



14 FEBRUARY 2023

Safety

ELECTRICAL SAFETY PAMPHLET

ACCESSIBILITY: Publications and forms are available on the e-Publishing website at www.e-Publishing.af.mil for downloading or ordering

RELEASABILITY: There are no releasability restrictions on this publication

OPR: 75ABW/SEG

Certified by: 75ABW/SE
(Greg Hoffman)

Pages: 36

This publication implements DAFMAN 91-203, *Air Force Occupational Safety, Fire and Health Standards*, AFMAN 32-1065, *Grounding and Electrical Systems*, NFPA 70E, *Standard for Electrical Safety in the Workplace*, NFPA 70, *National Electric Code*, and UFC 3-560-01, *Operation and Maintenance: Electrical Safety*. It provides informational guidance on safe electrical procedures. Refer recommended changes and questions about this publication to the OPR listed above using the DAF Form 847, *Recommendation for Change of Publication*; route DAF Forms 847 from the field through the appropriate chain of command. Ensure all records created as a result of processes prescribed in this publication are maintained in accordance with AFI 33-322, *Records Management and Information Governance Program*, and disposed of in accordance with the Air Force Records Disposition Schedule (RDS) located in the Air Force Records Management System. 75 ABW/SE will review and update this pamphlet annually following any changes in the national electrical safety and National Fire Protection Association (NFPA) standards.

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Chapter 1

PLAN OVERVIEW

1.1. Purpose.

1.1.1. This Electrical Safety Pamphlet (ESP) details best practices for Hill Air Force Base (HAFB) organizations to accomplish and document electrical safety practices. The ESP provides a framework for HAFB commanders, directors, flight chiefs, supervisors, and work leads to provide a safe work environment for personnel relative to electrical hazards. This ESP addresses employee exposure at or above 50 volts; however, voltages below 50 volts may still present a hazard and shall be considered during hazard and risk analysis as described in this ESP.

1.2. Scope.

1.2.1. This ESP adopts the 2020 NFPA 70E and does not require update upon version release. Should NFPA 70E change in a way that affects operations at AFB the ESP will be updated as necessary.

1.3. Recommendations.

1.3.1. Due to the age of facilities, and changes to the electrical code the status of electrical infrastructure at HAFB should be treated as unknown. Some recommendations from the Electrical Safety Working Group (ESWG) are given below:

- 1.3.1.1. Make risk management part of every task that involves work on or near electrical systems.
- 1.3.1.2. The inherent hazards associated with the electrical infrastructure's condition of maintenance shall be communicated to all affected electrical workers to include contracted workers.
- 1.3.1.3. Implement a thorough Job Safety Analysis (JSA) for every job/task.
- 1.3.1.4. Incorporate this document into electrical safety work practices.
- 1.3.1.5. Provide training, for general, and task-specific safe electrical work practices.

Chapter 2

GUIDANCE AND PROCEDURES

2.1. Work Practices.

2.1.1. All electrical parts and equipment shall be installed and maintained in a safe manner in accordance with current standards. All electrical work will be accomplished on de-energized equipment unless de-energization will cause additional and unacceptable hazards. Employees will not perform testing or troubleshooting on energized equipment if the hazards have not been fully assessed, understood and/or mitigated to acceptable levels.

2.1.2. Energized Work will be avoided as much as possible. In the rare event that energized maintenance work must be done, it shall be approved by the Installation Base Civil Engineer (BCE), or authorized equivalent, using an energized work permit.

2.1.2.1. Energized work is defined as service or maintenance performed on or near exposed energized equipment.

2.1.2.2. Energized troubleshooting includes visual inspections and electrical, infrared, and ultrasound measurements, taken with rated equipment on or near exposed and energized equipment.

2.2. Employee and Management Responsibilities.

2.2.1. Employees need to report all electrical near misses, injuries and unsafe conditions to their supervisors and the safety office. Management will provide the resources to correct unsafe conditions and will both promote and influence safe behavior.

2.3. ESP Alignment with Air Force Core Values.

2.3.1. This ESP implements the Air Force Core Values of “Integrity first, Service before self, and Excellence in all we do,” through alignment with existing standards, Air Force Manuals and industry best practices. Using this ESP as guidance for complying with the supporting standards will ensure our warfighting team is protected.

Chapter 3

TRAINING

3.1. Training Requirements.

3.1.1. Training requirements apply to employees who are exposed to electrical hazards. Employees shall be trained to understand the specific hazards associated with electrical energy and understand the relationship between electrical hazards and potential injury. Supervisors shall maintain training records in a way that makes an electrical workers qualifications accessible and clear.

3.2. Qualifications.

3.2.1. Supervisors, Work Leads and Trainers of qualified electrical workers shall be trained to at least the qualified level. This training will take place prior to supervising or training employees working on or around electrical hazards.

3.2.2. Qualified electrical worker is a Journeyman, or equivalent, having completed a minimum of 30 hours of required training on and demonstrating proficiency in the following:

3.2.2.1. Skills and techniques necessary to distinguish exposed live parts from other parts of electrical equipment.

3.2.2.2. Skills and techniques necessary to determine nominal voltage of exposed live parts.

3.2.2.3. Clearance distances specified in 29 CFR § 1910.333(c) and the corresponding voltages.

3.2.2.4. The selection and use of proper Personal Protective Equipment (PPE), and insulating materials and tools.

3.2.2.5. The selection of appropriate test instruments and shall demonstrate how to use a device to verify the absence of voltage.

3.2.2.6. Understanding the limitations of test instruments and verifying that an instrument is operating properly.

3.2.2.7. Decision-making process necessary to perform job safety planning, identify electrical hazards, assess the associated risks and select appropriate risk controls from the hierarchy of controls.

3.2.2.8. First Aid Training, Cardiopulmonary Resuscitation (CPR), controlling bleeding, blood-borne pathogens, shock management, emergency care of a person having open wounds or burns, and using an Automated External Defibrillator (AED).

3.2.2.9. Developing and performing Lock-out/Tag-out (LOTO) procedures IAW 29 CFR § 1910.147, *The Control of Hazardous Energy (Lockout/Tagout)* and HILLAFBI 91-203, *Hazardous Energy Control (Lockout/Tagout)*. **NOTE:** Qualified or certified may not mean an employee is proficient at a particular task. Proficiency shall be determined through continued demonstrated knowledge, skill and ability. Training requirements for qualified electrical workers is listed in 29 CFR § 1910.331 to 335, NFPA 70E, UFC 3-560-01 and AFMAN 32-1065.

3.2.3. An Unqualified worker (Apprentice) does not meet qualification and training standards for a qualified electrical worker. Unqualified electrical workers shall be trained in the safety-related work practices listed in 29 CFR § 1910.332(b)(2) and those that pertain to their work assignments.

3.2.4. Authorized worker, for the purposes of hazardous energy control, is trained in proper LOTO methods. At no time may an employee work on equipment that has been locked and tagged by another authorized employee unless group LOTO procedures are being implemented.

3.2.5. Retraining of electrical workers in safety-related work practices due to applicable changes to this ESP, or the NFPA 70E shall be performed at intervals not to exceed 3 years. An employee shall also be retrained as soon as possible for the following reasons:

3.2.5.1. Workplace change that creates a new hazard or safety-related work practice

3.2.5.2. Tasks not performed more often than once per year

3.2.5.3. The employees' job duties change

3.2.5.4. The employee lacks the skills and knowledge to work on electrical equipment based on observations and inspections.

3.2.6. Licensed journeymen are the preferred new hire selection. Licensed new hires are not automatically qualified for all tasks by virtue of their license. Fully-qualified journeymen will be proficient at the performance knowledge training (code-pk) level listed in the Career Field Education and Training Plan (CFETP). Before electricians can be considered fully qualified, they must show proficiency by testing and or observation. Tasks that require an additional certification before allowing unsupervised work are listed on the AF IMT 797, *Job Qualification Standard Continuation/Command JQS*. Shop specific requirements will be listed on attachment 3 of the CFETP. If a new employee is not a licensed Journeyman, they will be considered unqualified (Apprentice). A qualified trainer will determine the scope of required training. Testing and observation will be used to certify knowledge. Apprentice electricians cannot work without direct supervision of a fully-qualified electrician unless the specific task is signed-off to the appropriate level in the training records.

