

Electrical Safety Training for the Manufacturing Industry

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read verbatim

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read verbatim

This Training is for Affected Employees

WARNING: This training will not teach you how to work on electrical equipment. It will not teach you how to become an electrician. You will see pictures of the inside of electrical panels where arc flash accidents start, but you should never open these panels yourself.

read verbatim



This Training is for Affected Employees

This is not training for qualified employees - who are trained to work on electrical devices

Workers can be either qualified or affected

This is not training for qualified employees. Only qualified employees can work on electrical equipment.

For each situation, an employee is either qualified or affected.

Qualified Employees:

Have training to avoid the hazards of working on or near an exposed electrical parts

Are trained to work on energized electrical equipment

Can lock out or tag out machines and equipment

Know the safety-related work practices of the OSHA regulations and the NFPA standards, including required PPE

Qualified employees have the training to know how to recognize and avoid any dangers that might be present when working on or near exposed electrical parts.

Qualified employees know how to lock out and tag out machines so the machines will not accidentally be turned on and hurt the employees that are working on them.

Qualified employees also know safety-related work practices, including those by OSHA and NFPA, as well as knowing what personal protective equipment should be worn.

Affected Employees:

Can work on a machine or piece of equipment

Cannot work on electrical devices

DO NOT have the training to work on energized parts

*If you are not qualified to work on electrical equipment, but are still required to work **near** electrical equipment, you are considered to be an affected employee.*

Safe working practices for affected employees are just as important as practices for qualified employees.

*As an affected employee, you will be working on machines and other pieces of equipment, but not on electrical devices. You will, though, still be working **around** electrical parts that can kill you.*

Since you do not have the training to work on these parts, you are considered to be an affected employee because just being near some of these parts can be very dangerous.

Determine whether the following employees are qualified or affected. The situation involves a 480 volt electrical panel.

affected

John is a maintenance employee who is often cleaning work areas around the panel box

Kurt is a line worker who unloads boxes near the panel box

Mike is a production worker who walks by the panel box each day

qualified

Sally is a seasoned electrician who often needs to inspect the inside of the panel box

Tim is a certified electrician who has been maintaining electrical equipment for a long time

Introduction

1. Recognize electrical hazards
2. Avoid arc flash injury
3. Lessen injury if an arc flash occurs
4. Prevent arc flashes from happening



This training will help you become aware of some of the dangers of working around electrical devices in a manufacturing setting, especially hazards involving arc flash.

You will learn how to recognize electrical hazards, how to avoid injuries from arc flashes, how to lessen injury to yourself and others if an arc flash occurs, as well as how to keep arc flashes from ever happening.

Objectives/Agenda

What is electricity?

Electrocution and shock hazards

Arc flash and arc blast

Protective clothing, tools, and labels

Industry standards

As you go through the training, you will learn some of the basics about electricity and how it is related to arc flash hazards.

You will then learn about some of the hazards involving electrocution and shock.

After that we will cover arc flash in detail - how it happens, what happens during an arc flash, how to keep arc flash accidents from happening, and how to protect yourself from arc flash accidents if they do happen.

We will also cover choosing proper protective clothing, using the right tools, and understanding arc flash hazard labels.

You will also learn about the four industry standards for preventing arc flash accidents.

What three items will be covered in this training?

yes

How to work safely around electrical equipment

How to recognize hazardous electrical situations

Industry standards related to arc flash accidents

no

How to become an electrician

How to work on electrical equipment with electricity running through it



What Is Electricity?

Electricity is a type of energy

Electricity is everywhere: motors, heaters, lights, speakers

To help you understand what an arc flash is, we will start by introducing electricity.

Electricity is a type of energy. In your home you can see electricity being used everywhere.

Electricity can make the motors of a washing machine, refrigerator, or blender spin.

Electricity can heat up rooms with a heater, dry your clothes in a dryer, and toast bread in a toaster.

Electricity can also be used to light up rooms, create sounds in speakers, and run a computer.

How Is Electricity Used In Manufacturing?

Lights in the building

Motors

Welders

Control devices



In a manufacturing setting, electricity is used even more. Electricity provides power to practically every piece of equipment in a manufacturing facility.

It is used to light the buildings, provides power to electric motors, gives the power needed to run a welder, and also provides the control power needed so an operator can run a piece of machinery from a distance.

Select the three situations where electricity is being used.

yes

Turning on a radio to listen to music

Operating a large machine at a power plant

Turning on a computer to play a game

no

Sitting outside to read a book

Writing a note on a piece of paper

Electricity

Electricity is the flow of energy from one place to another

A flow of electrons (current) travels through a conductor

Electricity travels in a closed circuit

When you think of electricity you should think of it as a form of energy that flows from one place to another.

*Electricity involves the flow of electrons in a closed circuit through a conductor. But don't worry if you don't understand all of this yet. We will cover each of these items **and more** in detail as we progress through the training.*



Electric Charge, Static Electricity, and Current Electricity

When an electric charge builds up in one place it is called **static electricity**

Electricity that moves from one place to another is called **current electricity**

The electrons that are involved in electricity have an electric charge. When an electric charge builds up in one place it is called static electricity.

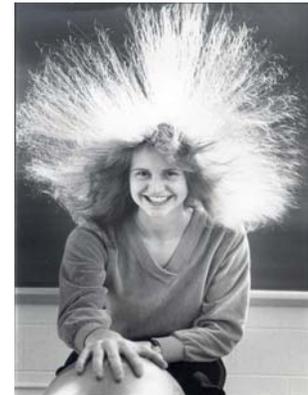
We can understand electric charge by looking at someone touching a static electricity generator. In the picture her hair is standing up because of an electric charge that builds up in her hair.

The electricity that builds up when you scoot your feet on the floor on a cool, dry day and shock someone is also because of static electricity.

Lightning is another spectacular display of static electricity.

Electricity that moves from one place to another is called current electricity.

*An electric current, then, is the **flow** of electric charge. Electric currents move through wires to make motors spin, lights light up, and heaters warm a house.*



<http://www.phys.vt.edu/~demo/demos/e10.html>

<http://explainthatstuff.com/electricity.html> on 11-3-2010

Select whether the following refer to electric charge, static electricity, or current electricity

*A buildup of electrons/a buildup of electric charge - **Static electricity***

*Electricity that moves from one place to another - **Current electricity***

*This is what electrons provide in electricity - **Electric charge***

Conductors

Conductors allow the flow of electricity

| | | |
|----------|--------|-------------|
| silver | iron | mercury |
| copper | steel | graphite |
| gold | brass | dirty water |
| aluminum | bronze | concrete |

Electric current flows through electrical conductors.

A conductor is anything that allows the flow of an electric charge. A common conductor you probably already know about is copper. Copper wires conduct electricity.

Copper, as well as aluminum, is often used to deliver electric current to machines in manufacturing settings as well as any electric appliances at home.

As you can see from the slide, most metals are good conductors. Some of the conductors listed that might surprise you are dirty water and concrete.

Insulators

Insulators do not normally allow the flow of electricity

| | | |
|------------|--------------|------------|
| glass | porcelain | (dry) wood |
| rubber | ceramic | plastic |
| oil | quartz | air |
| asphalt | (dry) cotton | diamond |
| fiberglass | (dry) paper | pure water |

An insulator is just the opposite of a conductor. It does not allow the flow of an electric charge and keeps electricity from getting to unwanted areas.

The plastic insulation around a copper wire is an example of an insulator. Others you might not have thought of are glass, oil, and pure water.

As we go further into the training we will find out that electricity can flow through insulators under certain circumstances.

An arc flash is one of the circumstances where air actually acts as a conductor.

Select whether the following are examples of conductors (4 items) or insulators (3 items).

conductor

Easily allows the flow of electric current

Copper

Gold

Aluminum

insulator

Does not allow the flow of electric current
Plastic

Rubber

Ways To Measure Electricity

Voltage

Current

Resistance

Power/Wattage



Now that you have a basic understanding of what electricity is, we can move on to discussing how electricity is measured.

Four common measurements of electricity are voltage, current, resistance, and wattage.

Voltage

Voltage: Most homes are 120 and 240 volts - it gets much higher in manufacturing.

Voltage is an electrical force or pressure that pushes electricity through a wire. Voltage is measured in units called volts.

The more voltage a circuit has, the more electricity is trying to move through the parts in the circuit. A battery, for example, with more volts will make a flashlight shine brighter.

Most homes in the U.S. run on 120 and 240 volts. Voltage in manufacturing settings are often much higher.



<http://www.explainthatstuff.com/electricity.html>) 11-3

Current

Current: a measure of the flow of electricity

Voltage is not the part of electricity that moves through a wire. The part of electricity that moves through a wire is current.

Current is measured in amperes or amps.

If you know anything about fuses, you know that fuses are rated by how much current can flow through them without melting and then stopping the flow of current because of the broken, melted wire.

Too much current, then, will get wires hot and melt them. In an arc flash, there is so much current that parts not only melt, but they vaporize and explode.

<http://www.explainthatstuff.com/electricity.html>) 11-3

Determine whether the following items refer to voltage or current.

voltage

Measured in volts

The electrical force or pressure trying to move electricity through a wire

current

The measure of the flow of electricity

Measured in amps

Too much of this will blow a fuse

Resistance

Resistance: a measure of how difficult it is for the energy to flow

Toasters use resistance to toast bread

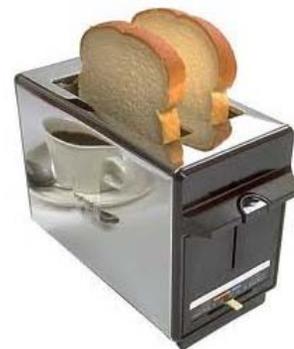
Often associated with voltage and current is resistance. Resistance is how much the electricity is being held back, or how difficult it is for electricity to flow through part of a circuit. Resistance is measured in ohms.

Different materials have different levels of resistance. Remember the difference between conductors and insulators?

Copper and aluminum wires have a very low resistance to the flow of electrical current. That is why they are conductors of electricity.

The plastic around a copper wire has a very high level of resistance. That is why it is an insulator. Plastic will not allow electricity to easily flow through it.

Toasters work on resistance. When electric current passes through the wires of a toaster, the resistance causes the wires to heat up, toasting your bread.



Factors Affecting Resistance

Material

Diameter

Temperature

Length

Four factors determine the resistance of a material to the flow of electricity. The first is the type of material.

As you have already learned, conductors are made of materials, such as copper and aluminum, that allow the flow of electricity because they do not have much resistance. Insulators, though, are made of materials with a high level of resistance.

The shape of the material is another factor that affects resistance.

The diameter of a wire, for example, helps determine the resistance of an object - more material for current to flow through means less resistance.

A wire that is very thin has more resistance than a similar wire that is much thicker.

Temperature is another factor that affects resistance.

A hot wire will often have a higher resistance to the flow of electricity than a similar wire that is cold.

Length also affects the resistance of a wire.

A long wire will resist electricity more than a short wire if they are made from the same material, are the same thickness, and are at the same temperature.

Determine whether the following wires will have more resistance or less resistance than a 1 foot wire made of copper. The wire is $1/16^{\text{th}}$ of an inch in diameter and is at room temperature.

more resistance

A wire 30 feet long having the diameter of a human hair

The original wire heated up in a furnace

less resistance

A 1 inch wire with a diameter of $1/4^{\text{th}}$ of an inch

The original wire cooled down in liquid nitrogen

Power/Watts

Watts = Voltage X Current

Current = Watts / Voltage

0.83 amps = 100 volts / 120 watts



Voltage and current working together is what gives you electrical power. More voltage and current will provide more electrical power. Electrical power is measured in watts.

The electric power in a circuit is equal to the voltage multiplied by the current. In other words: watts equals volts times amps.

So, if you have a 100-watt light bulb in your house with 120 volts, the current will be around .83 amps. This is because 100 divided by 120 equals 0.83.

We will remember this .83 amps when we get into electrical safety to see just how dangerous small amounts of current can be.

(<http://www.explainthatstuff.com/electricity.html>) 11-3

Determine whether the following items refer to voltage, current, resistance, or wattage.

A measure of the flow of electricity - **Current**

A measure of the force or pressure of electricity - **Voltage**

A measure of how much electricity is being held back - **Resistance**

A measure of power, or voltage multiplied by current - **Wattage/power**



Energy used

Measured in kilowatt-hours

It is often useful to measure how much energy has been used. Your electric bill is based on how much electricity you use over a period of time, usually a month.

To find out the total amount of energy an electric appliance uses, you have to multiply the power it uses by the amount of time you use it. The result is measured in units of power multiplied by time, often converted into a standard unit called the kilowatt hour.

