**Appendix A**

**Risk Assessment for Modified/Lab-Made Electrical Equipment**

*Please fill out the form and place in your Unit Specific Plan*

Date:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Principal Investigator:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Person/s completing this risk assessment: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Title: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Room and Building: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**SCOPE / INSTRUCTIONS:**

The PSU electrical safety program is founded on the principle of avoiding energized work unless it is absolutely necessary. Live parts will be deenergized in accordance with the PSU Lockout/Tagout Program before laboratory workers are permitted to work on or near live parts unless one of the following conditions applies:

* **Deenergizing introduces additional hazards or increased risk.** Examples of “additional hazards or increased risk” would include interruption of life support equipment, deactivation of emergency alarm systems, or shutdown of hazardous location ventilation systems.
* **Deenergizing is not possible due to equipment design or operational limitations.** Examples of this situation would include diagnostic work such as voltage measurements, troubleshooting, and testing of electrical equipment.
* **Live parts are operating at less than 50 volts and there is no increased exposure to electrical burns or to explosion due to electrical arcs.**

Completing this documented risk assessment **IS NOT REQUIRED** for any of the following:

1) Equipment with a maximum system voltage less than 50 Volts.

2) Appliance type devices used as originally intended by the manufacturer. Examples include, but aren’t limited to, those bought at any department store, appliances, hot plates, power strips, wood/metal working machines, refrigerators, microwaves, ovens, computers, televisions.

3) Instruments/devices typically found in lab/research settings used as originally intended by the manufacturer. Examples include, but aren’t limited, signal generators, analyzers, amplifiers, waveform generators, frequency counters.

**If your equipment aligns with the description in Section 1 of this assessment this form is required to be completed and documented.**

**Section 1**: Check the box that best relates to your situation:

* Modifying an electrical device (i.e. installing/adding new circuits, circuit parts, or devices intended to alter/repair any equipment or system that is not part of the original manufacturers/builders original design).

 Building home-made/shop-made/lab-made equipment (includes self-assembled systems comprised of components or equipment from different manufacturers).

**Section 2**:

Is the assessment completed by person/s deemed qualified to conduct this assessment? (Is Appendix B signed?)

* YES
* NO – if no, do not proceed

**Section 3**: Determine if interaction with live parts is necessary.

Will there be interaction with live parts (energized)?

* No. There are no tasks that require any interaction with live parts AND/OR the equipment will be disconnected from power source (i.e Lockout Tagout) before troubleshooting/servicing/maintenance.
* Yes, list all tasks where the person/s are required to interact with live parts:

-i.e. during normal operation, voltage testing/troubleshooting, etc.

|  |  |
| --- | --- |
|  |  |
|  |  |

**Section 4**: Perform a visual inspection and continuity test with a Nationally Recognized Testing Laboratory (NRTL) approved multimeter to ensure equipment is properly grounded to prevent shock. List of NRTLs can be found here: <https://www.osha.gov/nationally-recognized-testing-laboratory-program/current-list-of-nrtls>

|  |  |
| --- | --- |
| * Not properly grounded. Do not proceed: explain what will be done to ensure proper grounding of equipment:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ * Properly grounded. Check all that apply: * Ensure that all enclosures/equipment chassis are grounded. (pay special attention to painted enclosures/equipment that could cause a “floating ground” situation). (continue to next column……) | * Equipped with a 3-prong plug. * A portable GFCI outlet is used. * Equipment is connected to a wall outlet that is a GFCI. * Equipment is connected to a circuit breaker that is designed to operate as a GFCI. |

**Section 5**: Signage and labeling of equipment:

* Not necessary: All live parts are enclosed during operation and the maximum system voltage is less than 600 Volts.
* Necessary: All live parts are enclosed during operation BUT the equipment has a maximum system voltage of 600 Volts or greater. Must have a “Danger-High Voltage” sign/label placed on the machine.
* Not Applicable
* Live parts that are exposed during operation.
  + Explain how these parts will be distinguished (notes, labels, signs (“Danger-High Voltage”, etc.): \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Section 6**: Safety devices/equipment to eliminate/reduce the hazard:

CHECK EACH THAT APPLY

* Components (i.e. plugs, wires, connectors, parts installed) are designed/rated to withstand the maximum voltage?
* Yes. **Must answer Yes to proceed**.
* Non-conductive insulators, guards, or enclosures.