3.2.7. Training will be documented using an effective method that allows a supervisor, lead, or trainer to determine an employee's proficiency level prior to assigning tasks.

3.2.7.1. Methods for documentation of training include but are not limited to: Air Force Training Records (AFTR), CFETP, Production Acceptance Certification (PAC), Advanced Distributed Learning Service (ADLS), Training Scheduling System (TSS), and AF Form 55, *Employee Safety and Health Record* or equivalent methods.

3.2.7.2. Affected tenant units may use tracking methods determined by their parent organization. The methods selected will still be audited by this ESP for sufficiency.

Chapter 4

WORK PRACTICES

4.1. Hazardous Energy Control (HEC).

4.1.1. HEC, also known as LOTO, shall be applied when working on or near exposed electrical equipment. Electrical work requiring de-energization, shall follow a written step-by-step HEC procedure. Authorized employees (see [paragraph 3.2.4](#)) shall be permitted to develop and perform HEC procedures.

4.2. Pre-Work Brief.

4.2.1. Qualified electrical workers will brief hazards to electrical workers and affected employees in the area prior to work based on the results of mandatory Job Safety Planning (JSP) using a JSA. At a minimum, the briefing will include:

- 4.2.1.1. Hazards associated with the job
- 4.2.1.2. Specific work procedures
- 4.2.1.3. Special precautions
- 4.2.1.4. Energy source controls
- 4.2.1.5. Special tools
- 4.2.1.6. PPE requirements

4.3. Right to Stop Work.

4.3.1. Any employee working on or around energized equipment or parts has the authority to give a stop work command if there is a perceived hazard. Work will not start until the hazard has been addressed and mitigated.

4.4. Working on Energized Electrical Systems.

4.4.1. Only Base Civil Engineering qualified electrical workers are authorized to perform service or maintenance on energized equipment with an approved energized work permit (AF Form 1213, *Civil Engineer Energized Electrical Work Permit*). Testing, troubleshooting and taking voltage measurements. Energized work or troubleshooting can only be performed when JSP has taken place, a JSA has been documented and the results of the JSA have been briefed to other affected electrical workers. An Electrical Energized Work Permit is not required if the restricted approach boundary is only crossed by equipment rated for troubleshooting within the restricted approach boundary. See NFPA 70E for exceptions to this requirement.

Table 4.1. Qualified Worker Minimum Approach Distances – AC Systems.

Nominal System Voltage Range Phase to Phase ¹	Limited Approach Boundary		Restricted Approach Boundary ^{2,3}
	Exposed Movable Conductor	Exposed Fixed Circuit Part	Includes Standard Inadvertent Movement Adder
<50 V	Not specified.	Not specified.	Not specified.
50 V to 150 V	10 ft 0 in (3.0 m)	3 ft 6 in (1.0 m)	Avoid contact
>151 V to 750 V	10 ft 0 in (3.0 m)	3 ft 6 in (1.0 m)	1 ft 0 in (0.3 m)
>750 V to 15 kV	10 ft 0 in (3.0 m)	5 ft 0 in (1.5 m)	2 ft 2 in (0.7 m)
>15 kV to 36 kV	10 ft 0 in (3.0 m)	6 ft 0 in (1.8 m)	2 ft 9 in (0.8 m)
>36 kV to 46 kV	10 ft 0 in (3.0 m)	8 ft 0 in (2.5 m)	2 ft 9 in (0.8 m)
>46 kV to 72.5 kV	10 ft 0 in (3.0 m)	8 ft 0 in (2.5 m)	3 ft 6 in (1.0 m)
>72.5 kV to 121 kV	10 ft 8 in (3.3 m)	8 ft 0 in (2.5 m)	3 ft 6 in (1.0 m)
>121 kV to 145 kV ⁴	11 ft 0 in (3.4 m)	10 ft 0 in (3.0 m)	3 ft 10 in (1.2 m)

Notes:

1. For single phase systems above 250 volts, select the range that is equal to the system’s maximum phase to ground voltage times 1.732.
2. The restricted approach boundary is defined as the distance between energized parts and grounded objects without insulation, isolation or guards.
3. The restricted approach distance applied to hot sticks is the distance between a worker’s hand and the working end of the stick.
4. Refer to NFPA 70E for AC voltages above 145 kV.

Table 4.2. Qualified Worker Minimum Approach Distances – DC Systems.

Nominal System Voltage Range Phase to Phase	Limited Approach Boundary		Restricted Approach Boundary
	Exposed Movable Conductor	Exposed Fixed Circuit Part	Includes Reduced Inadvertent Movement Adder
<50 V	Not specified	Not specified	Not specified
50 V to 300 V	10 ft 0 in (3.0 m)	3 ft 6 in (1.0 m)	Avoid contact
>300 V to 1 kV ¹	10 ft 0 in (3.0 m)	3 ft 6 in (1.0 m)	1 ft 0 in (0.3 m)

Note:

1. Refer to NFPA 70E for DC voltages above 1,000 V.

4.4.2. Maintenance on Uninterruptible Power Supply (UPS) batteries is allowed without an energized electrical work permit IAW UFC 3-560-01, Table 8-1, under “Batteries and Backup Power Systems.” when Standard Operating Procedures contained in [Attachment 4](#) are followed.

4.4.3. Any work required on or near energized equipment or parts shall require an Energized Work Permit (EWP). Only Base Civil Engineering qualified electrical workers are authorized to perform service or maintenance on energized equipment. The AF Form 1213 shall be used as the EWP and filled out as required by AFMAN 32-1065. EWPs shall be approved by BCE before maintenance work can be performed on energized electrical equipment.

4.4.4. Escalation of risk due to energized work shall follow the following hierarchy:

4.4.4.1. Eliminate the hazard and de-energizing equipment should be the preferred method of performing work on electrical systems.

4.4.4.2. Providing backup power to equipment in a way that allows work to be performed in a de-energized state while plant equipment remains in service.

4.4.4.3. Energized work to be performed only in rare circumstances that de-energization creates a greater risk, or other reasons not related to mere inconvenience.

4.5. Personal Protective Equipment (PPE).

4.5.1. PPE shall be used as required and defined in 29 CFR § 1910.137, NEC 70E and the JSA. Arc- and shock-rated PPE shall be clearly marked with class IAW 29 CFR § 1910.137(a)(1)(ii)

4.5.2. Insulating rubber gloves will be inspected prior to use, and ensure testing is current.

4.5.3. Leather over-gloves will be worn over insulating gloves IAW 29 CFR § 1910.137 (c)(2)(vii) and 29 CFR § 1910.335(a)(1)(iii).

4.5.4. Eye protection will conform to ANSI/ISEA Z87.1, *American National Standard For Occupational And Educational Personal Eye And Face Protection Devices*.

4.5.5. Non-conductive (Class E or G) head protection will conform to ANSI/ISEA Z89.1, *American National Standard For Industrial Head Protection*.

4.5.6. Foot protection will conform to ASTM F2412, *Standard Test Methods for Foot Protection* and ASTM F2413, *Standard Specification for Performance Requirements for Protective (Safety) Toe Cap Footwear*.

4.5.7. Arc-rated clothing will have an arc rating equal to or greater than the estimated incident energy, covering entire arms and legs.

4.5.8. Floor-insulating matting, if used, will comply with the requirements of T 00-25-232, *Control and Use of Insulating Matting for High-Voltage Application*.

4.5.9. Hearing protection as required.

4.6. Electrical Work Inspections.

4.6.1. All installed, modified and repaired electrical equipment will be inspected prior to re-energizing. The person conducting the inspection will be a qualified electrical worker other than the qualified electrical worker that performed the work. These inspections shall be documented.

