

# Selection of Electrical PPE Tables

Starting with Table 1, find the task you plan to do in one of the four lists. These lists are broken into conditions of equipment and likelihood of arc flash incidence. There are three states of condition, (NORMAL, ABNORMAL or ANY). For the condition to be described as NORMAL all the following must be true about the equipment you plan to work on:

- *The equipment is properly installed*
- *The equipment is properly maintained (per the manufacturer's requirements)*
- *All equipment doors are closed and secured*
- *All equipment covers are in place and secured*
- *There is no evidence of impending failure*

The second condition state (ABNORMAL) applies **if any one** of the following conditions is true, indicating the overall default condition of the equipment is an abnormal condition.

- *The equipment is not properly installed*
- *The equipment is not properly maintained*
- *Equipment doors are open or not secured Equipment covers are off or not secured*
- *There is evidence of impending failure*

The third state of equipment condition is "ANY". This means that the condition of the equipment has no bearing on whether PPE is required. In this situation the task is the sole factor in determining if you require PPE.

If your task is found in Lists 1.3 or 1.4, arc-rated PPE will be needed for the task. Move to Table 2.

**In Table 2**, determine the equipment type along with the highest voltage range your equipment contains.

**NOTE:** Table 2 has separate sections for AC systems and DC systems, so ensure you are on the correct page according to your system's current flow type.

The lists are separated by arc flash PPE categories. Finding the equipment type you will be working will identify the PPE category. The arc flash boundary will also be identified. This is the distance from the source where you are required to wear that level of arc-rated clothing and gear.

**Table 3** - Once you have the arc flash category and distance from the source that the PPE is needed, go to Table 3 to determine what you are required to wear for the arc flash category you are working with. The abbreviations in the text can be found described in the notes below the table.

## Table 1- Estimating Likelihood of Occurrence of an Arc Flash Incident (AC and DC systems)

### List 1.1 Equipment In Any Condition<sup>a</sup> Without a Likelihood of Arc Flash Incident Occurrence<sup>b</sup>

- Reading a panel meter while operating a meter switch.
- Performing infrared thermography and other noncontact inspections outside the restricted approach boundary. This activity does not include opening of doors or covers.
- 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.
- Examination of insulated cable with no manipulation of cable.
- For dc systems, maintenance on a single cell of a battery system or multi-cell units in an open rack.

### List 1.2 Equipment in Normal Condition<sup>a</sup> with No Likelihood of Arc Flash Incident Occurrence<sup>b</sup>.

- Operation of a CB, switch, contactor, or starter.
- Voltage testing on individual battery cells or individual multi-cell units.
- 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.
- Opening a panelboard hinged door or cover to access dead front overcurrent devices.
- Removal of battery nonconductive intercell connector covers.
- Maintenance and testing on individual battery cells or individual multi-cell units in an open rack
- Insertion or removal of individual cells or multi-cell units of a battery system in an open rack.
- 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 CBs from cubicles
  - Insertion or removal (racking) of ground and test device
  - Insertion or removal (racking) of voltage transformers on or off the bus

### List 1.3 Equipment in Any Condition<sup>a</sup> With a Likelihood of Arc Flash Incident Occurrence<sup>b</sup>

- For ac systems, work on energized electrical conductors and circuit parts, including electrical testing.

- Operation of a CB or switch the first time after installation or completion of maintenance in the equipment.
- For dc systems, working on energized electrical conductors and circuit parts of series-connected battery cells, including electrical testing.
- Removal or installation of CBs or switches.
- 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.
- Application of temporary protective grounding equipment, after voltage test.
- Working on control circuits with exposed energized electrical conductors and circuit parts, greater than 120 volts.
- Insertion or removal of individual starter buckets from motor control center (MCC).
- Insertion or removal (racking) of circuit breakers (CBs) or starters from cubicles, doors open or closed.
- Insertion or removal of plug-in devices into or from busways.
- Examination of insulated cable with manipulation of cable.
- Working on exposed energized electrical conductors and circuit parts of equipment directly supplied by a panelboard or motor control center.
- Insertion or removal of revenue meters (kW-hour, at primary voltage and current).
- Insertion or removal of covers for battery intercell connector(s).
- For dc systems, working on exposed energized electrical conductors and circuit parts of utilization equipment directly supplied by a dc source.
- Opening voltage transformer or control power transformer compartments.
- Operation of outdoor disconnect switch (hookstick operated) at 1 kV through 15 kV.
- Operation of outdoor disconnect switch (gang-operated, from grade) at 1 kV through 15 kV.

