

Table 3-4. Approach boundaries to energized electrical conductors or circuit parts for shock protection, 50/60 Hz AC.

(1)	(2)	(3)	(4)	(5)
Nominal System Voltage Range, Phase to Phase	Limited Approach Boundary		Restricted Approach Boundary	Prohibited Approach Boundary
	Exposed Movable Conductor ¹	Exposed Fixed Circuit Part ²		
< 50	Not specified	Not specified	Not specified	Not specified
50 – 300 V	3.05 m (10'0")	1.07 m (3'6")	Avoid contact	Avoid contact
301 – 750 V	3.05 m (10'0")	1.07 m (3'6")	304 mm (1'0")	25 mm (0'1")
751 V – 15 kV	3.05 m (10'0")	1.53 m (5'0")	660 mm (2'2")	178 mm (0'7")
15.1 – 36 kV	3.05 m (10'0")	1.83 m (6'0")	787 mm (2'7")	254 mm (0'10")
36.1 – 46 kV	3.05 m (10'0")	2.44 m (8'0")	838 mm (2'9")	432 mm (1'5")
46.1 – 72.5 kV	3.05 m (10'0")	2.44 m (8'0")	1.0 m (3'3")	660 mm (2'2")
72.6 – 121 kV ³	3.25 m (10'8")	2.44 m (8'0")	1.02 m (3'4")	838 mm (2'9")
138 – 145 kV	3.36 m (11'0")	3.05 m (10'0")	1.15 m (3'10")	1.02 m (3'4")
161 – 169 kV	3.56 m (11'8")	3.56 m (11'8")	1.29 m (4'3")	1.14 m (3'9")
230 – 242 kV	3.97 m (13'0")	3.97 m (13'0")	1.71 m (5'8")	1.57 m (5'2")
345 – 362 kV	4.68 m (15'4")	4.68 m (15'4")	2.77 m (9'2")	2.79 m (8'8")
500 - 550 kV	5.8 m (19'0")	5.8 m (19'0")	3.61 m (11'10")	3.54 m (11'4")
765 – 800 kV	7.24 m (23'9")	7.24 m (23'9")	4.84 m (15'11")	4.7 m (15'5")

NOTES:

¹ Exposed Movable Conductor means that the bare conductor can move (e.g., an overhead transmission line conductor). This is unlikely indoors.

² Exposed Fixed Circuit Part means that the bare conductor or other circuit part is stationary and will not move. This is the most common Limited Approach Boundary value used.

³ It is unlikely that a worker will work near exposed conductors over 100 kV.

3.5.2 Approach Boundary Analysis for DC

Approach Boundary values for DC are not found in NFPA 70E, but can be inferred because the principles of air breakdown distance are similar. Differences in the physics of air gap break-down from 60 Hz AC to DC are small compared to the conservative values chosen for the boundaries. To determine a similar value for DC, the AC phase to phase voltage was converted to peak of a phase to ground. This would give a value that is 0.82 x value of the phase to phase voltage used in NFPA 70E. The higher voltage values from NFPA 70E were used and are more conservative. Table 3-5 gives approach boundaries to energized electrical conductors or circuit parts for DC, which are applicable to DC circuits, batteries, and capacitors. Notes help to explain the content and use of the table.

Table 3-5. Approach boundaries to energized electrical conductors or circuit parts for shock protection, DC.