4.7. Electrical Distribution Drawings.

4.7.1. If an electrical distribution system's physical configuration is modified, changes shall be tracked and single-line diagrams will be updated and reviewed at least every 5 years.

4.8. Emergency Equipment.

4.8.1. Emergency procedures will be included in the JSA. Emergency equipment should be located in an easily-accessible area and maintained in serviceable condition. Supervisors and leads may desire to have emergency equipment available at each operating location where maintenance is performed on energized circuits. Variations of the equipment staged at the job site will depend on the nature of the work and job site conditions. Additional items may be added as determined by the supervisor or lead. The equipment may be displayed on a board, stored in a cabinet, or available in a portable kit. Emergency equipment will be situated in a conspicuous and prominent location at each site, clearly-marked, and readily accessible to personnel. In addition to mandatory PPE requirements for working on or near low-, medium-, or high-voltage equipment, the following items may be included in an emergency equipment kit or board:

- 4.8.1.1. The safety instructions or procedures for the site.
- 4.8.1.2. CPR instructions.
- 4.8.1.3. CPR facemask with disposable mouthpiece.
- 4.8.1.4. Emergency phone numbers and building number.
- 4.8.1.5. First aid kit (This item is required if work is remote from the nearest medical facility).
- 4.8.1.6. Disposable gloves, which are impervious (leak proof) to body fluids, for first aid use.
- 4.8.1.7. Nonconductive cane or hook with an insulated handle, less than 180 degree bend.
- 4.8.1.8. High-voltage, insulating linesman's gloves.
- 4.8.1.9. 15 foot length, ½ or 5/8" natural fiber rope.
- 4.8.1.10. Insulated fuse pullers (where required).
- 4.8.1.11. Flashlight with nonmetallic case in operating condition.
- 4.8.1.12. Grounding stick (shorting stick).
- 4.8.1.13. Wool blanket.
- 4.8.1.14. Portable emergency signs constructed of nonconductive materials.

4.8.1.15. Air Force Visual Aids (AFVA) 91-303, DANGER—DO NOT ENERGIZE—PERSON WORKING ON ANTENNA; 91-304, DANGER—DO NOT ENERGIZE—WORK IN PROGRESS ON EQUIPMENT; 91-305, DANGER—INTERLOCKS DISABLED; and 91-306, DANGER—HIGH VOLTAGE, are available through the local publications distribution office.

4.8.1.16. Snake bite kit (remote work sites).

Chapter 5

RISK MANAGEMENT

5.1. Electrical Risk Assessments (ERAs).

5.1.1. The following paragraphs describe documents and processes that will be created and used for assessing and managing risks related to electrical work in accordance with AFI 90-802, *Risk Management*.

5.2. Single-Line Diagrams (SLDs).

5.2.1. NFPA 70E defines SLDs as: “A diagram that shows, by means of single lines and graphic symbols, the course of an electric circuit or system of circuits and the component devices or parts used in the circuit or system.” SLDs are used as the primary tool for maintaining configuration and control of the electrical power distribution systems.

5.2.2. All changes to the power system shall be approved and verified by SLD administrators before master copies of the SLD are modified. SLDs shall be reviewed at least every 5 years for their accuracy compared to the system’s physical configuration.

5.3. Electrical Drawings (EDs).

5.3.1. EDs show the building floor plan on a grid system. Each grid is divided up into individual drawings that show detailed floor plans and locations of electrical power distribution equipment throughout the facility. These drawings supplement the SLDs by showing where equipment is physically located. This aids in configuration and control, LOTO, and planning for modifications to the system.

5.4. Power System Models (PSMs).

5.4.1. PSMs are the primary tool for ERAs, power system analysis and power system modeling. The current software version of “EasyPower” shall be used by all HAFB organizations. SLDs shall be drafted in EasyPower. The SLD is referred to as a PSM when it is drafted in a version of EasyPower that is capable of power system analysis. Utilities in EasyPower shall be modeled using data from the utility provider. Utility models should begin on the line-side of the Overcurrent Protection Device (OCPD) nearest the primary side of the utility transformer. This ensures models are accurate and include the primary OCPD in the modeling.

5.5. SLD, ED and PSM Quality Control.

5.5.1. Processes shall be created to ensure that SLDs, EDs and PSMs are created or updated when HAFB facility power systems are modified. Standards shall be established to ensure that these critical drawings and models are created with consistency (See [Chapter 7](#)).

5.6. Contracted Power System Modifications.

5.6.1. When facility power systems are installed, modified, inspected, or tested by contracted manpower, the following references shall be followed, but not limited to: ESP, NFPA 70E, UFC 3-560-01, UFC 3-520 -01, *Interior Electrical Systems*, OO-ALCI 21-110, *Depot Facility Maintenance*, and section 14A of AFMAN 32-1065. When contradictions between the applicable references and the contractor's own ESP emerge, a documented meeting between the host employer (HAFB) and the contract employer shall be documented with the resulting determination of policy and procedures to follow.

5.7. Organic Power System Modifications.

5.7.1. When created by organic manpower, qualified engineering technicians, electricians, and electrical engineers will work together to collect system data in the field to create and/or update SLDs, EDs, and PSMs. Whether the SLDs, EDs and/or PSMs are created by contracted or organic manpower, 309th MXSG/MXDEQ Engineers shall be consulted for the technical requirements for creating these safety and mission critical documents.

5.8. Arc-Flash Assessment Methods.

5.8.1. The Calculation Method. All calculations shall follow guidance from the latest version of the IEEE 1584, *Guide for Performing Arc Flash Hazard Calculations*. Calculation software used should be implementing the latest version of the IEEE 1584 for the calculation of incident energy.

5.8.1.1. When PSMs are created, for entire buildings or individual circuits, and electrical testing has not been completed, arc-flash hazard analysis can be conducted to determine estimated incident energy (at 18" working distance), estimated arc-flash boundary, and an estimation of arc-rated PPE required within the arc-flash boundary. When electrical testing has been completed, the arc flash hazard analysis is still an estimate, but the level of confidence in the resulting analysis is much higher.

5.9. Arc-Flash Labeling.

5.9.1. Arc-Flash labeling is intended to communicate the potential hazard to electrical workers in the event that equipment requires servicing or maintenance while energized. The information helps electrical workers understand if their PPE will protect them against the arc-flash and shock hazards at the equipment in question.

5.9.2. Power system data collection and arc-flash studies are an ongoing effort. Buildings on the Priority Plan will be labeled as organic/contracted manpower becomes available. Any organization who is in need of labeling, as a result of their own internal risk-assessment, shall contact their unit's safety or engineering office. The requesting unit's safety/engineering office shall consult with ESGW engineers for support or consultation on the labeling efforts desired. Units shall not pursue labeling that is not in alignment with this ESP. If the date on any given label has exceeded 5 years, an updated arc-flash hazard analysis shall be required prior to exposing energized parts.

5.9.2.1. Smart Labels utilizing some form of QR code, barcode, or other method, can be deployed to display arc-flash and shock information to qualified electrical workers using an approved scanning device. Smart Labels must be capable of displaying, at a minimum, all arc-flash and shock information IAW the most recent version of the NFPA 70E.

5.9.3. Equipment with an estimated incident energy of 25 cal/cm² or greater shall be labeled with a detailed arc-flash DANGER label. See **Figure 5.1** below. Locations with an estimated incident energy less than 25 cal/cm² shall be labeled with a detailed WARNING label (See **Figure 5.2** below). The primary difference between the two is: 1) DANGER labels forbid qualified electrical workers from exposing the equipment’s energized **parts** 2) WARNING labels would indicate that equipment could be opened for troubleshooting.

5.9.4. According to NFPA 70 section 408.6, equipment labeling shall include the Available Fault Current (AFC). This ensures properly rated equipment has been selected for each location. See **Figure 5.1** and **Figure 5.2** for an example of how HAFB intends to meet this requirement.

