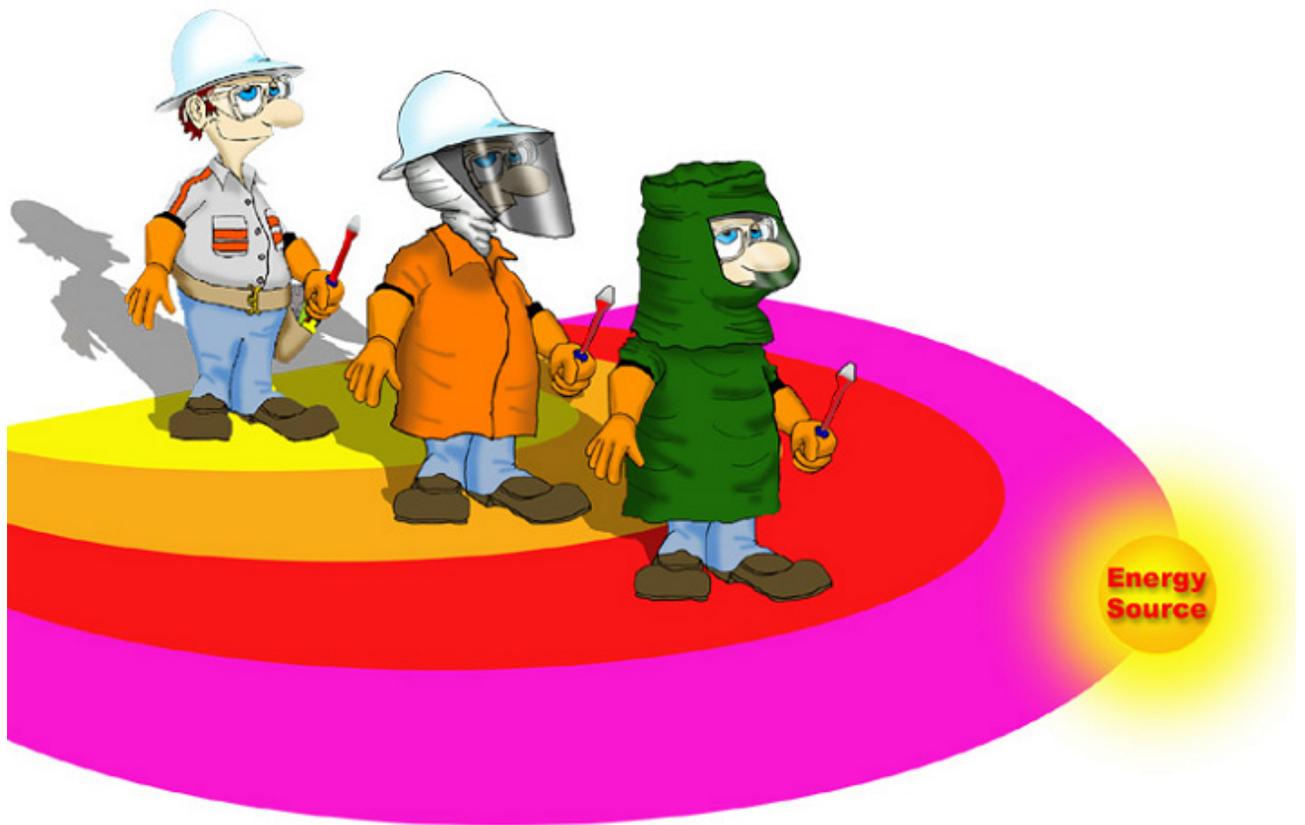


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Safety Practices and Requirements

# Electrical Arc Flash Hazard Protection



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**Knowledge Check**

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# Electrical Arc Flash Hazard Protection

## Purpose of the Electrical Arc Flash Hazard Protection Learning Guide

The purpose of Electrical Arc Flash Hazard Protection Standard Learning Guide is to inform and train employees on the safety practices and personal protection equipment requirements associated with working near sources of potential arc flash hazards.

It is intended that upon completion of the lessons in this learning guide, the worker will be knowledgeable of the hazards, safety practices and equipment requirements to prevent injury from potential arc flash hazards, and be able to determine the arc flash hazard boundaries and required PPE for performance of tasks associated with working near sources of potential arc flash hazards. Armed with this knowledge, the worker will be able to complete tasks safely.

The goal of all safety programs at Your Company's, Inc. is to eliminate injuries, and fatalities, in the work place. Your Company's wants its employees to go home after a day of work in the same good physical condition as when they arrived at work.

# Lesson One: Introduction to the Electrical Arc Flash Hazard Protection Standard

The Electrical Arc Flash Hazard Protection standard is in place to guide electrical managers and workers in working around potential electrical arc flash hazards. Manager and works must comply with the Electrical Arc Flash Hazard Protection standard.

## Learning Steps and Performance Expectations

Read all sections of the Introduction to the Electrical Arc Flash Hazard Protection Standard.

After reading all of the sections of Introduction to the Electrical Arc Flash Hazard Protection Standard, complete the Self Check. Check your answers with the Answer Key for the Self Check

You must score 100% on the Self Check. If you miss answers review the section of Introduction to the Electrical Arc Flash Hazard Protection Standard relating to the question. Retake the self-check.

## Why Electrical Arc Flash Hazard Protection?

The primary reason Electrical Arc Flash Hazard Protection was developed, and implemented, is to prevent what you are about to see from happening to our people. These incidents were over, literally, in a flash. There is no way to jump out of the way of an arc flash. To avoid arc flash hazards they must be engineered out, or the worker must be protected from them.

Cooper Bussman's Handbook for Electrical Safety indicates that as many as 80% of all documented electrical injuries are burns related to radiant energy from electric arcs, with as many as 2000 people admitted to burns centers with severe burns each year. With statistics like that it is vital that your employees be knowledgeable of hazards and risks associated with working on or near sources of arc flash hazards.

Some examples of things that can be put into place to reduce or eliminate the risk of arc flash hazards are:

- Eliminate the potential of an arc flash hazard by engineering design;

- Grounding
- Barriers
- Wear appropriate levels of PPE;
- Work at a distance that exceeds the arc flash hazard boundary.

## How does an Electrical Arc Flash happen?

An electrical Arc, simply defined, is electrical current passing through air. Dry air is normally a very good insulator and will not conduct until the voltage exceeds 75,000 volts per inch. In most cases, during an arc the current is actually passing through a mixture of ionized air and vaporized conductor.

Most electrical arcs occur as a result of a short circuit. Let's say an electrician accidentally gets a pair of pliers across the conductors in a motor circuit. Because the pliers present a much lower resistance than the motor, a very large current will flow. The only limit to the amount of current that will flow is the ability of the power source to provide current and the resistance of the conductors and the pliers.

## The Effect of an Electrical Arc Flash

It can be calculated that in the time it would take for the circuit breaker or fuse to react to a high current situation, and open the circuit, the pliers would reach a temperature of 2680°. This would occur in an instant! Since the melting point of common steel is only about 1516° the pliers would at least melt and probably vaporize, as would the conductors at the point of contact. It is this vaporized conductive material that is typically the principle path of an electrical arc.