(1)	(2)	(3)	(4)	(5)
Nominal Voltage Conductor to Ground	Limited Approach Boundary		Restricted Approach Boundary	Prohibited Approach Boundary
	Exposed Movable Conductor ¹	Exposed Fixed Circuit Part ²		
< 100 V	Not specified	Not specified	Not specified	Not specified
100 – 300 V	3.05 m (10'0")	1.07 m (3'6")	Avoid contact	Avoid contact
301 V – 1 kV	3.05 m (10'0")	1.07 m (3'6")	304 mm (1'0")	25 mm (0'1")
1 kV – 5 kV	3.05 m (10'0")	1.53 m (5'0")	450 mm (1'7")	100 mm (0'4")
5 kV – 15 kV	3.05 m (10'0")	1.53 m (5'0")	660 mm (2'2")	178 mm (0'7")
15 kV – 45 kV	3.05 m (10'0")	2.5 m (8'0")	0.8 m (2'9")	0.44 m (1'5")
45 kV – 75 kV	3.05 m (10'0")	2.5 m (8'0")	1 m (3'2")	0.65 m (2'1")
75 kV – 150 kV ³	3.4 m (10'8")	3 m (10'0")	1.2 m (4'0")	1 m (3'2")
150 kV – 250 kV ³	4 m (11'8")	4 m (11'8")	1.6 m (5'3")	1.5 m (5'0")
250 kV – 500 kV ³	6 m (20'0")	6 m (20'0")	3.5 m (11'6")	3.3 m (10'10")
500 kV – 800 kV ³	8 m (26'0")	8 m (26'0")	5 m (16'5")	5 m (16'5")

NOTES:

¹ Exposed Movable Conductor means that the bare conductor can move (e.g., an overhead transmission line conductor). This is unlikely indoors.

² Exposed Fixed Circuit Part means that the bare conductor or other circuit part is stationary and will not move. This is the most common Limited Approach Boundary value used.

³ It is unlikely that a worker will work near exposed conductors over 100 kV.

3.5.3 Flash Hazard Analysis for Facility Power Systems

For Classes 1.2a, 1.2b, 1.2c, 1.3a, 1.3b, 1.3c and 1.4 (facility power systems) determine the Flash Protection Boundary as follows:

- A. **Preferred method:** Calculate the Flash Protection Boundary using an appropriate method described in IEEE Std 1584a; include the clearing time considerations in §9.10.4. IEEE Std 1584a arc flash calculations related to facility power systems
- B. **Alternate method:** Use 48 inches as the Flash Protection Boundary provided that the product of fault current and overcurrent protective device clearing time does not exceed 100 kA cycles (1,667 ampere seconds).

NOTE 1: § is a symbol for referring to a specific code section.

NOTE 2: An arc flash hazard need not be considered where all of the following conditions exist: (1) the circuit is rated 240 volts or less, (2) the circuit is supplied by one transformer, and (3) the transformer supplying the circuit is rated less than 125 kVA. Refer to §130.3, Exception 1, NFPA 70E, 2009.

NOTE 3: At locations immediately downstream of service entrance main circuit breakers and main circuit breakers in panel boards served by dry-type transformers, it is possible that the arc fault current will be in the circuit breaker long-time trip band instead of the instantaneous trip region. (This is because the arc fault current is significantly less than the bolted fault current in low-voltage systems.) Such a condition will result in a great increase in the Flash Protection Boundary because of the long time delay before the circuit breaker trips (e.g., 30 seconds (s) instead of 0.015 s). Refer to §9.14 in IEEE Std 1584a.

3.5.4 Flash Hazard Analysis for R&D Systems (supplement R&D)

Engineering supervision should be used to determine the DC arc flash boundary.

For R&D, capacitor, and battery systems, consider that an arc flash hazard potentially exists and perform a flash hazard analysis in accordance with either NFPA 70E or IEEE 1584a where any of the following conditions can exist on exposed parts:

NOTE: If the available energy is less than that listed below, an arc flash hazard analysis does not need to be performed.

- A. alternating current (AC) systems up to 3 kHz: Available short-circuit energy exceeds:
 - 1) 0.85 megavolt-ampere-seconds (MVA-seconds), 0.85 Megajoules (MJ) for an arc in open air
 - 2) 0.53 MVA-seconds (0.53 MJ) for an arc in a cubic box.

NOTE 1: Systems such as this are placed in Hazard Class 2.4.

NOTE 2: 0.85 MVA-seconds will deposit approximately 5 J/cm² (1.2 cal/cm²) on skin located 457.2 mm (18 in) from a 60Hz AC arc, assuming that the arc current equals the bolted-fault current. NFPA 70E uses a power factor of 0.5 in

calculating the arc power.

NOTE 3: There is approximately 1.6 times the deposited energy from an arc in a cubic box than from an arc in open air due to reflecting and focusing effects of the box.