If you use an electric toaster rated at 1000 watts (or 1 kilowatt) for a whole hour, you have used 1 kilowatt hour of energy.

You'd use the same amount of energy burning a 2000-watt toaster for half an hour or a 100-watt lamp for 10 hours.

<http://www.explainthatstuff.com/electricity.html> 11-3-2010

*Put the following situations in order by determining how much a person's electric bill will be. Kelly always turns off the lights at night, but because she has 4 kids, she runs her clothes dryer about 2 hours a day. - **About average, \$100***

*James tries to save as much on electricity as possible. He dries his clothes on a clothes rack and never turns on a light unless he has to. - **Pretty low, \$40***

*Linda lives in a large house that is very old. She runs the air conditioner constantly and rarely turns off her lights. - **Higher than average, \$250***

http://openbookproject.net/electricCircuits/DC/DC_1.html 11-3-2010

Ohm's Law

$$V = I \times R$$

$$I = V / R$$

$$R = V / I$$

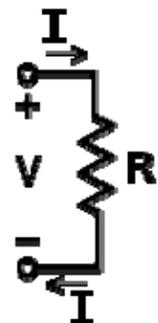
Voltage, current, and resistance are related through equations from Ohm's Law. These three equations are really the same; if you know two of the values, you can find the third value.

In most settings, both at home and in manufacturing, voltage often remains the same. Your outlets at home are around 120 volts, but in manufacturing, the voltage is often much higher, from 480 volts up to several thousand volts.

The equations of Ohm's Law are: voltage equals current times resistance, ... current equals voltage divided by resistance, ... and resistance equals voltage divided by current.

Current is what kills workers when they are electrocuted. Lots of current is also what makes an arc flash so powerful. These equations will help you understand why.

When someone is shocked, current is passing through their body. The second equation, then, with current on the left, is what we will focus on.



Ohm's Law

$I = V / R$ (highlight equation as it is discussed)

100 volts / 100 ohms = 1 amp

100 volts / 10 ohms = 10 amps

100 volts / 1 ohm = 100 amps

The level of current in someone's body when they are shocked or electrocuted, or the amount of energy released in an arc flash, is determined from the voltage supplied and the amount of resistance that is holding back the flow of electricity.

Let's go through some examples to see how this works.

100 volts divided by 100 ohms is 1 amp. 100 volts divided by 10 ohms is 10 amps, and 100 volts divided by 1 ohm is one 100 amps.

As you can see, if the top number, the voltage, stays the same, the result, the current, goes up as the bottom number, the resistance, goes down. If we take resistance down to 1/10th of an ohm, the current would then go up to 1000 amps.

If the level of current depends on the resistance, a high resistance, similar to the top equation, will lead to a low current.

If the resistance is small, similar to the bottom equation, the current will be dangerously high.

So the more insulated a person is, the more resistance they will have to the electricity. The more resistance there is, the less current that will flow through the body, lessening the chance of injury or death.

Voltage Matters

High voltage will create high current even with high resistance

13,800 Volts / 1000 Ohms = 13.8 Amps

480 Volts / 0.1 Ohms = 4,800 Amps

480 Volts / 0.01 Ohms = 48,000 Amps

The amount of voltage present is often the biggest factor to consider when dealing with shock and arc flash.

If several thousand volts are present, the resistance of the body will have little effect on the amount of current flowing through the body. The current will be enough to shock or kill you no matter what.

In the first example, notice that with a high enough voltage, even 1000 ohms worth of resistance will still be enough to shock and injure you.

In an arc flash, air (which is normally an insulator with high resistance to the flow of electricity) breaks down and loses its resistance, becoming conductive. The very low resistance causes the current to be very high, causing the dangers of an arc flash.

You can see this from the second and third equations. With a voltage of 480 volts (very common in manufacturing settings), a sharp drop in resistance can lead to thousands, or even tens of thousands of amps of current flowing through the circuit.

We will dig deeper into arc flash after we learn a bit more about electricity.

Determine the current in the following situations

example: Voltage is 120 volts. Resistance is 12 ohms. Current, then, is $120/12 = 10$ amps.

*Voltage is 120, resistance is 20 - **6 amps***

*Voltage is 480, resistance is 1 - **480 amps***

*Voltage is 1080, resistance is 0.25 - **4320 amps***

Water Example for Electricity

Water pressure (psi) = voltage

Water flow rate (gpm) = current

A thin pipe = resistance

Sometimes electricity makes more sense if you think of water flowing through a pipe.

If we have a water pump that exerts pressure to push water around a circuit, the pipes have some resistance.

If the pipe becomes very narrow at one point, though, the flow of water will be more restricted and will slow down.

The water flowing through the pipes is similar to the electrons that flow in a circuit to create electricity.

The water pressure created by a pump is similar to the voltage of a circuit.

Voltage is electrical pressure.

The flow rate of the water is similar to the current of a circuit.

The higher the flow rate, the more water or electricity will flow.

The amount of water being restricted because of a narrow pipe is similar to the resistance in a circuit.

A wide pipe will allow more water to flow just as a wire with very low resistance will let lots of current flow.

To summarize: Voltage, the electrical pressure in a circuit, is similar to water pressure. Current, the flow of electricity in a circuit, is similar to water flow. And resistance, a measure of how difficult it is for electricity to flow, is similar to thin pipes in a system of larger pipes.

Determine whether the following are related to voltage, current, or resistance.

*Water pressure - **Voltage***

*Water flow (as in gallons per minute) - **Current***

*A restricted pipe (as in a thin pipe) - **Resistance***

Electricity - Water Example

Lots of water moving very slowly

A tiny bit of water moving very fast

A tiny bit of water moving very slowly

Lots of water moving very fast (electrocution and arc flash)

Here are some examples that show you how electricity is like flowing water. When you are shocked with static electricity, the voltage is usually very high. You don't get hurt, though, because the current is usually very low. This is similar to a large amount of water flowing very slowly.

When you start your car, the voltage is low, but the current is high. This is similar to a tiny bit of water flowing quickly.

The interior lights in your car are low voltage as well, and the current is also low. This is the same as a tiny bit of water moving slowly.

Just as lots of water moving quickly can sweep you away and drown you, lots of both current and voltage can kill you.

During an arc flash, high voltage allows tremendous amounts of current to flow, leading to an explosion.

Match the electrical examples with the water examples

*Lots of voltage, not much current - **High water pressure but only a fine mist of water***

*Lots of voltage AND lots of current - **High water pressure, high flow rate***

*Not much voltage, but lots of current - **Lots of water, but moving very slowly***

*Not much current OR voltage - **Low pressure and just a few drops a second***

Changes in Voltage, Current, and Resistance

If resistance stays the same, then voltage determines current

If voltage stays the same, then resistance determines current

Current is dependent on the voltage and the resistance

Staying with the similarities between electricity and water, let's see what happens when voltage and resistance change.

When voltage in a circuit changes, with resistance staying the same, current changes.

If you hook up a light bulb to a 1.5 volt battery, and then change the battery out for a 9 volt battery, the light will shine brighter due to more current flowing through the circuit because of the higher voltage.

The resistance comes from the light and does not change.

Similarly, if you increase water pressure in a pipe, more water will flow through it.

When resistance in a circuit changes, with voltage staying the same, current changes. In an arc flash, resistance drops close to zero on a high voltage circuit, leading to current drastically increasing, and creating an explosion.

Similarly, if you accidentally cut into a high volume, high pressure water pipe, the sudden explosion of water could harm you.

Current is difficult to control in a circuit. That is why it is so important to be aware of arc flash hazards. The rapidly increasing current in an arc flash can cause life altering injuries and even death.

Changes in Ohm's Law

$$I = V / R$$

So, to summarize: In a circuit, if the resistance stays the same, the voltage will determine the current. If voltage goes down, current goes down. If the voltage goes up, the current will go up. They change in the same direction.

If the voltage stays the same, then the resistance will determine the current. If the resistance goes down, current goes up - and if resistance goes up, current will go down. These move in opposite directions.

In an arc flash, resistance goes down and current goes up as in this last equation.

http://openbookproject.net/electricCircuits/DC/DC_2.html 11/5/2010

Match the following situations with how voltage and resistance are affecting current.

*If the resistance to water flow stays the same and the pump pressure increases, the flow rate must also increase (more water pressure, more water flows) --- **voltage goes up, current goes up***

*If the water pressure stays the same and the resistance increases (changing out large pipes for thin diameter pipes, making it more difficult for the water to flow), then the flow rate must decrease: --- **resistance goes up, current goes down***

*If the resistance to water flow stays the same and the pump pressure decreases, the flow rate must also decrease (less water pressure, less water flows) --- **voltage goes down, current goes down***

*If the water pressure stays the same and the resistance decreases (changing out thin pipes and putting in wider pipes, making it easier for the water to flow), then the flow rate must increase: --- **resistance goes down, current goes up***

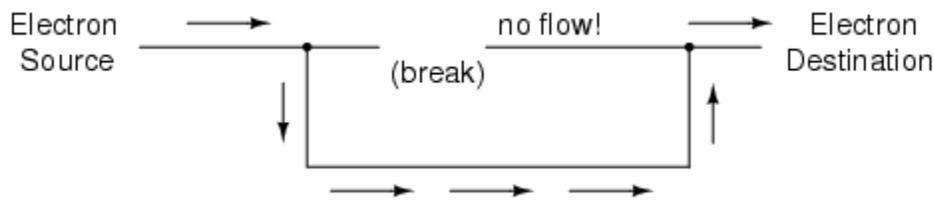
Circuits

Continuous loop

Electricity source

Conductor

Circuits are open or closed



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Since we have a good understanding of how a circuit is similar to water flowing through pipes, we can now see how a simple circuit is constructed.

This is important when learning about arc flash because, in an arc flash, a circuit is completed through the air.

A circuit is a continuous path that allows electrons to flow around and around. A source of power and something that needs power are also needed.

A battery, some wire, and a light, then, are all that are needed to create a complete circuit.

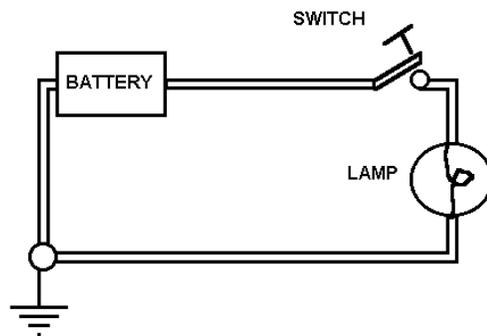
If a circuit is "broken," that means its conductors, usually wires, no longer form a complete path, and continuous electron flow cannot happen.

Electricity will not be able to flow in a circuit that is broken, no matter where the break in the circuit is. If you blow a fuse in a piece of equipment, the circuit is broken, but you can easily replace the fuse to complete the circuit.

Some circuits are broken on purpose. A light switch is a break in a circuit that is made on purpose. It allows you to stop the flow of electricity to turn a light off.

A circuit with no break in it is called a closed circuit. A circuit that is broken is called an open circuit.

In an arc flash, an open circuit is accidentally closed, creating a short circuit that causes an explosion.



http://www.allaboutcircuits.com/vol_1/chpt_1/3.html 11/3/2010

Determine whether the following circuits are open or closed

open

The light switch is turned on, but the filament in the light bulb is broken, so the light does not work.

A flash light that is turned off

closed

A fully completed circuit with no breaks

A battery, some wires, and a light bulb that are working in a circuit to light a room

Dangerous Circuits

Wires are not always needed

Air can conduct electricity and create a circuit

Lighting and arc flashes are examples of this

You don't always need wires to make a complete circuit. There is a circuit formed between a storm cloud and the Earth when lightning strikes. The air is acting as a conductor in the circuit.

Now normally air does not conduct electricity. However, if there is a big enough electrical charge in the cloud, it can cause the air to act as a conductor, working like an invisible cable linking the cloud above and the earth below - completing the circuit.

The same thing happens in an arc flash. In an arc flash electricity travels through the air, with little resistance, between the copper cables in an electrical panel or other electrical device, leading to a high current with disastrous effects.

<http://www.explainthatstuff.com/electricity.html> 11/3/2010

Short Circuit:

$$I = V / R$$

One thing you will find in all safely completed circuits is a load offering resistance to the flow of electricity. A light bulb, for instance has resistance, and when the current passes through the bulb, it glows, lighting up the room. The light bulb is the load in the circuit.

A short circuit, however, is a circuit offering little to no resistance to the flow of electricity. With little- to-no resistance, the flow of current goes up.

Short circuits are dangerous because, with high voltage power sources, the high currents encountered can cause large amounts of energy to be released. The energy released is the explosion of an arc flash.