With the vaporization, or the act of metal flashing to a vapor, the effect of an explosion would also be felt. In fact, as an example, that is how munitions are designed. Solid material flashes to a gas (vapor) in an instant resulting in extreme force moving away from the point of the flash. With the solid explosive material incased in metal shrouding, the metal casing will shatter and even melt. These pieces of metal are propelled outward causing injury to anything they strike.

In some cases, the concussion of the explosion provides the disabling effect. If you doubt the significance of concussion, remember the military has a weapon called a "Daisy Cutter". It uses concussion to clear landing zones for helicopters, and disable personnel dug in behind shrapnel proof fortifications.

The dangers of an arc flash hazard are *burns, concussion and flying metal*. That means you are exposed to the same type of injuries soldiers face in combat.

The following pages show some graphic examples of burns suffered by electrical workers. They show the horror of electrical burns. Proper PPE would have provided protection for these people and lessened the injuries they suffered. The goal of Electrical Arc Flash Hazard Protection is to prevent such injuries to our workers.

## Arc Flash Incident Examples

### *Electrical Worker Killed by Electrocution*



### *Line Worker Severely Burned (no pictures)*

The line worker was out viewing a repair job at a northern US utility. The presumption was that a single unit in a three-phase transformer bank had been struck by lightning during a storm. One of the three transformers had been replaced but the secondary line was still not energized. The crew was replacing the second transformer. And the line worker was standing below the scene watching the progress of the work when the conductor apparently broke at the point where the lightning struck and fell. It landed away from his feet but created an electric arc as it fell apart. The radiated heat from the arc hit his arm and flame resistant shirt. This caused little damage to his upper torso but it ignited his denim jeans and burned them completely off of his body except for a bit of denim jean fabric underneath his leather belt.

He had first and second degree burns on the front of his legs but mostly third degree burns on the back of his legs and hips. The arc may have blown the front of his jeans off quickly so that the front of his legs were not as severely burned by the fire which swept over his lower torso as the heavy jean material continued to burn. Wally Benhke, retired DuPont scientist, and one of the developers of the copper calorimeter currently used in burn prediction, said something that came home in this accident: "Heavy cotton is good until it ignites, and the ignition energy is almost directly proportional to the weight of the cotton material, but once the heavy cotton ignites you just have more fuel to burn on the body." The line worker would have been much better protected with a pair of arc and flame resistant jeans that he could have selected in the company's clothing allowance.

### ***Severe Burns to Worker***



Here is an example of painful burns suffered by a worker due to an arc flash. Not only is it horrible to look at, the pain suffered by the victim is excruciating. The incident is over in an instant but its effect last for a lifetime.

## **Scope and Purpose of the Electrical Arc Flash Hazard Protection Standard**

The Electrical Arc Flash Hazard Protection Standard mandates the minimum safety rules, design criteria and practices for personnel working within the Electrical Arc Flash Hazard Boundary of electrical systems operating at greater than 50 volts, Ac or DC, 50 to 60 Hertz. The standard applies to all Your Company's-owned, Your Company's-managed, and Your Company's-leased facilities worldwide, and to all Your Company's personnel, contractors, subcontractors, vendors, and visitors.

Personnel working within or around and Electrical Arc Flash Hazard Boundary shall know, understand and follow the safe work practices contained within the standard.

In addition, location personnel shall follow local legislative codes or accepted employee safety standards, design criteria, etc., when they are more stringent than those identified in the Electrical Arc Flash Hazard Protection standard.

The purpose of the Electrical Arc Flash Hazard Protection standard is to eliminate injury to Your Company's personnel, contractors, subcontractors, vendors, and visitors caused by Electrical Arc Flash Hazards.

Each location shall perform an Arc Flash Hazard Assessment to determine if Arc Flash Hazards exist.

## **Definitions**

### ***Arc Fault Current***

For Arc Flash Hazard Analysis calculations, use the short circuit symmetrical amperes from a bolted 3-phase fault. Select the value at time of circuit interruption.

### ***Arc Flash Hazard***

Danger due to Arc thermal energy from an electric arc fault.

### ***Arc Flash Hazard Analysis***

Calculations to predict the Arc thermal energy from the source of an electric arc fault.

### ***Arc Flash Hazard Assessment***

A process to determine if an Arc Flash Hazard exists.

### ***Arc In A Box***

The estimated Arc Thermal Energy created in a six-sided metal enclosure. The Arc Flash Hazard is present due to one side open.

### ***Arc Thermal Energy***

Radiant heat intensity in calories/cm<sup>2</sup> emitted by an electrical arc.

### ***Arc Thermal Performance Value (ATPV)***

Amount of heat energy in cal/cm<sup>2</sup> a fabric or garment is rated to protect the wearer from a second-degree burn. (Note: The onset of a second-degree burn to the skin is 1.2 calories/cm<sup>2</sup>.)

### ***Close Proximity***

Close enough to reach, fall into, or otherwise accidentally contact an electrical source. Working in Close Proximity would be within the Electrical Arc Flash Hazard Boundary.

### ***Electrical Arc Flash Hazard Boundary***

The distance from an arc flash hazard source where Arc Thermal Energy applied to the skin is equal to 1.2 calories/cm<sup>2</sup> which are the onset of a second-degree burn to the skin. Additional PPE is required within this area for protection from arc thermal energy.

### ***Energy of Break Open Threshold (E<sub>BT</sub>)***

Amount of heat energy in calories/cm<sup>2</sup> a fabric or garment is rated before the garment fabric breaks open. E<sub>BT</sub> is averaged from the highest five energy values.

***Flame Resistant (FR)***

Material treated with a chemical flame retardant to prevent clothing ignition, or natural materials that are inherently flame resistant (e.g. wool, PR 97, Nomex).

***Live Line Tools***

Tools electrically rated for the voltage involved and used to touch or come in close proximity to exposed, energized conductors or equipment.

***Personal Protective Equipment (PPE)***

Clothing and equipment that protects the wearer from injury.

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## Lesson One Self Check

- 1) The purpose of the Electrical Arc Flash Hazard Protection Arc Flash Hazard Standard is to:
  - a) Detail requirements for working around motors.
  - b) Detail requirements for working with high voltage.
  - c) Guide electrical managers and workers in working around potential electrical arc flash hazards.
  - d) Detail requirements for working around low voltage sources.
- 2) Flame resistance clothing and equipment are:
  - a) Treated with ceramic material that will resist burning.
  - b) Treated with an asbestos based material that is flame resistant.
  - c) Are specifically man made materials designed to resist fire.
  - d) Material treated with a chemical flame retardant to prevent clothing ignition, or natural materials that are inherently flame resistant.
- 3) Arc in a box is:
  - a) A new breakfast material.
  - b) The estimated Arc Thermal Energy created in a six-sided metal enclosure.
  - c) An Arc Flash Hazard present due to one side open.
  - d) An Arc Flash Hazard present in the air outside of a breaker.
  - e) b & c
- 4) The Electrical Arc Flash Hazard Protection Standard mandates the minimum safety rules, design criteria and practices for personnel working within the Electrical Arc Flash Hazard Boundary of electrical systems operating at
  - a) greater than 50 volts Ac
  - b) greater than 50 volts DC
  - c) 50 to 60 Hertz
  - d) All of the above.
- 5) Arc Flash Hazard Analysis
  - a) Calculations to predict the Arc thermal energy from the source of an electric arc fault.
  - b) Calculations to predict the length of time an arc is in the air.
  - c) Calculates the ATPV.
  - d) Calculates the fault current.
- 6) Electrical Arc Flash Hazard Boundary is:
  - a) The distance from an arc flash hazard source where Arc Thermal Energy applied to the skin is equal to 1.2 calories/cm<sup>2</sup>.
  - b) A physical barrier used to restrain workers when arc welding.
  - c) The distance from an arc flash hazard source where level 4 PPE is required.
  - d) None of the above.