**Reminder: Non-conductive insulators/guards/enclosures/etc. must be used when possible.**  If a non-conductive item cannot be utilized because of the equipment’s function (i.e. due to noise shielding, etc) explain the alternative methods used to achieve a safe working condition (eliminate shock hazard).

If a non-conductive item cannot be utilized, at a minimum the equipment must be protected via barrier guards/taped-roped off (i.e. guarded by distance) with signage describing the hazard.

i. Describe the design/functional limitations of the equipment as to why it can only be protected via barrier guarding: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

* Switches (safety interlocks) attached to guards and enclosures to automatically:
  1. Activate an output disable feature available on many High Voltage amplifier/supplies.
  2. Disconnect the high voltage supply from the system (example: the switch could control a relay designed to open under high voltage load).
  3. Close a relay to discharge stored electrical energy (a proper discharge resistor should be used for this).
  4. Turn on a Warning/Caution light, sign, or another indicator.
* An analog/digital meter which displays the actively applied voltage.
* Auxiliary grounds (2nd ground connection to act as a backup; should be installed by a qualified person).
* GFCI protection.
* DC Isolation Monitors.
* Note any safety devices/equipment that are not mentioned above: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* None required/Not Applicable: If so, why?\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Have all safety devices that have been checked/noted above been tested for proper operation according to the manufacturer’s instructions?**

 Yes.

 No. If no, why?\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Section 7**: Determine the operational voltage and maximum system voltage output possible (if applicable):

What is the operational voltage? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

What is the maximum system voltage output possible?\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

* + *PPE requirements may change depending on voltage exposure.*

**Section 8**: Determine distances to exposed live parts during tasks. If tasks (troubleshooting/testing, etc.) are required to be conducted within the Restricted Approach Boundary of an exposed live part/circuit, then shock protection PPE (voltage rated gloves, etc) is required.

*See Page 8 of this document.*

List the distances:

* + Limited Approach Boundary:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  + Restricted Approach Boundary:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

 Not Applicable: **No tasks** will be conducted on exposed live parts/circuits.

* + - **If Not Applicable, skip to section 12.**

**Section 9**: Determine appropriate PPE:

Electrical installations in laboratory or research areas often contains custom or specially designed electrical equipment that may have unique and varying electrical safety related hazards.

Arc flash PPE and/or shock protection PPE may be necessary depending on the hazard/s associated with the task, equipment design and voltage.

As part of your PPE risk assessment also follow any PPE guidance documented by the manufacturer of the equipment (typically found in owner’s manual/operation manual).

*-* ***Section 8 (above)*** *determine if/when Shock Protection PPE is required.*

*-* ***Pages 9-14*** *of this document serves as guidance for determining if an arc flash risk exists as well as providing the types of PPE for that risk.*

 No PPE Required. No serving/maintenance/testing/troubleshooting will occur by lab personnel. (i.e. will be conducted by 3rd party or PSU maintenance technician).

* PPE Required: Designate the PPE for servicing / maintenance / voltage testing / troubleshooting:

*NOTE: PPE is required for testing/troubleshooting electrical components at or above 50 Volts and/or until the electrical components are verified to be de-energized.*

|  |  |
| --- | --- |
| Safety Glasses | Arc Flash Face Shield |
| Leather Gloves | Arc Flash Balaclava |
| * Voltage Rated Rubber Gloves   (NOTE: gloves are required to be sent to a 3rd party every 6 months to ensure they are still in a non-conductive state. Alternatively, a new pair of gloves can be purchased every 6 months and the old pair discarded.) Contact Safety Officer for 3rd party information. | Hardhat (non-conductive and rated for the voltage) |
| Arc Flash Clothing | Safety Shoes |
| Other PPE: |  |

**Section 10**: Determine the appropriate insulated tools needed:

* No insulated tools are required because there are no tasks that require interaction with live parts.
* Yes, interaction with live parts may be necessary such as testing/troubleshooting. The following tools are required to be insulated (pliers, sockets, strippers, crimpers, wrenches, etc):
  + List the tools below:

|  |  |  |
| --- | --- | --- |
|  |  |  |

**Section 11**: Determine the appropriate voltage rated test instruments to utilize if/when interaction with live parts is necessary:

* No test instruments are required
* Yes, test instruments are required:
* List the test instruments below:

|  |  |  |
| --- | --- | --- |
|  |  |  |

**Section 12**: Determine the appropriate training required for those who will be designated to  **service/maintenance** the equipment (i.e. Lockout/Tagout (LOTO) procedures):

* Cord and plug powered equipment.
  + Cord must be unplugged before servicing/maintenance can begin. To ensure that the tool cannot be re-energized the cord must be kept under the continuous control of the person performing the servicing/maintenance (i.e. kept within reach of the person performing the servicing/maintenance).
  + No additional training is required.
* Hard-wired equipment: (i.e. wired into a circuit breaker/disconnect lever/Bus bar, etc.).

Those performing servicing/maintenance are required to have LOTO training. Have all of these personnel been identified and been through the PSU EHS LOTO training?

 Yes  No. Explain corrective action:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Section 13**: Perform a **visual inspection and function** test of the equipment to verify proper condition and operation:

(Physical damage could be an indication of impending equipment malfunction; further examination is required to ensure safety)

 No issues found  Damage and/or improper function found.

If so, explain issues and corrective actions:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Section 14:** Attach the task specific procedures / processes / instructions / SOP’s to this form.

Minimum topics which must be covered include the following:

|  |  |
| --- | --- |
| * + 1. Location | 7) Emergency shutdown procedures |
| * + 1. Equipment Name | 8) Spill response |
| * + 1. Other hazards (besides electrical- i.e. chemical, high temperature surfaces, lasers, radiation) | 9) Waste disposal |
| * + 1. Information on the controls used to eliminate/reduce hazards | 10) Reporting equipment failures/problems |
| 5) Personal Protective Equipment (PPE) | 11) Description/directions of how to perform the experiment/operation |
| 6) Procedures to control energy sources prior to performing servicing/maintenance (Lockout/Tagout Procedure) |  |

Additional topics can be added as deemed necessary by the PI/Qualified Person.

**Shock Protection Approach Boundaries to Exposed Energized Electrical Conductors or Circuit Parts**

**(All dimensions are distance from fixed live part to employee)**

**Alternating Current (AC)**

|  |  |  |
| --- | --- | --- |
| **Nominal System Voltage** | **Limited Approach Boundary** | **Restricted Approach Boundary** |
| Less than 50 V | Not Specified | Not Specified |
| 50 V to 150 V | 3 feet, 6 inches | Avoid Contact |
| 151 V to 750 V | 3 feet, 6 inches | 1 foot |
| 751 V to 15 kV | 5 feet | 2 feet, 2 inches |
| *Over 15 kV or a movable conductor (a condition in which the distance between the conductor and a person is not under the control of the person)*  *See NFPA 70 E Table 130.4 (D)(a)* | | |

**Direct Current (DC)**

|  |  |  |
| --- | --- | --- |
| **Nominal Potential Difference** | **Limited Approach Boundary** | **Restricted Approach Boundary** |
| Less than 50 V | Not specified | Not specified |
| 50 V - 300 V | 3 feet, 6 inches | Avoid Contact |
| 301 V - 1 kV | 3 feet, 6 inches | 1 foot |
| *Over 1 kV or a movable conductor (a condition in which the distance between the conductor and a person is not under the control of the person)*  *See NFPA 70 E Table 130.4 (D)(b)* | | |

Definitions

* Limited Approach Boundary - is an approach limit at a distance from an exposed live part within which a shock hazard exists.
* Restricted Approach Boundary - An approach limit at a distance from an exposed energized electrical conductor or circuit part within which there is an increased likelihood of electric shock, due to electrical arc-over combined with inadvertent movement.