Remember from earlier in the training that when voltage stays the same in a circuit, a decrease in resistance leads to an increase in current, so with little-to-no resistance, the current can increase far beyond safe limits.

Identify the following terms.

*This circuit has very little resistance, leading to too much current - **Short circuit***

*The circuit has been broken by an interruption in the path for electrons to flow - **Open circuit***

*A complete circuit, with good continuity throughout - **Closed circuit***

*A device designed to open or close a circuit under controlled conditions - **Switch***

Other Electrical Terms

Direct current

Alternating current

Frequency

Phases

There are a few more things we need to cover before really getting into arc flash hazards, so let's go over them now.

Direct current is electricity that flows in one direction. Direct current has a steady flow that does not reverse. A battery provides direct current.

Alternating current is current that reverses direction at a steady rate. You have alternating current coming out of the outlets at your house. The rate at which alternating current reverses is called its frequency.

Frequency is the number of times per second alternating current switches back and forth. Frequency is measured in Hertz. Electricity generated in the United States is 60 cycles per second or 60 Hertz.

In most homes, electricity is 120- and 240-volt single phase, but in manufacturing settings, electricity is often supplied in three phases at a much higher voltage.

Three-phase power is three single phases of electricity, all at different points on their frequency curve.

While the definition of phases seems complicated, the reason three phase power is used in manufacturing is that three phase motors have higher starting power, run more smoothly, and are more efficient than single phase motors.

Identify the following terms.

*Electricity that flows in one direction - **Direct current***

*Electricity that reverses direction at a steady rate - **Alternating current***

*The number of times per second alternating current switches back and forth in direction - **Frequency***

*Two types of AC power: single _____ or three _____ - **Phases***

Electrical Devices

Switch

Circuit breaker

Control system, Switchgear, Buckets

Energized/deenergized

A switch is used to start or stop the flow of electricity in a circuit. In our water example, a valve would be a switch that starts or stops the flow of water.

A circuit breaker is an automatically operated electrical switch designed to protect a circuit from damage caused by too much current or a short circuit.

A circuit breaker automatically opens when current gets too high. You have circuit breakers in your house that sometimes open when you have too many things plugged into an outlet.



A controller, or a control system, controls the electricity in manufacturing settings. They often work along with switchgear and buckets to operate electrical equipment.

Although you don't really need to know how these work, you do need to know that arc flash accidents can occur near these devices.

Knowing the difference between an electrical device that is energized with electricity and one that is de-energized is important if you are going to work on electrical equipment. While only qualified employees are trained to determine whether something is energized or de-energized, you still will need to know what they mean.

If an electrical device is energized it is connected to a power source and voltage is present. If it is de-energized, then it is free from an electrical connection to a source of voltage or charge.

But remember, many electrical devices are complicated and, just because you cut the power to a device, does not mean that it is safe. Energy can still be stored in some parts and can cause shock, electrocution, and arc flashes.

(http://en.wikipedia.org/wiki/Circuit_breaker) 11/5/2010

Identify the following terms.

*A device that controls the flow of electricity in a circuit - **Switch***

*A device that automatically opens the circuit when current gets too high - **Circuit breaker***

*Arc flash accidents can occur in or near these three devices - **Control system / Switchgear / Bucket***

*A piece of electrical equipment that has no remaining sources of electricity in it - **Deenergized***

*A piece of electrical equipment that still has a source of electrical power connected to it or still has a remaining charge even though the energy source has been disconnected - **Energized***

Electrical Devices

Fuse

Ground

Fault/ground fault

Receptacle

Plug



A fuse is a protective device that can open a circuit if there is too much current flowing through it. Since a fuse melts when there is too much current, it protects the rest of the circuit from being damaged.

Ideally, the fuse will be the weakest point in the circuit and will be the only place that a circuit will melt.

If a circuit is grounded, it means that the circuit is physically connected to earth ground by a conductor. This connection to the actual ground, or dirt outside, allows unwanted electricity to flow to the earth.

Being grounded can prevent the buildup of static electricity and can help prevent electric shock from faults.

A fault is temporary, unexpected current in a conductor. A short circuit is a type of fault that allows damaging amounts of current to flow through a circuit.

An arc flash is a type of short circuit.

A receptacle is an outlet for electricity. You have these all over your house and plug items such as irons and vacuum cleaners into them.

A plug, then, is what gets plugged into a receptacle, allowing an electrical device to get electricity.

Identify the following terms.

*A protective device that can open a circuit if there is too much current flowing through it - **Fuse***

*A circuit that is physically connected to earth by a conductor - **Ground***

*A temporary, unexpected current in a conductor - **Fault/ground fault***

*An outlet for electricity - **Receptacle***

*What gets plugged into a receptacle, allowing an electrical device to work - **Plug***

Electrical Devices

Load

Personal protective equipment (PPE)

Panel board

Transformer

A load is any device that converts electrical energy into light, sound, motion, or heat. One example would be a light bulb.

A load gives resistance to the current in a circuit.

A light bulb is a load in a circuit that converts electricity into light.

Personal Protective Equipment, or PPE, is clothing and other items that are worn to help keep you safe when working near arc flash hazards. PPE protects you from the intense light, heat, sound, and explosion of an arc flash.

The type of PPE required is determined by the amount of voltage and current available. We will cover determining what type of PPE is needed later in the training.

A panel board is a cabinet containing a group of circuit breakers, fuses, and short circuit protection devices for lighting, appliances, or other circuits; it is usually placed in or on a wall with access to the front through a panel door.

You have an electrical panel in your house where the circuit breakers are located.

Transformers help electricity travel over long distances without losing much energy. Transformers are the only way to get electricity cheaply to your house.

Transformers allow electricity to get to your house by taking the high-voltage, low-current electricity from the power lines and turning the electricity into 120 volt, higher current electricity.

http://tonto.eia.doe.gov/kids/energy.cfm?page=electricity_science-basics_11-18-2010

Transformers are important when learning about arc flash because one of the key components of how bad an arc flash will be is how much current is available from the transformer supplying the electricity.

Identify to following terms.

*A device that converts electrical energy into light, sound, motion, or heat - **Load***

*The clothing that keeps you safe when working around arc flash hazards - **Personal protective equipment (PPE)***

*A cabinet containing circuit breakers or fuses, usually placed in or on a wall - **Panel board***

*This device takes high voltage, low current electricity and changes it to the electricity you use in your home or at work - **Transformer***

Identify the following terms. (no back button since this is a review question)

*The amount of electrical pressure in a circuit - **Voltage***

*How much electricity is flowing in a circuit - **Current***

*A measure of electrical power - **Watts***

*Something in a circuit that offers resistance - **Load***

*A dangerous circuit with voltage, but no load (resistance) - **Short Circuit***

Three Basic Hazards

Shock/Electrocution

Arc Flash

Arc Blast

Now that you have a fairly good idea of what electricity is, let's go over some of the hazards involved in working around electrical devices.

They include shock, electrocution, arc flash, and arc blast.

These hazards are present in any circuits over 50 volts.

Dangers of Shock and Electrocution

Electricity can kill you

Most deaths are preventable

While electricity is useful, it can also hurt or kill you. Accidents from electricity happen far more often than you would like to think.

Electricity has long been recognized as a serious workplace hazard, exposing employees to electric shock, electrocution, burns, fires, and explosions.

If a person is killed by getting shocked, then they are considered to have been electrocuted.

In 1999, 278 workers died from electrocutions at work, accounting for almost 5 percent of all on-the-job fatalities that year, according to the Bureau of Labor Statistics.

30,000 victims each year are lucky enough to only get shocked and not killed.

What makes these statistics more tragic is that most of these fatalities and injuries could have been easily avoided by using safe work practices such as making sure that electrical equipment is locked out, tagged out, and deenergized.

www.osha.com 11/15/2010

Identify the following terms

*When current travels through your body - **Shock***

*When current travels through your body and KILLS YOU - **Electrocution***

*When a short circuit leads to an explosion - **Arc flash***

Scare Pictures

While no one likes seeing pictures of injuries, we do need to show you just how devastating electrical injuries can be. These next five pictures are from OSHA's web site.

Entrance Wound

When you are shocked, electricity travels through your body. Severe injuries can show up where the electricity enters and leaves your body.

This picture shows how the resistance of the body turns electricity into heat. This man was lucky to survive since the electricity entered his body so close to his spinal cord.



Exit Wound

Here is a picture of where electricity exited a man's foot.

The charred hole is just the surface of the wound. As the electricity traveled through his foot, it created lots of heat and burned the inside of his foot so much that the doctors had to cut the foot off a few days after the injury.



Internal Injuries

In this picture, the worker was shocked by the metal tool he was using, such as a pair of pliers. The resistance of the metal made it heat up, causing the burnt skin below his thumb.

The visible part of the wound looks bad, but there were severe internal injuries that were not immediately visible. These internal injuries were from the current flowing through his hand.



Internal Injuries

This is the same hand a few days later. As you can see there was so much damage that skin had to be sliced open to make room for all the swelling.

The injury below the burn from the metal tool was caused from heat as well, but the heat in these areas was from the current going through his hand, not the heat of the tool.



Involuntary Muscle Contraction

In this picture, a worker fell and grabbed a power line to catch himself. There was so much current in his hand that his first two fingers were mummified and had to be removed.

His hand is bent like this because as the tendons in his hand were cooked, they shrunk, painfully drawing up the workers hand.



Identify the following terms

*A visible injury at the place where electricity enters the body - **Entrance wound***

*A visible injury at the place where electricity leaves the body as it completes the circuit - **Exit wound***

*Sometimes not immediately visible, this type of injury can occur inside the body where current passes through - **Internal injuries***

Getting Shocked

You become part of the circuit

The current traveling through your body can kill you

Most people know what an electrical shock is. The pictures gave you a good idea of what can happen when you are shocked, but let's go over some of the details of shock and electrocution some more.

Electric shocks can be harmless like getting shocked when touching a doorknob after walking on carpet, or a shock can be deadly.

An electric shock occurs when current passes through the body. The current can cause damage to muscles (including heart muscles), the nervous system, and other parts of the body.

Getting shocked means your body is becoming part of the circuit. You become a conductor because of the current running through your body.

Causes of Electric Shock

Two different live wires

A live wire and a ground wire

There are many ways that a person's body can become part of an electrical circuit and get shocked.

You will get an electric shock if you touch a live wire and an electrical ground or if you touch a live wire and another wire of a different potential.

So, if you touch any live wire and then touch either a different live wire or a ground wire, you can get shocked.

Many have been shocked at home, but at the work place, voltage and current are much higher-creating a greater chance of getting hurt.

Select the three dangerous situations where a worker could get shocked.

Helen is working on live wires and is not wearing electrical gloves

To check to see if the circuit breaker has opened, Phil places his screwdriver on two wires in a three phase system

Jim is in a hurry, so he does not turn off power to the mill before working on it

Randy properly locks out the conveyor motor and checks to see if it is still energized before working on it

Kelly sees an open panel box with exposed wires so she stays away and alerts her supervisor immediately

Electrocution

Electrocution means death by electricity

Less resistance leads to more current passing through the body

Affected employees must pay special attention to electrical hazards that can cause electrocution because they often work near electrical circuits.

Electrocution, then, occurs when a person is shocked with enough current that they die. This is because the large amounts of current flowing through the body can cause severe internal and external injuries.

The chances of being electrocuted go up when working around water or when you are sweating OR when you are not wearing the proper protective clothing.

Select the three true statements.

When a person dies from being shocked, they are said to have been electrocuted

Getting shocked means your body has become part of the circuit.

Electric shock can still cause death through indirect accidents such as falling

Wearing rubber shoes will always keep you from getting shocked

Electrocution is usually harmless

Video Example of Shock

To let you see how a person's body becomes part a circuit when shocked, watch this video.

<http://www.youtube.com/watch?v=-n1pSHzdahc>



Shock Can Occur Without Touching Live Parts

Circuits can be completed through the air

If you think you have to actually touch live wires to get shocked, you would be wrong. Just as static electricity can shock you even before you touch a door knob, electric currents can reach out and shock you if your body gets in a position that it could become part of the circuit.

This will be important to know when learning about arc flash because, in an arc flash, the circuit is completed through the air, not just through wires.

This is because, even though air has insulating values, it has its limits. If there is enough voltage, the circuit can be completed just by going through the air.

For example, with live parts at 72,500 volts, you must keep body parts and other grounded items more than two feet away to avoid current flowing through you because at that high of a voltage, the circuit can be completed even through a foot of air.

