

# RECLAMATION

*Managing Water in the West*

**Facilities Instructions, Standards, and Techniques**  
**Volume 5-14**

## **Arc Flash Hazard Program**



**U.S. Department of the Interior**  
**Bureau of Reclamation**  
**Denver, Colorado**

**May 2011**

# REPORT DOCUMENTATION PAGE

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<b>14. ABSTRACT</b> This document's purpose is to establish clear and consistent instructions and procedures for dealing with arc flash hazards. The Arc Flash Hazard Program establishes coordinated and consistent procedures and operating criteria for safe and reliable operation and maintenance of those facilities. This program prescribes procedures and minimum performance for the safety of service or maintenance personnel. These instructions and procedures supplement the requirements in the Reclamation Safety and Health Standards. Adherence to these procedures will enable workers to perform their duties with maximum confidence and safety. In the event of a difference between the requirements in this Facilities Instructions, Standards, and Techniques and those contained in the Reclamation Safety and Health Standard, the more rigorous requirement shall apply.					
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Volume 5-14**

# **Arc Flash Hazard Program**

**Hydropower Technical Services Group**



**U.S. Department of the Interior  
Bureau of Reclamation  
Denver, Colorado**

**May 2011**

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## Acronyms and Abbreviations

<b>ac</b>	alternating current
<b>AF</b>	arc flash
<b>AFH</b>	arc flash hazard
<b>AFH Coordinator</b>	Arc Flash Hazard Coordinator
<b>AFH Program</b>	Arc Flash Hazard Program
<b>ANSI</b>	American National Standards Institute
<b>ASTM</b>	American Society for Testing and Materials
<b>cal/cm<sup>2</sup></b>	calories per square centimeter
<b>CFR</b>	Code of Federal Regulations
<b>COR</b>	Contracting Officer's Representative
<b>CT</b>	current transformer
<b>dc</b>	direct current
<b>EPRI</b>	Electric Power Research Institute
<b>FIST</b>	Facilities Instructions, Standards, and Techniques
<b>FR</b>	flame resistant
<b>IE</b>	Incident Energy
<b>IEEE™</b>	Institute of Electrical and Electronics Engineers
<b>J/cm<sup>2</sup></b>	joule per square centimeter
<b>JHA</b>	job hazard analysis
<b>kA</b>	kiloampere
<b>kV</b>	kilovolt
<b>kVA</b>	kilovoltampere
<b>NERC</b>	North American Electric Reliability Corporation
<b>NFPA</b>	National Fire Protection Association
<b>non-FR</b>	non-flame resistant
<b>O&amp;M</b>	operation and maintenance
<b>OSHA</b>	Occupational Safety and Health Administration
<b>PPE</b>	personal protective clothing and equipment
<b>PT</b>	potential transformer
<b>Reclamation</b>	Bureau of Reclamation
<b>RSHS</b>	Reclamation Safety and Health Standards
<b>SOPs</b>	standard operating procedures
<b>V</b>	volt
<b>VA</b>	voltampere
<b>Vac</b>	volt alternating current
<b>Vdc</b>	volts direct current
<b>USACE</b>	U.S. Army Corps of Engineers
<b>°</b>	degree
<b>%</b>	percent



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## 1. Introduction

An arc flash hazard (AFH) is defined as a dangerous condition associated with the possible release of energy caused by an electric arc<sup>1</sup>. Employees working on energized electrical equipment, operating at 50 volts or more, have the potential for personal injury from arcing faults by conditions such as tools contacting electrical buses, insulation failures, loose connections, improper work procedures, impurities/dust buildup, corrosion, condensation, over-voltage conditions, or equipment malfunctions. Arcing faults produce hazards of extreme temperatures, light, sound, and pressure.

This document provides procedures to establish and maintain an Arc Flash Hazard Program (AFH Program) to be utilized by the Bureau of Reclamation (Reclamation). The requirements of this document are applicable to all Reclamation facilities that contain energized electrical equipment. Within this document, this program is referred to as the AFH Program and is a major component of a complete electrical safety program.

The complete mitigation of arc flash hazards is not possible in all cases. The most effective method to mitigate an AFH is to de-energize electrical equipment prior to maintenance activities. Only trained, qualified, and properly equipped personnel should be near energized equipment. The calculations and recommendations of applicable standards and this document are intended to identify and reduce arc flash incident energy levels. These procedures do not guarantee complete protection from arc flash hazards, however compliance with these procedures will reduce the possibility of burns and other injuries. Personnel who work in our facilities must be adequately protected from the risk of exposure to electric energy.

### 1.1 Applicability

This document is applicable for all Reclamation facilities that contain energized electrical equipment with voltages greater than 50 volts to ground. This document is not applicable to private leased facilities on Reclamation properties.

This document does not address safety considerations other than AFH and is to be used in conjunction with safety requirements for other hazards associated with operation, maintenance, and construction activities.

This document is to be used in conjunction with the Reclamation Safety and Health Standards (RSHS).

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<sup>1</sup> *Electrical Safety in the Workplace*, National Fire Protection Association (NFPA) 70E, 2009 edition.

Shock and electrocution have long been recognized as risks to those who work with electricity. In recent years, additional emphasis has been placed on the dangers associated with arc flash (AF) and arc blast energy. This risk arises not from the passage of electric current through the body but from the concentrated energy during an arcing fault. An electric arc can instantly vaporize material such as copper or steel. The arc, passing through the vaporized material, can create an extremely bright AF of very high and dangerous temperatures, resulting in severe burns to the hands, face, and body.

In 1979, the National Fire Protection Association introduced NFPA 70E, Standard for Electrical Safety in the Workplace. This standard covers methods to protect workers from harm due to exposure to electrical systems and devices. In 1995, NFPA 70E was revised to help protect individuals from AF dangers.

A 1999 study by the Electric Power Research Institute (EPRI)<sup>2</sup> concluded that hundreds of employees have been injured or killed by AF energy and that the cost to the related industries is significant.

Reclamation started the process of instituting arc flash protection when it revised RSHS in 2001. Section 12.1.3 b. (3) states: “use flash-protection clothing in accordance with NFPA 70E...” RSHS addresses the concept of the flash protection boundary and makes a statement on appropriate work clothing that should be worn around electrical equipment.

Protection from arc flash energy is required by:

- Occupational of Safety and Health Administration (OSHA) (Code of Federal Regulations [CFR] 1910.269(l)(6)(iii) and 1910.335(a)(1))
- NFPA 70E
- RSHS, sections 8.5.8, 8.5.9, and 12.1.3 b.(3) (2001)
- U.S. Army Corps of Engineers, Engineering Manual (EM) 385-1-1

Additional references are included in Appendix A, References.

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<sup>2</sup> EPRI Technical Report TR-108972-V4, *Disaster Planning and Mitigation Technologies, Interim Technology Inventory Report*, Report No. 4, November 1999.

## 2. General

**[Each Area Manager is responsible for ensuring a facility-specific AFH Program is developed and implemented.]** The AFH Program is a portion of a total Electrical Safety Program that includes electrical safe working practices. The AFH Program includes policies, practices, documentation, and standard operating procedures consistent with the requirements of this document.

Successful implementation of an AFH Program requires establishment and strong management endorsement of policies and a well-structured program. Arc flash protection policies and programs should be developed with assistance from the responsible safety office, qualified engineering personnel, and local bargaining units. An example of an AFH Program is provided in Appendix F.

Once the arc flash hazard analysis or assessment is complete, mitigation techniques will be incorporated. There may be scenarios identified that are either not covered or are in a category ranking above the maximum value that can be mitigated by personal protective clothing and equipment (PPE). To deal with these situations, the facility will need to develop a mitigation plan to address the specific hazards.

PPE procedures must address how PPE will be furnished (procured or rented) and maintained. The appropriate PPE selection can be made only after the arc flash hazard analysis or task based assessment is complete. The manager also must take into consideration the type of facility and what hazard/risk categories exist.

Protective device setting change procedures must address how to document and obtain approval for protective device setting changes as well as implement the result to potential arc flash hazards.

### **3. Roles and Responsibilities**

#### **3.1 Area Manager**

**[The Area Manager shall ensure that adequate resources are provided to comply with this regulation.]**

#### **3.2 Managers**

**[Managers shall:**

- (1) Mandate the development, implementation, and enforcement of the AFH Program.**
- (2) Establish the necessary policies, practices, controls, and training to ensure the communication of the hazards and necessary precautions to affected personnel.**
- (3) Provide resources for successful implementation of the AFH Program.**
- (4) Ensure that the AFH Program is updated when a major modification or renovation takes place and that, at a minimum, it is reviewed annually.**
- (5) Appoint an Arc Flash Hazard Coordinator (AFH Coordinator) for each facility to assist with implementing the AFH Program.**
- (6) Ensure that the Contracting Officer's Representative (COR) informs the contract employees of:**
  - (a) Known hazards that are covered by the AFH Program and that are related to the contract employer's work.**
  - (b) Facility information necessary for the contract employer to make required arc flash assessments.]**

#### **3.3 AFH Coordinator**

**[The AFH Coordinator (who may be the manager or supervisor) shall:**

- (1) Be a knowledgeable person to act as the facility's point of contact for AFH Program elements.**
- (2) Work in coordination with the manager and supervisor to ensure that a successful AFH Program is in place and is implemented.]**

### **3.4 Supervisors**

**[Supervisors are responsible for the day-to-day oversight and implementation of the facility AFH Program and associated policies. The supervisor shall:**

- (1) Ensure that personnel and visitors who will be in a flash protection boundary while electrical conductors or circuit parts are exposed are trained in arc flash hazards.**
- (2) Ensure safety precautions are in compliance with this regulation.**
- (3) Ensure that applicable Job Hazard Analyses address arc flash hazards.**
- (4) Ensure initial and refresher training is provided.]**

### **3.5 Employees**

**[Employees shall:**

- (1) Be knowledgeable of arc flash hazards.**
- (2) Be familiar with, and comply with, the facility's AFH Program.**
- (3) Report observed violations of the AFH Program according to established procedures.**
- (4) Report all arc flash related incidents and accidents to the supervisor.]**

### **3.6 Contractors**

The following information relates to contractors.

#### **3.6.1 Relationships with Contractors (Outside Service Personnel, etc.)**

**[Managers shall ensure that the Contracting Officer's Representative informs the contract employers of the following:**

- (1) Known hazards that are covered by the AFH Program and that are related to the contract employer's work.**
- (2) Information about the employer's installation necessary for the contract employer to make required arc flash assessments.**
- (3) Facility personnel shall report observed contract employer-related violations of the AFH Program according to established procedures.]**

### **3.6.2 Contractor Responsibilities**

**[Contractors are responsible for ensuring their employees and subcontractors, who will be working in an AFH area, are knowledgeable of the facility's AFH Program. Contractors shall ensure that their employees and subcontractors are trained in arc flash hazards, the proper use of arc flash PPE, and are provided appropriate PPE. The contractor will provide their AFH program and procedures to the COR as a submittal, which must be acceptable prior to beginning work. The Contractor shall advise the Government of:**

- (1) Any unique or unanticipated hazards presented by the contract employer's work.**
- (2) The measures the contractor took to correct any violations reported by the government to prevent such violations from recurring in the future.]**

## 4. Arc Flash Hazard Analysis

**[An AFH analysis is required if there is a possibility that employees may be exposed to energized electrical conductors at 50 or more volts.]** There are two forms of AFH analyses: detailed incident energy (IE) analysis and task based assessment.

### 4.1 Detailed IE Analysis

**[The detailed IE analysis is based on Institute of Electrical and Electronics Engineers (IEEE) 1584™. It is required for the following facilities: powerhouses, spillways, fish facilities, pumping stations, irrigation and domestic water facilities, maintenance shops, laboratories, mobile equipment, or similar type facilities.]** The detailed IE analysis determines the incident energy exposure of the worker, the flash protection boundary, hazard/risk category, and required PPE. It is the most accurate AFH analysis and provides tools for reducing potential incident energy exposure. Only qualified engineers shall conduct this analysis.

**[The AFH analysis must be updated when a major modification or renovation takes place. It shall be reviewed periodically, not to exceed 5 years, to account for changes in the electrical distribution system that could affect the results of the AFH analysis.<sup>3</sup> ]**

### 4.2 Task Based Assessment

The task based assessment refers to the tables 130.7(C)(9), 130.7(C)(10), and 130.7(C)(11) included in NFPA 70E (2009). It determines required PPE based on equipment voltage and task. **[The task based assessment may be used at the following facilities, if determined appropriate by a qualified engineer: recreational areas, offices, remote communications sites, or similar type facilities.]**

The task based assessment may be used as an interim step at all facilities until a detailed IE analysis is able to be funded and completed.

### 4.3 Resources for AFH Analysis

**[Only qualified engineers shall complete the detailed IE analysis and decide which analysis method is adequate for recreational areas, offices, remote communications sites, or similar type facilities.]** Area or regional offices may contain qualified engineers.

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<sup>3</sup> See NFPA 70E-2009, Article 130.3.

The Hydropower Technical Services Group (86-68440) of the Technical Service Center in Denver is the center of expertise for hydroelectric generation and large pumping plant engineering services within Reclamation. This office contains qualified engineers that can assist with the AFH analysis. Call 303-445-2300 for information.

Regional and area office personnel, engineering firms, or other government agencies also may be able to complete the detailed IE analysis. If regional or area office personnel, engineering firms, or other government agencies are to be used, they must utilize qualified engineers. Persons performing analyses are required to have similar experience with generation, heavy industry, and low to high voltage equipment.

#### **4.4 Detailed Incident Energy Analysis.**

Detailed IE analysis results are used to identify the flash protection boundary and the incident energy at assigned working distances throughout any position or level in the electric generation, transmission, distribution, or utilization system. Once the incident energy and flash protection boundaries are calculated, they become a basis for developing strategies to minimize burn injuries. Strategies include modifying protective device settings or ratings, specifying the thermal rating of PPE, working de-energized, applying arc resistant switchgear, and following other control techniques and work practices as described in Section 5, Mitigating Hazards.

The detailed IE analysis must be performed in tandem with a fault study and protective device coordination study. Fault study results are used to determine the momentary duty, interrupting rating, and the fault (withstand) rating of electrical equipment. Coordination study results are used to determine the time required for protective devices to isolate overload or fault conditions. Both studies provide information used for a detailed IE analysis and must contain current data, because the results of each study directly affect the detailed IE analysis results.

The level of incident energy that a worker might be exposed to depends on the magnitude of the fault current, the duration of the fault, and the worker's distance from the arc.

##### **4.4.1 Tools**

There are many software packages available to assist in AFH analyses. All must be used in conjunction with IEEE 1584™ and NFPA 70E guidelines.

Engineering judgment must be used in any analysis. To calculate the incident energy, there are generally two methodologies employed. The first is based on the circuit equations of IEEE 1584™, while the second is based on the physics of the arc. Detailed IE analysis based on physics of the arc typically is used for high voltage and open air applications.

#### **4.4.1.1 Power System Analysis**

Power system analysis is based on IEEE 1584™. This analysis requires building a software model of the facility being analyzed on a single-line diagram that includes all the appropriate equipment. It includes the following critical items: system voltage and impedance, bus voltages, transformer connections and impedances, bus and cable sizes and lengths, circuit breaker types and ratings, fuse types and ratings, locations of switches for configuring various operating schemes, current transformer locations and ratios, and relay types and settings. For each piece of equipment, include the type (open air, motor control center, enclosed, etc.) and determine the arc gap and working distance. Compute the incident energy for each mode of operation. Scenarios that produce maximum fault current will not necessarily yield maximum incident energy. The incident energy is determined by the arcing current, which is only a fraction of the bolted fault current. Operational procedures, physical layout, and site specific information all must be considered by the qualified engineer to correctly interpret the data.