**Arc flash Hazard Identification –**

**Alternating Current Equipment (AC) and Direct Current Equipment (DC) (page 1 of 3)**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Task** | **Equipment Condition** | | **Arc Flash PPE Required** | |
| Operation of a circuit breaker, disconnect (lever/knife switch), switch, contactor, or starter | **Note: All of the following requirements must be met to satisfy the “no arc flash PPE required” scenario:**   1. Covers/panels that enclose the circuit breaker (CB), switch, contactor, or starter are in place, and secure. 2. No visual damage to the enclosure of the circuit breaker (CB), switch, contactor, or starter. 3. No visual damage to the circuit breaker (CB) switch, switch, contactor, or starter. 4. No visual damage to the wires/conduits at entry/exit points to the enclosure. 5. No knockouts missing. 6. No evidence of water/liquid damage (puddling, rust, chemicals). 7. No evidence of heat/fire damage (discoloration). 8. No bolts, screws, fasteners missing. 9. No exposed live parts of the enclosure (proper blanks used to cover empty circuit breaker locations)   If conditions in 1-9 are found to be satisfactory, a circuit breaker (CB), disconnect (lever/knife switch), switch, contactor, or starter can be used to turn off/on a circuit without PPE.  **\*\*\*\*\*\*\*\*\*Resetting a tripped breaker\*\*\*\*\*\*\*\*\***  If conditions in 1-9 are found to be satisfactory and circuit breaker operation training has been completed, a tripped circuit breaker can be reset WITHOUT PPE ONLY IF after investigation reveals a probable cause of the trip (overloaded circuit). ADDITIONALLY, the circuit breaker is only permitted to be reset only 1 time.  A person who has been qualified to troubleshoot an electrical circuit (i.e. electrician) must be notified if the breaker trips a 2nd time. | | No | |
| **Task** | | **Arc Flash PPE Required** | |
| 1.) Operation of a CB or switch the first time after installation or completion of maintenance in the equipment. | | Yes | |
| 2.) Reading a panel meter while operating a meter switch | | No | |
| 3.) For ac systems: Work on energized electrical conductors and circuit parts, including voltage/electrical testing | | Yes | |
| 4.) For dc systems: Work on energized electrical conductors and circuit parts of series-connected battery cells, including voltage/electrical testing | | Yes | |
| 5.) Voltage testing on individual battery cells or individual multi-cell units | | No | |
| 6.) Removal or installation of circuit breakers or switches | | Yes | |
| 7.) Examination of insulated cable with no manipulation of cable. | | No | |
| 8.) Examination of insulated cable with manipulation of cable. | | Yes | |
| 9.) Removal or installation of covers for equipment such as wireways, junction boxes, and cable trays that does not expose bare, energized electrical conductors and circuit parts | | No | |
| 10.) Insertion or removal of covers for battery intercell connector(s). | | Yes | |
| 11.) Removal of battery non-conductive intercell connector covers. | | No | |
| 12.) Opening hinged door(s) or cover(s) or removal of bolted covers (to expose bare, energized electrical conductors and circuit parts). For dc systems, this includes bolted covers, such as battery terminal covers. | | Yes | |
| 13.) Opening a panelboard hinged door or cover to access dead front overcurrent devices. | | No | |
| 14.) Perform infrared thermography and other non-contact inspections outside the restricted approach boundary. This activity does not include opening of doors or covers. | | No | |
| 15.) Application of temporary protective grounding equipment after voltage test. | | Yes | |
| 16.) Working on control circuits with exposed energized electrical conductors and circuit parts,  nominal 125 volts ac or dc, or below without any other exposed energized equipment over nominal 125 volts ac or dc, including opening of hinged covers to gain access. | | No | |
| 17.) Work on control circuits with exposed energized electrical conductors and circuit parts, greater than 120 V | | Yes | |
| 18.) Insertion or removal of individual starter buckets from motor control center (MCC) | | Yes | |
| 19.) Insertion or removal (racking) of circuit breakers or starters from cubicles, doors open or closed | | Yes | |
| 20.) Insertion or removal of plug-in devices into or from busways | | Yes | |
| 21.) Work on exposed energized electrical conductors and circuit parts of equipment directly supplied by a panelboard or motor control center | | Yes | |
| 22.) Insertion and removal of revenue meters (kW-hour, at primary voltage and current) | | Yes | |
| 23.) For dc systems, maintenance on a single cell of a battery system or multi-cell units in an open rack | | No | |
| 24.) For dc systems, work on exposed energized electrical conductors and circuit parts of utilization equipment directly supplied by a dc source. | | Yes | |
| 25.) Opening voltage transformer or control power transformer compartments | | Yes | |