### List 1.4 Equipment in Abnormal Condition<sup>a</sup> with a Likelihood of Arc Flash Incident Occurrence<sup>b</sup>

- Operation of a CB, switch, contactor, or starter.
- Voltage testing on individual battery cells or individual multi-cell units.
- 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.
- Opening a panelboard hinged door or cover to access dead front overcurrent devices.
- Removal of battery nonconductive intercell connector covers.
- Maintenance and testing on individual battery cells or individual multi-cell units in an open rack
- Insertion or removal of individual cells or multi-cell units of a battery system in an open rack.
- 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 CBs from cubicles
- Insertion or removal (racking) of ground and test device
- Insertion or removal (racking) of voltage transformers on or off the bus

## Notes

- <sup>a</sup> Equipment is considered to be in a “normal operating condition” if all of the conditions in NFPA 70E, 110.2(B), Exception No. 1 are satisfied.
- <sup>b</sup> As defined in NFPA 70E, the two components of risk are the likelihood of occurrence of injury or damage to health and the severity of injury or damage to health that results from a hazard. Risk assessment is an overall process that involves estimating both the likelihood of occurrence and severity to determine if additional protective measures are required. The estimate of the likelihood of occurrence contained in this table does not cover every possible condition or situation, nor does it address severity of injury or damage to health. Where this list identifies “No” as an estimate of likelihood of occurrence, it means that an arc flash incident is not likely to occur. Where this table identifies “Yes” as an estimate of likelihood of occurrence, it means an arc flash incident should be considered likely to occur. The likelihood of occurrence must be combined with the potential severity of the arcing incident to determine if additional protective measures are required to be selected and implemented according to the hierarchy of risk control identified in NFPA 70E, 110.3(H).

## Table 2 - Arc Flash PPE Categories and Boundaries

### Section 2.1 - Arc Flash PPE Categories and Boundaries for Alternating Currents (AC)

#### List 2.1.1 Equipment with Arc Flash PPE Category 1

- Panelboards or other equipment rated 240 volts and below with the following parameters:
  - maximum of 25 kA available fault current;
  - maximum of 0.03 sec (2 cycles) fault clearing time;
  - minimum working distance 455 mm (18 in.).
  - The arc flash boundary is 485 mm (19 in.).

#### List 2.1.2 Equipment with Arc Flash PPE Category 2

- Panelboards or other equipment rated greater than 240 volts and up to 600 volts with the following parameters:
  - maximum of 25 kA available fault current;
  - maximum of 0.03 sec (2 cycles) fault clearing time;
  - minimum working distance 455 mm (18 in.)
  - The arc flash boundary is 900 mm (3 ft).
- 600-volt class motor control centers (MCCs) with the following parameters:
  - maximum of 65 kA available fault current;
  - maximum of 0.03 sec (2 cycles) fault clearing time;
  - minimum working distance 455 mm (18 in.).
  - The arc flash boundary is 1.5 m (5 ft).
- Other 600-volt class (277 volts through 600 volts, nominal) equipment with the following parameters:
  - maximum of 65 kA available fault current;
  - maximum of 0.03 sec (2 cycles) fault clearing time;
  - minimum working distance 455 mm (18 in.).
  - The arc flash boundary is 1.5 m (5 ft).

#### List 2.1.3 Equipment with Arc Flash PPE Category 4

- 600-volt class motor control centers (MCCs) with the following parameters:
  - maximum of 42 kA available fault current;
  - maximum of 0.33 sec (20 cycles) fault clearing time;
  - minimum working distance 455 mm (18 in.).
  - The arc flash boundary is 4.3 m (14 ft)
- 600-volt class switchgear (with power circuit breakers or fused switches) and 600-volt class switchboards with the following parameters:
  - maximum of 35 kA available fault current;
  - maximum of up to 0.5 sec (30 cycles) fault clearing time;

- minimum working distance 455 mm (18 in.).
- The arc flash boundary is 6 m (20 ft).
- NEMA E2 (fused contactor) motor starters, 2.3 kV through 7.2 kV with the following parameters:
  - Maximum of 35 kA available fault current;
  - maximum of up to 0.24 sec (15 cycles) fault clearing time;
  - minimum working distance 910 mm (36 in.).
  - The arc flash boundary is 12 m (40 ft).
- Metal-clad switchgear, 1 kV through 15 kV with the following parameters:
  - maximum of 35 kA available fault current;
  - maximum of up to 0.24 sec (15 cycles) fault clearing time;
  - minimum working distance 910 mm (36 in.).
  - The arc flash boundary is 12 m (40 ft)
- Metal enclosed interrupter switchgear, fused or unfused type construction, 1 kV through 15 kV with the following parameters:
  - maximum of 35 kA available fault current;
  - maximum of 0.24 sec (15 cycles) fault clearing time;
  - minimum working distance 910 mm (36 in.).
  - The arc flash boundary is 12 m (40 ft).
- Other equipment 1 kV through 15 kV with the following parameters:
  - maximum of 35 kA available fault current;
  - maximum of up to 0.24 sec (15 cycles) fault clearing time;
  - minimum working distance 910 mm (36 in.).
  - The arc flash boundary is 12 m (40 ft).