#### **4.4.1.2 Incident Energy Calculations**

Incident energy calculations are based on the physics of the arc. Software to calculate incident energy, based on the thermal characteristics of electric arcs, is appropriate for high voltage, single-phase faults in open air. User-supplied data generally includes gas properties, electrode materials, thermal radiation, convective energy dissipation, arc gap, system voltage, bolted fault current, arc current, clearing time, and the working distance. Only one location for a specific set of conditions is analyzed at a time.

#### **4.4.2 Fault Study**

Fault studies must be performed at all points where personnel might be exposed to arc flash energy. Fault current magnitude depends on the capacity of the system to supply current at the fault location and the sensitivity of the circuit protective devices. These require a thorough understanding of the system configuration and accurate data on components and protective devices. Results from this study are used to ensure that all devices are rated appropriately and are capable of interrupting the available fault current.

When used for the detailed IE analysis, minimum and maximum fault currents must be obtained. Fault currents for all operating configurations at 95- and 105-percent (%) voltage levels must be analyzed for the worst case incident energy scenario.

#### **4.4.3 Coordination Study**

A coordination study analyzes the time current characteristic curves of the protective devices and compares them against one another on log-log plots. Any areas lacking coordination will be apparent by overlapping of curves from the various devices. In general, the main protective device(s) at a switchboard or panelboard are compared against the largest feeder

protective device. If coordination exists at this level, coordination is guaranteed for all devices at the switchboard or panelboard in question.

The results of a protective device coordination study are used to increase equipment protection, ensuring protective device coordination by setting the protective devices to trip in sequence, as well as an increase in facility reliability by limiting the effects of a disturbance (fault/overload) to smaller areas of the distribution system.

When used for the detailed IE analysis, time current characteristic curves provide the fault duration. Refining the time current characteristic curves may have a significant impact on incident energy and mitigate protective measures. A 2-second maximum arcing time may be used where escape is possible.

The detailed IE analysis must be performed on the current conditions of the facility. Recommendations should be made to correct protective device coordination problems to mitigate high incident energy levels.

It is not acceptable to substitute similar devices when the actual equipment time current characteristic curve is not available. Minor differences in time current characteristic curves between these devices may lead to extremely dangerous situations. For worst case scenarios, these devices should be modeled as a switch with no automatic switching capability. An alternate to this, use the next overcurrent device upstream to define the clearing time where the data is known.

#### **4.4.4 Areas of Concern**

##### **4.4.4.1 Accumulated Energy**

Fault current often is delivered from multiple sources, each of which is cleared by its own protective device. The energy at the fault location varies as each source is cleared. This energy must be accumulated until there is no longer enough energy to sustain the arc. The accumulated energy must be properly accounted for whether using software or hand calculations. Instead of summing all sources together for the total clearing time, each source should be considered individually; and, then, those incident energy values are added.

##### **4.4.4.2 Inaccurate System Data**

Poor estimates of equipment impedances may have major impacts when the arcing fault current is near the transition between the long time pickup and the instantaneous pickup of a protective device. Figure 1, below, shows two arcing fault currents in this transition area. The 12.5-kiloampere (kA) arcing fault current clears in 0.05 seconds and results in an incident energy of 2 calories per square centimeter ( $\text{cal}/\text{cm}^2$ ). The 10.5-kA arcing fault current clears in 0.5 seconds and results in an incident energy of 17  $\text{cal}/\text{cm}^2$ . This difference of arcing fault current could easily happen due to an impedance mistake—e.g., incorrect transformer impedance or feeder cable information.

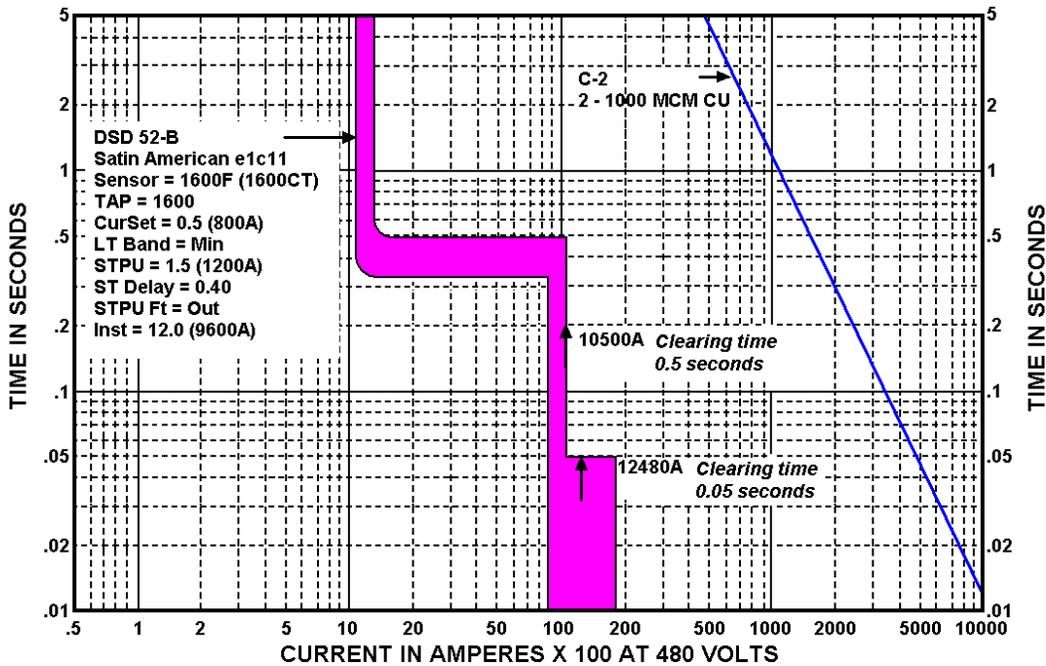


Figure 1. Typical Time Current Curve and Arcing Fault Currents.

#### 4.4.5 Generator Bus Calculations

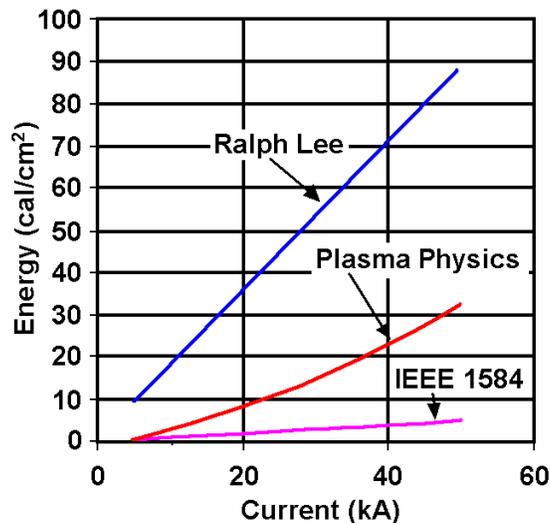
Hydrogenerators with large rotational inertia will continue to contribute fault current over a time of several seconds because there is no method to isolate the power source from the fault. The fault current will decay over this time, and calculations of the fault current must account for initial terminal voltage, excitation level, power angle, and the response of the exciter and governor. To correctly estimate the incident energy, it is necessary to use a complex dynamic simulation to integrate the combined effects of these elements over the arcing time period. Superposition of this and other current sources (often other machines) then must be used to arrive at the total incident energy.

Generators ordinarily can sustain arcing faults for long periods of time and will produce incident energies for all but the smallest units, which qualify as Hazard/Risk Category Dangerous. Therefore, it is acceptable to label all equipment in the generator zone as “Dangerous” since this is the highest category available. This may include the generator, iso-phase bus, unit breakers, excitation transformers, and station service taps, depending on the configuration. Work on exposed energized electrical conductors or circuit parts within these areas should not be done when the generator is online.

#### 4.4.6 Voltages Over 15 Kilovolts and Open-Air Situations

Several software methods based on IEEE 1584™ default to a solution based on equations developed by Ralph Lee when certain boundary conditions are exceeded. Ralph Lee’s paper, *The Other Electrical Hazard: Electric Arc Blast*

Burns,<sup>4</sup> published in 1982, introduced a revolutionary new concept for quantifying the arc flash hazard and defined arc energy, approach distance, and incident energy. Lee assumed maximum power transfer to the arc radiant energy but ignored the plasma physics effects. Lee's method results in overly conservative results above 1 kilovolt (kV), which get worse with increasing voltage. Most software presently available transitions from the IEEE 1584™ equations to the Ralph Lee equations when the voltage exceeds 15 kV—thus, producing overly conservative results for voltages above 15 kV. Figure 2 compares the calculated heat flux from software that includes plasma physics effects with results using the IEEE 1584™ equations and the Ralph Lee equations for a simple case at 15 kV, 6-inch gap, 26-inch distance, and clearing after 6 cycles.



**Figure 2. Comparison of IEEE 1584™, Ralph Lee and ArcPro™ Plasma Physics Equations.**

The plasma physics method uses equations based on conservative assumptions about arc physics and transport phenomena. Software that models plasma physics also will over predict the energy, but by much less than the Ralph Lee equations. The empirically derived IEEE 1584™ method is the most accurate method but is limited to those cases that were tested. In some cases, the plasma physics approach is much closer to reality than the Ralph Lee method and is the best tool available.

Finally, instead of calculating the arcing fault current, some less expensive commercial programs use the total bolted fault current. The qualified engineer must ensure that the arcing fault current is used for calculating incident energy.

<sup>4</sup> Ralph H. Lee, "The Other Electrical Hazard: Arc Blast Burns," *IEEE Transactions on Industrial Applications*, 1A-18 No. 3, May/June 1982.

#### **4.4.7 Equipment Duty**

After a fault study is performed, the protective devices interrupting capabilities should be investigated to ensure that these devices can interrupt the available fault current. Many software packages include this function as part of their capabilities. When available fault current reaches 90% of the interrupting capability of the protective device, a warning should be generated that will flag this device as a possible weak point in the protective circuit. The available fault current at this device should be closely watched to ensure that the fault current does not exceed the interrupting rating of the protective device. If the available fault current becomes greater than the equipment's interrupting rating, the device may not be able to interrupt the fault. This will invalidate the results of the arc flash energy calculations in this circuit as well as causing possible damage to the equipment.

#### **4.4.8 Process**

The following is a list of the steps in the detailed IE analysis:

1. Collect as-built single-line drawings.
2. Collect utility contribution.
3. Collect equipment data (voltage, size, current, impedance, x/r, etc.).
4. Determine protective device characteristics (types, settings, etc.).
5. Determine power system characteristics (voltage regulation, short circuit, x/r, etc.).
6. Determine plant or system operating modes.
7. Determine working distances, including hot stick usage.
8. Construct a power system model.
9. Perform fault studies.
10. Calculate the minimum and maximum bolted fault current.
11. Determine branch contributions.
12. Evaluate equipment interrupting capability.
13. Calculate the arcing current.
14. Perform a coordination study based on existing conditions.
15. Calculate arcing time.

16. Calculate incident energy for each device/location/operating mode.
17. Analyze results of the arc flash calculations.
18. Use strict criteria to choose the most conservative values.
19. Determine equipment operating conditions.
20. Can the operating condition change (auto switching)?
21. Can someone manually change the operating condition?
22. Calculate the flash protection boundary.
23. Determine PPE requirements.

#### **4.4.9 Flash Protection Boundary**

When using the empirically derived equation from IEEE 1584™, the flash protection boundary is calculated based on the incident energy, equipment type, and voltage. As such, the results can vary from very small to very large numbers. To facilitate work planning and training, round the calculated flash protection boundary up to the nearest whole foot with the minimum flash protection boundary being 3 feet.

#### **4.4.10 Model Ownership**

**[The AFH analysis must be updated when a major modification or renovation takes place as well as reviewed every 5 years at a maximum.]**

Changing one protective device setting can greatly affect the incident energy results. For these reasons, the facility, Area Office, Regional Office, or the Technical Service Center shall retain the software model or all data and calculations. Retaining model ownership facilitates maintaining and updating the arc flash hazard analysis, including tables in the report, and printing new labels for the equipment.

### **4.5 Task Based Assessment**

The NFPA 70E task based assessment method has two major drawbacks, which may result in either too much or too little protection. First, fault current is not calculated. Instead, current magnitude is assumed based on voltage. The determined incident energy is, therefore, only approximate and may be significantly in error, depending on the local configuration of cable, bus size, and effective system impedance. Second, the task based tables do not take into account actual clearing times of fuses and circuit breakers, which greatly affect the incident energy.

Extreme caution should be exercised when assuming fault current levels. An infinite bus or a bolted fault is assumed to be the worst-case; however, it may *not* produce the maximum AF energy. The actual fault current may cause a thermal, not instantaneous, trip; so the protective device may not operate instantly. Since AF energy depends on the duration of the arc as well as the current, the energy of the lower-current fault might be higher than that for the assumed bolted, infinite-bus fault.<sup>5</sup>

#### 4.5.1 Process

The following is a list of steps for the task based assessment.

1. Review NFPA and IEEE AF safety standards and evaluation methodologies.
2. Identify all locations and equipment in the facility that pose an AFH.
3. List the equipment and/or locations for which the flash protection boundary can be determined by look up tables or simplified formulas.
4. List the equipment and/or locations that must be analyzed using calculations that are an integral part of Phase 2 tasks.
5. Determine tentative flash protection boundaries and PPE requirements for all pertinent equipment using look up tables and simplified formulas.
6. Document the results of AFH analysis based upon look up tables.
7. Mitigate known arc flash hazards to the extent possible.

#### 4.6 DC and Single Phase

There is little guidance available for AFH analysis on direct current (dc) systems. NFPA 70E and IEEE 1584<sup>TM</sup> *do not specifically provide guidance for analyzing dc systems*. At the time this document was published, commercial dc AFH analysis software did not exist. There is current research in this area, but calculation methods are not expected to be available until 2011 at the earliest.

Crafts personnel tend to underestimate the AF risk associated with dc systems. Safe clearance procedures and activity hazard analysis focus strictly on voltage, while safety training typically deals only with electric shock. The exclusion boundary and risk estimate depend only on system voltage. Often, the typical 125-volt (V) battery system is considered no more hazardous than a typical 110-volt alternating current (Vac) wall outlet, and it is often considered acceptable to work on low voltage systems while they are energized. Historically,

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<sup>5</sup> See IEEE Standard (Std.) 1584-2002, section 4.1.

electrical safety practices that did not include AFH created a false sense of security when dealing with dc systems. The AFH associated with large battery systems is great and should be emphasized.

Typical station service battery systems have short circuit current capacities of 40 to 60 kA, which is much larger than the short circuit current capacity usually available from 110-Vac outlets. The plasma of dc arcs and alternating current (ac) arcs behave differently; and for systems of the same voltage, the incident energy of the dc arc can be much higher. Typical 110-Vac outlets are at the end of a system containing several protective devices, while battery system maintenance usually occurs at a point without such devices. Dc arcs can last much longer than ac arcs.

**[The following guidance, when working on energized dc or single phase electrical conductors or circuit parts, shall be followed until further tools are available:**

- (1) 125-volt direct current (Vdc) or below control circuits: Category 0**
- (2) 120-Vac single phase or below control or lighting circuits: Category 0**
- (3) dc switchgear, panelboards, battery rooms: Category 2**
- (3) The facility shall develop local procedures to address these areas.]**

## 5. Mitigating Hazards

In the past, the default mode for protecting employees has been to put them in personal protective clothing and equipment, usually because it is quick and easy. However, the use of safety management principals in which measures are considered in order of effectiveness is necessary for mitigating AFHs. This “hierarchy of controls” is discussed in detail in the American National Standards Institute (ANSI) Z10 standard, the first United States consensus standard for managing safety and health programs. The control strategies list the substitution and elimination of hazards as the first steps towards meeting the commitment to providing a safe workplace. Lower-tiered strategies then are considered in descending order of effectiveness, until workers are adequately protected. The mitigation of arc flash hazards is best achieved by a combination of controls in which PPE is always considered last.

Hierarchy of controls shall be used to remove, reduce, or achieve an acceptable level of risk.

