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John C. Stennis Space Center
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COMPLIANCE IS MANDATORY

John C. Stennis Space Center
Arc Flash Standard

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Document History Log

Change/ Revision	Change Date	Originator/ Phone	Description
Basic	10/22/15	Matt Willis 8-7678	Initial release.
Rev. A	5/16/16	Matt Willis 8-7678	6.2-e: Deleted, moving reference to Arc Flash Requirement Flow Chart to body of 6.2. 6.3: Revised to reflect arc flash hazard assessment data management. 6.4-c: Changed "panels" to "panels, equipment or devices." 7.0-b: Added SSC Form 928.
Rev. B	8/18/20	Delton Rodriguez / 8-2499 Matthew Ladner / 8-2386	Updated directorate titles on cover sheet as necessary. Updated references and acronyms. "Arc Flash Hazard Assessment" changed to "Arc Flash Hazard Study/Analysis" throughout document. Section 2.0-a: Added "SSTD-8070-0081-ELEC, and SCWI-8715-0006." Section 5.0: Revised Arc Flash Overview, defining electric arc/arching fault and the circumstances under which an incident energy analysis shall be reviewed and updated as necessary. Section 6.0: Revised in its entirety. Section 7.0: Added SSC Form 929. Verified and/or updated all SSC Arc Flash Analysis forms, as necessary. Section 9.0: Added definitions. Section 10.0: "Are electrical designs XFMR ≥125kVA and <240V or XFMR ≥15kVA and ≥240V?" changed to "Are electrical designs of three-phase equipment operating ≥ 208V to 15kV with available short-circuit current of ≥ 2kA AC?" "Does the mod have motor >50 HP?" changed to "Does the design have permanently installed generators?" "Will produce a short circuit current ≥4kADC?" changed to "Battery banks with voltage ≥100 VDC the short-circuit current ≥2kA DC?" Final approved Arc Flash Hazard Analysis submitted for entry into DDMS rather than CEF.

Table of Contents

1.0 PURPOSE

This John C. Stennis Space Center (SSC) standard (SSTD) establishes the requirements for electrical arc flash safety at SSC.

2.0 APPLICABILITY

a. This SSTD as well as SSTD-8070-0081-ELEC, and SCWI-8715-0006 apply to all SSC NASA organizations, resident agencies, contractors and subcontractors dealing with electrical systems at SSC.

b. The requirements in this SSTD apply to new construction, renovations, modifications, and maintenance, as well as to all employees working with or exposed to electrical hazards.

3.0 REFERENCES AND APPLICABLE DOCUMENTS

Referenced documents shall be the latest edition unless otherwise specified.

29 CFR 1910.132, *Personal Protective Equipment*
29 CFR 1910.147, *Control of Hazardous Energy (Lockout/Tagout)*
29 CFR 1910.269, *Electric Power Generation, Transmission, and Distribution*
29 CFR 1910.335, *Safeguards for Personnel Protection*
ANSI C37.50, *Switchgear - Low Voltage AC Power Circuit Breakers Used in Enclosures – Test Procedures*
ANSI Z535.4, *Product Safety Signs and Labels*
IEEE 1584, *IEEE Guide for Performing Arc Flash Hazard Calculations*
NEC/CEC Global Reference Guide
NEMA AB3-2001, *Molder Case Circuit Breakers and their Application*
NFPA 70E, *Standard for Electrical Safety in the Workplace*
SCWI-8715-0006, *SSC Electrical Safety Program*
SPR 1440.1, *SSC Records Management Program Requirements*
SSTD-8070-0005-CONFIG, *SSC Preparation, Review, Approval, and Release of SSC Standards*
SSTD-8070-0009-CONFIG, *SSC Preparation of Form SSC-625, Certificate of Completion (COC)*
SSTD-8070-0081-ELEC, *SSC Facility Electrical Standard*
SSTD-8070-0083-ELEC, *SSC Standard for 13.8kV Distribution System*
UL248, *NEMA® Electrical Installation Requirements*
UL489, *Circuit Breakers*
UL1004, *Standard for Rotating Electrical Machine*
UL1077, *Supplementary Protectors*

4.0 RESPONSIBILITIES

a. Users of this SSTD shall comply with its requirements, ensure use of the correct version of this SSTD and the documents it references, and inform the appropriate organization of needed changes in accordance with SSTD-8070-0005-CONFIG.

b. Responsibilities for the use and control of this SSTD and for the review and approval of revisions or cancellation of this SSTD shall be as specified in SSTD-8070-0005-CONFIG and the applicable documents referenced therein.