How Shock Is Measured

$$I = V / R$$

To understand how electric shock can hurt you, let's go back to the equation from Ohm's Law that had current on the left side, I equals V divided by R, or current equals voltage divided by resistance.

Remember that voltage will often stay the same, so the current will depend on how much resistance there is in the circuit.

If resistance is high, the shock will not be as bad as if the resistance is low. Higher resistance, then, is better.

Resistance is reduced if you are wet or sweaty, or are not wearing the proper gloves or shoes, making current (the part that kills you) much greater.

True or false?

When trying to stay safe around electrical hazards, keeping work areas dry and wearing proper clothing can help keep your body's resistance high and help keep you from getting shocked. - true

How Shock Is Measured

| Condition | Resistance (ohms) | |
|------------------------|--------------------|----------------|
| | Dry | Wet |
| Finger Touch | 40,000 - 1,000,000 | 4,000 - 15,000 |
| Hand Holding Wire | 15,000 - 50,000 | 3,000 - 6,000 |
| Finger Thumb Grasp | 10,000 - 30,000 | 2,000 - 5,000 |
| Hand Holding Pliers | 5,000 - 10,000 | 1,000 - 3,000 |
| Palm Touch | 3,000 - 8,000 | 1,000 - 2,000 |
| Hand around 1 1/2 pipe | 1,000 - 3,000 | 500 - 1,500 |
| Hand Immersed | - | 200 - 500 |
| Foot Immersed | - | 100 - 300 |

As you can see from this chart, wet, sweaty conditions can be much more dangerous than dry conditions because water and sweat decrease the resistance to electricity, allowing more current to flow through the body when someone is shocked or electrocuted.

It always makes good sense to stay away from energized parts, but especially so when conditions are wet.

This is why electricians are required to wear gloves and use special tools when working on electrical equipment. The proper clothing and tools keep the resistance through their body high enough to keep from getting shocked.

Other factors other than water or sweat will determine the resistance of someone being shocked.

Resistance will often depend on the path of the circuit through the body. A shock from one finger to another finger on the same hand will probably provide less resistance than a shock traveling from one hand to the other or from a hand to the ground through a foot.

In any situation where the circuit has a chance to go through the heart, the dangers can be life-threatening.

As you're looking over the chart, notice how the wet situations offer less resistance than the dry situations. This is because current will flow through dirty water and sweat much more easily than through air and dry skin.

Also, grabbing a wire would be much more dangerous than just barely touching a wire because more of your skin would be in contact with the wire.

Regular metal tools also increase the chance of getting shocked. This is why electricians often have specialized tools for working on electrical equipment.

Determine the resistance each situation would provide

*A foot in water - **100 to 300 ohms***

*A dry hand around a 1 1/2 inch pipe - **1,000 to 3,000 ohms***

*A wet finger touching a wire - **4,000 to 15,000 ohms***

*A dry hand holding pliers - **5,000 to 10,000 ohms***

Determinants of Shock Severity

| Electric Current (1 second contact) | Physiological Effect | Voltage required to produce the current with assumed body resistance | |
|--|---|--|------------------------|
| | | 100,000 ohms (dry) | 1,000 ohms (sweaty) |
| 1 mA | Threshold of feeling, tingling sensation. | 100 V | 1 V |
| 3 mA | Painful shock which may cause indirect accidents | 300 V | 3 V |
| 5 mA | Accepted as maximum harmless current | 500 V | 5 V |
| 10-20 mA | Beginning of sustained muscular contraction ("Can't let go" current.) | 1000 V | 10 V |
| 30 mA | lung paralysis- usually temporary | 3000 V | 30 V |
| 50 mA | Possible ventricular fibrillation (heart dysfunction, usually fatal) | 5,000 V | 50 V |
| 100-300 mA | Certain ventricular fibrillation, fatal | 10,000 V | 100 V |
| 4 Amps | Heart paralysis, severe burns | 400,000 V | 400 V |
| 5 Amps | Flesh burns, defibrillation, temporary respiratory paralysis | 500,000 V | 500 V |

This chart shows us how different levels of current affect the body.

5 milliamps is considered the limit for "harmless" current. Harmless does not mean that the shock does not hurt, just that the shock should not cause any lasting injury. (NEC)

As we go through these examples and others, remember that the amount of time you are shocked also plays a role on how badly you are hurt.

The less time you have current going through your body, the better.

We will also explain that the path the current takes through your body is important.

If we just stick with two general situations, dry and wet, we can see in this chart how different types of voltages will affect you if you are shocked.

Hopefully none of you taking this training have been shocked, but as you can see, even when you are dry, a 120-volt outlet at your house can still shock you.

*With wet situations, the 120-volt outlets at your house have enough current to **kill** you.*

At 480 volts, a common voltage used in manufacturing, a shock can turn into an electrocution and severely burn you as it kills you. In these situations, you will not only die because of a shock across your heart, your skin and internal organs will actually be cooked and charred.

If you look at the 30 milliamp and 50 milliamp rows in the chart, you will see that these amounts of currents can cause death by paralyzing the lungs and stopping the heart. This happens when the part of the circuit that travels though the body actually travels through the chest.

If the circuit goes through the palm of one hand it could still cause life threatening injuries. But it is much more dangerous to have the circuit go through the entire body since only a small amount of current is required to cause death when the current travels through the chest and heart.

Answer the questions below

*This voltage will temporarily paralyze your lungs even when the surroundings are dry. - **3,000 volts***

*This level of current is usually fatal - **50 milliamps***

*This voltage, in wet surroundings, will cause death - **100 volts***

Examples of Shock

$I = V / R$ or Current = Voltage / Resistance

If E= 120 volts, and

R = 1,500 Ohms, Holding Pliers Wet (1,000-3,000 from chart)

$I = 120/1,500 = 0.08$

I = 80 ma, Possible Heart Fibrillation, usually fatal

Let's go through a couple of examples to see just how dangerous getting shocked can be.

Let's assume that a worker is using damp pliers on a 120 volt circuit. From the previous chart, we can also assume that the resistance will be about 1,500 ohms.

The current traveling through the body, if shocked, will be about 80 milliamps since 120 volts divided by 1500 ohms is .08 amps.

If the worker is shocked and the circuit passes though the chest, possibly from the pliers in the right hand through the body to the left hand grabbing a piece of grounded metal, the 80 milliamp current will probably kill him.

Examples of Shock

$I = V / R$ or Current = Voltage / Resistance

If $E = 120$ volts, and

$R = 7,500$ Ohms, Holding Pliers Dry (5,000-10,000)

$I = 120 / 7,500$

$I = 16$ ma, muscular contractions

This example is similar, but this time the pliers are dry, providing around 7,500 ohms of resistance.

Luckily the 16 milliamps of current in this example should not kill the worker, but if he is on a ladder, the muscle contractions could cause him to lose his balance, fall off, and get killed anyway.

These two examples show you just how important it is to work safely around electrical hazards.

Examples of Shock

7 1/2 watt light bulb

$7.5 / 120 = 0.0625$ amps

0.0625 amps = 62.5 milliamps



Just to see how much current is needed to kill you, let's look at a 7-and-a-half-watt light bulb plugged into a 120-volt outlet in a home. Since wattage equals voltage times current, current can be found by dividing the wattage of the bulb by the voltage of the outlet.

This would be 7.5 divided by 120, or 62.5 milliamps, well above the 50-milliamp limit to stop your heart if it were to go through your chest.

Remember that when you have a 100-watt light bulb in your house with 120 volts, the current flowing must be .83 amps. This is because 100 divided by 120 equals 0.83. 0.83 amps is the same as 830 milliamps. If you had 830 milliamps of current going through your body, what would likely happen?

Would not feel anything

Just a small tingle

Maybe a painful shock

Lungs and heart would stop and internal organs could cook

How to Avoid Shock Hazards

Do not work on energized (live) equipment

Avoid working around water or wet locations

Stay away from electrical wires on the ground

Keep work areas clean and tidy

Never open an electrical panel

The best way to keep from getting shocked is to stay away from electrical shock hazards.

Obviously you should never work on live or energized electrical equipment, not only because it is dangerous, but also because you are not qualified to work on the equipment.

Another hazard involves live electrical wires in the wrong place. So if you see wires lying on the ground, do not go near them and tell your supervisor immediately.

Since you will often have to work near electric panels, make sure to never open them. Opening the panel increases the chances of getting shocked or setting off an arc flash.

Another hazard is water. Although sometimes it may be unavoidable, try to never work in wet areas that are near electrical equipment.

Keeping your work area clean and organized can help you spot electrical hazards that you might otherwise miss in a messy work area. If you need to clean a work area that is disorganized and dirty, be very careful so no unseen hazards will hurt you.

How to Avoid Shock Hazards

Never use a damaged outlet

Never use a damaged electrical cord

Never use a cord with the ground prong missing

Do not plug too many things into one outlet

Stay alert

Even when you are not working around high voltage equipment or electrical panel boxes, shock hazards still exist.

Damaged outlets should never be used. If you see a damaged outlet or suspect an outlet might be damaged, stop using it and notify your supervisor immediately.

The same goes for cords and plugs. If you see an electrical cord that looks worn out, it might have exposed wires. Also plugs that are damaged might not be properly grounded, increasing the chances of getting shocked.

Another possible hazard is having too many items plugged into the same outlet or on the same circuit breaker. Most often, the circuit breaker will safely open the circuit, but the sudden loss of electricity to electrical equipment could still cause injuries.

Above all, just stay alert. Always be on the lookout for hazards and be prepared to stop working, protect those around you, and get help to take care of the situation as fast and as safely as you can.

Select the three safe working situations.

John keeps his work area clear since there are electrical hazards near his station.

Kelly sees a wire on the ground that was not there yesterday. She has someone make sure no one goes near it while she immediately tells her supervisor

Howard is asking a qualified electrician for help since he sees some spilled water around an electrical panel box

Renaldo is too busy to make sure the motor controls are deenergized before cleaning them out

Stan is now dead since he opened an electrical panel box, causing an arc flash

Select the three true statements.

50 milliamps of shock can stop your heart

120 volt outlets at your house can be deadly

The amount of time your body is part of the circuit is a factor in how bad you are hurt when you are shocked

It is okay to work on energized equipment if you are really in a hurry

5,000 milliamps, or 5 amps, is not enough current to hurt you

Arc Flash

What Is An Arc Flash?



Now that we have a good idea about electricity and shock, we can finally get into what an arc flash is and just how dangerous it can be.

An arc flash is a short circuit through the air in an electrical panel box or any other piece of energized electrical equipment. Air, as you have already learned, is normally an insulator, but with a high enough voltage, a slipped tool, or a panel box that is dirty, the circuit can be completed, causing a short.

When the short happens and the circuit is completed through the air, the air breaks down to where it offers little-to-no resistance to the flow of electricity.

Remember, this is what a short circuit is. A short circuit will have almost zero resistance and will have very high levels of current. The high current is what is responsible for the arc flash.

The tremendous amounts of energy released in an arc flash make for a very bright, very hot, and very loud explosion.

Arc Flash vs. Safely Completed Circuits



Higher than normal currents

*Now in a safely completed circuit, such as when a motor turns on a manufacturing line, the circuit is complete, just like in an arc flash, **but** a safely completed circuit has a load on the circuit offering resistance.*

So in a safely completed circuit, the resistance affects the current in the circuit, keeping the current under dangerously high levels.

Think of a lamp plugged into the outlet of your house. When you turn it on, the circuit is completed, but the light bulb has resistance, so the current stays within safe limits.

If you were to stick a paper clip in an outlet, the circuit will also be completed, but this time it will be a short circuit because the metal paper clip offers very little resistance to the flow of electricity.

By the way, NEVER stick a paper clip into an electrical outlet. It is dangerous, and if you do it you will receive an electric shock or worse.

Dangerous Behavior



Just so you won't have to do this to see what would happen, watch this video.

<http://www.youtube.com/watch?v=cu0AOCu5bFQ&feature=related>

High Voltage Short Circuit



A short circuit, as shown in this next video, does not have a load providing resistance. The arc that forms goes right through the air with little-to-no resistance.

The same thing happens in an arc flash. The circuit is completed straight through the air.

<http://www.youtube.com/watch?v=PXiQQCRiSp0&feature=related>

Select whether the following refer to a safely completed circuit or a short circuit that could lead to an arc flash.

safely completed circuit

Turning on a light in an office

Starting a motor control device

short circuit that could lead to an arc flash

Accidentally touching the wires in a panel box with a screwdriver

Splashing water on energized high voltage electrical equipment

Where Does An Arc Flash Occur?

Electrical panel box

Copper cables

Low voltage, high current

To understand how an arc flash occurs, lets create an imaginary arc flash.