NFPA 70E largely is focused on the last three strategies: warnings, administrative controls, and PPE. A “nonmandatory” annex (Safety Related Design Requirements – Annex O) of NFPA 70E discusses the other methods. This document will describe providing worker safety with a standard of care that meets current best practices and improves on measures contained in NFPA 70E.

### 5.1 Substitution/Elimination

Substitution and elimination must be considered as the first steps towards hazard reduction. Working on de-energized circuits is the ideal method of eliminating AF injuries and must be taken into account in all work processes.

Substitution for less hazardous processes, materials, operations, and equipment can be achieved in many forms. Examples of design considerations are discussed below.

#### 5.1.1 Existing Installations

The following are examples of design considerations for existing installations.

- Substituting older breaker trip elements with newer solid-state trip elements, which have more options to allow better coordination between protective devices.
- Reducing energy levels as a result of device coordination studies, which could allow for tightening time delays for faster circuit interrupting.
- Extend the distance to the live exposed parts by integrating a longer hot stick or shotgun, remote racking systems, remote breaker operating systems, etc.

- Install a maintenance mode switch on a breakers trip element to reduce the instantaneous trip setting while work is being performed. This will decrease the arc flash energy level during maintenance activities.

### **5.1.2 New Installations**

The following are examples of design considerations for new installations.

- NFPA 70E, Annex O, states that owners have a responsibility to apply electrical hazard analysis during the design of electrical systems/installations. This nonmandatory annex suggests that this responsibility is indicated by the mandatory Electrical Hazard Analysis contained in 110.8.(B)(1).
- Consider specifying arc resistant switchgear, finger safe electrical components, insulated buses, transformers with high impedance values, and current limiting breakers with high speed operation among others.
- Remote monitoring of motor control equipment, which allows for information transfer and troubleshooting without opening unit doors. Similar emerging technologies (remote racking) that separate workers from energized equipment and reduce PPE levels should always be considered.

## **5.2 Engineering Controls**

The line between engineering controls and substitution/elimination is sometimes blurred. Some may consider “substitution of older equipment with new” as an engineering control. For this document, engineering controls are defined as barriers, covers, enclosures, insulated tools, and associated equipment that increases workers distance from energized circuits. Voltage meters designed with shotgun (hot stick) adapters are an example of an engineering control that provides distance.

## **5.3 Warnings**

Warnings are designed to inform and remind employees about hazards. Arc flash protection warnings include highly visible barricades, labels, signage, and danger warnings in equipment manuals/operating instructions. NFPA 70E stresses the use of electrical equipment labels that contains specific hazard information (see section 8).

## **5.4 Administrative Controls**

Administrative controls generally include procedures and training and are addressed in detail in NFPA 70E. Examples include:

- Job briefings – 110.7(G).
- Performing arc flash hazard analyses – 130.3.
- Implement and document a complete electrical safety program of which safety-related work practices is a component – 110.7(A).
- Develop energized electrical work permits on those occasions when qualified workers must work on circuits that are not in an electrically safe work condition – 110.8(B)(2) and 130.1.
- Hazardous energy control procedures – 120.2.
- Maintenance requirements such as maintaining overcurrent protective devices in accordance with manufacturer’s instruction or industry consensus standards – 205.3.
- Program audits/oversight – 110.7(H).
- Providing for safety in the equipment and system design stages – Annex O.
- Change control procedures – How to document and obtain approval for equipment setting changes.
- Training – 110.6 and Section 9, Training, of this document.

## **5.5 Personal Protective Equipment**

Although PPE is the last stage in the hierarchy of controls, its use is critical to providing comprehensive worker protection. In combination with the higher tiered controls, PPE is intended to provide workers with the necessary equipment to protect vision, hearing, and prevent burns more severe than second-degree. Section 7, Personal Protective Clothing and Equipment and Standard Work Clothing discusses PPE in detail.

## 6. Integration of Controls into Work Practices

There are several work practices that need to be altered to ensure that employees are protected from, as well as can identify, the potential damage of an arc flash hazard in the workplace. **[The facility shall review and alter established work practices to include protecting employees from this hazard, as this is a relatively new identified hazard. The following established safety tools will require alteration/update to address this hazard:**

- **Facility standard operating procedures (SOPs)**
- **Preventive maintenance and work order job tasks**
- **Switching orders (including arc flash reduction maintenance switches)**
- **Safe clearances**
- **Job hazard analyses]**

Job plan templates reside in the planning module – job plan application in the Capital Asset and Resource Management Application (CARMA).

### 6.1 Develop a Job Hazard (JHA)

Develop a job hazard analysis whenever the work involves a potential for arc flash hazards. The JHA shall include each work task, identify associated arc flash hazards, and list control/mitigation techniques that will eliminate, reduce, or control each arc flash hazard to an acceptable level. The JHA shall meet the requirements of RSHS, Section 4, and include PPE and other equipment needed.

A sample of a JHA for an AFH is located in Appendix D, Example Wording for a Typical Job Hazard Analysis. The JHA in Appendix D gives specific hazards due to AFHs only. An actual JHA will contain information on all hazards for the work being performed.

## 7. Personal Protective Clothing and Equipment and Standard Work Clothing

### 7.1 Background

NFPA 70E has created five hazard/risk category levels that relate directly to the arc thermal performance (arc rating) of the personal protective clothing and personal protective equipment required. Personal protective clothing consists of flame-resistant (FR) clothing. For the purposes of this document, the term PPE will encompass personal protective clothing and personal protective equipment.

### 7.2 General

The AFH analysis determines the AF protection boundaries and the hazard/risk category for selecting PPE that people within the AF Protection Boundary shall use. The PPE used by the worker must be selected based on the characteristics of the hazard. **[Reclamation shall provide appropriate PPE intended to protect a worker from AF hazards (to limit the thermal injury to the worker's face and chest to a second-degree [i.e., curable, burn]).]** PPE does not address protection against physical trauma injuries that could occur, other than exposure to the thermal effects of an AF.

The employer shall provide FR clothing and other PPE required for work on equipment rated as Hazard/Risk Categories 1 through 4. Protective clothing includes, but is not limited to, FR shirts, pants, coveralls, jackets, and parkas worn routinely by workers who, under normal working conditions, are exposed to momentary electric arc and related thermal hazards. FR rainwear worn in inclement weather also is included in this category. Protective equipment includes, but is not limited to, arc-rated face shields, gloves, boots, and insulated tools.

**[Employees working within the AF protection boundary shall use PPE that is designed and constructed for the specific part of the body to be protected and for the work to be performed. The entire body—to include the back of the head and torso—must be protected from thermal injury. PPE used for protection from thermal injury from an arcing fault must be arc-rated, FR equipment.]**

**[Each facility shall develop and maintain a list of needed PPE as determined by the results of the AF analysis. Facilities shall purchase (or rent), issue, and maintain PPE as required.]**

### **7.3 AF Hazard/Risk Categories and Associated Clothing and PPE Requirements**

The five hazard/risk category levels defined by NFPA 70E are Hazard/Risk Categories 0, 1, 2, 3, and 4. Each of these categories requires that all clothing that is non-flame resistant (non-FR) consist entirely of natural materials, as identified below. Non-FR clothing is comprised of nonmelting, flammable materials. Clothing made of flammable, synthetic materials or blends are prohibited within a flash protection boundary.

Levels above Category 4 are determined as Category Dangerous. There is no approved PPE for this category. The facility shall develop local procedures for situations requiring work within Category Dangerous flash protection boundaries. Administrative or engineering controls must be used to mitigate the hazard.

Flammable, synthetic materials are prohibited. These synthetic materials include acetate, acrylic, nylon, polyester, polyethylene, polypropylene and spandex, alone or in blends. These materials melt as a result of AF exposure conditions, form intimate contact with the skin, aggravate the burn injury, and are prohibited to be worn by workers who have the potential for exposure to AFHs. Other apparel (such as hard hat liners, hair nets, ear warmers, head covers, etc.), made from materials that do not meet these requirements for melting or made from materials that do not meet the flammability requirements, shall not be permitted to be worn. Ear warmers, head covers, hair nets, etc. that are made of arc-rated FR materials are available and may be worn.

Nonmelting, flammable (non-FR) materials are permitted. These materials include untreated cotton, silk, rayon, and wool fabrics (standard denim jeans, chinos, khaki slacks, etc.). Although permitted, these fabrics could ignite and continue to burn on the body, resulting in serious burn injuries.

### **7.4 Standard Work Clothing**

All employees within the AF protection boundary, regardless of work being performed, shall wear nonmelting, flammable (non-FR; untreated natural fiber) standard work clothing, including undergarments as a base to the appropriate PPE, as identified in the JHA, to protect the body from severe injury from an AF. Other standard work clothing shall not be worn as it could ignite and be trapped between the employee's skin and the PPE if an arc flash were to occur that had higher incident energy than the energy of breakopen threshold(EBT).

Employees are responsible for providing standard work clothing which does not include PPE. This clothing shall, as a minimum, be comprised of materials that are non-melting, flammable (non-FR). Avoid tight-fitting clothing. Loose-fitting clothing provides additional thermal insulation because of air spaces.

## **7.5 Personal Protective Clothing and Equipment**

### **7.5.1 General**

**[When FR clothing is worn, it must cover and prevent all ignitable clothing (to include undergarments) from igniting and burning.**

**Arc-rated FR protected equipment/clothing must contain a label or other mark that describes the maximum incident energy rating.**

**FR clothing shall allow for movement and visibility.]**

### **7.5.2 Fit**

The fit of FR clothing is important to the safety of the worker. When the surface of FR clothing is heated, heat is conducted through the material; and any FR clothing touching the skin can result in a burn. To minimize this, FR clothing must fit loosely to provide additional thermal insulation but must not fit so loose that it interferes with the worker's movements. The ability of the worker to see in the necessary direction must also not be restricted. One size does NOT fit all. When women wear PPE designed to fit men, the clothing must be selected such that risk of an incident is not increased as a result of the fit.

Employees shall remove all contents from pockets so clothing fit is loose in the pocket areas.

### **7.5.3 AF Suits**

**[The suit design shall permit easy and rapid removal by the wearer (avoid zippers in the back of the suit).]**

### **7.5.4 Head, Face, Neck, and Chin (Head Area) Protection**

**[Workers shall wear nonconductive, arc-rated, head protection (ANSI Z89.1, Class E or G) and nonconductive PPE for the face, neck, and chin wherever there is a danger of injury from electric shock, burns, arcs, or flashes or from flying objects resulting from electrical explosion. If employees use hair-nets and/or beard nets, these items must be nonmelting and flame-resistant.]**

### **7.5.5 Eye Protection**

**[Workers shall wear protective eyewear whenever there is a danger of injury from electric arc, flashes, or from flying objects resulting from electrical explosion. If the worker's head is within the AF boundary, the worker's eyes must be protected from the thermal hazard as well.] Safety glasses meeting requirements of ANSI Z87.1 provide protection from impact and also filter damaging ultraviolet energy.**

### **7.5.6 Face Protection**

**[If a faceshield is worn, it must have an arc rating at least as great as the predicted incident energy. If a hood is worn for thermal protection, viewing window must protect the worker's eyes from the thermal hazard. Protective eyewear, in the form of safety glasses, always must be worn under the face shield or viewing window. Goggles may be worn only if they have an arc rating.]**

### **7.5.7 Hearing Protection**

**[Hearing protection must be worn while performing work within an AF protection boundary.]**

### **7.5.8 Body Protection**

**[Employees shall wear FR clothing when they are within the AF protection boundary and wherever there is possible exposure to an electric AF above the threshold incident energy level for a second-degree burn (5 joule per square centimeter [J/cm<sup>2</sup>] [1.2 cal/cm<sup>2</sup>]).]**

Clothing shall cover potentially exposed areas as completely as possible. Fasten shirt sleeves at the wrist and fasten top buttons of shirts and jackets to minimize chance that heated air could reach underneath the FR clothing.

All flammable, nonmelting clothing in exposures above Hazard/Risk Category 0 must be protected by at least one layer of clothing that has an established incident energy rating. This clothing may be provided as an AF suit jacket and arc flash suit pants, shirts and pants, coveralls, or as a combination of jacket and pants or, for increased protection, as coveralls with jacket and pants.

Various weight fabrics are available and shall be considered for comfort, heat stress, fit, ease of movement, etc. Generally, the higher degree of protection is provided by heavier weight fabrics and by layering combinations of one or more layers of FR clothing.

In some cases, one or more layers of FR clothing may be worn over flammable, nonmelting clothing to achieve the degree of protection necessary. Layering increases the overall protective characteristics of FR clothing. If FR clothing is worn in layers, some air is trapped between the layers and provides extra thermal insulation.

### **7.5.9 Outer Garments**

**[Garments worn as outer layers over FR clothing (i.e., jackets, rainwear) shall also be made from FR material.]**

### **7.5.10 Under Layers**

Significant injuries occur when fabrics melt onto a worker's skin. Clothing made from materials that melt (i.e., acetate, nylon, polyester, polypropylene, spandex) are not permitted in fabric underlayers (underwear) next to the skin. An incidental amount of elastic used on nonmelting fabric underwear or socks is permitted.

### **7.5.11 Hand and Arm Protection**

**[Workers shall wear hand and arm protection rated for the voltage for which the glove will be exposed when working within the flash protection boundary.]**

The hands normally are the most exposed part of a worker's body. The apparel described by NFPA 70E 130.7(C) (13) (c) is required for protection of hands from burns. If an arcing fault does occur, the worker's hands likely are to be much closer to the arc than his torso. FR-rated gloves are available. Although not rated for thermal protection, voltage-rated gloves with leather protectors provide significant thermal protection. When the worker's hands are within the flash protection boundary, rubber insulating gloves must be worn with leather protectors. PPE that provides thermal protection offers no acceptable protection from shock or electrocution. Shirt sleeves should fit under the gauntlet of protective gloves to minimize chance that thermal energy could enter the shirt sleeves.

The same clothing worn for body protection must provide AF protection for the worker's arms. Clothing selected and worn to protect the upper torso from thermal exposure must have long sleeves, and be fastened at the wrist. The sleeves must not be shortened or rolled up. Apparel that provides thermal protection for the worker's arms shall be an integral part of the apparel that protects the upper torso. Arm protection shall be accomplished by apparel described in NFPA 70E 130.7(C)(5).

### **7.5.12 Foot/Leg Protection**

Experience has shown that worker's feet are less exposed than his/her hands or head. Shoes with an arc rating are not available. Heavy-duty leather, safety-toed shoes provide some AF protection to the feet and shall be used in all tasks in Hazard/Risk Category 2 and higher and in all exposures greater than 4 cal/cm<sup>2</sup>. Shoes made from lightweight material shall not be selected. If the AF analysis indicates that the worker's legs could be exposed to an AF, FR clothing worn to protect the lower torso also must protect the worker's legs from exposure.

### **7.5.13 Conductive Articles Being Worn**

**[Conductive articles of jewelry and clothing (i.e., large belt buckles, watchbands, bracelets, rings, key chains, necklaces, metalized aprons,**

**cloth with conductive thread, metal headgear or metal frame glasses) are prohibited within a flash protection boundary.]**

## **7.6 Maintenance**

**[PPE shall be maintained in a safe, reliable condition per the manufacturer's recommendations.]**

### **7.6.1 Inspection**

**[Workers shall inspect their arc-rated FR clothing, per the manufacturer's instructions, visually before each use to ensure that the clothing is not soiled or contaminated with grease, oil, flammable liquid, or combustible materials.]** The clothing must be free from tears, cuts, or rips. Workers shall be trained to understand how to inspect FR clothing and how to determine when the rating of the FR clothing is voided (presence of materials discussed above). PPE or AF suits that are contaminated or damaged to the extent their protective qualities are impaired, shall not be used. Regardless of use, FR apparel must be inspected monthly by a qualified worker to ensure its effectiveness when needed.

### **7.6.2 Storage**

**[PPE shall be stored in a manner to prevent physical damage and damage from moisture, dust, or other deteriorating agents or contamination from flammable or combustible materials.]** Contamination reduces the thermal protection provided by the clothing.