Figure 5.1. Example of Detailed Arc-Flash DANGER Label.



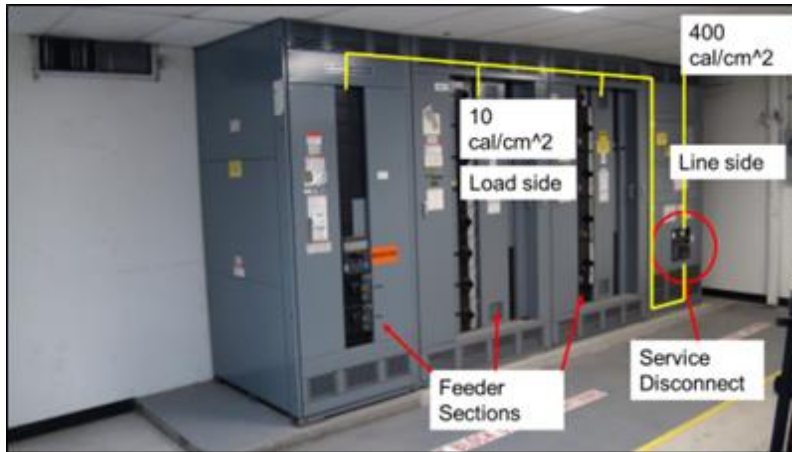
Figure 5.2. Example of Detailed Arc-Flash WARNING Label.



5.9.5. The interior construction of Service Entrance Switchboards (SESBs) aren’t known unless drawings have been stored in a readily accessible location for qualified electrical workers. The construction is an important factor when considering potential arc-flash exposure. **Figure 5.3** shows a SESB which is fed by a 3000kVA oil cooled transformer. The incident energy estimate on the line-side of the service disconnect is calculated at 400 cal/cm². On the load-side of the incident energy estimate is 10 cal/cm². It shall be assumed that SESBs have no arc-rated barricades between the feeder breaker sections and the section housing the

service disconnect. Therefore, labels will be applied for ALL sections stating that the incident energy is 400 cal/cm^2 . Qualified electrical workers exposing themselves to any of the feeder sections are potentially exposed to the line-side of the service disconnect. Because 400 cal/cm^2 is well above 25 cal/cm^2 , this SESB will have an affixed detailed DANGER label similar to [Figure 5.2](#).

Figure 5.3. Service Entrance Switchboard Example.



5.9.6. When work needs to be performed at locations where there is no existing arc-flash analysis, NFPA 70E, Table 130.7(C)(15)(a) may be used when the following information is known:

5.9.6.1. Available fault current (AFC) at the location where work is to occur, upstream overcurrent fault clearing time, and nominal system voltage at the location where work is to occur. If the AFC is not clearly marked on equipment, qualified electrical workers can use programs and applications designed to calculate AFC, make assumptions about clearing times and then use the table method to determine PPE. This process of selecting PPE based on the table method shall be documented on a JSA to be in compliance with this ESP. This method of assessing the hazard and selecting PPE shall only be an interim measure while units develop facility PSMs using EasyPower or other Air Force approved software. Where qualified workers are not available, units should contact their supervisor to have an electrical engineer perform an arc-flash hazard analysis.

5.9.6.2. When using NFPA 70E, Table 130.7(C)(15)(a) for PPE selection, consider estimated fault clearing times when working downstream of the following overcurrent protection devices:

5.9.6.2.1. Fuses as overcurrent protection: one-half cycle or 0.008 second clearing time can be assumed as the best case scenario. If there is a transformer between the job/task site and the upstream fuses, the fuses may not clear a fault that originates at the job/task site.

5.9.6.2.2. Molded-Case Circuit Breakers with no adjustability to its tripping mechanism: 1.5 cycles or 0.03 second tripping time can be assumed as the typical scenario.

5.9.6.2.3. Adjustable trip or electronic trip circuit breakers: tripping time can vary depending on the settings. With the instantaneous setting turned all the way down, the clearing time can be as low as 0.03 seconds. When turned up to maximum, the tripping time can be well over 0.5 seconds.

5.9.6.2.4. Other factors to consider during job safety planning can include but are not limited to:

5.9.6.2.4.1. Condition of the equipment:

5.9.6.2.4.1.1. Does it appear to have obvious signs of contamination?

5.9.6.2.4.1.2. Are there missing knockouts, large gaps on equipment enclosures?

5.9.6.2.4.1.3. Installation deficiencies?

5.9.6.2.4.2. Can the job wait until the equipment can be de-energized?

5.9.6.2.4.2.1. De-energization is also an electrical hazard.

5.9.6.2.4.2.2. De-energization is always the safest approach when conditions of equipment are unknown.

5.9.6.2.4.2.3. De-energize, open equipment, perform a risk analysis, then, re-energize to take voltage/current/infrared measurements.

5.9.6.2.4.3. Where in the system is the job/task? (highest to lowest perceived risk)

5.9.6.2.4.3.1. Service entrance equipment.

5.9.6.2.4.3.2. 480/277V system.

5.9.6.2.4.3.3. 208/120V system.

5.9.6.2.4.3.4. Branch circuit.

5.10. Electrical Preventive Maintenance (EPM).

5.10.1. According to the Memorandum of Understanding between 309th MXSG and 75th ABW Civil Engineering the 309th MXSG is responsible for, "Interior electrical systems up to 600 volts AC, from the main service disconnect or vault for the building to include conduits, outlets, and emergency exit lights below 10 feet, battery backup and emergency power packs." This applies to buildings occupied by the Groups within the OO-ALC. Therefore, the 309th MXSG/MXDEQ has initiated an EPM Program. According to UFC 3-560-01, "An electrical safety program does not comply with NFPA 70E if it fails to perform maintenance and testing of electrical equipment in accordance with established industry standards or manufacturer's recommendations."

5.10.2. The purpose of EPM is to reduce hazards to life and property that can result from failure or malfunction of electrical systems and equipment. NFPA 70B, *Recommended Practice for Electrical Equipment Maintenance*, is the recommended practice for an EPM program. This document gives guidance and defines the essential elements of an EPM program as follows:

5.10.2.1. Responsible and qualified personnel.

5.10.2.2. Survey and analysis of electrical equipment and systems to determine maintenance requirements and priorities.

5.10.2.3. Regularly scheduled inspection, testing, and servicing of equipment.

5.10.2.4. Accurate analysis of inspection and test reports so that proper corrective measures can be prescribed.

5.10.2.5. Performance of necessary work.

5.10.2.6. Concise but complete records.

5.10.3. Personnel assigned to EPM duties shall be selected from the most technically qualified electrical workers. All employees performing EPM inspections and tests shall have completed their initial electrical safety training and receive their refresher training At least every 3-years or when changes are made. They shall also have additional specialized training in testing, inspection and maintenance of electrical distribution equipment rated 600V and below.

5.10.4. EPM managers and Engineers shall be well-qualified. These individuals shall have a combination of education and experience to ensure they understand the design, function, construction, installation and operations of industrial electrical power systems. A Professional Engineer (PE) shall either be part of the team or be an advisor/contractor to the team.

5.10.5. A “Priority Plan” shall be developed to determine where to focus initial EPM efforts before expanding to the remaining campus of facilities.

5.10.6. Surveys and analysis shall be performed to determine the general status, condition and employee exposure of/to the equipment.

5.10.7. Considerations of physical condition, environmental risks and operational loads can be accomplished using an appropriately designed inspection process. The process used during inspections shall determine equipment conditions and environmental and loading considerations via visual, Infrared (IR), and ultrasound inspection and voltage/current measurements (See [Attachment 1](#) and [Attachment 2](#) for determining equipment conditions).

5.10.8. Using some form of an equipment maintenance software/database, equipment information shall be stored with a unique identifier and programmed to generate automatic work orders with prescribed frequencies. NFPA 70B gives a list of recommended frequencies for various inspection, test and maintenance tasks.