To create an arc flash, a small piece of copper wire is placed between two of the wires coming into a three phase panel box. When the power is turned on, the small metal wire quickly vaporizes because of the high current and allows the air to break down between the two copper cables, decreasing the resistance and allowing dangerous levels of current to flow in a circuit even after the small wire is gone.

The larger copper cables will also vaporize, adding to the explosive power and brightness of the arc flash.

Arc flashes can occur on any high voltage electrical equipment, not just in panel boxes.

Arc Flash Test Video

In this next video, you will see how scientists create arc flashes in order to study them.

<http://www.youtube.com/watch?v=-Qq7U7tFsvQ>



What Causes An Arc Flash?

Slipped tools or hands

Animals

Falling parts

Sometimes there is no known cause

Dust, water, corrosion, oil

When arc flashes occur by accident, they can sometimes be caused much like the way they are made on purpose.

An accidental slip of a tool, a loose part, or even your hand touching live parts can provide the start the current needs to jump from one cable to the next.

Loose connections in the electrical equipment, improper installation, and parts that break and fall are other possible triggers.

Dust, water, impurities, contamination, corrosion, oil, and grease can also provide a starting route for the short circuit.

Even animals or bugs can get into electrical devices and start an arc flash.

Typically there is a reason for arc flash accidents, although we may not always know what it was.

The unpredictable nature of arc flash accidents is why it is so important to know about them and stay away from dangerous situations.

Select three of the causes of arc flash accidents

A tool that accidentally touches exposed, live parts

Part falling in an energized panel box

Accidentally getting water on a exposed electrical parts of high voltage equipment

Making sure to never work near live electrical equipment that poses arc flash hazards

Staying away from arc flash hazards

Available Current and Amount of Time



Much of the severity of an arc flash comes from the amount of current that is available and the amount of time the short circuit exists before the circuit is broken.

Determining the maximum current available and the amount of time the arc flash will be active requires complex calculations and help from computer programs - and even then, experts will still disagree on the actual explosive capabilities of an arc flash when applied to an actual setting.

There is one thing all of them will agree on though - it is not good to be anywhere near an arc flash when it occurs.

What are the two main factors that determine how bad an arc flash is?

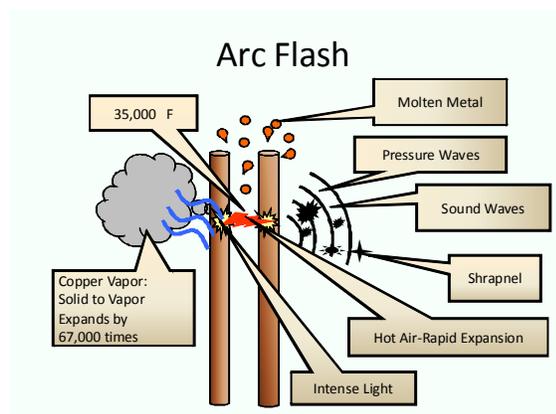
The available current to the piece of equipment

The amount of time the short circuit exists

The color of the equipment

How long the CBC relay has been monitoring the system

What Happens During An Arc Flash



We have already mentioned some of the dangers of an arc flash, but let's cover them more fully now.

An arc flash is brighter than the sun, hotter than the sun, sends metal pieces flying away from the explosion at over 700 miles per hour, and is louder than a jet.

Bright Light

Skin damage

Blindness

The bright light from an arc flash can cause severe skin damage, although you might not notice it since your skin would probably be burned so much from the extreme heat.

Your eyes, though, even if wearing safety glasses, can receive enough blinding light in that short instant that you will never be able to see again.

Going blind is just the first of many injuries an arc flash can give you.

Hot Temperatures

Welding arc = 3,000° F

Sun = 9000° F

Arc Flash = 35,000° F

When an arc flash occurs, it gets really hot, some of the highest temperatures known to man.

Just to show you how hot the 35,000 degrees Fahrenheit of an arc flash are, let's look at a couple of items we know are hot.

The temperature of welding arc is 3000° F. That is hot enough to melt and fuse together metal.

The temperature of the Sun is 9000° F. That is hot enough for atomic fusion.

The temperature of an electrical arc flash, though, can reach 35,000° F. It is difficult to really understand how hot that is and how destructive it can be, but luckily arc flashes don't last very long.

But you can get severe burns from the heat of an arc flash even though it lasts only for a fraction of a second.

The chances of getting severely burned can be reduced by wearing the proper protective clothing. We will go over the selection of personal protective clothing, or PPE, later in the training.

Select the temperatures associated with the following items

*An arc flash - **35,000° F***

*A welding arc - **3,000° F***

*The sun - **9,000° F***

Large Explosion

Vaporized copper expands to 67,000 times its original size

Metal flies toward you at 700 miles per hour

The intense heat from an arc flash can cause solid copper cables to change to liquid and then to vapor almost instantly.

When copper vaporizes, it expands to 67,000 times its original size, this leads to the large explosion - a very large explosion.

The explosion creates a pressure wave sending shrapnel (such as equipment parts flying like an exploding grenade) hurling at high speed (over 700 miles per hour).

Very Loud

You can lose your hearing

Ear plugs might not help

Since the explosion happens so fast, the quickly moving air can damage your ear drums, causing a worker near the blast to become deaf...never being able to hear again.

Severe arc blasts will have a noise level of more than 140 decibels at a distance of two feet away.

Most ear plugs provide effective protection up to about 105 dB. Regular ear plugs, then, do not provide adequate protection from arc flash accidents.

Select four of the things that happen during an arc flash

Temperatures can get hotter than the sun

The bright light can cause you to go blind

The loud noise can cause you to go deaf

The heat can char your skin

The injuries usually are not really that bad

Arc flash is a myth

Arc Flash/Arc Blast

They always occur together

An arc flash always causes an arc blast

You will often hear the terms arc flash and arc blast used together because they always happen together.

The bright light and high temperature is the arc flash. The explosion and the loud blast is the arc blast.

For this training, though, we will continue to use arc flash for the entire event: light, heat, sound, **and** explosion.

Arc Flash Videos

Let's look at a couple of videos of actual arc flash accidents to see just how fast they can happen and how explosive they can be.

<http://www.youtube.com/watch?v=W6Im7PLduwc>



As you can see the doors are open on this energized equipment.

These circuit breakers are normally motorized. In most cases the doors are closed when opening and closing a breaker.

If the door must be open, the bus or busbar, which is a thick strip of copper or aluminum that is used to carry very large currents or distribute current to multiple devices within switchgear or other equipment, should be de-energized before working on it. The worker does not have the proper PPE to be working near exposed live equipment.

Notice the piece of test equipment on the floor. There must be a problem with the motor, and it looks like they are trying to close the breaker manually.

The second worker, possibly the supervisor, gives the worker the OK to proceed just before the explosion.

<http://en.wikipedia.org/wiki/Busbar> 11.29.10

Arc Flash Videos

<http://www.youtube.com/watch?v=h10ALipDOR4>

In this video, the workers seem to be in the back of the panel where all the busses are located. They should not be working inside the energized panel.



The worker on the ground is in an especially hazardous position.

The worker on fire apparently has some flame resistant clothing on because it didn't burn for very long.

He doesn't appear to be badly injured and notice that his shirt is still white. The other two workers do not appear to be injured badly either.

Luckily, even though they were working in a dangerous situation, their clothing protected them.

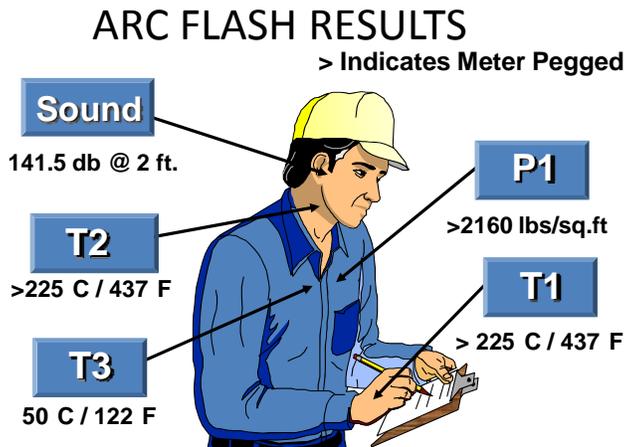
What are some of the things we can learn from the two previous videos? Select 2.

Flame resistance clothing can help protect you from arc flash burns

Open panels increase the hazard of an arc flash

Workers are never harmed from arc flash accidents
Working inside an area with energized parts is usually safe, so no PPE is required

Arc Flash Test



To see just how an arc flash affects the body, the Institute of Electrical and Electronics Engineers, or IEEE, published a report on a series of tests that were done in 1996 on a training dummy to measure the sound, temperature, and pressure the body would experience from an arc flash. (Jones and al 2000)

<http://www.bussman.com/library/docs/stagedtests.pdf> 11/29/2010

These tests were done to increase awareness of arc flash hazards in electrical equipment. In the test we will examine, an arc flash was started by placing a small wire between two of the wires in a 480-volt, three-phase system. Sensors were placed on the dummy to see how hot, how loud, and how strong the explosion from the arc flash would be.

Sensors were placed on the dummy's chest, neck, and hands, and a sound sensor was placed close to the ear.

Here is the data from the fourth test. In three of the measurements, the temperature and pressure readings were beyond the limits of the sensor.

The two temperature sensors that were over the limit, T, and T2, went over 437° F.

Arc Flash Test

| Skin Temperature | Time of Skin Temperature | Damage Caused |
|------------------|--------------------------|----------------------------|
| 110° F | 6 hours | Cell breakdown starts |
| 158° F | 1 second | Total cell destruction |
| 178° F | 0.1 seconds | Curable burn |
| 200° F | 0.1 seconds | Incurable 3rd degree burns |

Let's look at this chart to see just what that means for your skin. If your skin gets up to 178° F just for a tenth of a second, you will be burned, but your skin will heal - any higher or longer than that and it might not.

Remember that water boils as 212 degrees Fahrenheit, so 178 degrees will not feel good.

If your skin gets up to 200° F for just a tenth of a second, you will be burned so badly that the damage will not heal, so 200° F is the upper limit on this chart.

Select the two true statements about the chart above.

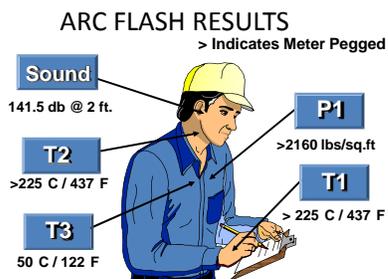
Sticking your hand in boiling water can cause incurable third degree burns

The length of time your skin is at a high temperature determines how bad the burn is

Third degree burns usually heal fast

Placing your hand on a hot skillet for 3 seconds will only give you 2nd degree burns

Arc Flash Test



Since the T1 and T2 sensors measured beyond 427 degrees F, there obviously would have been **massive** third degree burns if this were an actual accident. This should not be surprising since the arc flash itself can get up to 35,000° F.

The neck and hands of a victim in this type of arc flash, as we just said, would have suffered incurable 3rd degree burns.

But look at the sensor labeled T3. It only got up to 122° F. Pretty hot, but not hot enough to burn a worker. This is impor



Arc Flash Test

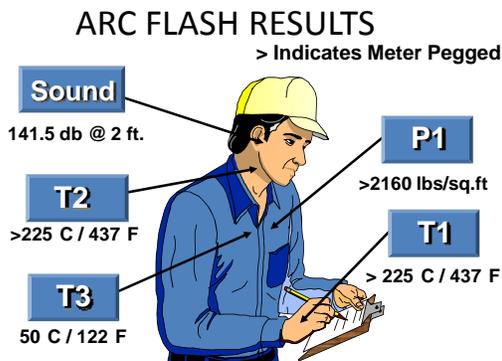
What makes T3 lower, and safer, is that the sensor was under clothing, as shown in this picture.

You can also see that the dummy's chest was further back than his hands, but since the sensor on the neck got as hot as the one on the hand, the clothing made more of a difference than the distance since the dummy was so close to the arc flash.

Since the clothing covering your skin is so important in protecting you from an arc flash, we will cover personal protective equipment later in the training.

[http://nicolet.asse.org/docs/Nicolet%20ASSE%2011.11.09%20Presentation%20\(Arc%20Flash\).p](http://nicolet.asse.org/docs/Nicolet%20ASSE%2011.11.09%20Presentation%20(Arc%20Flash).pdf)
df 11-20

Arc Flash Test



What about the noise from the arc flash in this test? Well at 85 decibels, hearing damage can occur if that level of noise is continued over the course of a work day.