5.0 ARC FLASH OVERVIEW

An electric arc or an arcing fault is a flashover of electric current through air in electrical equipment from one exposed live conductor to another or to ground. Arc flash hazard is the danger of excessive heat exposure and serious burn injury due to arcing faults in electrical power systems. Electric arcs produce intense heat, sound blast, and pressure waves. They have extremely high temperatures, radiate intense heat, can ignite clothes, and can cause severe burns that can be fatal.

An incident energy analysis shall be updated when changes occur in the electrical distribution system that could affect the results of the analysis. The incident energy analysis shall also be reviewed for accuracy at intervals not to exceed five (5) years.

5.1 Properties of Electrical Arc Flash

Properties of Electrical Arc Flash include:

a. Electric arcs produce some of the highest temperatures known to occur on earth – up to 35,000 degrees Fahrenheit (°F), four times the surface temperature of the sun.

b. All known materials are vaporized at this temperature. When materials vaporize, they expand in volume (copper, 67,000 times; water, 1,670 times). The air blast can spread molten metal to great distances with force.

c. The intense heat from arc causes the sudden expansion of air. This results in a blast with strong air pressure. (Lightning is a natural arc).

d. For a low voltage system (less than 600V), a 3- to 4-inch arc can become “stabilized” and persist for an extended period of time.

e. Energy released is a function of system voltage, fault current magnitude, and fault duration.

f. Arcs in enclosures, such as a Motor Control Center (MCC) or switchgear, magnify blast. Energy transmitted as the blast is forced to the open side of the enclosure and toward the worker.

5.2 Hazards of Arc Faults

Hazards of arc faults include:

5.2.1 Heat

Fatal burns can occur when the victim is several feet from the arc. Serious burns are common at a distance of 10 feet. Staged tests have shown temperatures greater than 437°F on the neck area and hands for a person standing close to an arc blast.

5.2.2 Objects

Arcs spray droplets of molten metal at high-speed pressure. Blast shrapnel can penetrate the body.

5.2.3 Pressure

Blast pressure waves have thrown workers across rooms and knocked them off ladders. Pressure on the chest can be higher than 2,000 lbs/sq.ft.

5.2.4 Fire

Clothing can be ignited several feet away. Clothed areas can be burned more severely than exposed skin.

5.2.5 Hearing loss from sound blast

The sound can have a magnitude as high as 140 dB at a distance of 2 feet from the arc.

6.0 ARC FLASH REQUIREMENTS

Arc Flash Hazard Study/Analysis may be used interchangeably to describe the Arc Flash Hazard calculation that is to be performed by a qualified Engineer to determine the thermal incident energy found at each location, which determines the arc flash boundary and what personal protective equipment (PPE) must be used in approaching the boundary. As part of the study, the Engineer should also provide recommendations to reduce the incident energy/arc flash hazard category.

The requirements of an arc flash hazard analysis are as follows:

6.1 An arc flash hazard analysis shall be performed for all new or modified work involving three-phase equipment operating at ≥208V to 15kV with an available short-circuit current of ≥2kA AC, permanently installed generators, and battery banks with the short-circuit current ≥2kA DC. Refer to the Arc Flash Requirement Flow Chart (see Section 10.0) and other design calculations as required by the NASA Project Manager (PM).

6.1.1 All arc flash hazard labels shall be:

- Compliant with SCWI-8715-0006.
- Compliant with ANSI Z535.4.
- Reviewed for accuracy at intervals not to exceed five (5) years.
- Recalculated if the modification of equipment or upgrade of the power system results in any change to the level of PPE protection required.