5.10.8.1. NFPA 70B states, “Analysis of inspection and test reports should be followed by implementation of appropriate corrective measures. Following-through with necessary repairs, replacement and adjustment is the end purpose of an effective EPM program.”

5.10.8.2. After an inspection, technicians record all recommended corrective actions. The completed inspection is reviewed by EPM engineers and technicians to determine the best way forward on corrective actions.

5.10.8.3. The leaders and team members of the EPM program shall be well-qualified with the appropriate knowledge, skills and abilities to ensure that the analysis of the inspections are accurate. Appropriate inspections forms and processes shall be implemented to ensure this process is efficient.

5.10.9. With older buildings, there will be many code and safety issues. Work shall be prioritized to what is necessary to avoid the highest safety and production risks.

5.10.9.1. Records should be accurate and contain all vital information. Care should be taken to ensure that all relevant information becomes part of the record. A solid record keeping system uses forms for recording information which allow technicians to compare the current state of a piece of equipment to its last inspection.

5.10.9.2. Newly installed or modified equipment shall require a documented inspection performed by a qualified worker.

5.10.9.3. EPM Engineers and Technicians will establish inspection type and frequency of all electrical real-property according to manufacturer specification, consensus standards, or equivalent codes and standards.

5.10.9.4. All inspection documentation will be kept, at least, until the next scheduled inspection of the equipment for which the inspection document is associated.

5.10.10. The above efforts shall be put on contract where the organic manpower/expertise is not sufficient or available. HAFB aims to implement a combination of organic and contracted manpower. The NFPA 70B Chapter 6, para 6.8 outlines outsourcing of EPM and gives a list of contract elements to consider for contractor requirements.

5.11. Electrical Best Practices for Troubleshooting Equipment.

5.11.1. De-Energized Troubleshooting. De-energization of equipment should always be pursued prior to opening equipment that is not on a periodic maintenance schedule. The following procedure outlines the safest route to minimize the risk of electrical hazards when opening enclosures or cabinets when troubleshooting facility electrical distribution equipment:

5.11.1.1. Written procedures shall be documented by the team of qualified workers who will be performing troubleshooting tasks.

5.11.1.2. Determine arc-flash estimate at location where power will be switched off to ensure proper PPE is worn for de-energization.

5.11.1.3. Don appropriate arc-rated PPE and de-energize the equipment. Follow LOTO procedures.

5.11.1.4. Check voltage measuring devices for proper function.

5.11.1.5. Open the enclosure and treat the equipment as if it is still energized.

5.11.1.6. Determine if there is still voltage present using an appropriately rated voltage meter or detector for that location of the system (Appropriately CAT-rated).

5.11.1.7. While equipment is de-energized, perform a risk analysis of troubleshooting this equipment prior to taking any energized voltage and current measurements or other energized troubleshooting tasks.

5.11.1.8. Inspect for loose connections, signs of overheating, bad fuses, low impedance to ground, etc.

5.11.1.9. Based on initial de-energized troubleshooting, a highly informed job safety analysis can be performed in anticipation of performing the necessary energized testing and troubleshooting.

5.11.2. Energized Troubleshooting. See [Attachment 4](#), Energized Troubleshooting.

5.11.3. Troubleshooting Best Practices Summary. The following best practices shall be used when working on or near energized equipment, especially in areas where EPM has not been implemented.

5.11.3.1. Category IV arc-rated PPE (40cal/cm²) shall be worn when workers are performing LOTO, no-voltage verification, or energized trouble-shooting (with a JSA filled out in advance).

5.11.3.2. All locations where electrical troubleshooting or work is to be performed shall require a documented JSA which documents that job planning was accomplished and briefed prior to troubleshooting being performed.

5.11.3.3. Any equipment with unknown conditions of maintenance shall have an elevated level of risk no matter its location.

5.11.3.4. When JSAs reveal a high risk of injury or damage to health, the work-lead or supervisor shall elevate the visibility of the job up to the squadron and/or group director level for a deliberate risk assessment.

5.12. Work Center Risk Assessment (Supervisor).

5.12.1. Job Safety Training Outline. The Electrical Safety section should be maintained at shop level to assist supervisors with their portion of the electrical program. Minimum supervisor responsibilities include:

5.12.1.1. Developing training and providing it to all employees.

5.12.1.2. Ensure only qualified employees work on electrical equipment.

5.12.1.3. Ensure all unqualified employees are directly supervised by a qualified employee.

5.12.1.4. Ensure employees do not work on energized equipment.

5.12.1.5. Ensure employees are trained to develop and follow LOTO procedures.

5.12.1.6. Ensure all necessary PPE, and evaluation equipment is provided and used.

5.12.1.7. Facilitate and enforce the preparation of an energize work permit for any work done on or near energized equipment.

5.12.1.8. Ensure the energized work permit is authorized, in writing, by the BCE or authorized equivalent.

5.12.2. Job/task safety planning shall be accomplished prior to any work where employees will operate circuit breakers, buss switches, disconnect switches, or be exposed to electrical energy greater than 50V. The safety planning will be documented using a JSA form and briefed to all affected employees prior to work. The elements of job safety planning:

5.12.2.1. Must be completed by a qualified person.

5.12.2.2. Must be documented (JSA)

5.12.2.3. Describe the job and the individual tasks.

5.12.2.4. Identify hazards associated with each task.

5.12.2.5. Include a shock risk assessment for tasks involving a shock hazard.

5.12.2.6. An arc-flash risk assessment for tasks involving an arc-flash hazard.

5.12.2.7. Work procedures involved, special precautions and energy source controls.

5.12.3. When employees are working on industrial plant equipment (utilization equipment) the minimum is category II arc-rated PPE. When employees are working on or near the facility electrical distribution equipment the minimum PPE shall be category IV arc-rated PPE. All other PPE requirements will be evaluated by the supervisor.

5.12.3.1. The job safety plan, along with an arc-flash/shock assessment, will determine if the PPE needed is category II, IV, or if the hazard is too high to conduct work. If the hazard is too high for employees exposed to energized parts while donning category IV arc-rated PPE, then the de-energized troubleshooting procedure outlined in [para 5.11](#) shall be followed.

5.12.3.2. PPE will be inspected in accordance with manufacturer's guidance.

5.13. Reporting Electrical Hazards, Mishaps, and Near Misses.

5.13.1. All electrical mishaps and near misses will be investigated by the responsible safety office with assistance from the ESWG. Electrical mishaps include events or occurrences that result in a fatality, injury or equipment damage. Near misses are events that could have resulted in injury or equipment damage but didn't (example: improperly installed or maintained equipment). Supervisors shall report mishaps and near misses to the responsible safety office for investigation. All electrical investigations will use the ESWG as subject matter experts to determine cause, corrective actions and recommendations. Employees' input should be encouraged and solicited to make recommendations to improve electrical safety and health conditions.

5.13.2. Report hazards that can't be eliminated to the responsible supervisor as soon as possible. If the hazard is eliminated on the spot, no further action is required. Attempt to fix hazards at the lowest level.

5.13.2.1. Hazard reporting can be done using an AF Form 457, *Hazard Report*.

5.13.2.2. Hazard reporting can be done electronically.

5.13.2.2.1. Use the Yellow flag icon on your desk top.

5.13.2.3. Hazard reporting can be done electronically using the Airman Safety Action Report (ASAP) found on the Air Force Portal under Safety.

Chapter 6

POWER OUTAGES

6.1. Utility Outages.

6.1.1. Utility outages for testing, troubleshooting, or maintenance will require a 21-day lead-time after all signatures of the “Base Civil Engineering Work Clearance Request” form. Work with facility managers, facility mayors, facility engineers, production flight chiefs and/or shop supervisors to determine a good date for the outage. Next, call and email each person on the list. Include the outage request form with the statement of work as an attachment. Once all signatures and confirmations are received, send the final form with all signatures and confirmations to the CE Operations Support Flight Superintendent who will provide the final approval/disapproval and signature.

