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**John C. Stennis Space Center**
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# John C. Stennis Space Center
# Electrical Safety Program

## Approved by:

***Original Signature on File*** ***4-4-11***

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Date

# Document History Log

| Status/Change/ Revision | Change Date | Originator/Phone | Description |
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| 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 |
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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, Subpart K, Electrical

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

c. 29 CFR 1910.332, Training

d. 29 CFR 1910.333, Selection and Use of Work Practices

e. 29 CFR 1926, Subpart S, Electrical

f. 29 CFR 1926.417, Lockout and tagging of circuits

g. NFPA 70, National Electrical Code®

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

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

j. SPR 8715.1, Safety and Health Program Requirements

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

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

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

n. SCWI-3410-3000, Training/Certification Plan and Schedule Report

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

p. ASTM F1505, Standard Specification for Insulated and Insulating Hand Tools

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

r. Energized Electrical Work Permit Process

s. NEC Article 110.16

t. NEC Article 400.8

u. NEC Article 590

v. SCWI-3410-3000, Training/Certification Plan and Schedule Report

w. SPR 8730.4, SSC Metrology and Calibration Control Program

## 4.0 Responsibility

### 4.1 NASA Employees

All NASA employees shall:

a. Not work on or near energized electrical equipment above 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) and National Electrical Code (NEC) electrical safety standards applicable to their area

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

### 4.3 NASA On-Site 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. Review electrical safety procedures of their sub-contractors (construction contractors) when the task of the sub-contractors involves electrical work

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

g. Conduct field audits of employees, sub-contractor, and construction contractor electrical safety practices to ensure compliance with federal regulations and compliance with this document

h. Conduct document audits

i. Ensure that when an electrical safety permit is used when applicable

j. 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.

### 4.4 Safety and Mission Assurance

The Safety and Mission Assurance (SMA) Office of NASA SSC and On-Site 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, National Fire Protection Association (NFPA), and 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, sub-contractors, and construction contractors' electrical safety work to ensure compliance with federal regulations and compliance with this document.

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 Stennis Space Center.

FOSC shall:

a. Promote electrical safety awareness to all employees

b. Ensure employees comply with the provisions of the electrical safety program

c. Ensure employees receive training appropriate to their assigned electrical tasks and maintain documentation of such training

d. Develop and maintain a listing of all qualified employees under their supervision

e. Ensure employees are provided with and use appropriate protective equipment

f. Ensure training of unqualified employees in electrical safety is completed as required

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

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

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

j. Maintain record keeping associated with the SCWI (e.g., documentation on electrical PPE, preventive maintenance, hot work permits)

### 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. Ensure timely follow up of any corrective actions

## 5.0 Safety Requirements for Qualified Persons

### 5.1 Working On or Near Energized Electrical Equipment

Working on energized electrical equipment means actually touching energized parts. Working near 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

b. Opening and closing disconnects

c. Racking breakers on and off the bus

d. Removing panels and dead fronts

e. Energized Electrical Work Permit

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 (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.

### 5.2 Approach Distances to Live Parts

The NFPA defines three (3) approach distances for shock hazards and one (1) for arc flash.

a. Approach boundaries are defined in Table 1.

b. The **limited approach boundary** is the distance from an exposed live part within which a shock hazard exists.

c. The **restricted approach boundary** is the closest distance to exposed live parts a qualified person can approach without proper PPE and tools. 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 work permit that is approved by the responsible 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 space

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

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 specified training to work on exposed live parts

2. Have a permit with proper written work procedures justifying the need to work that close to exposed live parts

3. Perform a risk analysis

4. Have numbers two (2) and three (3) approved by the appropriate supervisor.

5. Use PPE appropriate for working near exposed live parts and rated for the voltage and energy level involved.

e. The **Flash Protection 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. Use PPE appropriate for working near exposed live parts that are rated for the voltage and energy level involved.

2. For systems of six hundred (600) volts and less, the flash protection boundary is four (4) feet based on an available bolted fault current of 50 kA and a clearing time of six (6) cycles for the circuit breaker to act, or any combination of fault currents and clearing times not exceeding 300 kA cycles.

3. 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.