141.5 decibels is well beyond that limit, and any exposure to sounds that high can lead to permanent hearing loss, even for just a fraction of a second.

Pressure was another variable that was measured. The pressure measured over 2160 psi - beyond the upper limit of 1728 pounds per square foot for possible lung damage.

What all of these test results mean, of course, is that arc flash is dangerous. It gets very hot, it is very loud, and the explosion is substantial.

You should do everything you can to stay away from them.

Arc Flash Is Unpredictable

Every worker should assume the worst

Another item the test acknowledged is the highly unpredictable nature of arc flash accidents. The report stated “Workers and equipment may be at risk from electrical arc, even at times when codes, standards, and procedures are seemingly adequately addressed” meaning that even if everything is done right, an arc flash can still occur.

They also advised that “workers should ‘assume the worst’ and use available personal protective equipment.”

<http://www.bussman.com/library/docs/stagedtests.pdf> 11-20-2010

Select the three true statements.

Arc flash accidents can happen even if all the rules are followed.

Protective clothing can help reduce arc flash injuries

The pressure wave in an arc flash/blast can cause lung damage

If your skin gets up to 430 degrees F for a tenth of a second, your skin will be OK

Workers should “assume the best” and not worry about wearing PPE

What Injuries Can Occur?

arc flash explosion pic http://www.missouriinsurancelawyerblog.com/arcflash_1.png



Since we showed you some of the pictures involving shock and electrocution, let’s now look at some pictures of arc flash injuries.

We will also play a video of someone who survived an arc flash injury.

Severe Burns



Here you can see the severe burns that happen when someone is near an arc flash and does not have any protective clothing or equipment on.

You can see how the arc flash was hot and lasted for only a moment. The skin that was burned was not just reddened and blistered, but vaporized and charred.

<http://www.prlog.org/10074699-arc-flash-injuries-occur-2-000-times-year.jpg>

11-29-2010



Severe Burns

In this picture, both hands were injured in the arc flash.

It looks like most of the heat was centered on the thumbs, but remember from the electrocution and shock pictures that the injuries often look worse a few days after the accident.

It's very possible that this worker ended up with severe injuries and 3rd degree burns.

Arc Flash Burns

This worker was near an electrical panel box when an arc flash occurred. Even though he did not touch the box, electricity arced through the air and entered his body. The current was drawn to his armpits because perspiration is very conductive.



Remember that pure water is an insulator, but the salt in sweat makes for a potentially very dangerous conductor.

At first this picture does not look too bad, but because of the high current, the accident might have caused substantial internal injuries that are not seen in this picture.

Injuries from Burning Clothing



http://www.ebranders.com/images/arc_flash/image9.jpg 11-29-2010

Although this is not a picture of a real arc flash, it does depict what can happen to your clothes right after the explosion occurs. Not only can the initial arc flash hurt you, but the heat from burning clothing can continue to cause damage.

That is why it is so important to select and wear the appropriate personal protective equipment, or PPE. Hopefully as an affected employee you will not have to be in situations where you need to wear PPE for working near arc flash hazards, but if you do, make sure to wear them.

Even if a seasoned electrician does not wear his PPE, you should still wear yours if required. Remember that two dead bodies are always worse than one.

Injuries from Burning Clothing



In this picture, current exited the worker at his knees, catching his clothing on fire and burning his upper leg.

Proper PPE in this situation might not have kept the arc flash from happening, but it could have saved the worker from being off work getting better and the pain of the burns.

Select the three true statements about arc flash injuries.

An arc flash can quickly burn the skin

After an arc flash is over you can still be burned from clothing that is on fire

An arc flash can start without your body actually touching live parts

Arc flash burns are much like those you would receive from a hot iron

Arc flash treatments are used in beauty salons to remove dead skin

Donnie's Accident

That's probably enough pictures to show you just how dangerous an arc flash can be. Here is a video of an arc flash survivor.



Just so you know, there is a happy ending. He does live, but I'm sure he would never want to go through it again. The story is told from the wife's perspective.

<http://www.youtube.com/watch?v=FMb5zhtR8hw&feature=fvwrel>

This is a good video about arc flash because Donnie survived.

One important comment he made about his video is that if he'd been wearing his gear, meaning the right personal protective equipment, he would have probably only needed to go to the hospital for a checkup instead of being in a coma and severely injured.

One thing that will probably never go away is the pain and suffering he and his family went through. Keep this in mind anytime you are working with or around electricity, you must respect it for what it can do to you

You might think you won't receive the injuries Donnie did since you will not be working on live electrical equipment, but you still could be working around live equipment.

So you could still be close enough to an arc flash to have bad enough injuries that you will be in a coma, have to get skin grafts, and go through the pain Donnie did.

Select some of the things Donnie went through.

Coma

Skin grafts

Pain

Amputation

Death

Approach boundaries

Flash protection boundary

Limited approach boundary

Restricted approach boundary

Prohibited approach boundary

NFPA 70E, which we will go over in more detail later, requires three shock boundaries and a flash protection boundary that must be known and observed.

The shock boundaries are calculated based on the amount of voltage being supplied to the equipment. The flash protection boundary requires more data.

*While the amount of current and the how long the arc flash lasts are the two big factors to consider when figuring out how severe an arc flash will be, how **bad** you get hurt also depends on how close you are to it.*

Just a few inches could be the difference between life and death when close to an arc flash.

If a very large arc flash accident happens and no one is near it, no one gets hurt. This is why arc flash boundaries are so important.

The four common boundaries around electrical hazards are the flash protection boundary, the limited approach boundary, the restricted approach boundary, and the prohibited approach boundary.

What are the three main factors that determine how badly you are hurt if you are near an arc flash?

How long the arc flash lasts

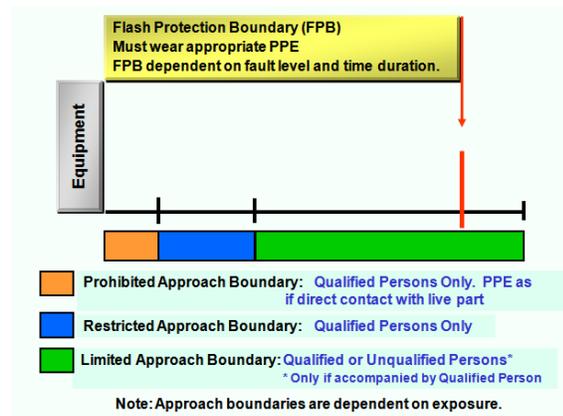
How far away you are when the arc flash happens

The power available to the short circuit

The day of the week

The type of shoes you are wearing

Arc flash protection boundary



The arc flash protection boundary is the point where a person could receive 2nd degree burns if an arc flash occurred.

2nd degree burns, by the way, are not at all pleasant, so don't think this boundary is the distance where you are completely safe. It's just the distance that your injuries will **probably** heal if there is an arc flash accident.

This again shows just how important it is to wear the right protective clothing.

The textbook definition of an arc flash protection boundary is "the distance from the arc flash where heat energy on the surface of the skin would be about 1.2 calories/cm²."

We will cover calories-per-centimeter-squared in the section on personal protective equipment.

Where the flash protection boundary is depends on a study of the hazard. Calculations use the amount of power the arc flash could have and how long the arc flash would probably last.

The more powerful the explosion and longer the arc flash will be in a completed short circuit, the farther out the arc flash protection boundary will be.

In theory, arc flash explosions explode in all directions equally, but what **usually** happens is that the panel box or piece of electrical equipment contains some of the explosion in one direction and sends the entire force toward the opening of the piece of equipment, usually facing toward the victim.

The best thing you can do when you see a hazard like this is to stay away, even well beyond the boundaries.

Remember, the farther away you are from an arc flash when it happens, the better.

What determines where the arc flash protection boundary is?

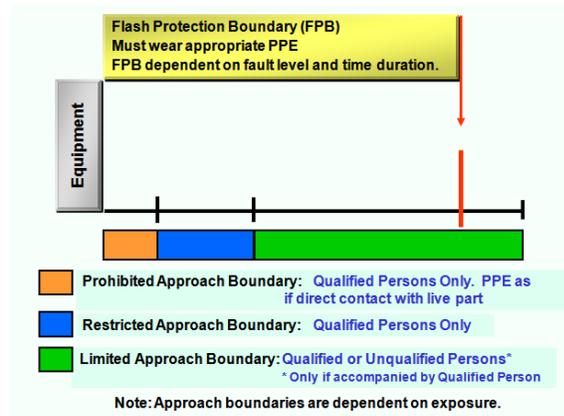
A wild guess

It is always 10 feet away from the hazard

The type of load on the safely completed circuit

A careful study of the power and time of the arc flash

Limited approach boundary



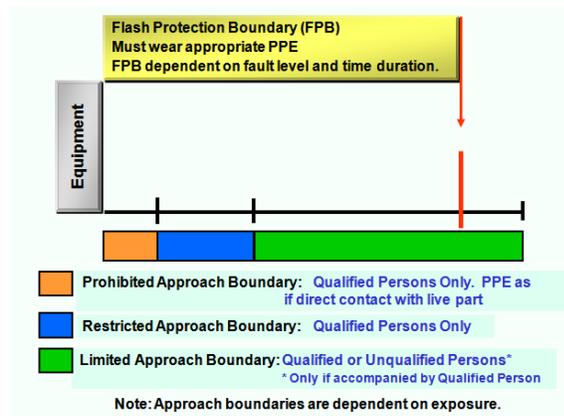
The next boundary we will look at is the limited approach boundary.

The limited approach boundary is the distance at which a shock hazard exists and is based on voltage.

The limited approach boundary defines a boundary around exposed live parts that may not be crossed by “unqualified” or “affected” personnel unless accompanied by “qualified” workers.

Affected employees, then, should never enter the limited approach boundary alone, and if you are required to go in with a qualified worker, make sure you are wearing the proper PPE.

Restricted approach boundary



Further in from the limited approach boundary is the restricted approach boundary.

The restricted approach boundary is the distance where there is an increased risk of electric shock due to an accident.

These accidents could be from slipped tools, losing your balance and grabbing a live part to hold yourself up, or just accidentally walking too close to an energized part.

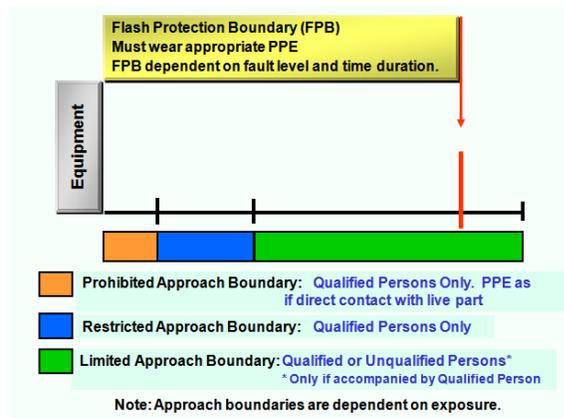
The restricted approach boundary can only be crossed by “qualified” persons using appropriate shock prevention techniques and equipment.

This means you should never be in the restricted approach boundary when equipment has electricity hooked up to it.

Although this has more to do with getting shocked or electrocuted than it does with an arc flash, this is usually well inside the area that would give you incurable third degree burns if an arc flash was to occur.

Just by being in this area, you could cause an arc flash to happen. And if you were not wearing the right PPE, you could be badly injured or even die.

Prohibited approach boundary



Even though you would never touch live electrical wires, you might think being close is OK, but it is not.

Being in the prohibited approach boundary is just as dangerous as touching the energized parts. This is because electricity can arc through the air, completing the circuit through your body.

At this distance it is considered the same at making contact with the part. This is a very dangerous area to be in, and as an affected employee, you should not have to worry about having to be in this area when equipment is energized.

The prohibited approach boundary can only be entered by “qualified” persons using the same protection as if direct contact with live parts is planned. This is determined by a calculation using voltage, just like in the limited and restricted boundaries.

To enter the prohibited approach boundary, the worker must: be qualified, have a plan that justifies the need for conducting the live work, be aware of potential risks, use PPE on all body parts in the space, and mark off a 4 foot x 4 foot boundary.

If you see a person working in the prohibited space, make sure to stay away so you will not cause any accidents that could harm you or the qualified employee doing the work.

Select the boundaries each item is referring to.