- 7) Personnel shall follow:
- a) Local legislative codes when in foreign countries because they supersede Electrical Arc Flash Hazard Protection.
  - b) Local legislative codes or accepted employee safety standards, design criteria, etc., whichever is least stringent.
  - c) Local legislative codes or accepted employee safety standards, design criteria, etc., when they are more stringent than those identified in the Electrical Arc Flash Hazard Protection standard
  - d) Whatever makes sense.

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## Lesson One Answer Key

1. c
2. d
3. e
4. d
5. a
6. a
7. c

# Lesson Two: Requirements of the Electrical Arc Flash Hazard Protection Standard

## Learning Steps and Performance Expectations

Read all sections of the Requirements of Electrical Arc Flash Hazard Protection Standard.

After reading all of the sections of Requirements of Electrical Arc Flash Hazard Protection Standard, complete the Self Check. Check your answers with the Answer Key for the Self Check.

You must score 100% on the Self Check. If you miss answers review the section of Requirements of Electrical Arc Flash Hazard Protection Standard relating to the question. Retake the self-check.

## Location Manager Responsibilities

The Location Manager shall be responsible for implementing location-specific practices and a procedure that meets or exceeds those contained within this document, and for providing personnel training that incorporates such information. The Location Manager may delegate the task of implementing the requirements of this document.

## Training Requirements

Arc Flash Hazards can change as distribution systems change, due to additional equipment or switching operations. Personnel exposed to Arc Flash Hazards shall be trained in:

- Identifying potential Arc Flash Hazard tasks and locations; and
- The safe work practices necessary to eliminate injury from an Arc Flash Hazard; and
- The use and care of PPE.

Personnel exposed to Arc Flash Hazards must be initially trained and retrained at a minimum of every two years. When the Arc Flash Hazard task, or PPE requirements change, additional training is required.

## Arc Flash Hazard Assessment

Locations must perform an Arc Flash Hazard Assessment to determine if Arc Flash Hazards exist. The following are the steps necessary for performing an Arc Flash Hazard Assessment:

### **Assess Tasks**

Location Management shall ensure the tasks listed in Table 4.3.1 are assessed. If there are no tasks involving an Arc Flash Hazard, the assessment is complete. If the task is operation of enclosed switchgear with doors closed, perform an Arc Flash Hazard Analysis per Section 4.4 or use the PPE Level described in Table 4.5 to complete the assessment.

### **Tasks associated with an Arc Flash Hazard.**

- Inspection or infrared testing in opened panels with exposed energized bus
- Voltage testing and phasing
- Racking circuit breakers (open or enclosed switch ear
- Switching
- Grounding
- Cleaning bushings and insulators
- Opening doors or compartments to exposed bus
- Using Live Line Tools/Voltage Rated Tools
- Electrical equipment operation with doors opened
- Operation of enclosed switch gear with doors closed
- Performing other activities that may initiate an Arc Flash Hazard

### **Hazard Control**

Priority must be given to eliminating the Arc Flash Hazard. Determine if equipment design or work practices will control the Arc Flash Hazard. Arc Fault rated switchgear complete with viewing windows and integral-grounding (earthing) switches is an example of equipment designed to eliminate the Arc Flash Hazard.

Examples of work practices to control Arc Flash Hazards include remote operation of switches and circuit breakers, remote grounding of switches and circuit breakers, or use of rated electrical isolation blankets or barriers. If the equipment design or work practice results in elimination of the Arc Flash Hazard, the assessment is complete.

### **Determine Electrical Arc Flash Hazard Boundary**

When an Arc Flash Hazard is present, personnel must know the Electrical Arc Flash Hazard Boundary. The Electrical Arc Flash Hazard Boundary is the distance from the arc source at which the Arc Thermal Energy is equal to 1.2 calories/cm<sup>2</sup>. To calculate the Electrical Arc Flash Hazard Boundary, refer to Arc Hazard Assessment lesson in this Learning Guide. If the task is performed outside the Electrical Arc Flash Hazard Boundary, further analysis is not required.

### ***Determine the Arc Thermal Energy for the task to be performed***

To calculate the Arc Thermal Energy, refer to Arc Hazard Assessment lesson in this Learning Guide. If the voltage is 600 volts or greater, use software, or refer to Arc Hazard Assessment lesson in this Learning Guide. . If the task involves enclosed switchgear with doors open and the switchgear is rated greater than 600 volts, refer to Personal Protective Equipment lesson in this Learning Guide to complete the assessment.

### ***Determine PPE***

Select PPE to protect from the Arc Thermal Energy at the worker location within the Electrical Arc Flash Hazard Boundary. Refer to Personal Protective Equipment lesson in this Learning Guide to complete the assessment.

### ***Control the Arc Flash Hazard area***

Create a Safe Work Zone, refer to Create a Safe Work Zone lesson in this Learning Guide to complete the assessment..

## **Arc Flash Hazard Analysis ( Details in Lesson Three)**

The Electrical Arc Flash Hazard Boundary and the Arc Thermal Energy to which a worker could be exposed must be calculated. The calculations for these are covered in detail in the Arc Flash Hazard Analysis section of this learning guide.

## **Creating a Safe Work Zone (Details in Lesson Three)**

Personnel without appropriate PPE shall not cross an Electrical Arc Flash Hazard Boundary and enter a work area where an Arc Flash Hazard is present.

To establish a Safe Work Zone where voltages are less than 1000 volts AC, establish appropriate safe work practices to protect personnel from hazards present in the work zone. To establish a Safe Work Zone where voltages are greater than 1000 Volts AC, follow the requirements in High Voltage.1, Section 8.0. This section refers to standard Tag-Lock-Try procedures and establishment of barriers around the designated work zone. The work zone is determined by the Arc Flash Hazard boundaries and minimum approach distances as defined in High Voltage.

Electrical personnel will normally control the boundary with equipment having signage to illustrate distances.

## **Personal Protective Equipment (Details in Lesson Four)**

If an Arc Flash Hazard Analysis is not performed, personnel must wear the PPE Level as described in the Personal Protective Equipment section of this learning guide.

Personnel must wear the appropriate PPE for the determined Arc Flash Hazard level. In order to protect personnel from injuries greater than second-degree burns, the PPE must reduce Arc Flash Hazard exposure to less than 1.2 cal/cm<sup>2</sup>. Refer to the Personal Protective Equipment section of this learning guide.

## **Care and Maintenance of PPE (Details in Lesson Four)**

PPE shall be inspected, maintained, and cared for according to the manufacturer's specifications. PPE shall be inspected before each use per the manufacturer's recommendations. Any damaged PPE shall be removed from service. PPE soiled with grease or flammable liquids shall be removed from service and properly cleaned. PPE damaged in an arc flash incident shall be removed from service.