### **7.6.3 Cleaning, Repairing and Affixing Items**

**[Arc-rated FR clothing and other arc-rated PPE must be maintained in a clean and sanitary condition and must be cleaned and maintained as defined by the clothing manufacturer.]** The manufacturer's instructions for cleaning and care of their products will be very specific, since certain cleansers and chemicals will affect the FR characteristics.

#### **7.6.3.1 Options**

When workers launder their own PPE, they must follow those instruction that generally require different wash/rinse cycles than are used for household washing. When using a laundry service, the laundry facility must be aware of the FR clothing manufacturer's laundering instructions that must be implemented with regard to retaining the FR characteristics.

If FR clothing is shared by workers, consider health aspects of shared PPE when determining cleaning frequency.

When FR clothing is repaired, the same FR materials used to manufacture the FR clothing shall be used to complete repairs.

When trim, name tags, patches or labels are affixed to FR clothing, guidance in American Society for Testing and Materials (ASTM) F 1506, Standard Performance Specification for Textile Material for Wearing Apparel for Use by Electrical Workers Exposed to Momentary Electric Arc and Related Thermal Hazards, shall be followed. They also must be made of arc-rated, FR material.

## 8. Labeling and Boundary Markers

### 8.1 Warning Labels

Equipment warning labels serve as a reminder to employees that, the equipment they may be working on, presents serious hazards and their work procedures need to take these hazards into account.

NFPA 70 (2008), National Electric Code, article 110.16 states:

**110.16 Flash Protection.** Electrical equipment, such as switchboards, panel boards, industrial control panels, meter socket enclosures, and motor control centers that are in other than dwelling occupancies and are likely to require examination, adjustment, servicing, or maintenance while energized shall be field marked to warn qualified persons of potential electric arc flash hazards. The marking shall be located so as to be clearly visible to qualified persons before examination, adjustment, servicing, or maintenance of the equipment.

NFPA 70E (2009), Electrical Safety in the Workplace, article 130.3 states:

**130.3 (C) Equipment Labeling.** Equipment shall be field marked with a label containing the available incident energy or required level of PPE.

**[Warning labels are required to state the existence of an AFH and have either the incident energy or required level of PPE.]** This information is easily gathered after having performed a detailed IE analysis. Further information included after the detailed IE analysis may include: flash protection boundary; working distance; PPE level description; shock hazard; and glove class, as well as limited, restricted, and prohibited approach boundaries. In this way, employees more readily can assess the risk and better ensure proper work procedures and the use of protective equipment required to keep them safe.

For the temporary task based assessment, the requirement for listing the incident energy is impossible to meet, and listing the required level of PPE is not practical. This is because the task based assessment uses NFPA 70E look-up tables based on tasks, not on calculated values. **[Therefore, the label for the task based assessment will be general in nature. These labels must be replaced after the detailed IE analysis has been completed.]**

### 8.2 Label Design

Labels shall be based on ANSI Z535.4. Category 0 shall contain the word “CAUTION” in black letters on a yellow background. Category 1 through 3 shall contain the word “WARNING” in black letters on an orange background.

Category 4 shall contain the word “DANGEROUS” in black letters on a red background. Category Dangerous (above category 4) shall contain the word “DANGEROUS” in white letters on a red background.

### 8.3 Label Style for Detailed IE Analysis

The style of label provided for the equipment being studied depends on the physical location of the main protective device(s). Both label styles are explained below, followed by two one-line diagram examples of where each style would be used.

#### 8.3.1 Bus Side Fault Label

The bus side fault label is used for equipment that is main lug only or has nonautomatic mains. Figure 3 shows an equipment arrangement example for a bus side only fault. Notice that for any fault located inside equipment LQ1.1, protective device PD-1 is the only device capable of clearing the majority arcing fault current. This arrangement yields only one possible arc hazard category at the studied equipment dictating that a bus side label be used.

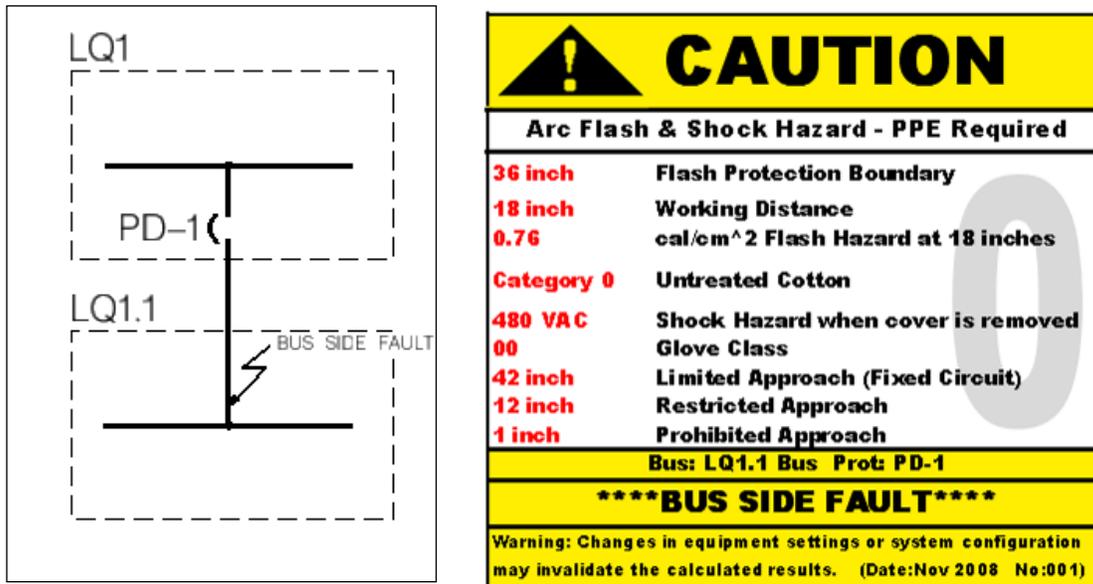


Figure 3. Label Layout for Bus Side Fault.

#### 8.3.2 Bus and Line Side Labels

Bus and line side labels are used for equipment that has a protective device local at the equipment being studied. Figure 4 shows an equipment arrangement example for a line side fault.

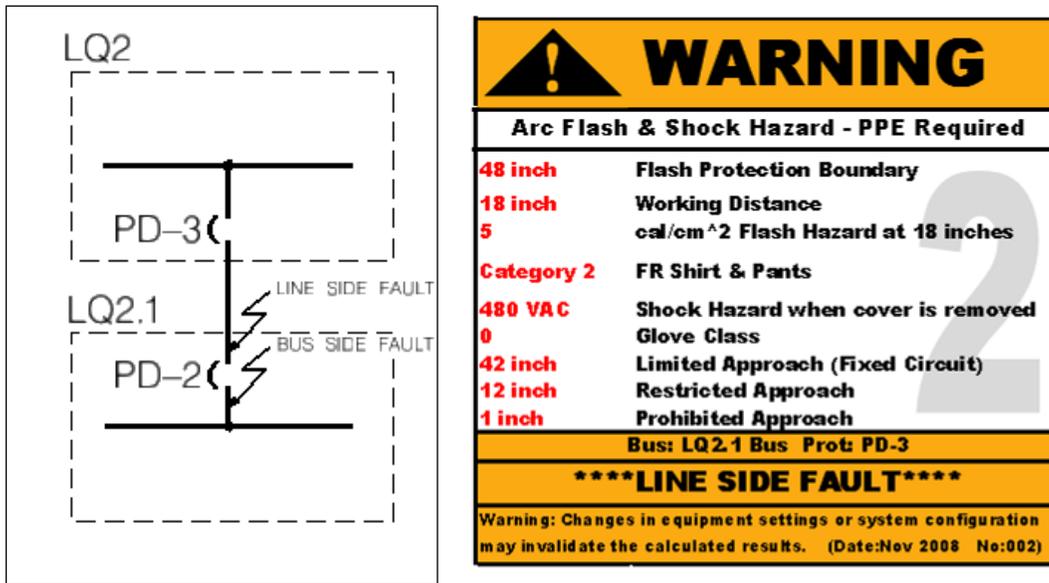


Figure 4. Label Layout for Line Side Fault.

Notice that for a fault located inside equipment LQ2.1 on the bus side of local protective device PD-2, protective devices PD-2 and PD-3 are both capable of clearing the majority arcing fault current. If proper protective device coordination is present, the arcing fault clearing time will be dictated by device PD-2; and you will receive a bus side fault arcing hazard category for this scenario. The bus side label dictates the required PPE for working on this equipment.

However, notice that for a fault located inside equipment LQ2.1 on the line side of local protective device PD-2, protective device PD-3 is the only device capable of clearing the majority arcing fault current. This arrangement yields a line side fault arcing hazard category that may be significantly different from the bus side fault arcing hazard previously explained.

Bus side labels and line side labels are placed on LQ2.1 to give both arcing hazard values so that an informed decision based on the work being performed can be made on a case-by-case basis.

### 8.3.3 Minimum Information on Label.

At a minimum, the incident energy, PPE requirement, flash protection boundary, and working distance shall be included on the labels. Figure 5 is an example of a simplified label.

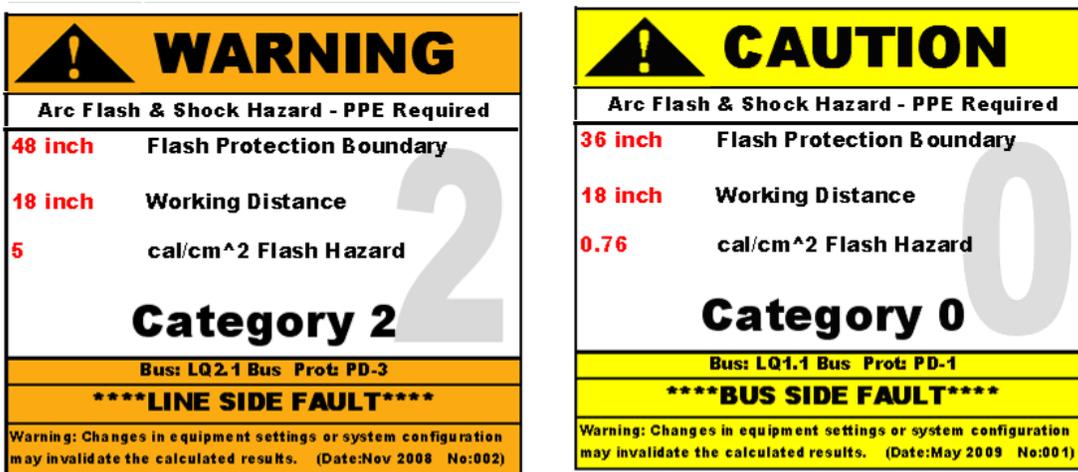


Figure 5. Simplified Label.

#### 8.4 Labels for a Task Based Analysis

For facilities where a task based assessment has been performed, the information required to meet the label requirements of NFPA 70E is not available. Labels for these facilities will have to be generic in nature, such as the warning label of figure 6. The AFH Program for the facility should include a task list similar to those provided in appendix C.

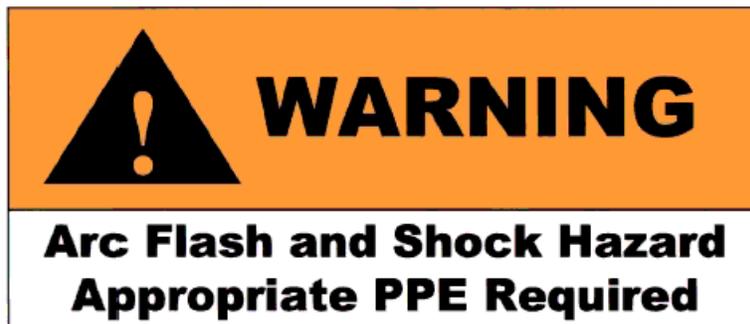


Figure 6. Label for Task Based Analysis.

#### 8.5 Placement on Equipment

[Locate the label so it is clearly visible to qualified persons before examination, adjustment, servicing, or maintenance of the equipment.] Even if equipment is in close physical proximity, its electrical characteristics can vary greatly; therefore, equipment may require different labels.

## **8.6 Boundary Markers**

**[Boundary markers shall clearly identify the flash protection boundary.]  
They may be of the retractable belt barrier type, safety tape, spotter, or of a similar nature. Painted lines on the floor, by themselves, are not adequate.**

## 9. Training

Much of the material for arc flash may be new to employees. Electrical safety training that incorporates use of new and existing PPE shall be given to all employees who could be exposed to electrical equipment. This assists them in understanding the scope of what is involved in the dangers of an AFH and helps them to identify possible electrical hazards in the field.

AFH training may be performed by classroom training or on-the-job training, but most effective training will be comprised of both types. Any training given, whether classroom or on-the-job, must be documented with instructor, trainee, content, and date that the training was received.

Instructors, whether government or contractor, shall have an appropriate level of technical knowledge, skills, or abilities in the subject of AFHs. Instructors shall be competent in delivery techniques and methods appropriate to adult learning.

### 9.1 Training Requirements

**[AFH training for all qualified and unqualified personnel must concentrate on how to recognize and avoid electrical AFHs. AFH training is required upon employment, and additional training is required:**

- (1) If a supervisor or annual inspections indicate that the employee is not complying with the safety-related work practices.**
- (2) Upon new technology, new types of equipment, or changes in procedures that have been implemented at the facility.**
- (3) If new safety-related work practices are required.**
- (4) At least annually (may be performed in conjunction with other safety training—i.e., electrical safety training, control of hazardous energy training, etc.).]**

### 9.2 Training of Qualified Personnel

**AFH training for qualified personnel includes individuals responsible for working on or near energized equipment, interpreting the Detailed IE Analysis/NFPA 70E Task Based Assessment, and developing the AFH Program. These individuals are also responsible for tasks subject to AFHs and the PPE requirements for those tasks, and they must address, at a minimum, the following:**

- (1) Review of the local AFH Program.**
- (2) How to avoid exposure to arc flash hazards.**
- (3) How to determine the degree of each hazard: labels, work permits, one-line diagrams.**
- (4) How to minimize risk by body position.**
- (5) How flash protection boundaries are implemented and enforced.**
- (6) Required level, proper use, fit, and location of PPE and FR clothing for each hazard/risk category.**
- (7) Required maintenance and inspection procedures of PPE.**
- (8) Required maintenance practices and tools to mitigate energy levels.**
- (9) Emergency procedures.**
- (10) Incident/accident reporting.**

### **9.3 Training of Unqualified Personnel**

**AFH training for unqualified personnel must address the following:**

- (1) Review of local AFH Program.**
- (2) AFH awareness—definition and recognition.**
- (3) How AFHs affects the body.**
- (4) How to recognize an AF label and flash protection boundary.**
- (5) Emergency procedures.**
- (6) Accident/incident reporting.]**

## 10. Inspection and Program Review

### 10.1 Periodic Inspections and Program Reviews

Periodic inspections and program reviews shall be designed and conducted to identify and correct any weaknesses or deficiencies in the program or procedures, employee training, or enforcement of the requirements.

Management shall ensure that periodic inspections and program reviews are performed.

**[A team knowledgeable in the AFH Program, to include a qualified person, shall perform periodic inspections and program reviews at least annually. Personnel internal to the facility shall conduct the inspection and program review one year and personnel external to the facility shall conduct it the next year.]**

Periodic program reviews shall cover all elements of the written AFH Program, assess implementation of this program in the facility, and employee understanding.

Periodic inspections and program reviews shall be documented (date, persons involved, results) and identified deficiencies noted. Corrective actions taken to improve the program or employee knowledge of the program must include how any revision of specific procedures or a general change is communicated to the workers.