#### List 2.1.4 Equipment Where Arc Flash PPE and Arc Flash Boundaries Are Not Applicable

- Arc-resistant equipment up to 600-volt class with the following 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.
  - For DOORS OPEN refer to the corresponding non-arc-resistant equipment section of these lists.
- Arc-resistant equipment 1 kV through 15 kV with the following 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.
  - DOORS OPEN refer to the corresponding non-arc-resistant equipment section of these lists.

## Notes

- For equipment rated 600 volts and below and protected by upstream current-limiting fuses or current-limiting molded case circuit breakers sized at 200 amperes or less, the arc flash PPE category can be reduced by one number but not below arc flash PPE category 1.
- The following are typical fault clearing times of overcurrent protective devices:
  - 0.5 cycle fault clearing time is typical for current-limiting fuses and current-limiting molded case circuit breakers when the fault current is within the current limiting range.
  - 1.5 cycle fault clearing time is typical for molded case circuit breakers rated less than 1000 volts with an instantaneous integral trip.
  - 3.0 cycle fault clearing time is typical for insulated case circuit breakers rated less than 1000 volts with an instantaneous integral trip or relay operated trip.
  - 5.0 cycle fault clearing time is typical for relay operated circuit breakers rated 1 kV to 35 kV when the relay operates in the instantaneous range (i.e., “no intentional delay”).
  - 20 cycle fault clearing time is typical for low-voltage power and insulated case circuit breakers with a short time fault clearing delay for motor inrush.
  - 30 cycle fault clearing time is typical for low-voltage power and insulated case circuit breakers with a short time fault clearing delay without instantaneous trip.
- See Table 1 of IEEE 1584, Guide for Performing Arc Flash Hazard Calculations, for further information regarding list items (2) through (4) in Note No. 2 above
- See IEEE C37.20.7, Guide for Testing Switchgear Rated Up to 52 kV for Internal Arcing Faults, for an example of a standard that provides information for arc-resistant equipment referred to in this table.
- See NFPA 70E, Informative Annex O.2.4(9) for information on arc-resistant equipment.

## Section 2.2 - Arc Flash PPE Categories and Boundaries for Direct Current (DC) Systems

Storage batteries, dc switchboards, and other dc supply sources greater than 150 volts and less than or equal to 600 volts; maximum arc duration and minimum working distance: 2 sec 455 mm (18 in.)

- Available fault current less than 1.5 kA
  - arc flash PPE Category 2;
  - **arc flash boundary** is 900 mm (3 ft)
- Available fault current greater than or equal to 1.5 kA and less than 3 kA
  - arc flash PPE Category 2;
  - **arc flash boundary** is 1.2 m (4 ft);
- Available fault current greater than or equal to 3 kA and less than 7 kA

- arc flash PPE Category 3;
- **arc flash boundary** is 1.8 m (6 ft.)
- Available fault current greater than or equal to 7 kA and less than 10 kA
  - arc flash PPE Category 4;
  - **arc flash boundary** is 2.5 m (8 ft)

## Notes

- Apparel that can be expected to be exposed to electrolyte must meet both of the following conditions:
  - Be evaluated for electrolyte protection. See ASTM F1296, Standard Guide for Evaluating Chemical Protective Clothing, for information on evaluating apparel for protection from electrolyte
- Be arc rated. See ASTM F1891, Standard Specification for Arc and Flame Resistant Rainwear, for information on evaluating arc-rated apparel.
- A two-second arc duration is assumed if there is no overcurrent protective device (OCPD) or if the fault clearing time is not known. If the fault clearing time is known and is less than 2 seconds, an incident energy analysis could provide a more representative result.
- See NFPA 70E Appendix D.5 for the basis for table values and alternative methods to determine dc incident energy. Methods should be used with good engineering judgment. When determining available fault current, the effects of cables and any other impedances in the circuit should be included. Power system modeling is the best method to determine the available short-circuit current at the point of the arc. Battery cell short-circuit current can be obtained from the battery manufacturer.
- 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
- See the following references for dc voltages below 150 volts nominal:
  - J. G. Hildreth and K. Feeney, "Arc Flash Hazards Station Battery Systems," 2018 IEEE Power & Energy Society General Meeting (PESGM), 2018, pp. 1–5.
  - US Department of Energy Bonneville Power Administration Engineering and Technical Services Report BPA F 5450.05, "DC Arc Flash: 125V, 1300 amp-hour battery," May 11, 2017, doi: 10.1109/PESGM.2018.8586181.
  - K. Gray, S. Robert, and T. L. Gauthier, "Low Voltage 100–500 Vdc Arc Flash Testing," 2020 IEEE IAS Electrical Safety Workshop (ESW), 2020, pp. 1–7, doi: 10.1109/ESW42757.2020.9188336.