## **Periodic Reviews**

Annual self-assessments of the location's electrical safety program shall be conducted to ensure personnel are complying with the requirements of this document, and that personnel are wearing the proper PPE to eliminate Arc Flash Hazard injuries. Action plans shall be developed to close any identified gaps.

## **Modifications, Changes or Additions to Electrical Systems**

If modifications, changes or additions to the electrical system occur, a reassessment shall be completed to verify the Arc Flash Hazard and PPE requirements. The reassessment documentation shall include modifications completed, modified Arc Flash Hazard or PPE required, date and assessor's name.

## **Design of Electrical Systems to Limit Arc Flash Hazards**

An Arc Flash Hazard Assessment shall be conducted on any newly designed electrical systems. Priority must be given to eliminating the Arc Flash Hazard through the appropriate engineering and design.

After January 1, 2004, new switchgear rated for 1000 volts and above must be arc fault rated with integral grounding switches and viewing windows.

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## Lesson Two Self Check

- 1) Training on Electrical Arc Flash Hazard Protection Arc Flash Hazard Protection is required :
  - a) During initial training.
  - b) Bi-Annually.
  - c) Each time the Arc Flash Hazard task, or PPE requirements change.
  - d) All of the above.
- 2) Arc Flash Hazard self assessments are performed:
  - a) Weekly
  - b) Monthly
  - c) Semi-annually
  - d) Annually
  - e) Every two years
- 3) Which of the following is not a task where Arc Flash Hazard Assessment is required.
  - a) Inspection or infrared testing in opened panels with exposed energized bus
  - b) Voltage testing and phasing
  - c) Switching and Grounding
  - d) Cleaning around the outside of sub-stations
  - e) Opening doors or compartments to exposed bus
  - f) Using Live Line Tools/Voltage e Rated Tools
- 4) PPE is required only when there has been evidence of an arc flash incident
  - a) True
  - b) False
- 5) The Arc Flash Hazard Analysis determines the arc thermal energy.
  - a) True
  - b) False
- 6) The Arc Thermal Energy is required to determine the required PPE level.
  - a) True
  - b) False

- 7) Which of the following are part of the Arc Flash Hazard Assessment (circle all that apply)
- a) Assess Tasks
  - b) Hazard Control
  - c) Determine Electrical Arc Flash Hazard Boundary
  - d) Determine Arc Thermal Energy for tasks to be performed
  - e) Determine maintenance requirements of PPE
  - f) Control the Arc Flash Hazard area
- 8) PPE shall be inspected:
- a) when initially unpacked
  - b) after each cleaning
  - c) after each use
  - d) before each use
- 9) PPE soiled with grease or flammable liquids;
- a) shall be removed from service and properly cleaned.
  - b) shall be removed from service and discarded.
  - c) shall be cleaned with solvent that will cut the grease.
  - d) shall be removed from service cleaned according to the manufacturer's specifications.
- 10) Remove PPE from service only when it is damaged in an arc flash hazard incident.
- a) True
  - b) False
- 11) A Safe Work Zone can be established when voltages are less than 1000 volts AC by appropriate safe work practices
- a) True
  - b) False
- 12) To establish a Safe Work Zone where voltages are greater than 1000 Volts AC, follow the requirements in High Voltage.1, Section 8.0.
- a) True
  - b) False
- 13) Which of the following are examples of equipment designed to eliminate the Arc Flash Hazard?
- a) Arc Fault rated switchgear with viewing windows.
  - b) Arc Fault rated switchgear with integral grounding (earthing) switches.
  - c) Arc Fault rated switchgear with special gray paint.
  - d) a & b
- 14) You must perform an Arc Flash Hazard Analysis when working on Arc Fault related switchgear even if the switchgear is equipped with viewing windows and integral grounding switches.
- a) True
  - b) False
- 15) What amount of heat exposure is required to produce a second degree burn.

- a) 5 cal/cm<sup>2</sup>
- b) Less than 1.2 cal/cm<sup>2</sup>
- c) 8.1 cal/cm<sup>2</sup> or more
- d) 1.2 cal/cm<sup>2</sup> or more

16) Which of the following are Hazard Controls that would eliminate Arc Fault Hazards.

- a) Arc Fault rated switchgear complete with viewing windows and integral grounding switches.
- b) Remote operation of switches and circuit breakers.
- c) Remote grounding switches.
- d) All of the above.

---

## Lesson Two Answer Key

- 1) d
- 2) d
- 3) d
- 4) False
- 5) True
- 6) True
- 7) a, b, c, d, e, f
- 8) d
- 9) d
- 10) False
- 11) True
- 12) True
- 13) D
- 14) False
- 15) D
- 16) d

# Lesson Three: Determining the Electrical Arc Flash Hazard Boundary

The Electrical Arc Flash Hazard Boundary is the distance from the arc source at which the Arc Thermal Energy becomes less than or equal to 1.2 calories/Cm<sup>2</sup>. The boundaries are established for the safety of the worker who must perform tasks near known arc flash hazards.

## Learning Steps and Performance Expectations

Read all sections of the Determining the Electrical Arc Flash Hazard Boundary.

After reading all of the sections of determining the Electrical Arc Flash Hazard Boundary, complete the Self Check. Check your answers with the Answer Key for the Self Check

You must score 100% on the Self Check. If you miss answers review the section of determining the Electrical Arc Flash Hazard Boundary relating to the question. Retake the self-check.

## Derivation of Formulas

The formulas for calculating boundaries for safe work zones, where there is the potential for an arc flash hazard and the formulas for calculating the amount of thermal energy present as a flash occurs, are derived from several sources. The formulas have some component numbers that are constant and others that are variable. Also, they are accepted as the rule by safety agencies and by recognized experts in industry.

These calculations occur in the AES (Your Company's Engineering Standard) Electrical Arc Flash Hazard Protection.1, and are integral elements of the AES High Voltage.1 for high voltage safe work practices and the soon to be mandated AES 32.69.1 for low voltage levels.

The primary resource for the research that went into deriving these calculations was based upon research performed by the NFPA (National Fire Protection Association) comprised of some of the industries' leading experts in the field of electrical safety. Other standards organizations such as the IEEE and Edison Electrical Institute had input. Many leading industries such as DuPont, Duke Energy, and Ontario Hydro have performed countless research activities and have developed computer software

to facilitate and support end-user implementation of arc flash hazard protection measures.

The electrician must understand the basic concepts of arc hazard potential and the requirements for working safely in such identified areas. However, the electrician performing a task does not need to know the physics behind the calculations for either thermal energy released in an arc blast or the associated safe work zone dimensional boundaries established.

## Formula for Calculating Electrical Arc Flash Hazard Boundaries

For calculating the Electrical Arc Flash Hazard Boundary, the formula below can be used. Or use a software package as referenced in this section to calculate the Electrical Arc Flash Hazard Boundary. Or use Table 1 in this section to establish the Electrical Arc Flash Hazard Boundary.

### The Formula

$D_c = [2.65 \times MVA_{BF} \times t]^{1/2}$  This formula is used when Short Circuit Current ( $I_{sc}$ ) is known.

Variables:

- $D_c$  represents the distance (in feet) of a person from an arc source for curable second-degree burns
- $t$  equals the time (in seconds) of arc exposure.
- $MVA_{BF}$  is the bolted fault MVA (megavolt-amperes) at the point involved.
- MVA equals the MVA rating of transformer (for transformers with MVA ratings below 0.75 MVA, multiply the transformer rating by 1.25). The MVA value is used only in simple, one-transformer calculations.