6.1.2 Arc flash hazard analysis shall be performed by, or under the direction of:

a. SACOM: Experienced and qualified Electrical Engineer who has completed formal commercial training in power quality, short-circuit studies, NFPA 70E, and IEEE 1584, and who has significant commercial experience in performing arc flash hazard analysis.

b. Outside Contractor/A&E firm: Professional Engineer (PE) familiar with power quality, short-circuit studies, NFPA 70E, and IEEE 1584.

6.1.3 Arc flash hazard analyses developed for SSC shall be reviewed and approved by NASA, or its designee's Electrical Engineering Lead, to be considered delivered and complete.

6.1.4 Data shall be submitted to the onsite facility contractor's Design Engineer in the most current version of SKM Power Tools for Windows or other electronic format as approved by the NASA PM.

6.2 SSC arc flash hazard analysis data modeling procedures are as follows:

6.2.1 Each building will be identified within the Design and Data Management System (DDMS) with a subfolder under Electrical Systems, Power Systems, Electrical Arc Flash Analysis, which will serve as the authoritative repository for that building's completed arc flash hazard analysis report and subsequent updates to that report.

6.2.2 The subfolder within DDMS shall contain a zip file of each version/iteration of arc flash hazard analysis information, including but not limited to SKM electronic modeling files, library files, project files, associated relay files, nameplate photo, and original arc flash hazard analysis field sheets.

6.2.3 Use equipment evaluation ANSI short-circuit results to verify all equipment passes Kilo Ampere Interrupting Capacity (KAIC) rating and coordinated Time Current Curve (TCC) over current setting.

6.2.4 When a modification to the SKM model is required by SACOM or designated subcontractor, the SACOM Design Engineer shall upload that modification to the appropriate subfolder defined above as follows:

a. "Check out" the most current version of the zipped file object.

1. Modify SKM Modeling one-line diagram to add or remove equipment as required:

- Remove equipment: Destroy (SKM language indicating the deletion or removal of) equipment within the model and remove photo of nameplate on SKM one-line diagram and photo folder. Proceed to 6.2.4-b.

- Add Equipment: Verify project involves a new utility feeder or equipment replacement.

i. New utility feeder
   - Verify Mississippi Power Company (MPC) utility impedances in the system and collect installation data such as busses, conductors, lengths, size of equipment, impedances, KAIC, vertical conductors/electrodes inside a metal box/enclosure (VCB), vertical conductors/electrodes terminated in an insulating barrier inside a metal box/enclosure (VCBB), horizontal conductors/electrodes inside a metal box/enclosure (HCB), vertical conductors/electrodes in open air (VOA), and horizontal conductors/electrodes in open air (HOA) photo of nameplate of equipment.
   - Build SKM modeling with new data, including photo of nameplate.
   - Proceed to Step 6.2.4-b.

ii. Equipment replacement
- Verify data of equipment on existing SKM Modeling.
- Conduct equipment evaluation to determine its KAIC rating.
- Determine the equipment electrode configuration, such as VCB, VCBB, HCB, VOA, and HOA.
- Re-select data input on existing SKM Modeling to match new equipment.
- Proceed to 6.2.4-b.

b. Run arc flash calculations using worst-case scenarios, and submit report with labels to SACOM/NASA for verification and approval prior to printing.

c. Provide PDF electronic files of the following documents to SACOM/NASA for verification and approval:
- SSC Arc Flash Analysis (see Section 7.0, *Records and Forms*)
- SKM one-line data input
- SKM one-line current flow analysis
- SKM one-line Arc Flash Analysis
- SKM Arc Flash reports
- SKM equipment evaluation
- SKM Fault Analysis Summary
- TCC diagram, including overcurrent setting
- Arc flash labels

6.2.5 The SKM model and all supporting documentation shall be zipped into a single folder and managed as a single object in DDMS.

6.2.6 "Check in" the zipped file of the SKM Model within DDMS.

6.2.7 Route the zipped file, including SKM Model and all supporting documentation, on DDMS for verification and approval by SACOM/NASA.