# Table 3 - Personal Protective Equipment (PPE) by Arc-flash Category

## Arc Flash PPE Category 1

- **Arc-Rated Clothing, Minimum Arc Rating of 4 cal/cm<sup>2</sup> (16.75 J/cm<sup>2</sup>)<sup>a</sup>**
  - Arc-rated long-sleeve shirt and pants or arc-rated coverall
  - Arc-rated face shield<sup>b</sup> or arc flash suit hood
  - Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (as needed)<sup>f</sup>
- **Protective Equipment**
  - Hard hat
  - Safety glasses or safety goggles, selection required
  - Hearing protection (ear canal inserts)<sup>c</sup>
  - Heavy-duty leather gloves, arc-rated gloves, or rubber insulating gloves with protectors, selection required<sup>d</sup>
  - Leather footwear<sup>e</sup>, as needed

## Arc Flash PPE Category 2

- **Arc-Rated Clothing, Minimum Arc Rating of 8 cal/cm<sup>2</sup> (33.5 J/cm<sup>2</sup>)<sup>a</sup>**
  - Arc-rated long-sleeve shirt and pants or arc-rated coverall
  - Arc-rated flash suit hood or arc-rated face shield<sup>b</sup> and arc-rated balaclava
  - Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (as needed)<sup>f</sup>
- **Protective Equipment**
  - Hard hat
  - Safety glasses or safety goggles (selection required)
  - Hearing protection (ear canal inserts)<sup>c</sup>
  - Heavy-duty leather gloves, arc-rated gloves, or rubber insulating gloves with protectors (selection required)<sup>d</sup>
  - Leather footwear<sup>e</sup>

## Arc Flash PPE Category 3

- **Arc-Rated Clothing Selected so That the System Arc Rating Meets the Required Minimum Arc Rating of 25 cal/cm<sup>2</sup> (104.7 J/cm<sup>2</sup>)<sup>a</sup>**
  - Arc-rated long-sleeve shirt (as required)
  - Arc-rated pants (as required)
  - Arc-rated coverall (as required)
  - Arc-rated arc flash suit jacket (as required)
  - Arc-rated arc flash suit pants (as required)
  - Arc-rated arc flash suit hood
  - Arc-rated gloves or rubber insulating gloves with protectors (selection required)<sup>d</sup>

- Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (as needed)<sup>f</sup>
- **Protective Equipment**
  - Hard hat
  - Safety glasses or safety goggles (selection required)
  - Hearing protection (ear canal inserts)<sup>c</sup>
  - Leather footwear<sup>e</sup>

## Arc Flash PPE Category 4

- **Arc-Rated Clothing Selected so That the System Arc Rating Meets the Required Minimum Arc Rating of 40 cal/cm<sup>2</sup> (167.5 J/cm<sup>2</sup>)<sup>a</sup>**
  - Arc-rated long-sleeve shirt (as required)
  - Arc-rated pants (as required)
  - Arc-rated coverall (as required)
  - Arc-rated arc flash suit jacket (as required)
  - Arc-rated arc flash suit pants (as required)
  - Arc-rated arc flash suit hood
  - Arc-rated gloves or rubber insulating gloves with protectors (selection required)<sup>d</sup>
  - Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (as needed)<sup>f</sup>
- **Protective Equipment**
  - Hard hat
  - Safety glasses or safety goggles (selection required)
  - Hearing protection (ear canal inserts)<sup>c</sup>
  - Leather footwear<sup>e</sup>

## Notes

- <sup>a</sup>Arc rating is defined in Article 100.
- <sup>b</sup>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.
- <sup>c</sup>Other types of hearing protection are permitted to be used in lieu of or in addition to ear canal inserts provided they are worn under an arc-rated arc flash suit hood.
- <sup>d</sup>Rubber insulating gloves with protectors provide arc flash protection in addition to electric shock protection. Higher class rubber insulating gloves with protectors, due to their increased material thickness, provide increased arc flash protection.
- <sup>e</sup>Footwear other than leather or dielectric shall be permitted to be used provided it has been tested to demonstrate no ignition, melting or dripping at the minimum arc rating for the respective arc flash PPE category.
- <sup>f</sup>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