**Arc flash Hazard Identification –**

**Alternating Current Equipment (AC) and Direct Current Equipment (DC)**

**(page 3 of 3)**

|  |  |  |
| --- | --- | --- |
| **Task** | | **Arc Flash PPE Required** |
| 26.) Operation of outdoor disconnect switch (hookstick operated) at 1 kV through 15 kV | | Yes |
| 27.) Operation of outdoor disconnect switch (gang-operated, from grade) at 1 kV through 15 kV | | Yes |
| 28.) Maintenance and testing on individual battery cells or individual multi-cell units in an open rack. | Yes, Only if equipment condition considered to be “abnormal”. SEE NOTE AT END OF THIS TABLE | |
| 29.) Arc-resistant equipment with the DOORS CLOSED and SECURED, and where the available fault current and fault clearing time does not exceed that of the arc-resistant rating of the equipment in one of the following conditions:  -Insertion or removal of individual starter buckets;  -insertion or removal (racking) of circuit breakers from cubicles;  -Insertion or removal (racking) of ground and test device;  -Insertion or removal (racking) of voltage transformers on or off the bus. | Yes,  Only if equipment condition considered to be “abnormal”. SEE NOTE AT END OF THIS TABLE | |
| 30.) Insertion or removal of individual cells or multi-cell units of a battery system in an open rack. | Yes, Only if equipment condition considered to be “abnormal”. SEE NOTE AT END OF THIS TABLE | |

NOTE:

Equipment condition considered to be “normal” if all of the following circumstances apply:

* + 1. The equipment is properly installed in accordance with the manufacturer’s recommendations and applicable industry codes and standards.
    2. The equipment is properly maintained in accordance with the manufacturer’s recommendations and applicable industry codes and standards.
    3. The equipment is used in accordance with instructions included in the listing and labeling and in accordance with manufacture’s instruction.
    4. Equipment doors are closed and secured.
    5. Equipment covers are in place and secured.
    6. There is no evidence of impending failure such as arcing, overheating, loose or bound equipment parts, visible damage, or deterioration.

**Arc flash hazard PPE categories for**

**Alternating Current (AC) Equipment**

|  |  |
| --- | --- |
| **Equipment** | **Arc Flash PPE Category** |
| Panelboards or other equipment rated 240 V and below  *Parameters:*  *Maximum of 25 kA available fault current; maximum of 0.03 sec (2 cycle) fault clearing time; minimum working distance 18 in.* | 1 |
| Panelboards or other equipment rated greater than 240 V and up to 600 V  *Parameters:*  *Maximum of 25 kA available fault current; maximum of 0.03 sec (2 cycle) fault clearing time; minimum working distance 18 in.* | 2 |
| 600-volt class motor control centers (MCCs)  *Parameters:*  *Maximum of 65 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 18 in.* | 2 |
| 600-volt class motor control centers (MCCs)  *Parameters:*  *Maximum of 42 kA available fault current; maximum of 0.33 sec (20 cycles) fault clearing time; minimum working distance 18 in.* | 4 |
| 600-volt class switchgear (with power circuit fuses or fused switches) and 600-volt class switchboards  *Parameters:*  *Maximum of 35 kA available fault current; maximum of up to 0.5 sec (30 cycles) fault clearing time; minimum working distance 18 in.* | 4 |
| Other 600-volt class equipment (277 volts through 600 volts nominal)  *Parameters:*  *Maximum of 65 kA available fault current; maximum of 0.03 sec (2 cycle) fault clearing time; minimum working distance 18 in.* | 2 |
| Arc-resistant equipment up to 600-volt class  *Parameters:*  DOORS CLOSED and SECURED; with an available fault current and a fault clearing time that does not exceed the arc-resistant rating of the equipment. | N/A |

**Arc Flash Boundary**

For AC systems that are 600 volts or less, the arc flash boundary shall be a minimum of 20 feet or the entire room if a boundary of 20 feet cannot be obtained (i.e. room is smaller than 20 feet). If the equipment has an NFPA 70E label attached its stated arc flash boundary should be used.