NOTE 4: Time of exposure is usually determined by the clearing time of the upstream overcurrent protection at the arc current. The arc current may be substantially less than the bolted fault current; hence, the clearing time may be substantially longer than that for the prospective bolted fault current.

B. direct current (DC) systems: available short-circuit energy exceeds:

- 1) 0.425 megawatt-seconds (MJ) for an arc in open air
- 2) 0.266 MJ for an arc in a cubic box.

NOTE 1: 0.425 MJ for a DC arc is extrapolated from the equations in NFPA 70E for a 60 Hz arc and assumes that the DC arc current equals the DC bolted-fault current.

NOTE 2: Analysis must be performed to determine the short circuit energy deposited in an arc. Such systems fall into hazard Classes 2.3 and 2.4.

C. Capacitor systems: stored energy exceeds: add Table ref

- 1) 131 kilojoules for an arc in open air
- 2) 80 kilojoules for an arc in a cubic box.

NOTE 1: 131 kJ is based on converting 100% of capacitor stored energy into radiant heat to deposit 5 J/cm² 18 in from the arc.

NOTE 2: Large capacitor banks operating at high voltages (e.g., 1600 µF at 10 kV) would be required to approach these energy levels. Noise, pressure wave, and shrapnel hazards from an uncontrolled discharge will be the governing hazards with capacitors having stored energy less than the above values.

NOTE 3: A worker should never approach a charged capacitor or capacitor bank in excess of 10 kJ. The energy must be removed remotely before personnel access. Such systems fall into hazard Classes 3.4a, 3.4b, and 3.4d.

D. Battery systems: available short-circuit energy of battery string exceeds:

- 1) 0.425 MJ for an arc in open air
- 2) 0.266 MJ for an arc in a cubic box.

NOTE 1: 0.425 MJ for a DC arc is extrapolated from the equations in NFPA 70E for a 60 Hz arc and assumes that the DC arc current equals the DC bolted-fault current.

NOTE 2: Battery short-circuit current is determined by internal resistance and is often given in the battery manufacturer's product data. There are also rules of thumb used in the industry to compute short-circuit current: IEEE 946 uses 10 times the 1-min discharge current to 1.75 V per cell for a lead-acid cell.

NOTE 3: Time of exposure is usually determined by the clearing time of the upstream overcurrent protection at the arc current; with batteries there may be no upstream overcurrent protective device.

NOTE 4: Battery system arc flash hazards are present in relatively small UPS systems: A 480 V, 20 kW, 20 min UPS will have a 480 V battery bank consisting of about 240 50-A-hr cells capable of a short-circuit current of about 1500 A; the resulting arc power would be about 0.7 MW and the arc would persist for perhaps several seconds as the battery discharges.

NOTE 5: Hazards from contact with hot surfaces, molten metal, and corrosive chemicals will exist for battery short-circuit events even where energy levels are much lower than required to present an arc flash hazard.

NOTE 6: The 'short-circuit energy' of a battery is in Joules. That is the energy produced in each second. This is not the same as the total energy stored in a battery. For example, the 'short-circuit energy' of a car battery is about 10 kJ, but the battery stores a total of about 1 MJ.

3.6 ADMINISTRATIVE CONTROLS FOR ELECTRICAL WORK

Administrative controls to mitigate electrical hazards can be divided into four basic categories:

1. worker rules:
 - working alone rule
 - two-person rule
 - safety watch rule
2. qualification and training
3. work control (including EEWP)
4. personal protective equipment (PPE).

Each will be discussed briefly.

3.6.1 Working Alone, Two-Person, and Safety Watch Practices

Many sites use two-person and safety watch rules to provide a second person in case of emergency, or to provide a "second set of eyes".

Each electrical safety task should be analyzed to determine if risk of injury to a worker, while working alone, warrants a second person to be present. If the risk of injury from accidental contact with an electrical conductor is minimal, then a person may work alone.

If contact with an electrical conductor could result in ventricular fibrillation, serious burn, a no-let-go response, or other injury, the two-person practice should be followed. The second person should be a worker qualified to work on energized circuits, and should understand