## Performing an Electrical Arc Flash Hazard Boundary Calculation

Given the following information, calculate the Arc Flash Hazard Boundary.

- 50 MVA transformer (base MVA of 50)
- Impedance ( $Z$ ) of 6.75% on a 13,800 volt bus.
- Fault clearance time ( $t$ ) of 6 cycles (0.1 seconds for 60Hz).

**Table 1.**

Step 1- Calculate the bolted fault $MVA_{BF}$	$MVA_{BF} = MVA_{BASE}/Z$	$50/.0675 = 741$
Step 2- Calculate the flash hazard boundary ( $D_c$ )	$D_c = [2.65 \times MVA_{BF} \times t]^{1/2}$	$[2.65 \times 741_F \times 0.1]^{1/2} = 14$
Calculate the Short Circuit Current	$I_{sc} = (MVA_{BF} / (\sqrt{3} \times \text{bus voltage})) \times 1,000,000$	$(741/(\sqrt{3} \times 13,800)) \times 1,000,000 = 31,000$

Variables:

- $D_c$  represents the distance (in feet) of a person from an arc source for curable second-degree burns
- $t$  equals the time (in seconds) of arc exposure.
- $MVA_{BF}$  is the bolted fault MVA (megavolt-amperes) at the point involved.
- $Z$  = Transformer Impedance
- $I_{sc}$  = Short Circuit Current
- $\sqrt{\phantom{x}}$  is the square root

## Electrical Arc Flash Hazard Boundary for All Applications

When an Arc Flash Hazard is present, personnel must know the Electrical Arc Flash Hazard Boundary. If a person is within the Electrical Arc Flash Hazard Boundary, choose the PPE to protect to less than or equal to 1.2 calories/cm<sup>2</sup>. Elimination of the Arc Flash Hazard ends the need for an Electrical Arc Flash Hazard Boundary. Required PPE for common tasks is discussed in the Personal Protective Equipment section of this learning guide.

If a arc flash hazard boundary calculation has not been performed, Table 2 must be used to determine the boundary. Be sure the voltage levels and  $MVA_{BF}$  are less than or equal to those listed below.

**Table 2**

<i>Electrical System Voltage Phase to Phase</i>	<i>Electric Arc Flash Hazard Boundary <math>D_c</math></i>	
	<b>kV</b>	<b>Feet</b>
.051 - .600	4.0	1.2
.601 - .999	6.0	2.0
1.0 - 15	14.0	4.3
15.1 - 36	16.0	5.0
36.1 - 46	20.0	6.0

For values above 46kV, calculate the Electric Arc Flash Hazard Boundary.

The calculations in the above table are based on the following bolted faults:

- **51 – 600 volts:** 50 bolted fault MVA and a fault clearing time of 6 cycles (0.1 seconds)
- **601 – 999 volts:** 100 bolted fault MVA and a fault clearing of 6 cycles (0.1 seconds)
- **1 kV – 15 kV:** 750bolted fault MVA and a fault clearing of 6 cycles (0.1 seconds)
- **15.1 kV – 36 kV:** 1000 bolted fault MVA and a fault clearing of 6 cycles (0.1 seconds)
- **36.1 kV – 46 kV:** 1500 bolted fault MVA and a fault clearing of 6 cycles (0.1 seconds)

## Calculating Arc Thermal Energies

Calculated Arc Thermal Energies are used to determine the appropriate PPE required that will protect the worker from greater than second degree burns, and must reduce Arc Flash Hazard exposure to less than 1.2 cal/cm<sup>2</sup>.

When calculating Arc Thermal Energies, choose the distance from the arc source to the worker's torso. Choose distances of 18" or greater. Table 3, below, allows determination of potential Arc Thermal Energies, without calculation, if the Arc Fault Current is known.

Arc Flash incidents may occur in open air or in confined boxes (controllers). The resultant thermal energy associated with an arc flash is different based on the situation and therefore must be calculated differently.

Below are the formulas used.

### **Formula for Calculating Arc Thermal Energy for 600 volts or less in Open Air**

$$E_{MA} = 5271 \times D_A^{-1.9593} \times t_A \times [0.0016F^2 - 0.0076F + 0.8938]$$

where:

$E_{MA}$  = maximum open Arc Thermal Energy in calories/cm<sup>2</sup>

$D_A$  = distance in inches from the arc source to the worker's torso. Valid for distance of 18" and greater.

$T_A$  = arc duration in seconds

$F$  = bolted fault short circuit current in kA (valid for 16 to 50 kA).

### **Formula for Calculating Arc Thermal Energy for 600 volts or less in a Box**

$$E_{MB} = 1038.7 \times D_B^{-1.4738} \times t_A \times [0.0093F^2 - 0.3453F + 5.9675]$$

where:

$E_{MB}$  = maximum 20-inch cubic box Arc Thermal Energy in calories/cm<sup>2</sup>

$D_B$  = distance in inches from the arc source to the worker's torso. Valid for distance of 18" and greater.

$T_A$  = arc duration in seconds

$F$  = bolted fault short circuit current in kA (valid for 16 to 50 kA).

### **Potential Arc Thermal Energies in Open Air for known Short Circuit Currents**

For voltages in Open Air, use the table below or calculate Arc Thermal Energies using the appropriate software (discussed later).

**Table 3**

Supply Voltage in kV	Short Circuit Currents in kA							Arc Gap		Distance from Arc to worker's location		Arc Duration
	10	20	30	40	60	80	100					
	Total Calories/cm2 to workers							Inches	cm	Inches	cm	Seconds
0.300	.60	1.72	3.36	5.56	11.7	20.2	31.1	1.25	3	18	46	0.1
0.480	.60	1.72	3.36	5.56	11.7	20.2	31.1	1.25	3	18	46	0.1
0.600	.60	1.72	3.36	5.56	11.7	20.2	31.1	1.25	3	18	46	0.1
0.750	0.87	2.37	4.47	7.21	14.6	24.7	37.5	2	5	18	46	0.1
1.0	0.70	1.77	3.17	4.93	9.48	15.4	22.8	4	10	26	66	0.1
2.4	0.92	2.24	3.92	5.96	11.1	17.7	25.8	6	15	26	66	0.1
4.16	1.08	2.58	4.45	6.69	12.3	19.3	27.8	8	20	26	66	0.1
13.2	1.56	3.55	5.76	8.25	13.9	20.4	27.3	12	30	26	66	0.1
13.8	1.56	3.55	5.76	8.25	13.9	20.4	27.3	12	30	26	66	0.1
15	1.56	3.55	5.76	8.25	13.9	20.4	27.3	12	30	26	66	0.1
22	1.62	3.70	5.99	8.57	14.5	21.2	28.4	18	46	31	79	0.1
34.5	1.78	4.07	6.60	9.44	15.9	23.3	31.3	20	50	31	79	0.1
46	1.50	3.41	5.53	7.91	13.3	19.6	26.2	20	50	34	86	0.1

Above Arc Thermal Energy calculations based on using ARCPRO software version 2.0. ARCPRO is a product of Ontario Hydro Technologies, Toronto, Ontario, Canada.