### 10.2 AFH Analysis Review

**[Update the AFH analysis when a major modification or renovation takes place and have a qualified engineer periodically review the analysis, not to exceed 5 years.]** The review is to account for changes (fault current or protective device clearing times) in the electrical distribution system that could affect the results of the AFH analysis. This generally includes installation of new equipment or changes to the protection devices/settings. Also, any changes (utility contribution) exterior to the facility may affect accuracy and should prompt reevaluation of the entire facility model. These updates may result in raised or lowered energy levels, thus changing labeling, PPE, and procedures.



## Appendix A

# REFERENCES

### Industry Standards

29 Code of Federal Regulation (CFR) 1910.147, *The Control of Hazardous Energy Sources (Lockout/Tagout)*.

29 CFR 1910.269 (l) (6), *Electric Power Generation, Transmission, and Distribution*.

American National Standards Institute (ANSI) Z10, *American National Standard for Occupational Health and Safety Management Systems*.

ANSI Z87.1, *Occupational and Educational Personal Eye and Face Protection Devices*.

ANSI Z89.1, *American National Standard for Industrial Head Protection*.

ANSI Z535.4, *American National Standard for Product Safety Signs and Labels*.

American Society for Testing and Materials (ASTM) International F1506-08, *Standard Performance Specification for Flame Resistant Textile Materials for Wearing Apparel for Use by Electrical Workers Exposed to Momentary Electric Arc and Related Thermal Hazards*.

Institute of Electrical and Electronics Engineers (IEEE™) Standard 1584A, *Guide for Performing Arc Flash Calculations*.

National Fire Protection Association (NFPA) 70, *National Electric Code (NEC)*.

NFPA 70B, *Recommended Practice for Electrical Equipment Maintenance*.

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

Occupational Safety and Health Administration (OSHA) Standards 29 CFR, Part 1910.333.

### Bureau of Reclamation (Reclamation) Standards

*Reclamation Safety and Health Standards*



## Appendix B

### DEFINITIONS

**Arc Blast** – A rapid gas pressure buildup caused by an arcing fault.

**Arc Flash (AF)** – A concentrated release of electric energy caused by an arcing fault.

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

**Arc Rating** – The maximum incident energy resistance demonstrated by a material (or a layered system of materials) prior to break open or at the onset of a second-degree skin burn. Arc rating is normally expressed in calories per centimeter ( $\text{cal}/\text{cm}^2$ ). (Break open occurs when one or more holes form in the innermost layer of FR material that would allow flame to pass through the material.)

**Arc Thermal Protection Value (ATPV)** – Fire-retardant rating by ASTM International. The ATPV for a piece of clothing or fabric is the minimum incident thermal energy that will cause the onset of a second-degree burn based on the energy transmitted through the clothing.

**Category Dangerous** – Levels above category 4 are determined as Category Dangerous. There is no approved PPE for this category.

**Deenergized** – Free from any electrical connection to a source of potential difference and from electric charge; not having a potential different from that of the earth.

**EBT (Breakopen Threshold Energy)** – The largest amount of incident energy that a garment can protect a worker from in  $\text{cal}/\text{cm}^2$  before the onset of second-degree burns or before the garment breaks open and fails.

**Electrical Worker** – One who works with electricity used as a power source.

**Exposed (as applied to live parts)** – Capable of being inadvertently touched or approached nearer than a safe distance by a person. It is applied to parts that are not sufficiently guarded, isolated, or insulated from accidental contact or arc.

**Flame-Resistant (FR) Clothing** – Clothing whose properties provide protection from ignition when exposed to an electric arc or flame and which will not continue to burn. FR clothing that passes American Society for Testing Materials (ASTM) Standard Performance F1506-02ae1 for FR wearing apparel and/or F1891-02b for arc and flame resistant rainwear.

**Flame-Resistant Materials (FR)** – FR treated cotton, meta-aramid, para-aramid, poly-benzimidazole (PBI) fibers, provide thermal protection. These materials can ignite but will not continue to burn after the ignition source is removed. FR fabrics can reduce burn injuries during an AF exposure by providing a thermal barrier between the AF and the wearer.

**Flammable, Non-FR Materials** – Allowed/required for standard work wear. Cotton, silk, rayon and wool fabrics are flammable. These fabrics could ignite and continue to burn on the body, resulting in serious burn injuries.

**Flammable, synthetic materials** – These materials melt as a result of AF exposure conditions, form intimate contact with the skin, and aggravate the burn injury (i.e., acetate, acrylic, nylon, polyester, polyethylene, polypropylene, and spandex, alone or in blends, shall *not* be used.

**Arc Flash Hazard (AFH) Analysis** – A study investigating a worker’s potential exposure to arc flash energy, conducted for the purpose of injury prevention, the determination of safe working practices, and the appropriate level of personal protective clothing and equipment.

**Flash Protection Boundary (FPB)** – An approach limit at a distance from exposed live parts within which a person could receive a second-degree burn if an electrical AF were to occur.

**Flash Suit** – A complete FR clothing and equipment system that covers the entire body, except for the hands and feet. This includes pants, jacket, and bee-keeper-hood fitted with a face shield.

**Hazard/Risk Category Dangerous** – This designation is provided for any hazard *above* Category 4.

**Hazard/Risk Category Level** – A number (level 0 through level 4) based on the energy released during an arcing fault. A higher number indicates a higher energy level. The PPE needed to protect a worker is determined by the risk category level.

**Incident Energy** – The amount of energy impressed on a surface, a certain distance from the source, generated during an electrical arc event. One of the units used to measure incident energy is calories per centimeter squared ( $\text{cal}/\text{cm}^2$ ).

**Incidental Worker** – An employee who, under normal circumstances, would not be in an area where a system is under lockout and tagout but is required to enter or pass through such an area.

**Insulated Tools or Equipment** – Tools or equipment designed to provide insulation from an energized part or conductor. It may have conductive

parts and be coated or covered by a dielectric material, or it may be composed entirely of insulating materials. Insulated industrial hand tools are typically stamped on the handle with an emblem (a double triangle) and a voltage rating. Such tools must be ASTM certified.

**Limited Approach Boundary** – An approach limit at a distance from an exposed live part within which a shock hazard exists. This boundary is also referred to as the safe approach distance in National Fire Protection Association (NFPA) 70E, “Standard for Electrical Safety in the Workplace,” Annex C.

**Live Parts** – Energized conductive components.

**Natural Fibers** – Fibers produced by natural processes, as opposed to manufactured synthetic fibers. Cotton, silk, and wool are examples of natural fibers. Rayon and nylon are examples of synthetic fibers.

**Personal Protective Clothing and Equipment (PPE)** – Items of FR clothing or equipment, that provide a barrier between a hazard and a worker.

**Prohibited Approach Boundary** – An approach limit at a distance from an exposed live part within which work is considered the same as making contact with the live part.

**Qualified Engineer** – One who has skills and knowledge related to the engineering and design of the electrical equipment and installations—fault studies, coordination studies, arc flash studies.

**Qualified Person** – One who has skills and knowledge related to the construction and operation of the electrical equipment and installations and has received safety training to recognize and avoid the hazards involved.

**Restricted Approach Boundary** – An approach limit at a distance from an exposed live part within which there is an increased risk of shock, due to electrical arc over combined with inadvertent movement, for personnel working in close proximity to the live part. This boundary is to be crossed by only qualified persons.

**Standard Work Clothing** – Non-FR clothing that an employee is responsible for providing. This clothing shall, at a minimum, be comprised of materials that are nonmelting, flammable (non-FR), see “Flammable, Non-FR Materials.” This type of clothing is permitted to be used as underlayers to FR clothing. Tight-fitting clothing shall be avoided. Loose-fitting clothing provides additional thermal insulation because of air spaces.

**Working Distance** – The dimension between the possible arc point and the head and body of the worker positioned in place to perform the assigned task.



## Appendix C

# SAMPLES OF COMMON ELECTRICAL TASK LISTS

Table C-1 uses facility specific equipment designations to define tasks related to National Fire Protection Association (NFPA) 70E tables.

**Table C-1. Sample No. 1 of Common Electrical Task List**

<b>COMMON ELECTRICAL TASKS</b>	
<b>DESCRIPTION OF WORK</b>	<b>CATEGORY</b>
Walking into "S" Boards	0
Testing for voltage inside "S" Boards	1
Operating breakers in "S"Boards	0
Walking into "SB" Boards	1
Testing for voltage inside "SB" Boards	2
Panel board less than 240 volts (V)	
Circuit breaker or fused switch operation with cover on	0
Circuit breaker or fused switch operation with cover off	0
Testing for voltage	1
Removing dead front	0
Panel boards 480 V	
Circuit breaker or fused switch operation with cover on	0
Circuit breaker or fused switch operation with cover off	1
Testing for voltage	2
Removing dead front	1
Installing grounds	2
Racking in and out 480-V breakers SQO	3
Operating SQO board breakers; breakers locally door close	0
Operating SQO board breakers; breakers locally door open	1
Testing for voltage	2
Installing grounds	2
Removing bolted covers	2
Racking in and out 4160-V breakers doors open	3
Racking in and out 4160-V breakers doors closed	2
Operating 4160-V breakers locally doors closed	0
Testing for voltage	3
Installing grounds	3

**Table C-1. Sample No. 1 of Common Electrical Task List (continued)**

Operating XJ disconnects opening or closing with line energized	2
Operating XJ disconnects opening or closing with line de-energized	0
Operating XJ breaker locally with disconnects closed	2
Operating XJ breaker locally with disconnects open	0
Testing for voltage in XJ breaker	2
Operating T1/T2 reactor disconnect	2
Operating roof top disconnects	4
Testing for voltage on roof top disconnects	4
Installing grounds on roof top	4

Table C-2. Sample No. 2 of Common Electrical Task List

GENERAL LOCATION OR VOLTAGE	ACTIVITY	CATEGORY	PPE Requirements														
			COTTON UNDERWEAR	NAT LONG SLEEVES& PANTS	SAFETY GLASSES OR GOGGLES	HARD HAT	LEATHER GLOVES (AS NEEDED)	LEATHER GLOVES	FR SHIRT	PANTS (DENIM) 12 oz/yd-Arc Rating 4	FR PANTS (Arc Rating 8)	FACE SHIELD OR ARC FLASH HOOD	2X LAYER HOOD & HEARING PROTE	EAR PLUGS	LEATHER SAFETY SHOES	NAT SHORT SLEEVES& PANTS	FLASH SUIT HOOD
S	Walking into "S" Boards	0	x	x	x				x								
	Testing for voltage inside "S" Boards	1	x		x	x	x		x	x							
	Operating breakers in "S" Boards	0	x	x	x				x								
SB	Walking into "SB" Boards	1	x		x	x	x		x	x							
	Testing for voltage inside "SB" Boards	2	x		x	x			x	x	x	x	x	x	x		
<240	Circuit breaker or fused switch operation with cover on	0	x	x	x				x								
	Circuit breaker or fused switch operation with cover off	0	x	x	x				x								
	Testing for voltage	1	x		x	x	x		x	x							
	Removing Dead Front	1	x	x	x				x								
480	Circuit breaker or fused switch operation with cover on	0	x	x	x				x								
	Circuit breaker or fused switch operation with cover off	1	x		x	x	x		x	x							
	Testing for voltage	2*	x		x	x		x	x	x	x	x	x	x	x		
	Removing Dead Front	1	x		x	x	x		x	x							
	Plugging into energized outlet	0	x	x	x				x								
	Installing Grounds	2*	x		x	x		x	x	x	x	x	x	x	x		
SQO (480V)	Racking in and out 480 V breakers SQO	3	x		x	x		x	x	x	x		x	x	x	x	x
	Operating SQO board Breakers breakers locally door close	0	x	x	x				x								
	Operating SQO board Breakers breakers locally door open	1	x		x	x	x		x	x							
	Testing for voltage	2*	x		x	x		x	x	x	x	x	x	x	x		
	Installing Grounds	2*	x		x	x		x	x	x	x	x	x	x	x		
4160 Switchgear	Removing Bolted covers	2*	x		x	x		x	x	x	x	x	x	x	x		
	Operating 4160 V breakers locally doors closed	2	x		x	x		x	x		x	x	x	x			
	Operating 4160 V breakers locally doors open	4	x		x			x	x				x	x	x	x	x
	Working on energized parts and Voltage Testing	4	x		x			x	x				x	x	x	x	x
	Working on energized parts 120 V or less, exposed	2	x		x	x		x	x	x	x	x	x	x	x		
	Working on energized parts >120 V, exposed	4	x		x			x	x				x	x	x	x	x
	Reading Meters and Guages	0	x	x	x				x								
	Racking in and out 4160 V breakers doors open	4	x		x			x	x				x	x	x	x	x
	Racking in and out 4160 V breakers doors closed	2	x		x	x		x	x	x	x		x	x	x		
	Removal of bolted covers to expose energized parts	4	x		x			x	x				x	x	x	x	x
	Testing for voltage	4	x		x			x	x				x	x	x	x	x
Installing Grounds	4	x		x			x					x	x	x	x	x	



Appendix D

**EXAMPLE OF WORDING FOR A TYPICAL JOB  
HAZARD ANALYSIS**

<b>JOB HAZARD ANALYSIS</b>		
<b>Clearance/LOTO for Main Unit</b>		
<b>PRINCIPAL STEPS/FEATURES</b>	<b>POTENTIAL HAZARDS</b>	<b>RECOMMENDED CONTROLS</b>
<p><b>15-kilovolt (kV) Circuits and Equipment:</b></p> <ul style="list-style-type: none"> <li>a. Racking out Main Unit ACB</li> <li>b. Removing Metering, Regulating, Relaying and Sync Potential Transformers )(PTs)</li> <li>c. Opening and tagging neutral disconnect</li> <li>d. Opening and tagging exciter direct current (dc) disconnect</li> </ul>	<ul style="list-style-type: none"> <li>1. Electrical shock</li> <li>2. Arc Flash Category 4</li> </ul>	<ul style="list-style-type: none"> <li>1. All equipment is considered energized until verified and clearance is issued. Keep in mind that the Restricted Approach Boundary (qualified persons) is 2 feet 2 inches and the Prohibited Approach Boundary (considered touching) is 7 inches for 15 kV. Voltage rated gloves are used with hot sticks.</li> <li>2. De-energize adjacent and upstream sources when practical creating a greater distance from known exposed energized circuits. Utilize remotely operated breakers to reduce risks.</li> <li>3. Category 4 Arc Flash personal protective clothing and equipment ( PPE) requirements are outlined in National Fire Protection Association (NFPA) 70E®, Article 130 as well as equipment labels. In addition, assure all clothing is nonmelting and free of nonessential metal, elastic or plastic parts. Remove jewelry, watches and metal belt buckles.</li> <li>4. The flash protection boundary is 8 feet.</li> </ul>
<p><b>480 V Breakers and Exposed 125 V:</b></p> <ul style="list-style-type: none"> <li>a. Opening 480-volt (V) auxiliary supply breakers</li> <li>b. Opening 480-V field flash breaker</li> <li>c. Racking out regulator alternating current (ac) supply breaker</li> <li>d. Opening 125-V terminal board slides</li> </ul>	<ul style="list-style-type: none"> <li>1. Electrical shock</li> <li>2. Arc flash Category 2 For checking Category 2*</li> </ul>	<ul style="list-style-type: none"> <li>1. All equipment is considered energized until verified and clearance is issued. Keep in mind that the Restricted Approach Boundary (qualified persons) is 1 foot and the Prohibited Approach Boundary (considered touching) is 7 inches for 480 V.</li> <li>2. De-energize adjacent and upstream sources when practical creating a greater distance from known exposed energized circuits.</li> <li>3. Category 2 Arc Flash PPE requirements are outlined in NFPA 70E®, Article 130 as well as equipment labels. In addition, ensure that all clothing is nonmelting and free of nonessential metal, elastic or plastic parts. Remove jewelry, watches and metal belt buckles.</li> <li>4. The flash protection boundary is ___ feet.</li> </ul>