4. Have an energized work permit that is approved by the responsible supervisor if the parts cannot be de-energized.

**Table 1. Approach Boundaries to Live Parts for Shock Prevention**
(All dimensions are 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.

## 5.3 Personal Protective Equipment

### 5.3.1 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.

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 American Society of Testing and Materials (ASTM) and by the America National Standards Institute.

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. 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 must be non-conductive.

m. 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.

n. Documentation of electrical PPE testing shall be maintained and made available for audit and review.

### 5.3.2 Flame-Resistant Apparel and Underlayers

a. Flame-resistant (FR) apparel shall be visually inspected before each use. FR 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 FR apparel shall be followed.

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

d. FR apparel must cover potentially exposed areas as completely as possible. FR shirt sleeves must be fastened and FR 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 underlayers beneath FR apparel.

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

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

h. Flash suits must permit easy and rapid removal by the user.

### 5.3.3 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 must 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.

### 5.3.4 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 shall be rated for the voltages on which they are used.

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

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

e. Ropes and hand-lines used near exposed energized parts shall be nonconductive.

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

### 5.3.5 Access Limiting Equipment

a. Barricades/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.

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.

### 5.3.6 Hazard Risk Category Classifications for Determining PPE

a. A Flash Hazard Analysis shall be performed per NFPA 70E 130.3 when working within the Arc Flash Protection Boundary.

b. If a Flash Hazard Analysis is not performed, Table 2, Table 3, and  shall be used when selecting PPE.

If there is not a task listed in Table 2, a Flash Hazard Analysis shall be performed.

**Table 2. 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 | 0 | N | 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 1** | | | |
| 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 2 (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 3 | 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) | 4 | N | N |

| | | | |
|---|---|---|---|
| – Note 3 | | | |
| Opening hinged covers (to expose bare, energized electrical conductors and parts) – Note 3 | 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 4** | | | |
| 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 2 (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** | | | |
| 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** | | | |
| 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)** | | | |
| 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** | | | |
| 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)(9)*

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 (½ cycle fault clearing time or less), the hazard/risk category required may be reduced by one number.

Specific Notes (as referenced in the table):
1. Maximum 25 kA short circuit current available, 0.03 second (2 cycle) fault clearing time.
2. Maximum 65 kA short circuit current available, 0.03 second (2 cycle) fault clearing time.
3. Maximum 42 kA short circuit current available, 0.33 second (20 cycle) fault clearing time.
5. Maximum 35 kA short circuit current available, up to 0.5 second (30 cycle) fault clearing time.

## Table 3. 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 | | Shirt (long sleeve)<br>Pants (long) |
| FR Protective Equipment | | Safety glasses or safety goggles (SR)<br>Hearing protection (ear canal inserts)<br>Leather gloves (AN) (Note 2) |
| **Hazard/Risk Category 1** | | |
| FR Clothing, Minimum Arc Rating of 4 (Note 1) | | Arc-rated long sleeve shirt (Note 3)<br>Arc-rated pants (Note 3)<br>Arc-rated coverall (Note 4)<br>Arc-rated face shield or arc flash suit hood (Note 7)<br>Arc-rated jacket, parka, or rainwear (AN) |
| FR Protective Equipment | | Hard hat<br>Safety glasses or safety goggles (SR)<br>Hearing protection (ear canal inserts)<br>Leather gloves (AN) (Note 2)<br>Leather work shoes (AN) |
| **Hazard/Risk Category 2** | | |
| FR Clothing, Minimum Arc Rating of 8 (Note 1) | | Arc-rated long sleeve shirt (Note 5)<br>Arc-rated pants (Note 5)<br>Arc-rated coverall (Note 6)<br>Arc-rated face shield or arc flash suit hood (Note 7)<br>Arc-rated jacket, parka, or rainwear (AN) |
| FR Protective Equipment | | Hard hat<br>Safety glasses or safety goggles (SR)<br>Hearing protection (ear canal inserts)<br>Leather gloves (Note 2)<br>Leather work shoes |
| **Hazard/Risk Category 2*** | | |
| FR Clothing, Minimum Arc Rating of 8 (Note 1) | | Arc-rated long sleeve shirt (Note 5)<br>Arc-rated pants (Note 5)<br>Arc-rated coverall (Note 6)<br>Arc-rated face shield or arc flash suit hood (Note 10)<br>Arc-rated jacket, parka, or rainwear (AN) |
| FR Protective Equipment | | Hard hat<br>Safety glasses or safety goggles (SR)<br>Hearing protection (ear canal inserts)<br>Leather gloves (Note 2)<br>Leather work shoes |
| **Hazard/Risk Category 3** | | |