6.2.8 A new Equipment Room One-Line diagram shall be created that complies with the requirements of NFPA 70 and is 11-by-17 inches in size, laminated, and magnetically attached to the switchgear. Components of double-ended unit substations that are not in physical sight of each other will receive individual copies of the facility Equipment Room One-Line prepared and attached as indicated above.

6.2.9 The modified electrical work and arc flash evaluation shall be documented in accordance with SSTD-8070-0009-CONFIG.

7.0 RECORDS AND FORMS

a. Records and forms required by the procedures of this SSTD shall be maintained in accordance with SPR 1440.1.

b. All records and forms are assumed to be the latest edition unless otherwise indicated. Forms may be obtained from the SSC Electronic Forms repository or from the NASA SSC Forms Management Officer. Quality Records are identified in the SSC Master Records Index.

Forms

SSC Arc Flash Analysis forms for this SSTD are as follows:

SSC Form 920, *UPS Data Acquisition*
SSC Form 921, *ATS and MTS Data Acquisition*
SSC Form 922, *Generator Data Acquisition*
SSC Form 923, *Low Voltage Panelboard Data Acquisition*
SSC Form 924, *Transformer Data Acquisition*
SSC Form 925, *Low Voltage Feeder Data Acquisition*
SSC Form 926, *Low Voltage MCC/MOTOR Data Acquisition*
SSC Form 927, *Low Voltage Switchgear Data Acquisition*
SSC Form 928, *High Voltage SF 6 Switch*
SSC Form 929*, Low Voltage Switch*

8.0 ACRONYMS AND ABBREVIATIONS

AC	Alternating Current
CFR	Code of Federal Regulations
°	degrees
dB	decibels
DC	Direct Current
DDMS	Design and Data Management System
F	Fahrenheit
HCB	Horizontal conductors/electrodes inside a metal box/enclosure
HOA	Horizontal conductors/electrodes in open air
IEEE	Institute of Electrical and Electronics Engineers
lbs/sq.ft.	pounds per square foot
kA	Kilo Amps
KAIC	Kilo Ampere Interrupting Capacity
MCC	Motor Control Center
MPC	Mississippi Power Control
NASA	National Aeronautics and Space Administration
NEMA	National Electrical Manufacturers Association
NFPA	National Fire Protection Agency
OSHA	Occupational Safety and Health Administration
PDF	Portable Document Format
PE	Professional Engineer
PM	(Project Manager)
PPE	Personal Protection Equipment
SCWI	John C. Stennis Space Center Common Work Instruction
SSC	John C. Stennis Space Center
SSTD	John C. Stennis Space Center Standard
SPR	Stennis Procedural Requirements
TCC	Time Current Curve
UL	Underwriters Laboratories
V	Volts
VCB	Vertical conductors/electrodes inside a metal box/enclosure
VCBB	Vertical conductors/electrodes terminated in an insulating barrier inside a metal box enclosure
VOA	Vertical conductors/electrodes in open air

9.0 DEFINITIONS

Arc Blast – A pressure wave resulting from arcing.

Arc Flash Boundary - When an arc flash hazard exists, an approach limit from an arc source at which incident energy equals 1.2 cal/cm2 (5 J/cm2).

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 Hazard – A source of possible injury or damage to health associated with the release of energy caused by an electric arc.

Arc Flash Hazard Study/Analysis – Study and/or analysis may be used interchangeably to describe the Arc Flash Hazard calculation that is to be performed by a qualified engineer to determine the thermal incident energy found at each location which determines the various arc flash boundaries and what personal protective equipment (PPE) must be used in approaching each boundary. As part of the study, the Engineer should also provide recommendations to reduce the incident energy/arc flash hazard category. An Arc Flash Risk Analysis should only be performed by experienced and qualified Electrical Engineers familiar with power quality, short-circuit studies, NFPA 70E, and IEEE 1584.

Arc Flash Risk - A source of possible injury or damage to health associated with the release of energy caused by an electric arc.

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

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

Destroy – SKM language indicating the deletion or removal of equipment.

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

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

Electrical Safety - Identifying risks associated with the use of electrical energy and taking precautions to reduce the risk associated with those risks.

Electrical Safety Program - A documented system consisting of electrical safety principles, policies, procedures, and processes that directs activities appropriate for the risks associated with electrical systems.