Notes:

Arc energies computed by ARCPRO have been verified by comparison with measured results from high current laboratory tests involving controlled vertical arcs in air. ARCPRO results have shown good agreement with measured values from a series of tests covering the following ranges of parameters: currents from 3.5 kA to 21.5 kA, arc durations from 4 cycles to 30 cycles, arc lengths from 1 inches to 12 inches, and distances of 8 inches to 24 inches from the arc.

ARCPRO assumes ac symmetrical currents with 60-Hz frequency free-burning vertical arcs in air. ARCPRO does not account for the following additional criteria: movement of the arc, electrode materials such as aluminum, hot particles being ejected from the arc, 3-phase arcs or arcs in enclosures. ARCPRO is most applicable to arcs longer than 25 cm and arc currents above 200 A rms.

Duke Heat Flux Calculator Freeware provides reasonable estimates within the range of 1kA and 10 kA. Heat Flux limitations include: program termination for values outside of modeled ranges for arc gap and voltage, and poor estimates for small arc gaps at higher currents and voltages.

**Potential Arc Thermal Energies in a Cubic Box for known Short Circuit Currents**

For voltages in a Cubic Box, use the table below or calculate Arc Thermal E using the "Formula for Calculating Arc Thermal Energy in a Box discussed earlier.

Supply Voltage in kV	Short Circuit Currents in kA				Arc Gap		Distance from Arc to worker's location		Arc Duration
	20	30	40	60			Inches	cm	
	Total Calories/cm <sup>2</sup> to workers				Inches	cm	Inches	cm	Seconds
0.300	1.72	3.36	5.56	11.7	1.25	3	18	46	0.1

---

## Lesson Three Self Check

### Show your work.

- 1) To determine the Arc Flash Hazard Boundaries for a potential Arc Flash Hazard, you must know:
  - a) Distance of the worker from the arc source.
  - b) Time, in seconds, of arc exposure.
  - c) Bolted fault megavolt-amperes at the point involved.
  - d) All of the above.
- 2) The formula for determining the Arc Flash Hazard Boundary is:
  - a)  $E_{MB} = 1038.7 \times D_B^{-1.4738} \times t_A \times [0.0093F^2 - 0.3453F + 5.9675]$
  - b)  $E_{MA} = 5271 \times D_A^{-1.9593} \times t_A \times [0.0016F^2 - 0.0076F + 0.8938]$
  - c)  $MVA_{BF} = MVA_{BASE}/Z$
  - d)  $Dc = [2.65 \times MVA_{BF} \times t]^{1/2}$
- 3) The formula for calculating the Arc Thermal Energy for 600 volts or less in open air is:
  - a)  $E_{MB} = 1038.7 \times D_B^{-1.4738} \times t_A \times [0.0093F^2 - 0.3453F + 5.9675]$
  - b)  $E_{MA} = 5271 \times D_A^{-1.9593} \times t_A \times [0.0016F^2 - 0.0076F + 0.8938]$
  - c)  $MVA_{BF} = MVA_{BASE}/Z$
  - d)  $Dc = [2.65 \times MVA_{BF} \times t]^{1/2}$
- 4) The formula for calculating the Arc Thermal Energy for 600 volts or less in a box is:
  - a)  $E_{MB} = 1038.7 \times D_B^{-1.4738} \times t_A \times [0.0093F^2 - 0.3453F + 5.9675]$
  - b)  $E_{MA} = 5271 \times D_A^{-1.9593} \times t_A \times [0.0016F^2 - 0.0076F + 0.8938]$
  - c)  $MVA_{BF} = MVA_{BASE}/Z$
  - d)  $Dc = [2.65 \times MVA_{BF} \times t]^{1/2}$
- 5) It is not necessary to use calculations for Arc Thermal Energies in open air or in a box because of tables that have been calculated for known short circuits.
  - a) True
  - b) False
- 6) Why calculate Arc Thermal Energies?
  - a) The calculation is used to determine electrical insulation.
  - b) The calculation is used to determine PPE requirements for workers.
  - c) OSHA requires it.
  - d) None of the above.

---

## Lesson Three Answer Key

1. d
2. d
3. b
4. a
5. True
6. b

# Lesson Four: Personal Protective Equipment

## Learning Steps and Performance Expectations

Read all sections of Personal Protective Equipment.

After reading all of the sections of Personal Protective Equipment, complete the Self Check. Check your answers with the Answer Key for the Self Check.

You must score 100% on the Self Check. If you miss answers review the section of Personal Protective Equipment relating to the question. Retake the self check.

## Arc Thermal Performance Value (ATPV)

Each piece of clothing worn by an employee will provide some level of protection from an arc flash. As layers of clothing, and air gaps, are applied they have a cumulative effect in protection. The level of PPE is the sum of the ATPV ratings for each layer.

## Determine PPE Required for a Task

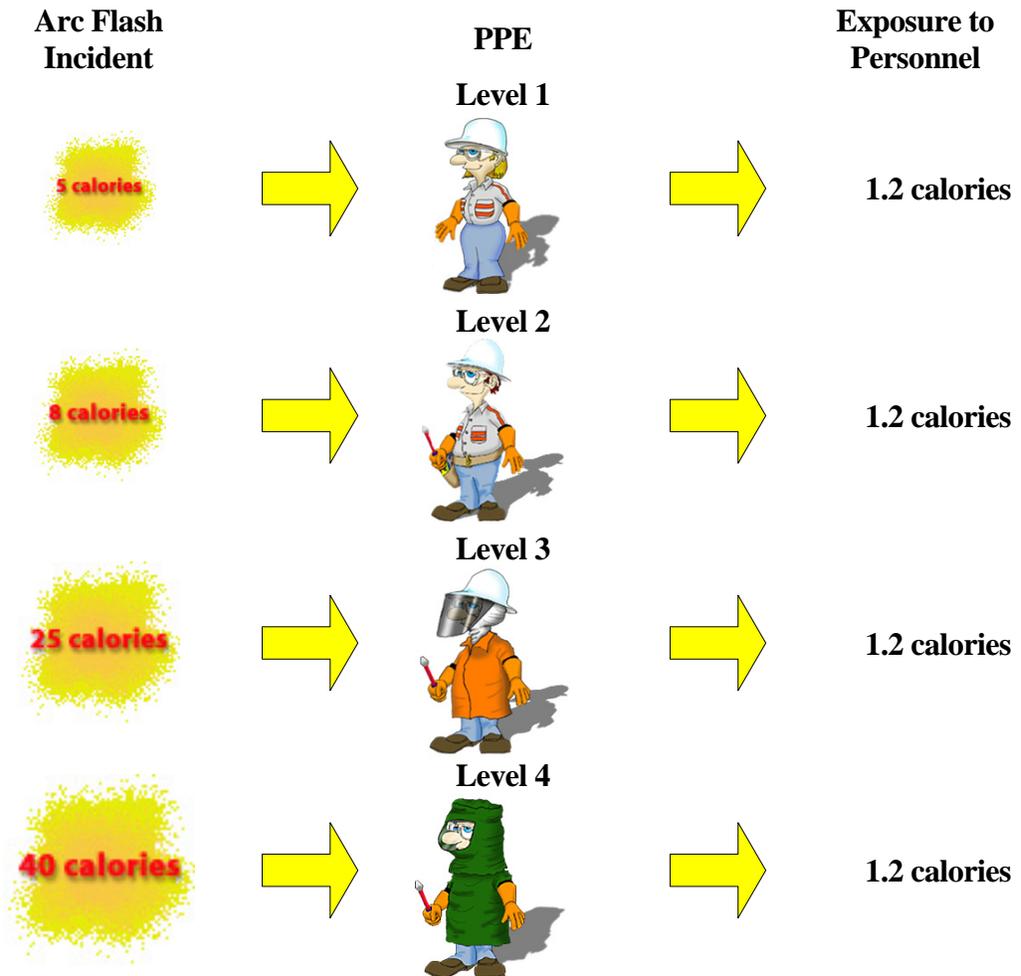
If an Arc Flash Hazard Analysis is not performed, personnel must wear the PPE Level listed in Table 4.