| | | |
|---|---|---|
| FR Clothing, Minimum Arc Rating of 25 (Note 1) | | Arc-rated long sleeve shirt (AR) (Note 8)<br>Arc-rated pants (AR) (Note 8)<br>Arc-rated coverall (AR) (Note 8)<br>Arc-rated arc flash suit jacket (AR) (Note 8)<br>Arc-rated arc flash pants (AR) (Note 8)<br>Arc-rated face shield or arc flash suit hood (Note 8)<br>Arc-rated jacket, parka, or rainwear (AN) |
| FR Protective Equipment | | Hard hat<br>FR hard hat liner (AR)<br>Safety glasses or safety goggles (SR)<br>Hearing protection (ear canal inserts)<br>Arc-rated gloves (Note 2)<br>Leather work shoes |
| **Hazard/Risk Category 4** | | |
| FR Clothing, Minimum Arc Rating of 40 (Note 1) | | Arc-rated long sleeve shirt (AR) (Note 9)<br>Arc-rated pants (AR) (Note 9)<br>Arc-rated coverall (AR) (Note 9)<br>Arc-rated arc flash suit jacket (AR) (Note 9)<br>Arc-rated arc flash pants (AR) (Note 9)<br>Arc-rated face shield or arc flash suit hood (Note 9)<br>Arc-rated jacket, parka, or rainwear (AN) |
| FR Protective Equipment | | Hard hat<br>FR hard hat liner (AR)<br>Safety glasses or safety goggles (SR)<br>Hearing protection (ear canal inserts)<br>Arc-rated gloves (Note 2)<br>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 FR shirt and pants used for Hazard/ Risk Category 1 shall have a minimum arc rating of 4.
4. Alternate is to use FR coveralls (minimum arc rating of 4) instead of FR shirt and FR pants.
5. FR shirt and FR pants used for Hazard/ Risk Category 2 shall have a minimum arc rating of 8.
6. Alternate is to use FR coveralls (minimum arc rating of 8) instead of FR shirt and FR pants.
7. A face shield with a minimum arc rating of 4 for Hazard/Risk Category 1 or a minimum arc rating of 8 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 FR clothing system and hood, which shall have a minimum arc rating of 25 for Hazard/Risk Category 3.
9. The total clothing system consisting of FR shirt and pants and/or FR coveralls and/or arc flash coat and pants and hood shall have a minimum arc rating of 40 for Hazard/Risk Category 4.
10. Alternate is to use a face shield with a minimum arc rating of 8 and a balaclava (sock hood) with a minimum arc rating of 8 and which covers the face, head and neck except for the eye and nose areas.

**Table 4. Protective Clothing Characteristics**

| Hazard/Risk Category | Clothing Description (Typical number of clothing layers is given in parentheses) | Required Minimum Arc Rating of PPE [J/cm$^2$ (cal/cm$^2$)] |
|---|---|---|
| 0 | Non-melting, flammable materials (i.e., untreated cotton, wool, rayon, or silk, or blends of these materials) with a fabric weight at least 4.5 ounce/yard$^2$ | N/A |
| 1 | Arc-rated FR shirt and FR pants or FR coverall | 16.74 (4) |
| 2 | Arc-rated FR shirt and FR pants or FR coveralls | 33.47 (8) |
| 3 | Arc-rated FR shirt and FR pants or FR coverall, and arc flash suit selected so that the system arc rating meets the required minimum | 104.6 (25) |
| 4 | Arc-rated FR shift and FR pants or FR coverall, and arc flash suit selected so that the system arc rating meets the required minimum | 167.36 (40) |

*Source: NFPA 70E, Table 130.7(C)(11)*

Note: Arc rating is defined in Article 100 and can be either ATPV or $E_{BT}$. ATPV is defined in ASTM F 1959, *Standard Test Method for Determining the Arc Thermal Performance Value of Materials for Clothing,* as the incident energy on a material or a multilayer system of materials that results in a 50% probability that sufficient heat transfer through the tested specimen is predicted to cause the onset of a second degree skin burn injury based on the Stoll curve, cal/cm2. $E_{BT}$ is defined in ASTM F 1959 as the incident energy on a material or material system that results in a 50% probability of break open. Arc rating is reported as either ATPV or $E_{BT}$, whichever is the lower value.