<p><b>Operating 125 V and Below ac or dc</b></p> <ul style="list-style-type: none"> <li>a. Opening 125-V control breakers</li> <li>b. Opening 125-V lighting/receptacle breakers</li> <li>c. Opening 125-V dc relaying breakers</li> <li>d. Opening regulator control 125-V supply</li> </ul>	<ul style="list-style-type: none"> <li>1. Electrical shock</li> <li>2. Arc flash Category 0</li> </ul>	<ul style="list-style-type: none"> <li>1. All equipment as well as circuits to be worked on shall be de-energized before work is started and personnel protected by clearance procedures and grounding.</li> <li>2. Category 0 Arc Flash PPE requirements are outlined in NFPA 70E®, Article 130 as well as equipment labels. Follow nonmelting, nonessential.</li> <li>3. The flash protection boundary is ____ feet.</li> </ul>
<p><b>Verification and Grounding:</b></p>	<p>Arc flash and shock hazards</p>	<p>All precautions and PPE for arc flash and shock hazards remain until the circuits are verified and grounded.</p>

Appendix E

**PERSONAL PROTECTIVE CLOTHING AND  
PROTECTIVE EQUIPMENT**

National Fire Protection Association (NFPA) 70E<sup>®</sup>, table 130.7(C)(10)

Hazard/Risk Category	Protective Clothing and PPE
<b>Hazard/Risk Category 0</b>	
Protective Clothing, Nonmelting (according to American Society for Testing and Materials (ASTM) F 1506-00) or Untreated Natural Fiber Flame Retardant (FR) Protective Equipment	Shirt (long sleeve) Pants (long)  Safety glasses or safety goggles (SR) Hearing protection (ear canal inserts) Leather gloves (AN) (Note 2)
<b>Hazard/Risk Category 1</b>	
FR Clothing, Minimum Arc Rating of 4 (Note 1)  FR Protective Equipment	Arc-rated long-sleeve shirt (Note 3) Arc-rated pants (Note 3) Arc-rated coverall (Note 4) Arc-rated face shield or arc flash suit hood (Note 7) Arc-rated jacket, parka, or rainwear (AN)  Hard hat Safety glasses or safety goggles (SR) Hearing protection (ear canal inserts) Leather gloves (Note 2) Leather work shoes (AN)
<b>Hazard/Risk Category 2</b>	
FR Clothing, Minimum Arc Rating of 8 (Note 1)  FR Protective Equipment	Arc-rated long-sleeve shirt (Note 5) Arc-rated pants (Note 5) Arc-rated coverall (Note 6) Arc-rated face shield or arc flash suit hood (Note 7) Arc-rated jacket, parka, or rainwear (AN)  Hard hat Safety glasses or safety goggles (SR) Hearing protection (ear canal inserts) Leather gloves (Note 2) Leather work shoes
<b>Hazard/Risk Category 2*</b>	
FR Clothing, Minimum Arc Rating of 8 (Note 1)  FR Protective Equipment	Arc-rated long-sleeve shirt (Note 5) Arc-rated pants (Note 5) Arc-rated coverall (Note 6) Arc-rated arc flash suit hood (Note 10) Arc-rated jacket, parka, or rainwear (AN)  Hard hat Safety glasses or safety goggles (SR) Hearing protection (ear canal inserts) Leather gloves (Note 2) Leather work shoes



## Appendix F

# EXAMPLE OF AN ARC FLASH HAZARD PROGRAM

GP-2020  
PRJ-1.00

VIA ELECTRONIC MAIL ONLY

August 13, 2009

GP Policy Memorandum PRJ – 03

### MEMORANDUM

To: Managers  
Attn: GP-1250, GP-1260, GP-2000, GP-3000, GP-4000  
Area Managers  
Attn: DK-100, EC-1000, MT-100, NK-100, TX-Trevino, WY-1000

From: Michael J. Ryan /s/ Michael J. Ryan  
Regional Director

Subject: Electrical Shock and Arc Flash Hazard Policy

This policy states the minimum requirements for personal electrical safety from Arc Flash and Shock Hazards during work on electrical equipment at all Bureau of Reclamation operated and maintained powerplants, pumping plants, and facilities with equipment operating at 480 VAC or higher in the Great Plains Region. For special circumstances not covered, this policy may be supplemented by local policy that is equal to or more conservative than the requirements contained herein. This policy includes requirements for shock and Arc Flash Hazard Analysis to determine protective boundaries, protective clothing and equipment to be used, and training for shock and Arc Flash protection. This policy shall also apply to those facilities operated and maintained for Reclamation through a formal operation and maintenance (O&M) contract where O&M responsibilities of the facilities have not been transferred to others. Recreational facilities or vendor operated facilities are not included in the scope of this policy. Definitions of key words and phrases are included in this policy as attachment 1. Familiarizing yourself with these definitions will provide a better understanding of the following information:

Policy:

- 1. Electrically Safe Working Condition** – Every effort shall be made to perform work only on electrical equipment that has been properly

de-energized per FIST 1-1, Hazardous Energy Control Procedures, and placed in an Electrically Safe Work Condition. See attachment 1 for the definition of Electrically Safe Working Condition. The mitigation of Arc Flash Hazards is best achieved by a combination of controls in which personal protective equipment (PPE) is always considered last.

2. **Work On Energized Electrical Conductors or Circuit Parts by Qualified Person(s)** – Work on or near energized electrical equipment containing energized electrical conductors or circuit parts operating at 50 volts or more shall be performed only by a Qualified Person. Unqualified Persons shall not be permitted to enter spaces that are not sufficiently isolated or guarded and which are to be accessible to Qualified Persons only unless the exposed electrical conductors and equipment involved are in an Electrically Safe Work Condition. See attachment 1 for the definition of a Qualified Person. Training requirements for Qualified Persons are discussed in No. 17.
3. **Electrical Shock and Arc Flash Hazard Analysis** – Each O&M office or field division shall perform, or have performed, an Electrical Shock and Arc Flash Hazard Analysis at all possible locations where energized electrical conductors or circuit parts may be worked on. The analysis shall be updated when a major modification or renovation takes place. It shall be reviewed periodically, not to exceed 5 years, to account for changes in the electrical distribution system that could affect the results of the analysis including changes to protective device settings and bolted short circuit fault levels (up or down). An effective analysis should also evaluate methods to mitigate the hazard risk, where applicable, in order to reduce clothing Hazard/Risk Category requirements. See attachment 2 for general information on Arc Flash Hazards and considerations for performing an Arc Flash Hazard Analysis.
  - a. The Shock Hazard Analysis shall include as a minimum at each location the Limited and Restricted Approach Boundary distances and the voltage class of the gloves or tools to be used. See attachment 3 for a visual representation of the Shock Hazard boundaries.
  - b. For the facilities included in the scope of this policy, the Arc Flash Hazard Analysis shall include detailed calculations to determine the Incident Energy and Arc Flash Protection Boundary using methods outlined in Annex D of NFPA 70E. The results of the Detailed Incident Energy Analysis calculations are to be used to determine the required protective clothing and other PPE to be worn within the protection boundary. The Incident Energy exposure level shall be based on the Working Distance of the employee from the potential arc source for the task to be performed. Note: For facilities where a detailed Arc Flash Hazard Analysis has yet to be performed, Hazard/Risk Categories based on the requirements of NFPA 70E, Articles 130.7(C)(9), (10) and (11)

and table 130.7(C)(9) may be used in the interim for the selection and use of protective clothing and other PPE. However, as the tables may be extremely inadequate for equipment and fault levels within our powerplants and pumping plants, it is required that a detailed analysis be performed as soon as possible. The tables may be used as a final analysis only if deemed appropriate by a Qualified Engineer.

4. **Warning Labels** – As a result of Shock and Arc Flash Hazard Analyses, approved warning labels shall be posted on equipment enclosures where such hazards exist. The warning labels shall include as a minimum the Incident Energy or required level of PPE. The labels may also include the Shock and Arc Flash Protection Boundaries, the voltage level of the equipment, and the glove and tool voltage class for the voltage level. See appendix D for an acceptable Arc Flash and Shock Hazard warning label.
5. **Compliance with Warning Label Requirements** – All requirements on the labels shall be strictly adhered to for any work within the shock and Arc Flash protection boundaries when the equipment is not in an Electrically Safe Work Condition. Workers shall not enter the flash protection boundary without proper protective equipment as required by the Hazard/Risk Category on the warning label. If not expressly mentioned on the label with the clothing requirements, protective equipment shall also include equipment for protection of the face, head, hand, eyes, ears, and feet. See attachment 5 for information on Hazard/Risk Categories and the required clothing and PPE for each category.
6. **Electrical Shock Limited Approach Boundary for Unqualified Person(s)** – Unqualified Person(s) shall not be allowed to cross the established electrical shock limited approach boundary unless a Qualified Person shall advise him or her of the possible hazards and continuously escort the Unqualified Person(s) while inside the boundary. See attachment 3 for a visual diagram identifying the approach boundaries and a table of distances for these boundaries based on voltage levels.
7. **Electrical Shock Restricted Approach Boundary for Unqualified Person(s)** – Under no circumstances shall the Unqualified Person(s) be permitted to cross the electrical Shock Hazard restricted approach boundary. See attachment 3 for a visual diagram identifying the approach boundaries and a table of distances for these boundaries based on voltage levels.
8. **Exposed Electrical Equipment To Be Considered Energized** – All electrical conductors or circuit parts of electrical equipment shall be considered energized, and the requirements of this policy shall be followed unless the equipment is placed in an Electrically Safe Work Condition. De-energizing electrical equipment and making it safe to work on including placement of grounds are in itself a potentially hazardous task. All protective

clothing and PPE requirements per this policy shall be in place while performing any testing on or near exposed equipment or while establishing an electrically safe working condition, including verification of electrical potential and the placement of personal protective grounding.

- 9. Energized Electrical Work Permit** – Work on energized electrical conductors or circuit parts shall be by written permit only. An Energized Electrical Work Permit per NFPA 70E or equivalent shall be developed specifically for all work on energized electrical conductors or circuit parts not placed in an Electrically Safe Work Condition. See attachment 6 for a sample of an acceptable Energized Electrical Work Permit.

  - a. Exceptions:** Work performed on or near energized electrical conductors or circuit parts by Qualified Persons related to tasks such as testing, troubleshooting, voltage measuring, etc., shall be permitted to be performed without an energized electrical work permit, provided appropriate safe work practices and personal protective clothing and equipment in accordance with this policy are provided and used. However, these exceptions shall not negate the requirement that a job hazard analysis (JHA) be completed prior to performing these tasks, including a briefing and discussion of job-related hazards.
- 10. Personal Protective Grounding** – Qualified Persons shall comply with the applicable provisions of FIST 5-1 when applying personal protective grounds which include the confirmation of the de-energized status of the energized electrical conductors or circuit parts to be grounded. Written grounding procedures per RSHS 12.6.1 are required for the placement of personal protective grounds on equipment above 600 volts. A JHA must include these procedures, and employees must discuss and agree to comply with these procedures before beginning work.
- 11. Work on Source Limited Current Transformer (CT) and Potential Transformer (PT) Circuits** – Work (including testing, troubleshooting, voltage measuring, etc.) on exposed connections of control circuits such as source limited CT and PT circuits in cubicles or walk-in enclosures not labeled as being arc-flash hazardous or otherwise not containing exposed high energy power circuit components may be performed by Qualified Persons using appropriate equipment for protection against electrical shock. Cubicles or enclosures containing only source limited CT and PT control wiring and connections, unless labeled otherwise, shall be considered as having an Arc Flash Hazard/Risk Category of “0.”
- 12. Breaker Racking and Switching Operations**

  - a. Unless all primary disconnects (stabs) on a breaker are de-energized, employees performing the racking operation within the flash protection

boundary, including closed door or remote racking operations, shall wear Flame-Resistant (FR) clothing and PPE as required by the Hazard/Risk Category on the warning label.

- b. Where the controls which open or close the breaker (or switch) are located on the same cubicle door of the device being operated and/or within the flash protection boundary of that device, employees operating these controls shall wear FR clothing and PPE as required by the Hazard/Risk Category on the warning label. Exceptions: Power and lighting panel boards containing molded case breakers that are routinely switched on and off to control loads are excluded from this requirement unless the wiring gutter cover is removed, exposing energized electrical conductors or circuit parts.

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**Note:** Arc Flash Hazards may be reduced or eliminated based on the worker's distance from the potential arc while performing specific tasks. An additional Detailed Incident Energy Analysis may be performed based on the expected distance of the employee's face and chest areas from the prospective arc source during the breaker racking or switching tasks. If the analysis indicates a reduced Incident Energy value for these tasks, this Hazard/Risk Category must be clearly marked on an additional warning label clearly indicating that this category applies to breaker racking or switching tasks only. In doing the Incident Energy calculations for the breaker racking or switching tasks, no allowance should be made for a closed door or any angle or position away from the direct opening of the cabinet or cubicle.

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**Note:** Where the Hazard/Risk Category is at or above level 3, considerations should be made for the installation of remote racking equipment and/or shunt trip and close controls for remote operation of the device outside of the flash protection boundary.

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### **13. Working on Exposed Equipment Not Containing Protective Devices –**

This policy prohibits Work On energized electrical conductors or circuit parts connected to a high source of energy that does not contain a protective device to interrupt the arcing fault current unless the equipment has been placed in an Electrically Safe Work Condition. Equipment of this type includes generator unit breakers and large motor starters as indicated below:

- a. Due to extremely high Incident Energy levels resulting from generator fault currents that cannot be cleared, Work On any energized electrical conductors or circuit parts inside of unit breaker enclosures or adjoining equipment cubicles on the generator side of the unit breaker shall not be

performed while the generator is in operation (or spinning). Adjoining equipment attached to the generator side of the generator breaker includes PTs, CTs, surge arrestors, exciter transformer fused disconnect switches, generator terminals, and etc.

- b. Due to possible large fault current contributions of large motors (>200 hp) to an arcing fault on the motor side of the starter contactor (breaker) that cannot be cleared. Work On energized electrical conductors or circuit parts inside motor starter enclosures shall not be performed while the motor is in operation.

#### **14. Arc Flash Protective Clothing and PPE (See Attachment 5)**

- a. Natural fiber clothing shall be worn by qualified workers. Clothing made from synthetic materials such as acetate, nylon, polyester, polypropylene, and spandex, either alone or in blends, shall not be worn. Natural fiber clothing shall be considered adequate for Hazard/Risk Category of “0.” Natural fiber shirts should be of the long-sleeve variety, and underwear should also be of natural fiber material.
- b. As our facilities contain large and diverse electrical systems and equipment, a simplified two category FR clothing system shall be implemented. The first category shall include clothing and equipment for both Hazard/Risk Category 1 and 2 combined. The second category shall include clothing and equipment for Hazard/Risk Category 3 and 4 combined. See attachment 5 for detailed requirements for each combined category.
- c. Each field division/maintenance organization shall procure and have Arc Flash protection kits available in a variety of sizes for workers involved in Hazard/Risk Category 1 and 2 work. These kits shall contain protective clothing complete with hard hats with face shields, face and neck hoods, safety glasses, gloves, glove protectors, etc., as contained in commercially available kits for such use with a minimum Arc Rating of  $8 \text{ cal/cm}^2$  as specified in attachment 5. Each field division/maintenance organization shall also procure and have FR Arc Flash Suits available for workers involved in Hazard/Risk Categories 3 and 4 work. The Arc Flash Suits shall include “bee keeper type” jackets, bib overalls, and Arc Flash Suit hoods with an overall clothing system minimum Arc Rating of  $40 \text{ cal/cm}^2$  as specified in attachment 5.
  - (1) Each individual field division/maintenance organization shall be responsible for proper care and laundering of FR clothing per manufacturer’s instructions. Coveralls or Arc Flash Suits that are contaminated or damaged to such an extent that their protective

qualities are impaired shall not be used. Protective items that become contaminated with grease, oil, flammable liquids, or combustible materials shall not be used.