Personnel must wear the appropriate PPE for the determined Arc Flash Hazard level. In order to protect personnel from injuries greater than second degree burns, the PPE must reduce Arc Flash Hazard exposure to less than  $1.2 \text{ cal/cm}^2$ .

Personnel shall not wear articles containing conductive material such as rings, metal watch bands, metal-framed eyewear, and dangling metal jewelry when within the Electrical Arc Flash Hazard Boundary. Wearing of post type earrings shall be determined by location policy.

The clothing and PPE required for a task is dependent upon the potential hazard exposure and are categorized into five levels that provide adequate protection. Descriptions of these levels are found on the following pages.

For PPE Levels 1 to 4, clothing and equipment providing the same level of protection (calories/cm<sup>2</sup>) may be used instead of the specific brands or fabric weights (oz/yd<sup>2</sup>). PPE selected should not increase other hazards. Natural fiber clothes and undergarments must be 100 percent cotton, 100 percent wool, or have equivalent ignition properties that will not increase the extent of bum injury. Undergarments may have elastic supports.



Arc hazard levels in Table 4 are based upon fault clearing times of less than or equal to six cycles (0.1 seconds), and fault currents not to exceed 40kA. If longer fault clearing times and/or fault currents greater than 40KA are exceeded, an Arc Flash Hazard Analysis SHALL be performed.

**Table 4.5 – PPE Levels for Common Voltage Tasks  
Performed within an Electrical Arc Flash Hazard Boundary**

<b>Common Voltage Task</b>	
<b>Panels, switches or enclosed switchgear 51 V – 240 V, 10 kA or greater short circuit current.</b>	
Switching or breaker operation with covers on with no exposed, energized parts, excluding wall mounted, covered toggle or similar switches typically used for lighting, etc.	0
Switching or breaker operation, testing, troubleshooting, doors opened. For less than 10 kA short circuit current available, the PPE Level required may be reduced by 1.	1
<b>Panels, switches or enclosed switchgear 241 V – 999 V.</b>	
Switching or breaker operation doors closed, no exposed, energized parts less than 600 amps. See Note 1.	0
Switching or breaker operation with doors closed, 600 amps or greater. See note 2.	1
Racking in or out Circuit Breakers, Cubicle doors open.	3
Removing bolted covers to exposed energized parts.	3
Switching or breaker operation, testing, troubleshooting with doors open. See Note 3.	2
<b>Enclosed switchgear 1kV and above.</b>	
Switching or breaker operation with doors closed. See Note 2.	2
Switching or breaker operation with doors open.	4
Voltage testing and applying safety grounds.	4
Work on control circuits near exposed, energized high voltage parts.	4
Opening panel doors or compartment covers to exposed, energized high voltage parts	4
<b>Outdoor Equipment, open air, 1kV and above.</b>	
Disconnect switch operation, gang operated from grade.	
Disconnect switch operation, live line tool (hot stick) operated.	
Work on energized parts, inducing voltage testing.	
Application of Safety Grounds after voltage testing.	

Note - Aluminum enclosures provide limited Arc Flash Hazard protection. If the fault level is above 25,000 Amps or the main over current device is 1200 Amps or greater, at a minimum, Level 1 clothing with hand and face protection is required.

Note 1- If there is increased danger of injury due to Arc Flash Hazard because of any openings in the door, panel or covers, including ventilation opening, hand protection and/or face protection may be required. Hand protection shall consist of a minimum weight of 2.75 ounce leather glove with gauntlet of sufficient length to provide wrist protection. Face Protection shall consist of a tinted, propionate, wrap around face shield over safety glasses or goggles.

Note 2 - PPE Level 0, if rated and tested Arc Fault Contained Switchgear.

Note 3 - Requires the use of Face Shield and Hearing Protection.

## Level 0 PPE

Level 0 PPE consists of untreated cotton clothing including a minimum of long sleeves and, long pants and safety glasses with side shields. This level provides no appreciable protection from Arc Flash Hazard energy.

## Level 1 PPE

Level 1 PPE must provide protection to 5 calories/cm<sup>2</sup> from potential Arc Flash Thermal Energy. Level 1 PPE total clothing weight usually is 4.5 oz/yd<sup>2</sup> to 8 oz/yd<sup>2</sup> and may consist of:

- FR long sleeve shirt and FR long pants, FR Coveralls or 50" FR smock;
- Safety glasses with side shields and electrically non-conductive frames;
- Polycarbonate or propionate goggles, if goggles are required;
- Electrically-rated safety shoes;
- Electrically non-conductive hardhat; and
- Arc Flash Hazard rated gloves shall be worn to protect against the Arc Flash Hazard energy for this level of PPE. Voltage rated gloves are required if electrical contact hazard exists or their use is mandated by other codes or standards. Voltage rated gloves with leather protection may meet the requirements for both Arc Flash Hazard and electrical contact hazard.

## Level 2 PPE

Level 2 PPE must provide protection to 8 calories/cm<sup>2</sup> from potential Arc Thermal Energy, Level 2 PPE total clothing weight of all layers usually is 9 oz/yd<sup>2</sup> to 12 oz/yd<sup>2</sup> and may consist of:



First Layer	<ul style="list-style-type: none"> <li>100 % cotton underwear, including short sleeve shirt.</li> </ul>
Second Layer	<ul style="list-style-type: none"> <li>FR long sleeve shirt and FR long pants, FR Coveralls or 50" smock.</li> </ul>
Other PPE:	<ul style="list-style-type: none"> <li>Safety glasses with side shield and electronically non-conductive.</li> </ul>
	<ul style="list-style-type: none"> <li>Electrically non-conductive hardhat.</li> </ul>
	<ul style="list-style-type: none"> <li>Hearing protection</li> </ul>
	<ul style="list-style-type: none"> <li>Arc Flash rated gloves shall be worn to protect against the Arc Flash Hazard energy for this level PPE. Voltage rated gloves are required if the electrical contact hazard exists or their use is mandated by other codes or standards.</li> <li>Voltage rated gloves with leather protection may meet the requirements for both Arc Flash Hazard and electrical contact hazard.</li> </ul>

## Level 3 PPE

Level 3 PPE must provide protection to 25 calories/cm<sup>2</sup> from potential arc fault energy. Level 3 PPE total clothing weight of all layers usually is 16 oz/yd<sup>2</sup> to 20 oz/yd<sup>2</sup> and may consist of:



First Layer	<ul style="list-style-type: none"> <li>• 100 % cotton underwear, including short sleeve shirt.</li> </ul>
Second Layer	<ul style="list-style-type: none"> <li>• FR long sleeve shirt and FR long pants, FR Coveralls or 50" smock.</li> </ul>
Third Layer:	<ul style="list-style-type: none"> <li>• Single layer Nomex 50" length smock or coveralls</li> <li>• Nomex hood or hood cape</li> <li>• Wrap around arc rated face shield</li> </ul>
Other PPE:	<ul style="list-style-type: none"> <li>• Safety glasses with side shields and electrically non-conductive</li> <li>• Polycarbonate or propionate goggles, if goggles are required</li> <li>• Electrically rated safety shoes</li> <li>• Electrically non-conductive hardhat</li> <li>• Hearing Protection</li> <li>• Arc Flash rated gloves shall be worn to protect against the Arc Flash Hazard energy for this level PPE. Voltage rated gloves are required if the electrical contact hazard exists or their use is mandated by other codes or standards.</li> <li>• Voltage rated gloves with leather protection may meet the requirements for both Arc Flash Hazard and electrical contact hazard.</li> </ul>

## Level 4 PPE

Level 4 PPE must provide protection to 40 calories/cm<sup>2</sup> from potential arc fault energy. Level 3 PPE total clothing weight of all layers usually is 24 oz/yd<sup>2</sup> to 30 oz/yd<sup>2</sup> and may consist of:



First Layer	<ul style="list-style-type: none"> <li>100 % cotton underwear, including short sleeve shirt.</li> </ul>
Second Layer	<ul style="list-style-type: none"> <li>FR long sleeve shirt and FR long pants, FR Coveralls or 50" smock.</li> </ul>
Third Layer:	<ul style="list-style-type: none"> <li>Multi-ply Nomex III 50" length switcher's coat</li> <li>Nomex switcher's hood with wrap around arc rated face shield</li> </ul>
Other PPE:	<ul style="list-style-type: none"> <li>Safety glasses with side shields and electrically non-conductive</li> <li>Polycarbonate or propionate goggles, if goggles are required</li> <li>Electrically rated safety shoes</li> <li>Electrically non-conductive hardhat</li> <li>Hearing Protection</li> <li>Arc Flash rated gloves shall be worn to protect against the Arc Flash Hazard energy for this level PPE. Voltage rated gloves are required if the electrical contact hazard exists or their use is mandated by other codes or standards.</li> <li>Voltage rated gloves with leather protection may meet the requirements for both Arc Flash Hazard and electrical contact hazard.</li> </ul>

## Care and Maintenance of PPE

PPE shall be inspected, maintained, and cared for according to the manufacturer's specifications. PPE shall be inspected before each use per the manufacturer's recommendations. Any damaged PPE shall be removed from service. PPE soiled with grease or flammable liquids shall be removed from service and properly cleaned. PPE damaged in an arc flash incident shall be removed from service.

## Creating a Safe Work Zone

Personnel without appropriate PPE shall not cross an Electrical Arc Flash Hazard Boundary and enter a work area where an Arc Flash Hazard is present. To establish Safe Work Zone where voltages are less than 1000 volts AC, establish appropriate safe work practices to protect personnel from hazards present in the work zone. To establish a Safe Work Zone where voltages are greater than 1000 Volts AC, follow the requirements in High Voltage.1, Section 8.0.

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## **Other High Voltage Requirements**

### **Periodic Reviews**

Annual self-assessments of the location's electrical safety program shall be conducted to ensure personnel are complying with the requirements of this document, and that personnel are wearing the proper PPE to eliminate Arc Flash Hazard injuries. Action plans shall be developed to close any identified gaps.

### **Modifications, Changes or Additions to Electrical Systems**

If modifications, changes or additions to the electrical system occur, a reassessment shall be completed to verify the Arc Flash Hazard and PPE requirements. The reassessment documentation shall include modifications completed, modified Arc Flash Hazard or PPE required, date and assessor's name.

### **Design of Electrical Systems to Limit Arc Flash Hazards**

An Arc Flash Hazard Assessment shall be conducted on any newly designed electrical systems. Priority must be given to eliminating the Arc Flash Hazard through the appropriate engineering and design.

After January 1, 2004, new switchgear rated for 1000 volts and above must be arc fault rated with integral grounding switches and viewing windows. See document 32.25.4 titled "4.16 Thru 34.5 kV Switchgear Centers Enclosed" for additional switchgear specifications.

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## Lesson Four Self Check

- 1) Why is PPE required for working around electrical arc flash hazards?
  - a) Exposure to the worker to burns from an arc flash hazard cannot exceed  $1.2 \text{ cal/cm}^2$ .
  - b) It is not required.
  - c) OSHA requires it.
  - d) None of the above.
- 2) When operating switchgear 600 amps or less, with the door closed;
  - a) Level 0 PPE is required.
  - b) Level 1 PPE is required.
  - c) Level 2 PPE is required.
  - d) Level 3 PPE is required.
  - e) Level 4 PPE is required.
- 3) When operating switchgear 600 amps or more, with the door closed;
  - a) Level 0 PPE is required.
  - b) Level 1 PPE is required.
  - c) Level 2 PPE is required.
  - d) Level 3 PPE is required.
  - e) Level 4 PPE is required.
- 4) When operating switchgear 1kV or more, with the door closed.
  - a) Level 0 PPE is required.
  - b) Level 1 PPE is required.
  - c) Level 2 PPE is required.
  - d) Level 3 PPE is required.
  - e) Level 4 PPE is required.
- 5) When removing bolted covers to exposed energized high voltage parts, which PPE listed below is not required.
  - a) 100% cotton underwear
  - b) FR long sleeves and FR long pants, or FR coveralls, or 50" smock.
  - c) Nomex hood
  - d) Arc flash rated gloves.
  - e) All are required.
- 6) When switching or operating a breaker with the doors open, which PPE is not required:
  - a) 100% cotton underwear
  - b) FR long sleeves and FR long pants, or FR coveralls, or 50" smock.
  - c) Nomex hood
  - d) Arc flash rated gloves.
  - e) All are required.

- 7) If you are wearing Multi-ply Nomex III 50" length switcher's coat, and Nomex hood with arc shield, what level of PPE do you have on.
- a) Level 0
  - b) Level 1
  - c) Level 2
  - d) Level 3
  - e) Level 4
- 8) The PPE that provides protection to 5 calories/cm<sup>2</sup>?
- a) Level 0
  - b) Level 1
  - c) Level 2
  - d) Level 3
  - e) Level 4
- 9) The PPE that provides protection to 25 calories/cm<sup>2</sup>?
- a) Level 0
  - b) Level 1
  - c) Level 2
  - d) Level 3
  - e) Level 4
- 10) After January 1, 2004 new switchgear rated for 1000 volts and above must be arc fault rated with integral grounding switches and viewing windows.
- a) True
  - b) False
- 11) If modifications, changes or additions to the electrical system occur, a reassessment shall be completed to verify the Arc Flash Hazard and PPE requirements.
- a) True
  - b) False
- 12) The reassessment documentation shall include:
- a) modifications completed
  - b) modified Arc Flash Hazard Assessment
  - c) PPE required
  - d) date and assessor's name.
  - e) All of the above.

---

## Lesson Four Answer Key

1. d
2. a
3. b
4. c
5. c
6. e
7. d
8. b
9. d
10. False
11. False
12. e