Enclosure - The case or housing of apparatus — or the fence or walls surrounding an installation to prevent personnel from unintentionally contacting energized electrical conductors or circuit parts or to protect the equipment from physical damage.

Exposed (as applied to energized electrical conductors or circuit parts) - Capable of being inadvertently touched or approached nearer than a safe distance by a person. It is applied to electrical conductors or circuit 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.

Fault Current - The amount of current delivered at a point on the system during a short-circuit condition.

Fault Current, Available. The largest amount of current capable of being delivered at a point on the system during a short-circuit condition.

Ground - The earth.

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. High Voltage work is considered Safety Critical and requires approval of the cognizant safety representative in addition to the cognizant engineer per SPR 8715.1 Safety and Health Program Requirements.

HCB – Horizontal conductors/electrodes inside a metal box/enclosure. An HCB may be found in a bucket with no breaker or with a fused switch. The HCB directs the arc flash directly out of the enclosure.

HOA – Horizontal conductors/electrodes in open air.

Incident Energy - The amount of thermal energy impressed on a surface, a certain distance from the source, generated during an electrical arc event. Incident energy is typically expressed in calories per square centimeter (cal/cm2).

Incident Energy Analysis - A component of an arc flash risk assessment used to predict the incident energy of an arc flash for a specified set of conditions.

Label - Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the Authority Having Jurisdiction and concerned with product evaluation, that maintains periodic inspection of production of labeled equipment or materials, and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner. (Note: The product shall only have NEC 500 USA markings [Class 1 Division 1 Groups A, B, C & D T6]. No other markings, e.g., EU/ATEX/IECEX, are permitted.")

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.

Maintenance (condition of) - The state of the electrical equipment considering the manufacturers' instructions, manufacturers' recommendations, and applicable industry codes, standards, and recommended practices.

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.

Panelboard - A single panel or group of panel units designed for assembly in the form of a single panel, including buses and automatic overcurrent devices, and equipped with or without switches for the control of light, heat, or power circuits; designed to be placed in a cabinet or cutout box placed in or against a wall, partition, or other support; and accessible only from the front.

Qualified Person/Employee – A person who has received training per 29 CFR 1910.332 and Section 9.0, Training Requirements, of SCWI-8715-0006; possesses the skills and knowledge related to the construction and operation of the electrical equipment/systems and installations; and has received safety training to identify the hazards involved and reduce the associated risks. 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.

Risk - A combination of the likelihood of occurrence of injury or damage to health and the severity of injury or damage to health that results from a risk.

Risk Assessments – An overall process that identifies risks, estimates the likelihood of the occurrence of the injury or damage to health, estimates the potential severity of injury or damage to health, and determine if protective measures are required. Note: Arc Flash Hazard Study/Analysis and Shock Risk Assessment are elements of risk assessments.

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 Risk Assessment - A shock risk assessment shall determine the voltage of the circuits and equipment to which personnel will be exposed, the boundary requirements (limited and restricted) and the required personal and other protective equipment required to safely perform the assigned task and to protect against the shock hazard.

VCB – Vertical conductors/electrodes inside a metal box/enclosure. The VCB directs the arc in the enclosure a further distance.

VCBB – Vertical conductors/electrodes terminated in an insulating barrier inside a metal box/enclosure. The VCBB directs the arc inside of the enclosure until it hits a barrier and then directs the energy out of the enclosure. The VCBB would be connections above a breaker within an enclosure.

VOA – Vertical conductors/electrodes in open air.

Working On (energized electrical conductors or circuit parts) - Intentionally coming in contact with energized electrical conductors or circuit parts with the hands, feet, or other body parts, with tools, probes, or with test equipment, regardless of the personal protective equipment (PPE) a person is wearing. There are two categories of "working on": Diagnostic (testing) is taking readings or measurements of electrical equipment with approved test equipment that does not require making any physical change to the equipment; Repair is any physical alteration of electrical equipment (such as making or tightening connections, removing or replacing components, etc.).

10.0 APPENDIX:
Arc Flash Requirements Flow Chart