6.2. Expedited Outages.

6.2.1. In emergency situations, building power may need to be interrupted at the main disconnecting means. Emergency situations of this type are those requiring immediate action. There are other scenarios where a potential safety hazard needs to be repaired which requires building outages. In this scenario, the requester shall work closely with Base Civil Engineering to determine if the outage should be expedited. If it can be expedited BCE shall work with the requestor on how to do so.

6.3. System and Equipment Outages.

6.3.1. Outages for systems and/or equipment within the building, that do not require utility power to be disrupted, should be coordinated with the appropriate facility operators, flight chiefs, and shop supervisors prior to performing outages.

Chapter 7

FACILITY CHANGE MANAGEMENT AND SAFETY RELATED DESIGN

7.1. Change Management.

7.1.1. Change management, or configuration and control, shall be a system where changes are systematically documented to ensure that the configuration of the electrical infrastructure is properly controlled. See OO-ALCI 21-110 for detailed recommendations on change management of EPM drawing sets and facility operator responsibilities.

7.2. Safety Related Design for Facility Electrical Distribution.

7.2.1. Some design considerations for facilities that are directly linked to electrical safety and occupational health are: grounding, bonding, static grounding systems and lightning protection systems. These design considerations shall be incorporated into facility electrical construction, modifications and redesigns.

Chapter 8

AUDITS

8.1. Conducting Audits.

8.1.1. Units with workloads who fall under the scope of this ESP will conduct a self-assessment at least annually. The ESWG will conduct an assessment of each unit's compliance, with this ESP, at least every two years and/or in conjunction with the safety program assessments IAW AFI 91-202, *Air Force Mishap Prevention Program*. The assessment team will consist of an electrical engineer, safety professional, and a qualified electrician from a unit other than the unit being inspected. Quality assurance may be included if available. Audit reports will be routed through the BCE, AFSC/SE, AFMC/SE, AFSEC and AFCEC. It is preferred to review the ESP after a new version of NFPA 70B and 70E are released. Documents will be maintained in accordance with Electronic Records Management rules.

8.2. Unit Self-Assessments.

8.2.1. Employee qualification training.

8.2.2. HEC training.

8.2.3. HEC Procedures, shop JSAs

8.2.4. PPE training certificates.

8.2.5. PPE inspection certification documentation.

8.2.6. Prior to work safety briefings.

8.2.7. Safe work practices observations (documented over the shoulder evaluations).

8.2.7.1. OO-ALC uses a Quality Verification Inspection is performed by the Quality Assurance Flight using their own in-house check-list

8.2.7.2. 75 ABW/CEG will document work card or other means.

8.2.8. AF Form 1213, *Energized Electrical Work Permits*

8.2.9. AF Form 269, *Electrical Facilities Safe Clearance*

8.3. ESWG Assessment.

8.3.1. The ESP will be reviewed along with current industry standards to determine if updates are required.

8.3.2. New installation inspections will be documented in a method determined by the organization conducting the inspections.

8.3.2.1. The OO-ALC will use a Project Request Packet.

8.3.2.2. 75 ABW/CEG will use NexGen (Tririga).

8.3.3. Preventative Maintenance Inspections. Inspections will be documented, and assigned a status.

8.3.3.1. The OO-ALC will use an Equipment Inspection Form v5. Forms are located in 309th MXSG Shared drive. Completed forms are loaded in eFEMS.

8.3.3.2. OO-ALC equipment status is tracked on a spreadsheet named “Inspection Request Master.”

8.3.3.3. 75 ABW/CEG tasks are in NexGen (Tririga)

8.3.4. EPM Program Management. Organizations will be audited on creating a priority plan, tracking progress and briefing constraints to management.

8.3.4.1. Single line diagrams and electrical drawings and EasyPower system models

8.3.4.1.1. OO-ALC maintains them in the 309th MXSG Share drive

8.3.4.1.2. 75 ABW/CEG Drawings are located in CE Digital Vault along with CEN project manager active files/folders

8.3.4.2. OO-ALC Status is tracked using “Priority Building List,” spreadsheet located on 309th MXSG Shared Network Drive

8.3.4.3. Program Progress tracked in MICT. The continuous process improvement A-3 Table is updated regularly and located on: 309th MXSG Shared Network Drive

8.3.4.4. 75 ABW/CEG Preventative Maintenance documents are in NexGen

8.3.4.5. 75 ABW/CEG Status of will be tracked with a MICT checklist.

JEFFREY G. HOLLAND, Colonel, USAF
Commander

Attachment 1**GLOSSARY OF REFERENCES AND SUPPORTING INFORMATION*****References***

29 CFR § 1910, Subpart S, *Electrical*

29 CFR § 1910.147, *The Control of Hazardous Energy (Lockout/Tagout)*

AFI 33-322, *Records Management and Information Governance Program*, 28 July 2021

AFI 90-802, *Risk Management*, 31 Mar 2019

AFI 91-202, *Air Force Mishap Prevention Program*, 11 Mar 2020

AFMAN 32-1065, *Grounding and Electrical Systems*, 24 Feb 2019

AFVA 91-303, *DANGER—DO NOT ENERGIZE—PERSON WORKING ON ANTENNA*

AFVA 91-304, *DANGER—DO NOT ENERGIZE—WORK IN PROGRESS ON EQUIPMENT*

AFVA 91-305, *DANGER—INTERLOCKS DISABLED*

AFVA 91-306, *DANGER—HIGH VOLTAGE SIGN*

DAFMAN 91-203, *Air Force Occupational Safety, Fire and Health Standards*, 24 Mar 2022

T.O. 00-25-232, *Control and Use of Insulating Matting for High-Voltage Application*, 28 Feb 1997

HILLAFBI 91-203, *Hazardous Energy Control (Lockout/Tagout)*, 14 Jul 2021

OO-ALCI 21-110, *Depot Facility Maintenance*, 2 Feb 2021

UFC 3-520 -01, *Interior Electrical Systems*, 6 Oct 2015

UFC 3-560-01, *Operation and Maintenance: Electrical Safety*, 24 Jul 2017

ANSI/ISEA Z87.1, *American National Standard For Occupational And Educational Personal Eye And Face Protection Devices*, 2020 edition

ANSI/ISEA Z89.1, *American National Standard For Industrial Head Protection*, 2019 edition

ASTM F2412, *Standard Test Methods for Foot Protection*. 22 Aug 2018

ASTM F2413, *Standard Specification for Performance Requirements for Protective (Safety) Toe Cap Footwear*

IEEE 1584, *Guide for Performing Arc Flash Hazard Calculations*, 30 Nov 2018

IEEE 3007.3, *Recommended Practice for Electrical Safety in Industrial and Commercial Power Systems*, 12 Apr 2012

NFPA 70, *National Electric Code*, 2020 edition

NFPA 70B, *Recommended Practice for Electrical Equipment Maintenance*, 2019 edition

NFPA 70E, *Standard for Electrical Safety in the Workplace*, 2021 edition

Adopted Forms

DAF Form 847, *Recommendation for Change of Publication*

AF Form 55, *Employee Safety and Health Record*

AF Form 1213, *Civil Engineer Energized Electrical Work Permit*

AF Form 457, *USAF Hazard Report*

AF Form 269, *Electrical Facilities Safe Clearance*

Abbreviations and Acronyms

ADLS—Advanced Distributed Learning Service

AED—Automated External Defibrillator

AFC—Available Fault Current

AFDPO—Air Force Departmental Publishing Office

AFI—Air Force Instruction

AFMAN—Air Force Manual

AFPD—Air Force Policy Directive

AFTR—Air Force Training Records

AFVA—Air Force Visual Aids

ASAP—Airman Safety Action Report

BCE—Base Civil Engineer

CFETP—Career Field Education and Training Plan

CPR—Cardiopulmonary Resuscitation

DAF—Department of the Air Force

DAFI—Department of the Air Force Instruction

DAFMAN—Department of the Air Force Manual

DOD—Department of Defense

ED—Electrical Drawings

EPM—Electrical Preventive Maintenance

ERA—Electrical Risk Assessments

ESP—Electrical Safety Pamphlet

ESWG—Electrical Safety Working Group

EWP—Energized Work Permit

HEC—Hazardous Energy Control

HAFB—Hill Air Force Base

HAFBI—Hill Air Force Base Instruction

IR—Infrared

JSA—Job Safety Analysis

JSP—Job Safety Planning

LOTO—Lock-out/Tag-out

MCCB—Molded-Case Circuit Breakers

MOU—Memorandum of Understanding

OCPD—Overcurrent Protection Device

OPR—Office of Primary Responsibility

PAC—Production Acceptance Certification

PE—Professional Engineer

PPE—Personal Protective Equipment

PSM—Power System Models (Modules?)

