energy (Lockout/Tagout)), tested to ensure the absence of voltage, and grounded if determined necessary.

Electrical Shock – Occurs when current passes through the human body.

Energized – Connected to an energy source, or containing residual or stored energy.

Energized Parts – Electric conductors, buses, terminals, or components that are uninsulated or exposed, and where a possibility of a shock hazard exists.

Energy Isolation – The complete de-energizing of equipment that has the potential to receive or transfer electrical, mechanical, chemical, gravitational, and/or physical energy. Energy isolation or de-energization can occur through blockage, separation, or elimination of the sources of energy.

Equipment/Systems – A general term used to describe a single or group of fixtures, components, and devices assembled in connection with an electrical system.

Exposed (as applied to live parts) – Capable of being inadvertently touched or approached at less than a safe distance; it is applied to parts that are not suitably guarded, isolated, or insulated.

Exposed (as applied to wiring methods) – On or attached to the surface, or behind panels designed to allow access.

Exposed (for the purposes of NFPA 70E, Article 450) – An electrical conductor or circuit part is in such a position that direct contact with another circuit can result if supports or insulation fails.

Flash Hazard – A dangerous condition associated with the release of energy caused by an electric arc.

Flash Protection Boundary – The distance at which PPE is required to prevent incurable burns (second degree or worse) in the event of an arch flash.

Grounded – Connected to Earth or to some conducting body that serves in place of the Earth.

Ground-Fault Circuit Interrupter (GFCI) – A device intended for the protection of personnel that functions to de-energize a circuit, or portion thereof, within an established period of time when a current to ground exceeds the values established for a class A device.

Hazard Category – A hazard level determined by the voltage level of the equipment, the type of work performed by an employee within a predetermined boundary (limited, restricted, or prohibited) to exposed energized-electrical parts operating at 50 volts or more, and the required PPE to be worn by the employee while performing the work.

High Voltage – Any electrical equipment (lines, wires, switches, relays, transformers, buses, capacitors, rectifiers, etc.) that has the potential to carry or contain voltage equal to or greater than 600 volts.

Incident Energy Analysis - The incident energy analysis shall determine, and the employer shall document, the incident energy exposure of the worker (in calories per square centimeter). A component of an Arc Flash Hazard Analysis used to predict the incident energy of an arc flash for a specified set of conditions. Arc-rated clothing and other PPE shall be used by the employee based on the incident energy exposure associated with the specific task.

Limited Approach Boundary – The closest distance an unqualified employee can approach exposed, energized parts within which a shock hazard exists, unless accompanied by a qualified employee.

Lineman – Workers who will perform work on energized or potentially energized electrical equipment (voltage up to and including 13,800 volts AC).

Live Parts (as applied to electricity) – Energized-conductive components.

LO/TO – The placement of a lockout and/or tagout device to an energy-isolation device in accordance with established energy-control procedures to obtain a zero-energy state safe working condition by ensuring the energy-isolating device and equipment being controlled cannot be operated until the lockout and/or tagout device is removed.

Low Voltage – Any electrical equipment (lines, wires, switches, relays, transformers, buses, capacitors, rectifiers, etc.) that has the potential to carry or contain voltage up to 600 volts.

Mission Critical Equipment/Systems – Equipment/systems that form an integral part of a system supporting the Space Station, Shuttle mission, or other NASA-required system.

Nationally Recognized Testing Laboratory – A program in OSHA's Directorate of Science, Technology, and Medicine. It recognizes private sector organizations as NRTLs, and this recognition signifies that an organization has met the necessary qualifications specified in the regulations for the program. The NRTL determines that specific equipment and materials ("products") meet consensus-based standards of safety to provide the assurance (required by OSHA) that these products are safe for use in the United States workplace.

Organization Point of Contact – An individual within the organization requesting that work be performed and who is to be contacted prior to beginning the work.

Potentially Energized – Electrical equipment capable of containing electrical energy that has not been locked-out, tagged-out, grounded, and verified as de-energized by proper testing methods.

Prohibited Approach Boundary – The minimum approach distance permitted to exposed, energized parts to prevent flashover or arcing. Approaching any closer is considered comparable to making direct contact with the energized part.

Qualified Person/Employee – A person who has received training per 29 CFR 1910.332 and Section 9.0, Training Requirements, of this SCWI; possesses the skills and knowledge related to the construction and operation of the electrical equipment/systems and installations; and can recognize the shock or arc flash hazards involved. Such persons shall be capable of working safely on energized circuits and shall be familiar with the proper use of special precautionary techniques, personal protective equipment, barricades, insulating and shielding materials, and insulated tools.

Restricted Approach Boundary – An approach limit at a distance from an exposed energized electrical conductor or circuit part within which there is an increased risk of shock, due to electrical arc-over combined with inadvertent movement, for personnel working in close proximity to the energized electrical conductor or circuit part.

Requestor Organization – The organization requesting the work to be performed.

Responsible Organization – The organization having the primary responsibility for the equipment/systems and making the determination whether the equipment/systems cannot be de-energized to perform the work.

Safe-Work Practices – Techniques used by the worker to ensure safety of the worker and the equipment/systems. This can include the use of such items as PPE, barriers, insulated tools, and on-the-job training.

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

Shock Hazard Analysis - A shock hazard analysis shall determine the voltage of the circuits and equipment to which personnel will be exposed, the boundary requirements (limited, restricted, prohibited) and the required personal protective equipment necessary in order to minimize the possibility of electric shock to personnel.

Simple Equipment/Systems – Equipment/systems that operate at 120 volts or less, have a hazard category rating of one (1) or less, and have a single energy source that, when de-energized, places it in a safe working condition where there is no possibility to accumulate stored energy.

Unqualified Person/Employee – A person not having the training (or knowledge and skills) related to the construction and operation of the electrical equipment/systems, installations, and hazards involved. Any employee who is not a qualified person is an unqualified person.

Working Near (energized parts) – Any activity inside a limited approach boundary (or within close proximity to energized parts) that poses a risk even though the work may be being performed on de-energized parts.

Working On (energized parts) – Actually touching or coming in contact with energized parts with the hands, feet, or other body parts with tools, probes, or test equipment regardless of the PPE an employee is wearing.