## 5.4 Working Space about Electrical Equipment

### 5.4.1 Spaces Around Electrical Equipment

a. Sufficient access and working space 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 5 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 5. Distances shall be measured from the exposed live parts or from the enclosure or opening if the live parts are enclosed.

**Table 5. 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 required by NFPA 70E 400.15(E). 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 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.

### 5.4.2 Other Working Space Requirements

Entrance to and egress from working spaces, illumination, headroom, and dedicated equipment space shall be maintained in accordance with NFPA 70E Article 110.26C**.**

## 5.5 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.

### 5.5.1 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 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.

### 5.5.2 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 130.5 (E)(1).

### 5.5.3 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.

## 5.6 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 5.3.6.

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 lockout/tagout devices in accordance with a formal, written lockout procedure.

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 Extension Cords

a. NEC Article 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 90 days.

c. Use of extension cords and relocatable 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 a qualified employee knowledgeable in wiring methods as required by the NEC for electrical equipment.

3. Be constructed with cable conductor sized appropriately for the voltage and amperage (amp) rating required for the intended use.

4. Be verified for correct phasing of the cord, hot-to-hot, neutral-to-neutral, and ground-to-ground, by the employee constructing the extension cord during assembly.

f. Damaged cords shall be replaced, not repaired.

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

h. Continuity of electrical wall receptacles shall be checked during facility safety inspections.

i. 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.

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

k. 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.

l. 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.

m. Portable cord-and-plug-connected equipment and extension cords must be visually inspected before 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.

n. 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.

o. Extension cords must be protected from damage. Sharp corners must be avoided. Flexible cords may 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 may 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.

p. 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.

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

r. 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.

s. Extension cords must be of the three-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.

t. 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.

u. 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.

v. 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.

w. 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.
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.

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

y. 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.

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

### 6.2 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.

b. Branch circuits must originate in an approved power outlet or panel board.

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.

g. Lamps for general illumination shall be protected from accidental contact or damage, either

by elevating the fixture or by providing a suitable guard.

h. Hand lamps supplied by flexible cord shall be equipped with a handle of molded composition or other approved material and equipped with a substantial bulb guard.

### 6.3 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, such as coffee makers and microwave ovens.

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.

### 6.4 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. Portable electrical tools, lamps, and extension cords shall be inspected before use.

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

e. Portable electrical tools, except for approved, intrinsically safe instruments, shall meet the standards for use in any area that meets the NFPA Classification for Class I/Division I or Class I/Division II per SCWI-8715-0012.

f. Only pneumatic tools shall be used in areas that meet the NFPA Class I/Division I and Class I/Division II classification.

g. 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.

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

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

j. The operating control on hand-held 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.

k. 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.

l. Hand-held powered drills, horizontal/vertical/angle grinders with wheels greater than two (2) inches in diameter, disc sanders with discs greater than 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.

### 6.5 Electric Drills

a. If an operator is required to guide the drill with his/her hand, the drill shall be equipped with a bushing that fits over the drill bit.

b. When large powered drills are used, small pieces of wood shall be clamped/anchored to prevent whipping.

c. Drills shall not be modified by installing a larger capacity chuck than it is designed for and supplied from the manufacturer. If a larger drill size than the chuck capacity is needed, then a step-down shank drill is to be utilized.

d. Only screw-on handles supplied by the drill manufacturer shall be used to counteract drill motor torque. Damaged and/or homemade handles are not permitted.

### 6.6 Portable Hand Lamps/Temporary Lighting

a. Only explosion-proof lamps shall be used in areas classified by NFPA 70E 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 12 volts or must be protected by GFCIs.