## **15. New/Replacement Installations**

- a. An electrical hazard analysis shall be applied during the design of new or replacement electrical systems/installations.
- b. Consider specifying arc resistant switchgear, finger safe electrical components, insulated buses, transformers with high impedance values, and current limiting breakers with high speed operation, among others.
- c. Consider remote monitoring or motor control equipment, which allows for information transfer and troubleshooting without opening unit doors. Similar emerging technologies (remote racking) that separate workers from energized equipment and reduce PPE levels should always be considered.

## **16. Roles and Responsibilities**

- a. Management will:
  - (1) Be responsible for implementing and enforcing the requirements of this policy and put in place the necessary practices, controls, and training to ensure the communication of the hazards and necessary precautions to affected personnel.
  - (2) Budget, resource, and schedule the Arc Flash Hazard Analysis for each facility, and ensure the analysis is updated when a major modification or renovation takes place and that it is reviewed periodically, not to exceed 5 years.
  - (3) Keep apprised of Arc Flash practices, controls, and training through staff meetings and other maintenance management reporting procedures.
  - (4) Ensure contract documents contain provisions for compliance with Arc Flash safety-related work practices, ensure contractors are aware of this policy as it relates to the contractor's work within or on Government facilities and equipment, and shall ensure the contractor is aware of the contractor's responsibilities per this policy.
- b. First Line Supervisors will:
  - (1) Ensure management is apprised of shock and Arc Flash policy implementation status, problems, and concerns.

- (2) Ensure Unqualified Persons and visitors are aware of the shock and Arc Flash Hazards where Work On energized electrical conductors and circuits is being performed and that protective barriers or other means to limit Unqualified Persons access to the work site are in place.
- (3) Ensure Qualified Persons who may be exposed to a possible shock or Arc Flash event receive the appropriate level of shock and Arc Flash Hazard training.
- (4) Ensure safety precautions are in compliance with this policy and appropriate FR clothing and other PPE are available to personnel working in an affected area.
- (5) Ensure JHAs address any possible shock or Arc Flash Hazards and, where required, an Energized Electrical Work Permit has been completed and approved for all Work On energized electrical conductors or circuit parts.
- (6) Ensure contractors are informed of known hazards covered by this policy. Hazards that are related to the contract work might not be recognized by the contractor or his employees. Report any observed violations of this policy by the contractor's employees to the Government Contracting Officers Representative and the contractor.
- (7) Ensure system maintenance is being performed to minimize Arc Flash Hazards due to poor equipment condition.

c. Qualified Persons will:

- (1) Comply with this shock and Arc Flash policy and any local supplements to this policy.
- (2) Ensure they receive the necessary training commensurate with the work to be performed as outlined in this policy.
- (3) Participate in JHA development and briefings.
- (4) Be responsible to correctly don the appropriate FR clothing and other PPE prior to working in a shock or Arc Flash Hazard affected area.
- (5) Be responsible to notify their supervisor and others when Arc Flash labeling is unclear or missing or when other questions arise pertaining to shock and Arc Flash safety.
- (6) Report all incidents or accidents and near misses to their supervisor.

- d. Unqualified Persons (and visitors) will:
    - (1) Comply with this shock and Arc Flash policy and any local supplements to this policy as it pertains to their job function.
    - (2) Ensure they are knowledgeable of the basic shock and Arc Flash Hazards present in a power/pumping plant environment.
    - (3) Understand the requirements to not approach areas where Work On exposed electrical conductors or circuit parts is being conducted or where Arc Flash Hazards may be present during breaker racking or switching operations.
  - e. Contracting Officer will:
    - (1) Ensure that Contractors, their employees, subcontracted employees, and any contractor-invited visitors or consultants who will be working in a Shock and Arc Flash Hazard area are knowledgeable of the facility's Shock and Arc Flash policy, practices, and controls.
    - (2) Ensure that Contractors, their employees, and subcontracted employees are trained in shock and Arc Flash Hazards; trained in the proper use of Arc Flash FR clothing and PPE; and don the appropriate equipment while working in a Shock and Arc Flash Hazard affected area in accordance with the requirements of this policy.
- 17. Training** – Employees shall perform electrical work only to the level commensurate with their knowledge and experience. Training shall be provided to ensure each Qualified Person understands the basic hazards involved with Shock Hazards and Arc Flash exposure for the types of equipment the person will be working on, including how to avoid the electrical hazards that might be present with respect to that equipment or work method.
- a. Training required by this section shall be classroom or on-the-job type, or a combination of the two. Training may be held in conjunction with the training required for the maintenance office's Hazardous Energy Program.
    - (1) Initial Training:
      - (a) Upon approval of this policy letter, classroom training shall be provided for all currently employed Qualified Persons to review and discuss the requirements of this letter and the local provisions.

- (b) Initial training for proposed qualified workers new to the organization shall also be provided. The training shall include, as a minimum, the contents outlined below for refresher training and a review and discussion of the requirements of this policy letter.

(2) Training for Specific Work-Related Task:

- (a) Prior to working on energized equipment, on-the-job training shall be provided to each participating Qualified Person. Training shall as a minimum contain the instructions and associated hazards as contained in the JHA and the energized electrical work plan as applicable. Training shall also review and discuss proper inspection methods and the use and operation of any specialized test equipment to be employed.

(3) Refresher Training

- (a) Refresher training can be combined with other annual training such as the annual HECP training.
- (b) Retraining for Qualified Persons shall be provided annually or more frequently under the following conditions:
  - i. When supervision or inspections indicate the employee is not complying with the safety-related work practices.
  - ii. If new technology, new types of equipment, or changes in procedures necessitate the use of safety-related work practices different from those the worker would normally use.
  - iii. If the worker must employ safety-related work practices not normally used during the worker's regular job duties.
  - iv. When the worker has not performed the task or similar work within 1 year.
  - v. An employee requests additional training in order to perform a specific task or series of tasks safely.
- (c) Refresher training should include the following minimum content:
  - i. General Electrical Safety
    - Effects of current flow on the human body.

- Grounding hazards and step potential.
  - Concept of electric shock versus Arc Flash.
  - Clothing including jewelry and watches.
  - Proper and safe use of portable ladders around electrical equipment.
  - Methods used to place equipment in an electrically safe working condition.
  - How to distinguish exposed energized electrical conductors and circuits from other parts of electrical equipment.
  - How to determine the nominal voltage level of exposed energized electrical conductors or circuit parts.
- ii. Shock Hazards
- Definitions, concept of and use of limited, restrictive, and prohibitive approach boundaries for personnel shock protection.
  - Approach boundary distances at various voltage levels.
  - Flash over distances at various voltages.
  - Equipment labels for approach boundary data.
  - Qualified versus Unqualified Person and requirements and restrictions for each around energized electrical conductors or circuit parts.
- iii. Arc Flash Hazards (attachment 2 may also be used as a guide for subjects to discuss during Arc Flash training)
- Prohibition of synthetic materials.
  - FR clothing and proper maintenance and care.
  - Hazards associated with breaker racking.
  - General concept of why, how, and what factors are involved in an Arc Flash.

- Concept and use of Arc Flash protective boundary for personnel protection. When workers should be aware of boundaries and when boundaries are no longer needed.
- Arc Flash Hazard/Risk Categories and type of protective clothing and equipment required for each category. The use and concept of a layered system of protective clothing and the advantages over high arc-rated single category clothing.
- Typical equipment labels for Arc Flash Hazards.
- How exposure may be reduced by protective clothing and equipment, barriers, or distance.

iv. Site Policies

- Site specific shock and Arc Flash policies.
- Hazardous energy control procedures.

v. Emergency Procedures

- How to respond in an electrical emergency.
- Location of external defibrillator.
- Procedures used to remove workers from energized conductors.
- Methods of resuscitation, including cardiopulmonary resuscitation.

b. Documentation of Training:

- (1) Documentation of local initial and refresher training received shall be maintained for all qualified workers at each maintenance organization. As a minimum, the documentation shall include the signatures of the trainer and trainees, date, and a printed outline or agenda of the material covered during the training. The documentation shall be maintained for the duration of the employee's employment.
- (2) On-the-job training received prior to performing energized work shall be documented via names recorded on the JHA or similar documentation and verified by the signature of the job supervisor or reviewing official.

- (a) Suggested list of tutorials/training CDs and videos are available from the Regional Safety Office in the Great Plains Regional Office (406-247-7761).

- 18. Effective Date: Effective upon issuance.
- 19. Expiration Date: This policy will remain in effect until superseded or cancelled.
- 20. Authorities: OSHA 1910.132, Personal Protective Equipment; OSHA 1910, Subpart S 1910.331-335, Electrical Safety Work Practices; National Fire Protection Association (NFPA) 70 E, Chapter 1 and Annex C, D and H (2009 Edition); NEC 2008, Article 110.16; IEEE Std 1584 -2002, Guide for Performing Arc Flash Calculations; FIST 5-1, Personal Protective Grounding for Electrical Power Facilities and Power Lines; FIST 1-1, Hazardous Energy Control Procedures; Reclamation Safety and Health Standards (RSHS), 8.5.8, 8.5.9 and 12.6; and ASTM D120 - 02a(2006), Standard Specification for Rubber Insulating Gloves.

**Contacts:** GP-2020 406-247-7636

**Date of Last Review:** \_\_\_\_\_  
(Month) (Year) (Initial/GP-Code)

Attachments - 6

**Filing Instructions:**

Remove:  
None.

Insert:  
GP Policy Memorandum PRJ -03  
Dated: 08-13-09

**Policy Available at:** <http://intra.gp.usbr.gov/admin/policy.htm>

cc: 96-00000 (Karl Wirkus)  
86-61600 (Erin Foraker)



**GP Policy Memorandum PRJ – 03**

**Attachment 1**

**Definitions**

**Arc Blast.** A rapid gas pressure buildup caused by an arcing fault. The high pressures can easily exceed hundreds or even thousands of pounds per square foot, knocking workers off ladders, rupturing eardrums, and collapsing lungs.

**Arcing Current.** Abnormally high current flow maintained by heated plasma and vaporized copper in air between live conductors and/or ground limited only by the available energy at the arcing site and the low resistance of the arc itself.

**Arc Flash.** An explosion generated when current short-circuits through air, ionizing it to form a super-heated plasma. The temperatures generated can often exceed 5,000 degrees Fahrenheit and have been known to reach as high as 35,000 degrees in a few thousandths of a second. Conductors melt and vaporize, expanding to several thousand times their normal volume. The sudden expansion of air from the heating causes a pressure wave to blast away from the arc fault, carrying drops of molten metal and hitting surfaces with forces of several hundred pounds per square inch. Arc Flash can cause serious injury or death. Arc Flash is a possibility any time a conducting material approaches exposed live parts. There are two major contributing factors that can influence the likelihood of an Arc Flash: equipment failure and human error.

**Arc Flash Suit.** A complete flame resistant (FR) clothing and equipment system that covers the entire body, except for the hands and feet. This includes pants, jackets, and bee-keeper-type hood fitted with a face shield. An Arc Flash Suit is used in conjunction with other protective equipment for protection of the hands, eyes, ears, and feet.

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

**Arc Flash Hazard Analysis.** A study investigating a worker's potential exposure to Arc Flash energy, conducted for the purpose of injury prevention and the determination of safe work practices, Arc Flash protection boundary, and the appropriate levels of FR clothing and other personal protective equipment (PPE).

**Arc Rating.** The value attributed to materials that describe their performance to exposure to an electrical arc discharge. Arc Rating is expressed in calories per centimeter squared ( $\text{cal}/\text{cm}^2$ ).

**Boundary, Arc Flash Protection.** An Arc Flash Hazard boundary. When an Arc Flash Hazard exists, an approach limit at a distance from a prospective arc source within which a person could receive a second-degree burn if an electrical Arc Flash were to occur. The Incident Energy at this distance is usually calculated to be 1.2 cal/cm<sup>2</sup>.

**Boundary, Limited Approach.** An electrical Shock Hazard boundary determined by the voltage level of the equipment. An approach limit at a distance from an exposed energized electrical conductor or circuit part within which a Shock Hazard exists. Note: This boundary is the limit at which an Unqualified Person should not cross.

**Boundary, Prohibited Approach.** An electrical Shock Hazard boundary determined by the voltage level of the equipment. An approach limit at a distance from an exposed energized electrical conductor or circuit part within which work is considered the same as making contact with the electrical conductor or circuit part. In other words, depending on the voltage level, the electricity will arc to the tool or body part so electrical contact with the exposed part is initiated.

**Boundary, Restricted Approach.** An electrical Shock Hazard boundary determined by the voltage level of the equipment. An approach limit at a distance from an exposed energized electrical conductor or circuit part within which there is an increased risk of shock, due to electrical arc over combined with inadvertent movement, for personnel working in close proximity to the energized electrical conductor or circuit part. Note: This boundary defines the area within which a qualified worker may need to work with energized electrical conductors or circuit parts being properly guarded or with proper insulated tools, gloves, and equipment or with proper insulation from other conductive objects as with live-line bare-hand work.

**Detailed Incident Energy Analysis.** An analysis using calculations to determine the Incident Energy exposure of the worker ( in cal/cm<sup>2</sup>) based on the Working Distance of the employee's face and chest areas from a prospective arc source for the task to be performed. Arc-rated FR clothing and other PPE is then selected based on the calculated Incident Energy exposure.

**Electrically Safe Work Condition.** A state in which an electrical conductor or circuit part has been disconnected from energized parts, locked/tagged in accordance with established standards, tested to ensure the absence of voltage, and grounded if determined necessary.

**Exposed 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.

**Flame-Resistant (FR).** The property of material whereby combustion is prevented, terminated, or inhibited following the application of a flaming or non-flaming source of ignition, with or without subsequent removal of the ignition source.

**Hazard/Risk Category.** An identified Hazard/Risk Category, numbered 0 through 4, based on a range of Incident Energy values available at the Working Distance from a potential Arc Flash site. Specific protective clothing and PPE with minimum Arc Rating are required and listed for each Hazard/Risk Category.

**Incident Energy.** The amount of energy impressed on a surface, a certain distance from the source, generated during an electrical arc event. Incident Energy is measured in joules per centimeter squared ( $J/cm^2$ ) or calories per centimeter squared ( $cal/cm^2$ ).

**Personal Protective Equipment (PPE).** Clothing or equipment generally designed to afford protection from a single hazard and for a specific body part.

**Qualified Engineer.** One who has skills and knowledge related to the engineering and design of the electrical equipment and installations—fault studies, coordination studies, and Arc Flash studies.

**Qualified Person.** One who has the skills and knowledge related to the construction and operation of the electrical equipment and installations and has received safety training to recognize and avoid the hazards involved in accordance with the training requirements of this policy.

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

**Shock Hazard Analysis.** An analysis to determine the voltage to which personnel will be exposed, boundary requirements, and the PPE necessary to minimize electrical shock.

**Unqualified Person.** A person without the specific knowledge, skills, and training of a qualified person.

**Working Distance.** The distance between the possible arc point and head and body of the worker positioned in place to perform the assigned task. This distance is used to calculate the Arc Flash Incident Energy and corresponding Hazard/Risk category.

**Work Near (energized electrical conductors or circuit parts).** Any activity inside a Limited Approach Boundary.

**Work On (energized electrical conductors or circuit parts).** 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 a person is wearing.

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**Attachment 2**

**General Information on Arc Flash Hazards  
and Analysis**

**General Arc Flash Hazard Considerations:**

1. The energy in an Arc Flash is dependent on the Arcing Current and how long the arcing lasts and does not necessarily depend on the voltage level. Lower voltage circuits can have very high Arc Flash energy levels also.
2. Arc Flash boundary distances are calculated based on a person getting a recoverable second-degree burn. Parts of the body next to the flash may be burned more severely.
3. The Arc Flash also includes an arc blast as the results of the expansion of vaporized copper. This blast can knock a person off his feet or ladder.
4. Burns can result from molten copper as well as the Incident Energy of the arc.
5. Main station service breakers generally have higher Arc Flash Incident Energy levels than the other load breakers in the switchgear. Special attention should be paid to the Arc Flash labels on these breaker cubicles for racking in and out operations.
6. Arc Flash levels depend on the correct operation of a breaker or fuse. If a breaker or fuse is not installed ahead of the equipment or fails to operate, extremely high energy levels will be available to burn and melt down the equipment.
7. Electrical panels or enclosures at the end of long circuit runs may have much higher arc fault levels due to reduced fault currents through the long conductor runs and the slower protective breaker speeds resulting from these lower levels of current. Pay special attention to Arc Flash labels on remote equipment panels such as panels in dam audits and at remote valve and gate locations.
8. Arc Flash energy levels are often calculated based on the energy produced in the first 2 seconds. It is assumed the worker will move away from the arc or

blast within this time. The hazard may be greater than published on the label if the worker is confined within the enclosure or otherwise cannot move away from the arc in a fast manner.