QVI—Quality Verification Inspection

RDS—Records Disposition Schedule

SESB—Service Entrance Switchboards

SLD—Single-Line Diagrams

TSS—Training Scheduling System

UPS—Uninterruptible Power Supply

Terms

Accountable Forms—Forms that the Air Force stringently controls and which cannot be released to unauthorized personnel, since their misuse could jeopardize DOD security or result in fraudulent financial gain or claims against the government.

Administrative Change—Change that does not affect the subject matter content, authority, purpose, application, and/or implementation of the publication (e.g., changing the POC name, office symbol(s), fixing misspellings, etc.)

Approval Authority—Senior leader responsible for contributing to and implementing policies and guidance/procedures pertaining to his/her functional area(s) (e.g., heads of functional two-letter offices).

Authentication—Required element to verify approval of the publication; the approval official applies his/her signature block to authenticate the publication. The signature block includes the official's name, rank and title (not signature).

Guarding—Barrier, cabinet, safety attendant, fence

Must, shall, will—mandatory requirement

Proficient—May complete a task with no refresher training.

Qualified—Employee that is trained, experienced, demonstrates ability and can identify normal conditions and existing or potential hazards for a specific task.

Should, may—Optional requirement but recommended good practice

Attachment 2

MXDEQ EQUIPMENT CONDITION CLASSIFICATION TABLE

A2.1. This table can be used by anyone performing a visual inspection. It allows one to assign a classification in terms of the conditions of maintenance. This table was created by the 309th MXSG to allow the consideration of conditions of maintenance in accordance with the NFPA 70E.

Table A2.1. Equipment Condition Classification.

Equipment Condition Description	Classification
<u>ALL</u> of the following: Equipment is installed properly; No obvious code violations; No mechanical defects such as cracks, gaps, missing knock-outs, inadequate covers, that could allow contamination/contact with live parts; No contamination on equipment exterior; No excessive contamination of interior; No signs of overheating	Class I
<u>ANY</u> of the following: Equipment has minor installation/code issues ¹ ; Mechanical defects that may allow contamination of the interior/contact with live parts; Excessive contamination on equipment exterior that equipment <u>is</u> rated to withstand; Possible signs of overheating	Class II
<u>ANY</u> of the following: Equipment has major installation/code issues ² ; Significant mechanical defects that are directly contributing to contamination of the interior/contact with live parts; Contamination on equipment exterior that equipment <u>is not</u> rated to withstand; Excessive and/or conductive contamination of equipment interior; Definite signs of overheating	Class III
<p>Notes:</p> <p>1. Minor issues being defined as code violations which do not pose an immediate risk to bodily harm of employees and bystanders.</p> <p>2. Major issues being defined as code violations which do pose an immediate risk to bodily harm of employees and bystanders.</p>	

Attachment 3

BUILDER DIRECT CONDITION RATING (DCR) DEFINITIONS

A3.1. This Table is used specifically for those entering equipment information into the BUILDER database.

Table A3.1. Direct Condition Rating (DCR) Definitions.

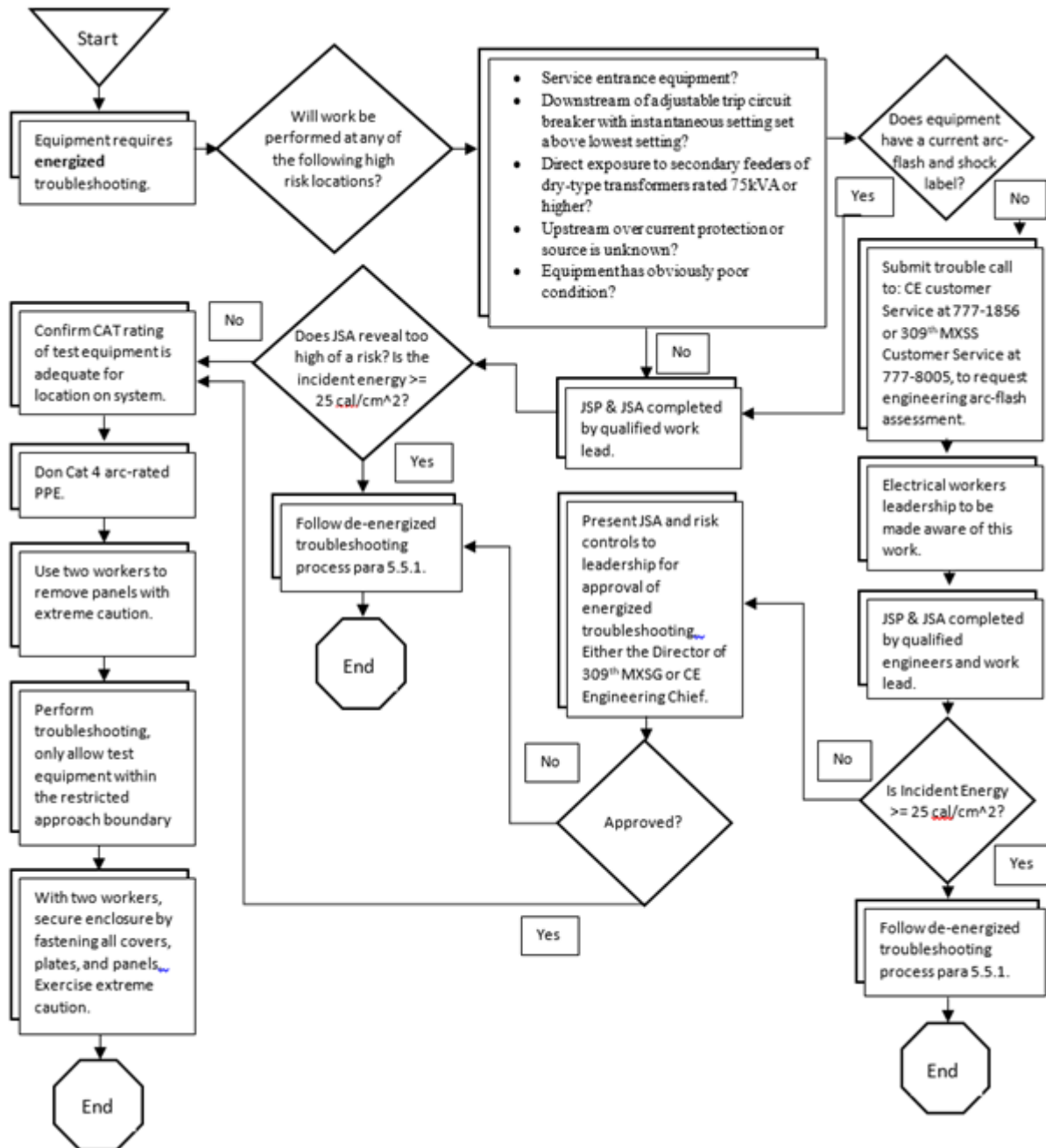
Rating	Observation
Green (+)	Fully Operational – Free of known or observable defects <i>Continue PM – No action necessary</i>
Green	Fully Operational – Slight Deterioration and/or Minimal Wear <i>Continue PM – No action necessary</i>
Green (-)	Fully Operational – Normal wear and/or serviceability defects <i>Continue PM – Begin rehabilitation planning</i>
Amber (+)	Reduced Operation – Minor wear and/or serviceability defects <i>Repairs may be accomplished and replacement planned within 8-10 years (Investment may extend life)</i>
Amber	Reduced Operation – Moderate wear and/or serviceability defects <i>Repairs may be accomplished and replacement planned within 6-7 years (Investment may extend life)</i>
Amber (-)	Reduced Operation – Significant wear and/or serviceability defects <i>Repairs may be accomplished and replacement planned within 3-5 years (Investment may extend life)</i>
Red (+)	Loss of Operation – Moderate wear and/or serviceability defects <i>Repairs may be accomplished and replacement planned within 2 years (Run to failure - investment unwise)</i>
Red	Loss of Operation – Significant wear and/or serviceability defects <i>Repairs may be accomplished and replacement planned within the next year (Run to failure - investment unwise)</i>
Red (-)	Loss of Operation – Complete wear and/or serviceability failure