Being in this area is as dangerous as actually touching live parts. - **Prohibited**

In this area there is an increased risk of electric shock due to an accident from the worker. - **Restricted**

The distance where a shock hazard exists and affected employees must be accompanied by a qualified employee - **Limited**

This is the point where a person could receive 2nd degree burns if an arc flash occurred - **Arc flash protection**

Arc Flash Boundary Table

Table 130.2(C) Approach Boundaries to Energized Electrical Conductors or Circuit Parts for Shock Protection (All dimensions are distance from energized electrical conductor or circuit part to employee.)

| (1) Nominal System Voltage Range, Phase to Phase ² | (2) Limited Approach Boundary ¹ | | (4) Restricted Approach Boundary ¹ ; Includes Inadvertent Movement Adder | (5) Prohibited Approach Boundary ¹ |
|---|---|-------------------------------|---|---|
| | Exposed Movable Conductor ³ | Exposed Fixed Circuit Part | | |
| Less than 50 | Not specified | Not specified | Not specified | Not specified |
| 50 to 300 | 3.05 m (10 ft 0 in.) | 1.07 m (3 ft 6 in.) | Avoid contact | Avoid contact |
| 301 to 750 | 3.05 m (10 ft 0 in.) | 1.07 m (3 ft 6 in.) | 304.8 mm (1 ft 0 in.) | 25.4 mm (0 ft 1 in.) |
| 751 to 15 kV | 3.05 m (10 ft 0 in.) | 1.53 m (5 ft 0 in.) | 660.4 mm (2 ft 2 in.) | 177.8 mm (0 ft 7 in.) |
| 15.1 kV to 36 kV | 3.05 m (10 ft 0 in.) | 1.83 m (6 ft 0 in.) | 787.4 mm (2 ft 7 in.) | 254 mm (0 ft 10 in.) |
| 36.1 kV to 46 kV | 3.05 m (10 ft 0 in.) | 2.44 m (8 ft 0 in.) | 838.2 mm (2 ft 9 in.) | 431.8 mm (1 ft 5 in.) |
| 46.1 kV to 72.5 kV | 3.05 m (10 ft 0 in.) | 2.44 m (8 ft 0 in.) | 991 mm (3 ft 3 in.) | 661 mm (2 ft 2 in.) |
| 72.6 kV to 121 kV | 3.25 m (10 ft 8 in.) | 2.44 m (8 ft 0 in.) | 1.016 m (3 ft 4 in.) | 838 mm (2 ft 9 in.) |
| 138 kV to 145 kV | 3.36 m (11 ft 0 in.) | 3.05 m (10 ft 0 in.) | 1.168 m (3 ft 10 in.) | 1.016 m (3 ft 4 in.) |
| 161 kV to 169 kV | 3.56 m (11 ft 8 in.) | 3.56 m (11 ft 8 in.) | 1.295 m (4 ft 3 in.) | 1.143 m (3 ft 9 in.) |
| 230 kV to 242 kV | 3.97 m (13 ft 0 in.) | 3.97 m (13 ft 0 in.) | 1.727 m (5 ft 8 in.) | 1.575 m (5 ft 2 in.) |
| 345 kV to 362 kV | 4.68 m (15 ft 4 in.) | 4.68 m (15 ft 4 in.) | 2.794 m (9 ft 2 in.) | 2.642 m (8 ft 8 in.) |
| 500 kV to 550 kV | 5.8 m (19 ft 0 in.) | 5.8 m (19 ft 0 in.) | 3.607 m (11 ft 10 in.) | 3.454 m (11 ft 4 in.) |
| 765 kV to 800 kV | 7.24 m (23 ft 9 in.) | 7.24 m (23 ft 9 in.) | 4.852 m (15 ft 11 in.) | 4.699 m (15 ft 5 in.) |

Note: For Arc Flash Protection Boundary, see 130.3(A).

¹ See definition in Article 100 and text in 130.2(D)(2) and Annex C for elaboration.

² For single-phase systems, select the range that is equal to the system's maximum phase-to-ground voltage multiplied by 1.732.

³ A condition in which the distance between the conductor and a person is not under the control of the person. The term is normally applied to overhead line conductors supported by poles.

Here is an example of some shock boundaries from the National Fire Protection Association, or NFPA, so you can get a feel for how far away these boundaries are.

Notice that at 480 volts, the prohibited boundary is only one inch, but if the voltage gets up to 765,000 volts, the prohibited approach boundary grows to more than 15 ft.

That means that at this level of voltage, being 15 feet away is just as dangerous as touching the energized conductors.

Specific Restricted Areas and Boundaries for the Company Involved

This will change for each company and will be 5 to 10 minutes long, or will be deleted if the company requests so.

Let's look at a few places where you might be working that contains an arc flash or shock hazard... (add custom content from each company)

Q over company specific hazards

Calculating Arc Flash Hazards

Available current and volts

Time

Distance

PPE

We have already mentioned four things that contribute to how bad you are hurt in an arc flash accident: the available current and voltage, how long the arc flash lasts, how far away you are from the arc flash, and what type of personal protective equipment, or PPE, you are wearing.

You are responsible for making sure you are wearing the right PPE, but the arc flash boundaries will already be calculated for you and put on a label.

The intensity of the arc flash can range from a small flash of light to an explosion. The available current and how long it takes for the short circuit to be broken are the two factors used in calculating the flash protection boundary.

Just A Fraction of A Second

Arc flashes don't last very long, but they are still powerful enough to kill

Since alternating current is what manufacturing companies use to power most of their equipment, arc flash incidents are sometimes measured in cycles.

If a company is using 480-volt, three-phase AC at 60-hertz and the short circuit stays complete for six cycles, then it lasted one-tenth of a second.

This is easily enough time to allow an explosion large enough to kill you even if you are up to 10 feet away.

So just a tiny amount of time, then, is needed for an arc flash to cause horrible injuries to affected workers near a piece of electrical equipment.

The incident can be so rapid that you will not have any time to react or to get away. The event occurs too fast.

Calculating Arc Flash Hazards

The NFPA 70E formulas to calculate arc-flash boundaries:

$$D_C = \sqrt{2.65 \times MVA_{bf} \times t} \quad \text{or} \quad D_C = \sqrt{53 \times MVA \times t}$$

D_C = Flash Protection Boundary (Distance of person from an arc source for a just curable burn [in ft.])

MVA_{bf} = Bolted 3-phase fault MVA at point involved

$$= 1.73 \times \text{voltage}_{L-L} \times \text{available short-circuit current} \times 10^{-6}$$

MVA = MVA rating of transformer (For transformers with MVA ratings below 0.75 MVA, multiply the transformer MVA rating by 1.25.)

t = Time of arc exposure in seconds

Here are a couple of formulas that can be used to find out the arc flash boundary around a piece of electrical equipment.

The first one says that D sub C , or the flash protection boundary, in feet, is equal to the square root of the product of 2.65, the bolted 3-phase fault measured in megavolt amps, and the time the arc flash will last.

What that means is that you take 2.65 and multiply it by the power available and the time the arc flash will last. You then take the square root of what you find to get the arc flash boundary in feet.

The second equation is almost the same, except this equation uses the power of the transformer supplying power to the equipment.

The MVA, or megavolt amps in both equations, is a measure of the power available to an arc flash. One is measured at the point where an arc flash can happen. The other is measured from the transformer supplying energy to the equipment where an arc flash could occur.

$$D_C = \sqrt{2.65 \times MVA_{bf} \times t}$$

or

$$D_C = \sqrt{53 \times MVA \times t}$$

Flash Protection Boundary Example

40,896 amps

480 volt, 3-phase system

About 34 MVA_{bf}

0.1 seconds

$$D_C = \sqrt{2.65 \times 34 \times 0.1}$$

$$D_C = \sqrt{9}$$

$$D_C = 3$$

Let's go through an example with the first equation to see how these boundaries are calculated.

This is not the only method of calculating an arc flash protection boundary, but going through this example will help you understand the boundary better.

<http://www.arcflash.me/ieee-1584-arc-flash-calculations.php> 11-29-2010

If you have 40896 amps of available bolted fault current on a 480-volt three-phase system (which is about 34 megavolt amps), and a tenth of a second to open the short circuit of the arc flash, you will have a flash protection boundary at 3 feet.

In situations where a detailed analysis is not needed, 4 feet is the minimum boundary set by the national fire protection association, or NFPA.

You will not have to determine these boundaries, but you still need to have an idea of how they are calculated.

You can see that, if power or time goes up, the arc flash boundary will be farther out.

What happens to the arc flash protection boundary when the following change?

Flash protection boundary increases

Arc flash lasts longer

More power is available

Flash protection boundary decreases

Arc flash is shorter

Less power is available

Megavolt amps is a measure of _____ .

Power

Time

Speed

Distance

Current

Personal Protective Equipment (PPE)

You can see how important clothing is to protecting your body from an arc flash by taking a piece of fabric, say from a t-shirt, and putting it over your finger and touching it quickly to a hot iron. You will probably not feel any heat since you touched it for just a fraction of a second.

Of course if you held your finger there for more than a second or two your finger would get burned and blister, but this is not what happens in an arc flash.

In an arc flash, the temperature is much higher, but hopefully lasts only a short amount of time, sort of like quickly touching a hot iron – only at tens of thousands of degrees for the arc flash instead of a couple of hundred of degrees for the iron.

When this level of heat is involved for such a short amount of time, the part of clothing or skin that does come in contact with the heat will be completely destroyed. Hopefully it will be your protective equipment and not your skin that is destroyed in the arc flash accident.

This is one of the reasons why wearing personal protective clothing is so important. If something is going to get burned and destroyed, you want it to be your clothing and not your skin.

Calories

Calories measure energy

1.2 calories per centimeter squared

Same as holding your finger over the flame of a lighter

When dealing with personal protective equipment, or PPE, you will often hear the word calorie. This “calorie” is the same you are used to hearing when talking about food.

Its formal definition is “the energy required to raise one gram of water one degree Celsius at one atmosphere” or the amount of energy it takes to heat up a few drops of water one degree.

You will get second-degree burns at 1.2 calories per centimeter squared per second.

This might be a little hard to grasp, but think of it this way: One calorie per centimeter squared per second, is like holding your finger over the tip of the flame of a cigarette lighter for one second.

This could easily give you a second degree burn.

What might happen if you held your hand over the tip of the flame of a cigarette lighter for one second (the same as 1.2 calories per centimeter per second)?

You would not feel any pain

If might feel warm

It would hurt and you could get second degree burns

Your hand would explode

When You Need To Wear PPE

If you...

- Open electrical panels that have energized (live) conductors inside
- Work on, install, or maintain energized conductors or equipment
- Stand within about 4 ft. of an open electrical panel

...you need to be qualified and wear the proper PPE

Let's look at some situations where you would need to wear PPE for arc flash hazards.

The first is if you need to open electrical panels that have energized or live conductors inside.

As an affected employee, you will not have to do this.

You would also have to wear the right PPE if you work on, install, or maintain energized conductors or electrical equipment.

Again, only qualified employees need to do this type of work. As an affected employee, you will not do this type of work.

What about the next one? Standing within four feet of an open electrical panel.

*Now you **might** be doing this, so although you will not be working on live equipment, you still might need to work in an area that will require you to wear arc flash personal protective equipment.*

As an affected employee (remember, you are an affected employee and not a qualified employee), when would you need to wear personal protective equipment (PPE).

When you need to open electrical panels that have energized (live) conductors inside

When you need to work on, install, or maintain energized conductors or equipment

When you need to stand within about 4 ft. of an open electrical panel

What PPE Do I Need To Wear?

Clothing

Full protection suits

Ear plugs

Voltage-rated gloves

Insulated blankets

Face shields

Safety glasses

Below is from <http://www.arcflash.me/arc-flash-PPE.php> 11-29-2010

Personal protective clothing includes not just cotton clothing and flame resistance clothing, but also includes voltage rated gloves, face shields, full-coverage flash suits, and insulated blankets.

Remember that any time you cross the arc flash protection boundary, you need to wear the proper PPE. This does not mean you will need to dress up in the full-coverage flash suit every time you cross the flash protection boundary, but you will need some level of protection.

When you go to work, you need to make sure to always wear cotton clothing. Materials like nylon or acetate will ignite and melt on your skin if an arc flash occurs, causing severe burns.

You should also always wear safety glasses and ear plugs if you are working near moving parts.

Let's look over some of the different levels of protection to see what you would need to wear in different situations.

PPE Requirements

| Risk/Hazard Category | Incident Energy (cal/cm²) | Examples of PPE Required* |
|-----------------------------|---|--|
| 0 | 2 or lower | Non-melting clothing |
| 1 | 2-4 | FR shirt and pants |
| 2 | 4-8 | FR shirt and pants, cotton underwear |
| 3 | 8-25 | FR shirt and pants, FR coveralls, cotton underwear |
| 4 | 25-40 and higher** | FR shirt and pants, full-coverage flash suit, cotton underwear |

Here are some examples of risk and hazard categories along with their associated energies in calories-per-centimeter squared and PPE requirements.