9. Working on energized panels may be more hazardous than working on switchgear. Hazard/Risk Categories (0 thru 4) are determined based on the worker's normal distance from the potential Arc Flash. Hands or arms closer to the arc will be exposed to higher energy. This distance, as used in the hazard calculations, varies depending on the type of equipment. As an example, it is assumed the distance that the worker will be at while working on a breaker panel will be closer than when he is working on low voltage switchgear with removable breakers. Thus, the hazard may be greater in front of a panel for the same amount of Arc Flash energy.
10. Working on small enclosures like a meter base enclosure may also be very hazardous. Tests indicate that Arc Flashes in the smaller open boxes generate more energy toward the worker than large open boxes or enclosures.
11. The required protective clothing depending on the Hazard/Risk Category is assumed to only prevent second-degree burns that are generally recoverable. Even with proper protective clothing, a person may not be completely burn free during an Arc Flash.
12. Values of Incident Energy posted on protective labels of generator unit breaker enclosures of Hazard/Risk Categories (0 thru 4) will normally apply to arcing faults on the system side (non-generator side) of the breaker assuming the breaker will interrupt the fault current contribution from the generator. Incident Energy levels on the generator side of the unit breaker with the generator in operation are normally in the "Extreme Danger" category with no level of PPE that will protect the worker. Work should never be done on live and exposed equipment in a unit breaker cubicle with the generator in operation. Also, unit breakers should not be racked in or out unless the generator is dead and not spinning.

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**Danger/Warning:** Never work on exposed equipment within a unit breaker enclosure, rack in a breaker, or rack out a breaker while the generator is still spinning as there is no protection against the high levels of available energy in the Arc Flash.

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### **Detailed Arc Flash Considerations for Performing an Arc Flash Analysis:**

1. The Incident Energy produced during an Arc Flash is the product of the arcing fault current and the time this current is available, time being just as

important as the current. Arc Flash Hazard Analysis assumes there are protective devices that limit or stop this current. No Arc Flash Hazard protection scheme or no amount of Personal Protective Equipment (PPE) will protect anyone if the arc cannot be stopped (is continuous) except by being far enough away or protected by a suitable barrier. Potential Arc Flash Hazards in a generator unit breaker cubicle with the generator in operation is an example of a location where there are no protective devices to interrupt the Arcing Current.

2. The so-called Arc Flash Boundary that is calculated in an Arc Flash Analysis assumes the protective equipment will stop the arc in the time calculated and does not apply if the arc is continuous. The Arc Flash Boundary only sets the distance from the arc source at which the onset of a second-degree burn could occur.
3. The arc fault current (which is limited by the arc impedance) depends mainly on the three-phase bolted fault level but is lower than the bolted fault level especially for applications under 1,000 volts and is still lower than the bolted fault level for medium voltage applications and must be calculated. For applications above 15 kilovolts (kV), the arc and bolted fault levels are approximately equal.
4. The Incident Energy produced is proportional to the arc fault current only if this current is above the instantaneous or short time rating of the protective device. Most protective devices have inverse-time operating characteristics. The Incident Energy produced by the Arc Flash is very much higher if the protective device is operating in this inverse-time range.
5. Being overly conservative in calculating the available three-phase bolted fault level (values of current higher than what is actually available) will not provide adequate protection during subsequent calculations if the actual arcing fault current is below the instantaneous settings of the protective devices. Determining minimum values of available fault currents may be as important as maximum available fault currents when making Arc Flash calculations.
6. Incident Energy during an arc is also dependent on the size and configuration of the enclosure (open box versus closed box) and the spacing of the bus (bus gap) inside the enclosure. Incident Energy also depends on the typical Working Distances away from the potential arc source.
7. Arc Flash incidents on 208-volt three-phase systems have occurred with high fault levels. However, tests indicate arcing faults are hard to sustain at voltages at or below 208 volts, and generally Arc Flash Hazard need only be considered for 208-volt systems fed by transformers larger than 125 kilovoltamperes (kVA).

8. The simplest method for determining personal protective equipment requirements for Arc Flash protection is to use the tables in National Fire Protection Association (NFPA) 70E-2004. These tables provide quick answers but are for specific types of equipment, fault levels, and clearing times and may not provide adequate protection in all cases. The Denver Technical Service Center suggests that these tables may be used as a starting point in an Arc Flash Hazard Analysis if no other analysis exists at the facility.
9. The Institute of Electrical and Electronics Engineers (IEEE) Standard 1584 - 2002 Guide for Performing Arc Flash Hazard Calculation that is referenced in and forms a part of Annex D of NFPA 70E includes a spread sheet calculator for solving the various equations. This guide also provides a short-cut method of hazard analysis for low voltage breakers below 600 volts at specific fault levels. This guide is based on Arc Flash tests and seems to be the best guidance available for Arc Flash analysis, especially for the low voltage equipment. However, this guide requires data from fault level studies and protective device and coordination studies as input.
10. Commercial software is available for use in performing a detailed Arc Flash analysis. Various engineering firms and the Denver Technical Service Center can perform a detailed Arc Flash study/analysis for the maintenance organizations with the aid of commercially available software as explained above.

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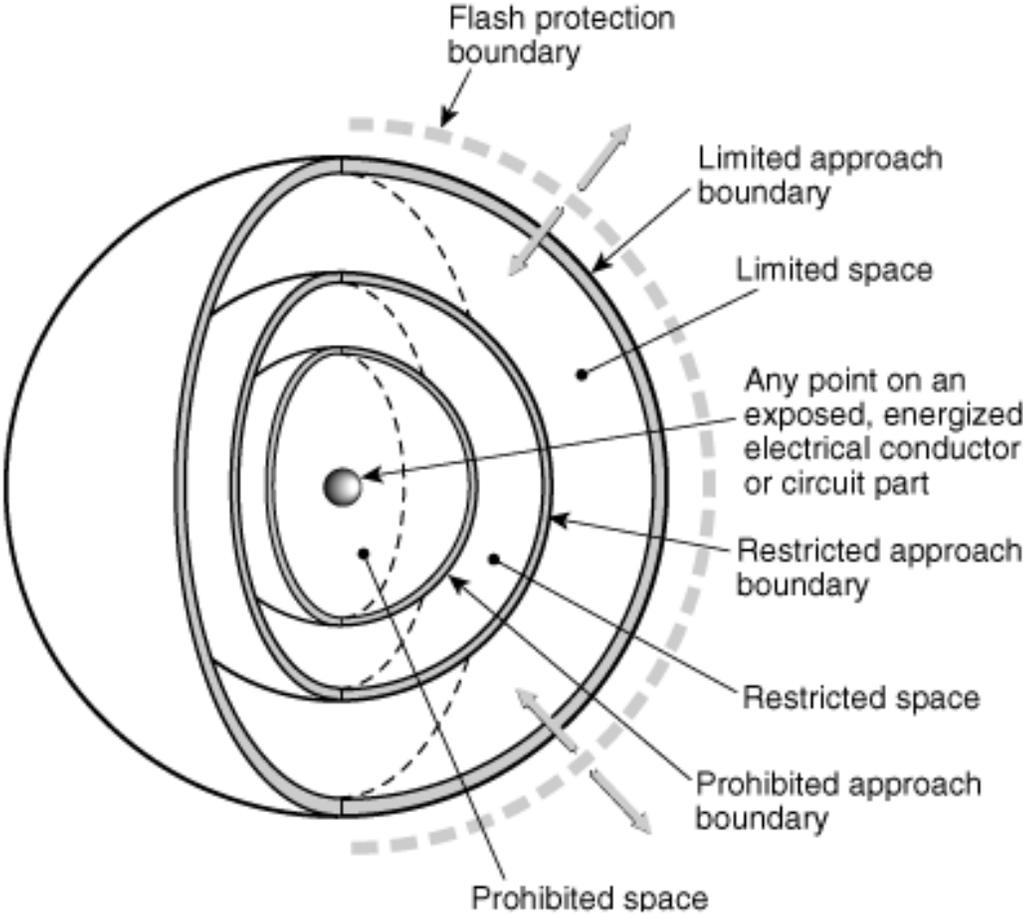
**Note:** Arc Flash guidance for performing a detailed Arc Flash analysis is being jointly developed by the U.S. Army Corps of Engineers and the Bureau of Reclamation. This guidance will be placed in a Reclamation Facilities, Instructions, Standards, and Techniques (FIST) document and will replace this entire attachment.

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Attachment 3

Electrical Shock Hazard Boundaries and  
Rubber Glove Insulation Classes



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**Note:** Flash protection boundary varies and may be within the shock approach boundaries and not on the outside as shown.

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**Attachment 3 (Continued)**

**Approach boundaries to exposed energized conductors/parts for qualified employees (All dimensions are distances from energized conductor/part to employee)**

Reference: Reclamation Health and Safety Handbook 12.3, table 12-1; National Fire Protection Association 70E (2009), table 130.2(C).

Nominal Voltage Phase to Phase, or Single Phase (volts alternating current)	Limited Approach Boundaries		Restricted Approach Boundary (Special Precautions and Job Hazard Analysis)	Prohibited Approach Boundary (Must Be Protected as if Touching)
	Exposed Live Moveable Conductor	Exposed Live Fixed Conductor		
0 to 50	Not specified	Not specified	Not specified	Not specified
51 to 300	10-feet (ft) 0- inches (in)	3-ft 6-in	Avoid contact	Avoid contact
301 to 750	10-ft 0-in	3-ft 6-in	1-ft 0-in	0-ft 1-in
751 to 15 kilovolts (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 232 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

**Voltage Class for Rubber Insulated Gloves** Reference: American Society for Testing Materials D1 20 - 02a(2006), Standard Specification for Rubber Insulated Glove

CLASS	Test AC Volts	Use < AC Volts	Use < DC Volts
00	2,500	500	750
0	5,000	1,000	1,500
1	10,000	7,500	11,250
2	20,000	17,000	25,500
3	30,000	26,500	39,750
4	40,000	36,000	54,000

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Attachment 4

Sample Arc Flash Label

# **! WARNING**

## **Arc Flash and Shock Hazard**

### **Appropriate PPE Required**

**240 inches** Flash Hazard Boundary

**36** cal/cm<sup>2</sup> Flash Hazard at 24 inches

**Category 4** FR Clothing, Minimum Arc Rating of 40

**480 VAC** Shock Hazard when cover is removed

**00** Glove Class

**42 inch** Limited Approach (Fixed Circuit)

**12 inch** Restricted Approach

**1 inch** Prohibited Approach

**Bus: BUS-A (ITE Low Voltage Switchgear) Prot: PD-52A**



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Attachment 5

**Hazard/Risk Category and Requirements for Personal Clothing and Personal Protective Equipment (PPE) Matrix based on Simplified, Two-Category, Flame-Resistant (FR) Clothing System**

Reference: National Fire Protection Association 70E (2009 Edition), Annex H, and table 130.7(C)(10) and table 130.7(C)(11), Reclamation Safety and Health Standards (Revised 2001), paragraph 8.5.9.

Incident Energy From (cal/cm <sup>2</sup> )	Incident Energy to (cal/cm <sup>2</sup> )	Hazard/Risk Category	Clothing Description	Required Minimum Arc Rating (cal/cm <sup>2</sup> )	Clothing layers	Head, Eye, and Ear Protection	Hand and Arm Protection	Foot Protection
0.0	1.2	0	Work clothes of non-melting natural fiber such as cotton, wool, rayon or silk ( <b>Note 1</b> )	N/A	1	Hardhat + Safety Glasses	Voltage Rated Electrical Gloves	Rubber soled leather work shoes
1.2	8.0	1 and 2	FR long-sleeve shirt and pants (minimum Arc Rating of 8) Or FR coveralls (minimum Arc Rating of 8) ( <b>Note 2</b> )	8	2	Hardhat + arc rated Face Shield (minimum Arc Rating of 8 with wrap around neck, ear and forehead guard) + Safety Glasses/Goggles	Voltage Rated Electrical Gloves with leather Protectors	Rubber soled, leather, heavy duty work shoes
8.0	40	3 and 4	Arc Flash Suit consisting of Arc Flash coat and pants (minimum Arc Rating of 40) ( <b>Note 3</b> )	40	2	Arc rated flash Suit hood (minimum Arc Rating of 40) + Hardhat + Safety Glasses/Goggles + Ear Canal Inserts	Voltage Rated Electrical Gloves with leather Protectors	Rubber soled, leather, heavy duty work shoes

1. RSHS. Paragraph 8.5.9 does not permit the wearing of synthetic clothing or conductive articles of jewelry or clothing and thus the use of such is not authorized.
2. Only FR shirts and pants or coveralls are listed for Hazard/Risk Categories of 1 & 2 per Table H.1 of NFPA 70E. However, FR clothing kits containing FR lab coats and leggings or FR hooded jackets and overpants with a minimum Arc Rating of 8 cal/cm<sup>2</sup> may be used.
3. If circumstances require, Arc Flash Suits with higher ratings or multilayered system of protective clothing with a minimum total clothing system rating of 40 Cal/cm<sup>2</sup> per Table H.1 of NFPA 70E may be used.



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**Attachment 6**

**Energized Electrical Work Permit**

**PART I: TO BE COMPLETED BY THE REQUESTER**

Job/Work Order Number \_\_\_\_\_

(1) Description of circuit/equipment/job location: \_\_\_\_\_  
\_\_\_\_\_

(2) Description of work to be done: \_\_\_\_\_  
\_\_\_\_\_

(3) Justification of why the circuit/equipment cannot be de-energized or the work deferred until the next scheduled outage  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

Requester/Title \_\_\_\_\_

Date \_\_\_\_\_

**PART II: TO BE COMPLETED BY THE ELECTRICALLY QUALIFIED PERSON(S) DOING THE WORK:**

**Check when Complete**

(1) Detailed job description procedure to be used in performing the above detailed work: \_\_\_\_\_  
\_\_\_\_\_

(2) Description of the Safe Work Practices to be employed: \_\_\_\_\_

(3) Results of the Shock Hazard Analysis: \_\_\_\_\_

(4) Determination of Shock Hazard Boundaries: \_\_\_\_\_

(5) Results of Arc Flash Hazard Analysis: \_\_\_\_\_

(6) Determination of Arc Flash Protection Boundary \_\_\_\_\_

(7) Necessary clothing and PPE to perform the task: \_\_\_\_\_

(8) Means employed to restrict the access of Unqualified Persons from the work area: \_\_\_\_\_

(9) Evidence of completion of a JHA including briefing of any job-related hazards: \_\_\_\_\_

(10) Do you agree the above described work can be done safely? \_\_\_\_ Yes \_\_\_\_ No (If no, return to requestor)

Electrically Qualified Person(s) \_\_\_\_\_

Date \_\_\_\_\_

**PART III: APPROVAL(S) TO PERFORM THE WORK WHILE ELECTRICALLY ENERGIZED:**

Safety Manager \_\_\_\_\_ Date \_\_\_\_\_

Job Supervisor/Plant Supervisor \_\_\_\_\_ Date \_\_\_\_\_

Electrically Knowledgeable Person \_\_\_\_\_ Date \_\_\_\_\_

Facility Manager \_\_\_\_\_ Date \_\_\_\_\_