### 6.7 Emergency Lighting

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

b. Adequate emergency lighting shall be provided for all occupied facilities.

c. A minimum of one (1) foot candle of illumination shall be provided throughout the major paths of exit travel, including angular pathway changes, intersections of corridors and passageways, stairways and stair landings, and emergency exit doors.

d. Emergency lighting shall provide minimum illumination of one (1) foot candle for 1.5 hours.

e. Emergency lighting shall energize automatically upon failure of the general and/or supplementary lighting systems.

f. Exit signs shall be suitably illuminated by a reliable light source of not less than five (5) foot candles on the illuminated surface.

## 7.0 Special Requirements for Electrical Safety

### 7.1 Grounding

a. Exposed noncurrent carrying metal parts of cord- and plug connected equipment that can become energized shall be grounded.

b. Portable electric tools protected by a system of double insulation shall not require grounding.

c. Where a system of double insulation is used, the equipment shall be distinctively marked.

d. Cord-connected portable tools likely to be used in wet and conductive locations shall be protected by a GFCI.

e. Portable electrical devices used inside/on conductive surfaces shall be equipped with a GFCI.

f. All electrical equipment using over 24 volts in a confined space shall be protected by a GFCI.

### 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.

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

    1. When initial installation is completed

    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. At intervals not to exceed one (1) year every six (6) months for explosive operations/facilities

h. 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.

i. 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.

j. Maximum Resistance to Ground: The maximum resistance to ground permitted for different types of equipment/systems is as follows:

    1. Hazardous Locations - All conductive parts of equipment shall be grounded so that resistance does not exceed 25 ohms. The exception is for lightning protection, which requires 10 ohms or less.

    2. Non-hazardous Locations - Non-electrical equipment in non-hazardous locations need not be grounded unless for static dissipation, but should be grounded as part of the lightning protection system if present (refer to NFPA 780).

k. 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-stats 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.

l. 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.

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

    1. Transfer of Flammable Solvents into Tanks - Free fall of liquid must be avoided. Liquid should be introduced below the surface of the liquid in the tank. A slowing down of this motion will reduce the rate of the generation of static electricity.

    2. 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.

n. ESD Measures for Hydrogen: ESD measures/controls for working with liquid/gaseous hydrogen:

1. Electrostatic Energy Ignition - Electrostatic energy can be a source of ignition with hydrogen requiring as little as 0.017 millijoules (Milliwatt-Seconds) of energy to ignite. Electrostatic energy of sufficient voltage to cause ignition can be generated by several mechanisms, including:

   a) Two (2) phase fluid flow.

   b) Solid particles traveling in fluid flow.

   c) Possible fluid flow through nonconductive enclosures/piping.

   d) Generation of static electricity in garments worn by operating personnel.

2. Conductive Piping - Facility piping shall be shown to be conductive throughout its entirety. Special concern shall be paid to means of joining to assure adequate flow to the facility ground.

3. Conductive Plastics - Conductive plastics (bonded/grounded) shall be given strong consideration for enclosures that must be used in temporary/permanent applications of testing at SSC.

4. Prevention of Charge Buildup - To preclude possible charge build up and subsequent ignition of hydrogen in nonconductive tubing/piping, the following actions will be given a high consideration (listed in order of priority) when designing hydrogen systems:

   a) Substitute conductive materials and provide facility grounding of such

   b) Substitute plastics that are designed to limit charge buildup

   c) Limit the flow rates to a level that will not induce a charge

   d) Preclude air/oxygen entrainment by use of facility purges

### 7.3 Equipment Labeling

a. NEC Article 110.16 requires switchboards, panel boards, industrial control panels, and motor control centers 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.

e. Labels shall be either of the two (2) examples (or similar) shown in Figure 1 or Figure 2 depending on the available resources of the agency.

f. The Figure 1 DANGER label shall be used when information is not presently available. This is the minimum NEC 110.16 requirement.

g. This DANGER label should remind a qualified worker who intends to open the equipment for analysis or work of the following:

    1. Electric arc flash hazard exists

    2. Turn off all power before opening

    3. Follow all requirements of NFPA 70E for safe work practices and wear appropriate PPE for the specific hazard

h. The DANGER label shown in Figure 2 shall be used when a qualified electrical worker or electrical engineer determines the values of the shock and flash protection information.

i. 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.

j. An unqualified person must not be near open-energized equipment.