**Arc flash hazard PPE categories for**

**Direct Current (DC) Equipment**

|  |  |  |
| --- | --- | --- |
| **Equipment** | **Arc Flash PPE Category** | **Arc-Flash Boundary** |
| Storage batteries, dc switchboards, and other dc supply sources 100 volt or greater but less than or equal to 250 volts.  *Parameters:*  *Maximum arc duration and minimum working distance: 2 sec @ 18 in.* | | |
| Available fault current less than 4 kA | 2 | 3 feet |
| Available fault current greater than or equal to 4 kA and less than 7 kA | 2 | 4 feet |
| Available fault current greater than or equal to 7 kA and less than 15 kA | 3 | 6 feet |
| Storage batteries, dc switchboards, and other dc supply sources greater than 250 volts and less than or equal to 600 volts.  Parameters:  Maximum arc duration and minimum working distance: 2 sec @ 18 in. | | |
| Available fault current less than 1.5 kA | 2 | 3 feet |
| Available fault current greater than or equal to 1.5 kA and less than 3 kA | 2 | 4 feet |
| Available fault current greater than or equal to 3 kA and less than 7 kA | 3 | 6 feet |
| Available fault current greater than or equal to 7 kA and less than 10 kA | 4 | 8 feet |

The methods for estimating the dc arc flash incident energy that were used to determine the categories for this table are based on open-air incident energy calculations. Open-air calculations were used because many battery systems and other dc process systems are in open areas or rooms. If the specific task is within an enclosure, it would be prudent to consider additional PPE protection beyond the value shown in this table. Research with ac arc flash has shown a multiplier of as much as 3x for arc-in-a-box versus open air.

**Personal Protective Equipment Based on Arc Flash PPE Category**

|  |  |
| --- | --- |
| **PPE Category** | **PPE** |
| 1 | **Arc Rated Clothing, Minimum Arc Rating of 4 cal/cm2**  Arc-rated long-sleeve shirt and pants or Arc- rated coveralls  Arc-rated face shield (see Note 2) or arc flash suit hood  Arc-rated jacket, parka, high visibility apparel, rainwear or hard hat liner (AN)  **Protective Equipment**  Hard hat  Safety glasses or safety goggles  Hearing protection (ear canal inserts)  Heavy duty leather gloves with rubber insulating gloves (see note 1)  Leather footwear (AN) |
| 2 | **Arc Rated Clothing, Minimum Arc Rating of 8 cal/cm2**  Arc-rated long-sleeve shirt and pants or arc-rated coveralls  Arc-rated flash suit hood or arc-rated face shield (note 2) AND arc-rated balaclava  Arc-rated jacket, parka, high visibility apparel, rainwear, or hard hat liner (AN)  **Protective Equipment**  Hard hat  Safety glasses or safety goggles  Hearing protection (ear canal inserts)  Heavy duty leather gloves with rubber insulating gloves (see note 1)  Leather footwear |
| 3 | **Arc Rated Clothing Selected so That the System Arc Rating Meets the Required Minimum Arc Rating of 25 cal/cm2**  Arc-rated long-sleeve shirt (AR)  Arc-rated pants (AR)  Arc-rated coverall (AR)  Arc-rated arc flash suit jacket (AR)  Arc-rated arc flash suit pants (AR)  Arc-rated arc flash suit hood  Arc-rated gloves 1  Arc-rated jacket, parka, high visibility apparel, rainwear or hard hat liner (AN)  **Protective Equipment**  Hard hat  Safety glasses or safety goggles  Hearing protection (ear canal inserts)  Rubber insulating gloves  Leather footwear |
| 4 | **Arc Rated Clothing Selected so That the System Arc Rating Meets the Required Minimum Arc Rating of 40 cal/cm2**  Arc-rated long-sleeve shirt (AR)  Arc-rated pants (AR)  Arc-rated coverall (AR)  Arc-rated arc flash suit jacket (AR)  Arc-rated arc flash suit pants (AR)  Arc-rated arc flash suit hood  Arc-rated gloves 1  Arc-rated jacket, parka, high visibility apparel, rainwear or hard hat liner (AN)  **Protective Equipment**  Hard hat  Safety glasses or safety goggles  Hearing protection (ear canal inserts)  Rubber insulating gloves  Leather footwear |

AN: As Needed AR: As Required

Notes:

1. Face shields are to have wrap-around guarding to protect not only the face but also the forehead, ears, and neck, or, **alternatively**, an arc-rated arc flash suit hood is required to be worn.
2. The arc rating of outer layers worn over arc-rated clothing as protection from the elements or for other safety purposes, **and that** are not used as part of a layered system, shall not be required to be equal to or greater than the estimated incident energy exposure.