	Replace immediately
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Attachment 4

ENERGIZED TROUBLESHOOTING FLOW CHART

Figure A4.1. Energized Troubleshooting Flow Chart.



Attachment 5

REQUIREMENTS AND ARC-FLASH HAZARD ANALYSIS FOR UPS BATTERY SYSTEMS

A5.1. Requirements.

A5.1.1. Qualified workers shall trained to perform maintenance on UPS battery systems and training shall be documented and aligned with the CFETP.

A5.1.2. JSP shall be implemented IAW paragraphs 5.5.1 – 5.5.3 and a JSA shall be filled out and briefed to all effected personnel.

A5.1.3. Minimum PPE shall be category 4 arc-rated PPE, 1000V rated rubber gloves worn under heavy-duty leather gloves, hearing protection, and eye protection.

A5.1.4. Tools shall be insulated and rated for the voltage levels documented in the JSA.

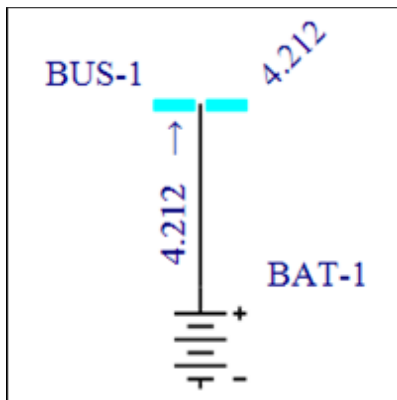
A5.1.5. Testing devices shall be tested and rated for the voltage levels documented in the JSA

A5.2. Arc-Flash Hazard Analysis Example for UPS System.

A5.2.1. Using an Eaton Power Xpert 9395, which is installed on HAFB at building 1515, as a case study, the following analysis was performed using EasyPower: Figure A-1 shows the circuit used in EasyPower. Figure A-2 shows the parameters needed in EasyPower to run the simulation. Figure A-3 shows the definitions of each parameter.

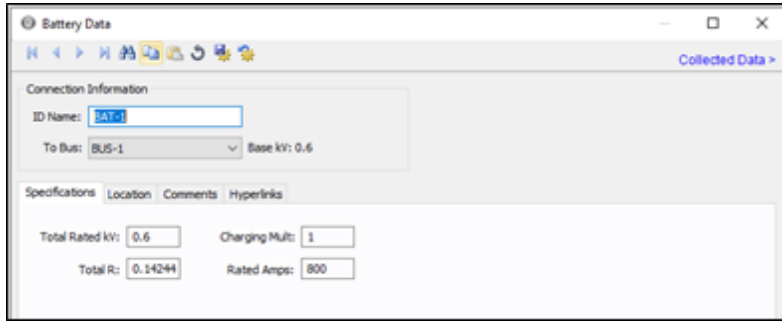
A5.2.2. Circuit:

Figure A5.1. Circuit used in EasyPower.



A5.2.3. Parameters.

Figure A5.2. Parameters needed in EasyPower.



A5.2.4. Definitions:

Figure A5.3. Definitions of each Parameter.

Specifications	
Option	Description
Total Rated kV	This is the total voltage rating of the battery string.
Charging Multiplier	This is multiplier for the battery voltage reflecting the charge condition. For example, a fully charged battery could have 1.05 and a slightly drained battery may have 0.95 as the charging multiplier.
Total R	This is the internal resistance of the battery string in ohms.
Rated Amps	The rated amperes of the battery or battery string. Most batteries typically have the ampere-hour rating on an 8-hour basis. The nominal amp rating is the ampere-hour divided by 8 for such batteries. If the battery rating in ampere-hours is given at a different discharge duration, then divide by the stated number.

Note: Batteries are modeled as a straight Thevenin voltage source behind a resistance. Thus, they HOLD voltage behind an internal resistance like a swing bus. Batteries thus have the ability to be the single source that enables a system to enter power flow and solve the system.

A5.2.5. Analysis:

A5.2.5.1. The Eaton Power Xpert 9395 was used as our case study because it is the largest system on base. When qualified workers perform maintenance on this system they will use the maintenance bypass switch which ensures that qualified workers won't be exposed to AC voltage, only the DC voltage of the battery string ~550VDC.

A5.2.5.2. Under the assumption that qualified workers will perform the required JSP and determine if exposure is limited to only the battery string, Figure A-1 was used to analyze the available fault current for the case study battery string at building 1515.

A5.2.5.3. **Figure 5.2** -A shows the parameters needed for the calculation.

A5.2.5.3.1. Rated kV is the voltage of the battery string, which is ~550VDC so a value of 600VDC was used to make calculations less conservative.

A5.2.5.3.2. Charging multiplier was left at 1.

A5.2.5.3.3. The Total R was calculated by contacting the battery manufacturer (C&D Technologies), the battery model is: UPS12-540MR. The manufacturer states that the internal resistance of one battery is 0.003561 ohms.

A5.2.5.3.3.1. To determine the total internal resistance of the entire string simply multiply the internal resistance of one battery by the number of batteries when the string of batteries is wired in series. The total number of batteries is likely closer to 50, however, 40 batteries was chosen to get a smaller resistance value to make our calculations less conservative. Therefore, 40 batteries multiplied by 0.003561 ohms equals 0.14244 ohms.

A5.2.5.3.4. The definition of rated amps is the battery's amp hours divided by the rated discharge duration. Which is equal to 147 amp-hours divided by 20 hours which equals 7.35 amps. The manufacturer lists these batteries as having a maximum current rating of 800 amps.

A5.2.5.3.4.1. During our analysis when we used each value above, the results did not change.

A5.2.6. Results:

A5.2.6.1. The manufacturer of these batteries have a short circuit current rating of 5,000 amps for a bolted fault at 0.1 seconds. This 0.1 seconds means that a bolted fault would drain the battery in 0.1 seconds.

A5.2.6.2. The EasyPower model (see Figure A-1) calculated 4.212 kA which is 4,212 amps.

A5.2.6.3. The 2020 NFPA 70E, Article 130, Table 130.7(C)(15)(b) "Arc-Flash PPE Categories for Direct Current (dc) Systems," breaks down arc-flash PPE categories based on available fault current.

A5.2.6.4. "Available fault current greater than or equal to 3 kA and less than 7 kA" shall require category 3 PPE and the arc-flash boundary shall be 1.8m (6ft).

A5.2.6.5. Informational note No. 1 states, "Battery cell short-circuit current can be obtained from the battery manufacturer."

A5.2.7. Hazard Analysis Example Conclusion:

A5.2.7.1. Given the 5 kA short circuit current from the manufacturer and the 4.2 kA EasyPower results, the required PPE shall be category 4 (HAFB only uses category 2 or 4 arc-rated PPE), and the arc-flash boundary shall be 1.8m (6ft).