The example label in Figure 1 shall be affixed to industrial control panels (every enclosure that may contain exposed energized conductors or components) immediately:


**Figure 1. Electric Arc Flash Hazard Warning Label.**

The label in Figure 2 is an example of a label to be affixed to industrial control panels after arc flash hazard analysis has been completed.


**Figure 2. Post-analysis Arc Flash Hazard Label.**

## 8.0 Safety Precautions and Warning Notes

a. **DO NOT DISTURB OR TAMPER** with any lock or tag that is placed on an energy-isolation device.

b. Electric shock is the leading cause of injuries and death due to electricity. Electrical injuries consist of four (4) main types:

   1. Electrocution (fatal)

   2. Electric shock

   3. Burns

   4. Falls (caused as a result of contact with electrical energy)

c. Electrocution (fatal) occurs when the human body is in direct contact with the electrical energy and becomes part of an active electrical circuit that has a lethal amount of current capable of overstimulating the nervous system or causing damage to the internal organs.

d. The extent of injury received from electrical energy depends on the following:

   1. The current's magnitude (measured in amps.

   2. The pathway of the current through the body.

   3. The duration of the current flow through the body.

e. Never touch anyone being shocked or you can also become shocked. To free someone from an electrical shock, disconnect the power or attempt to strike the person with a nonconductive object strong enough to knock him/her loose from the current (600 volts and below).

f. The frequency of the Alternating Current (AC) affects the human body. AC 60-cycle current is more dangerous than higher frequency currents.

g. AC is more dangerous than DC and is likely to cause a victim's heart to fibrillate and cause severe muscular contractions.

h. All voltages are considered dangerous, but the electrical current causes the damage. Current equals voltage divided by resistance (I = V/R). The resistance of the human body varies so

widely that it is impossible to state that one (1) voltage is "dangerous" and another is "safe."

i. The effects of electrical shock can vary from a slight tingle to immediate cardiac arrest.

j. The severity of shock from a given source depends on the current's path through the body.

## 9.0 Audit Process

The electrical safety program will be audited every twelve (12) months using SSC Form 827, Electrical Safety Audit Form.

## 10.0 Training Requirements

### 10.1 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 110.6(D) 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

d. Training shall be documented.

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 and refresher training on a yearly basis.

### 10.2 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 110.6(D) 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 NESHO program and a refresher training every three (3) years.

## 11.0 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.

## 12.0 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. SSC Form 222, Permit for Use of Small Appliance

b. SSC Form 869, Electrical Safety Audit

c. Energized Electrical Work Permit

## 13.0 APPENDIX A - ACRONYMS, ABBREVIATIONS, AND DEFINITIONS

### A.1 Acronyms and Abbreviations

| | |
|---|---|
| AC | Alternating Current |
| amp | Amperage |
| ASTM | American Society for Testing and Material |
| CB | Circuit Breaker |
| CFR | Code of Federal Regulations |
| DC | Direct Current |
| ESD | Electrostatic Discharge of Energy |
| FOSC | Facility Operating Service Contractor |
| FR | Flame Resistant |
| GFCI | Ground-Fault Circuit Interrupter |
| 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 |
| SMA | Safety and Mission Assurance |
| SCWI | Stennis Common Work Instruction |
| SSC | John C. Stennis Space Center |

### A.2 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.

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.

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 10.0, 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 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, insulating and shielding materials, and insulated tools.

Restricted Approach Boundary – The closest distance a qualified employee is permitted to approach exposed, energized parts without wearing PPE, using insulated tools due to the increased risk of electric shock from inadvertent movement while working in close proximity to energized parts.

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.

Safety Assessment – An evaluation of the work associated with the equipment or systems to identify the hazards and reduce them to an acceptable level. The process of determining what can go wrong, how the effects of the failure can be prevented, and implementing preventative measures (i.e., wearing PPE, safe-work practices).

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.

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.