Determining the appropriate level of PPE is important. Too little PPE exposes a worker to potentially lethal injuries.

On the other hand, high levels of PPE are extremely bulky, and may restrict vision and movement, increasing the chance of an accident as well as increasing work time and difficulty.

NFPA 70E defines five risk/hazard categories which determine the proper level of PPE for a given task, zero through 4. These risk categories will be visible on arc flash labels.

The risk level for a given task is determined either by conducting an arc hazard analysis or by consulting PPE tables from NFPA, the National Fire Protection Association, or I triple E (IEEE), Institute of Electrical and Electronics Engineers.

[http://nicolet.asse.org/docs/Nicolet%20ASSE%2011.11.09%20Presentation%20\(Arc%20Flash\).pdf](http://nicolet.asse.org/docs/Nicolet%20ASSE%2011.11.09%20Presentation%20(Arc%20Flash).pdf) 11-17-2010

Identify the following levels of PPE

Level 0 - **2 cal/cm² or lower**

Level 1 - **2-4 cal/cm²**

Level 2 - **4-8 cal/cm²**

Level 3 - **8-25 cal/cm²**

Level 4 - **25-40 cal/cm²**

PPE Level 0

| | | |
|--------------------------------|----------------|----------------|
| 2 cal/cm ² or lower | Long pants | Leather gloves |
| Non-melting clothing | Safety glasses | |
| Long sleeve shirt | Ear plugs | |

Level zero PPE is required when the energy levels of an arc flash are 2 calories per centimeter squared or lower at a distance of 18 inches from the source of the arc flash.

NFPA requires non-melting long sleeve shirts, long pants, safety glasses, hearing protection, and leather gloves in this situation.

Notice that if an accident were to occur, a worker's face could be badly burned.

PPE Level 1

| | | |
|------------------------------------|---|---------------------------|
| 2-4 cal/cm ² | Arc rated face shield or suit hood | Ear plugs |
| Flame resistant clothing | Arc rated jacket | Leather gloves |
| Arc rated long sleeve shirt | Hard hat | Leather work shoes |
| Arc rated long pants | Safety glasses | |
| Arc rated coveralls | | |

If the energy in an arc flash can get up to 4 calories per square centimeter at 18 inches, level 1 personal protective equipment, or PPE, is needed.

The big difference from level one to level two is that now the clothes must not only be non-melting, but they must be flame resistant and arc rated.

The worker would also need to add arc rated coveralls, an arc rated face shield and jacket, a hard hat, and leather work shoes to what he was wearing at level zero.

PPE Level 2

| | | |
|-----------------------------|------------------------------------|--------------------|
| 4-8 cal/cm ² | Arc rated face shield or suit hood | Ear plugs |
| Flame resistant clothing | Arc rated jacket | Leather gloves |
| Arc rated long sleeve shirt | Hard hat | Leather work shoes |
| Arc rated long pants | Safety glasses | |
| Arc rated coveralls | | |

If the energy in an arc flash can get up to 8 calories per square centimeter, level 2 personal protective equipment, or PPE, is needed.

If you look closely at the protective clothing and PPE table in the NFPA 70E, you will notice that the only difference between the level one and level two requirements are the arc flash ratings of the clothing.

“Level two” situations require clothing with a minimum protection from an 8-calorie-per-square-centimeter accident.

PPE Level 3

| | | |
|------------------------------------|---------------------------------------|-------------------------|
| 8-25 cal/cm ² | Arc rated flash suit pants | Safety glasses |
| Flame resistant clothing | Arc rated flash suit hood | Ear plugs |
| Arc rated long sleeve shirt | Arc rated jacket | Arc rated gloves |
| Arc rated long pants | Hard hat | Leather work shoes |
| Arc rated coveralls | Flame resistant hard hat liner | |
| Arc rated flash suit jacket | | |

If the energy at 18 inches from the arc flash gets up to 25 calories per square centimeter, level 3 PPE is needed. When this level is reached, the arc rated suit hood is required over just the face shield.

The worker will now be wearing the full “space suit,” as some workers call it, and all PPE will be rated at 25 calories per square centimeter or higher. This includes the flash suit jacket, pants, and hood.

Gloves must now be arc rated and the worker also needs a flame-resistant hard hat liner.

PPE Level 4

| | | |
|-----------------------------|-----------------------------|--------------------------------|
| 25-40 cal/cm ² | Arc rated flash suit jacket | Flame resistant hard hat liner |
| Flame resistant clothing | Arc rated flash suit pants | Safety glasses |
| Arc rated long sleeve shirt | Arc rated flash suit hood | Ear plugs |
| Arc rated long pants | Arc rated jacket | Arc rated gloves |
| Arc rated coveralls | Hard hat | Leather work shoes |

In situations where there could be over 25 calories per square centimeter of energy released, level four PPE is needed.

Just as with level 3, the worker will be in the full “space suit” and all PPE must be rated at 40 calories per square centimeter or higher.

If energies can get over 40 calories per square centimeter, special caution is needed to deenergize the equipment since companies do not always have PPE rater over 40.

Select the three true statements below.

All workers need some level of protective equipment, such as leather gloves, safety glasses, and hearing protection

Level 3 and 4 PPE have workers wearing the “space suit”

Level 4 situations can be more dangerous than level 1 situations

You can wear nylon and acetate clothing while working

Level 4 PPE is just jeans and a t-shirt

PPE Care and Inspection

The employee wearing the protective clothing and PPE must inspect them each time they need to wear them.

If you notice any damage to any of the PPE, report it immediately. Do not use the damaged PPE and do not enter any flash protection boundaries until the PPE is repaired or replaced.

Remember, if you are required to wear PPE, it is your responsibility to make sure it is in safe working order.

Since you will probably not be trained in how to inspect PPE properly, you will have to ask for help if you need to inspect arc rated PPE.

BUTTON

Who is responsible for inspecting PPE prior to wearing it?

The employee

The supervisor

The company

The employer

PPE Testing Video

<http://www.youtube.com/watch?v=AFIBLQjOAJI&feature=related>



Here is a video of different levels of PPE being tested. You see easily see from this video that choosing the correct PPE is very important.

Appropriate Tools for Safe Working



Tools are often made of metal, and metal is a good conductor.

This makes metal tools potentially very dangerous around electrical hazards, unless the tools are properly insulated.

Insulated tools, then, must be used whenever working on energized electrical equipment.

Here is a picture of some insulated tools for working on live parts. Notice the double triangle symbol to show workers that this is an insulated screwdriver.

Since you will not be working on energized equipment, you will not need to use insulated tools, but you should know what they look like since you might see them on the job.

<http://www.mi-wea.org/docs/ArmstrongT%20-%20What%20you%20don%27t%20know%20can%20hurt%20you%20%5BCompatibility%20Mode%5D.pdf> 11-15-2010

Why are metal tools dangerous when working near electricity?

Metal tools conduct electricity

Metal is an insulator

All metal tools are prohibited near live parts

Metal tools raise voltage

Arc Flash Labels

Required on all new and modified equipment

You must know what they look like and how to read them



Both the National Electric Code and the National Fire Protection Association require labels on hazardous electrical equipment.

All hazardous equipment installed or modified after 2002 must carry a warning label. This includes "switchboards, panel boards, industrial control panels and motor control centers that are likely to require examination, adjustment, servicing, or maintenance while energized." Many companies choose to label additional equipment for maximum safety.

Although you might not know what each of these pieces of equipment are, you will be expected to know what an arc flash hazard label looks like and how to read it.

Equipment is not labeled by the manufacturer, but by the employer at the place where it will be working. This is because equipment can be installed in many different ways and can offer different levels of danger for each situation.

As you go through the next few slides, pay careful attention to what the labels look like. In any hazardous situation, the label will be placed where you can easily see it so you can stay out of the way and not get hurt.

Select the following three true statements.

Labeling is the responsibility of the company operating the equipment.

Labels must be placed and sized so as to be visible to workers

You are required to know what an arc flash label looks like

You need to know how to operate and install all hazardous equipment

Arc flash labels do not need to be visible

Arc Flash Labels

Warning labels

Danger labels

Flash hazard analysis is needed first



Arc flash labels, as we have already mentioned, are what you will see that lets you know that there is an arc flash hazard on a piece of equipment.

The labels you see will be either orange and black warning labels or white and red danger labels.

There is a difference between the two, but before we cover that, let's go through how an arc flash label is filled out.

When it is determined that an arc flash hazard is present on a piece of electrical equipment, an arc flash hazard analysis is required to figure out the information that needs to go on the label.

<http://www.graphicproducts.com/tutorials/arc-flash-labels.html> 11-29-2010

An arc flash hazard analysis is a study to find out the force of the arc flash to determine safe working practices and set up boundaries around the equipment.

The calculations in an arc flash hazard analysis will be much more involved than the example we went through calculating the arc flash protection boundary. Specialized arc flash calculation software is used to come up with more accurate details of the hazards.

The software package will figure out and print the flash protection boundary, the three shock approach boundaries, the PPE level needed, and the typical protective clothing that is required.

Information on the Label

Equipment type/name

Voltage

Available bolted current

Grounding

Typical work distance

Incident energy at typical work distance

Flash protection boundary

Limited approach boundary

Restricted approach boundary

Prohibited approach boundary

Pressure of arc blast

PPE level/Hazard risk category

Typical protective clothing needed

Required glove rating

WARNING

Arc Flash and Shock Hazard

Appropriate PPE Required

| | |
|------------|---|
| 0 Ft 11 In | Flash Hazard Boundary |
| 0.5 | cal/cm ² Flash Hazard at 1 Ft 6 In |
| Category 0 | Untreated Cotton |
| 480 VAC | Shock Hazard when cover is removed |
| 00 | Glove Class |
| 3 Ft 6 In | Limited Approach (Fixed Circuit) |
| 12 In | Restricted Approach |
| 1 In | Prohibited Approach |
| 01/07/2008 | Arc Flash Study Date IEEE 1584-2004a |

Equipment ID (Name): MCC-1 (MCC-1)
Protective Device: MCC 1 MAIN

Scenario 1 - Normal with UPS SS Closed
Study Performed By PowerStudies.com (253) 639-8535

All equipment that has possible arc flash hazards must be labeled. A typical label will usually contain some of the following: the type of equipment, the voltage supplied to the equipment, its available short circuit current, how far workers usually are when they are working on the equipment, and the energy level in calories per square centimeter at the typical work distance if an arc flash were to happen.

*A label will not include **all** of this data because it would make the label too hard to read quickly. The important information would be lost in all the other information.*

What are some of the values that could be printed on an arc flash hazard label? Select three.

The type of equipment that is labeled

The voltage supplied to the equipment

The PPE level required

The temperature of the equipment

The day of the week the equipment operates

Sample Arc Flash Hazard Label

Let's look at a few labels to make sure you know what to look for when you need to work near a piece of electrical equipment that has a label on it.

This is a label for a 600-volt switchgear. 70,000 amps of bolted fault current is available, and with the other information gathered from the arc flash hazard analysis, a two foot arc flash protection boundary was calculated.

Within this boundary, level-one personal protective equipment, or PPE, needs to be worn. This will include arc rated protective clothing and a face shield.

|  WARNING | |
|---|--------------------------|
| Arc Flash and Shock Hazard Appropriate PPE Required | |
| Equipment type | 600 V Switchgear |
| Grounding | Grounded |
| Working distance | 500 mm |
| Available 3ph bolted current | 70 kA |
| Flash protection boundary | 24 inches |
| Incident energy at work distance | 1.56 cal/cm ² |
| PPE level | 1 |
| Equipment name | EDL-1575-185 |
| Label created using Arc-Flash-Analytic software www.arcadvisor.com | |

Sample Arc Flash Hazard Label

The label in the previous example did not have any shock boundaries listed, but this label does.

Remember that while labels will not list every piece of information from an arc flash hazard analysis, they will have the information you need to stay safe when working around the equipment that is labeled.

This label is for a 480-volt motor control center, or MCC, and has a 15-inch flash protection boundary. The PPE level needed in the flash protection boundary is level zero.

This will require you to wear what you might be wearing to work anyway: non-melting long sleeve shirts, long pants, safety glasses, hearing protection, and leather gloves.

The shock boundaries listed are for when the cover to the equipment is removed. When this happens, there is a three-and-a-half foot limited approach boundary, a one-foot restricted approach boundary, and a one-inch prohibited approach boundary.

With these boundaries set up, you should not be within three-and-a-half feet of the motor control center without being escorted by a qualified employee and you should never be within one foot of the MCC if the cover is removed, exposing energized parts.

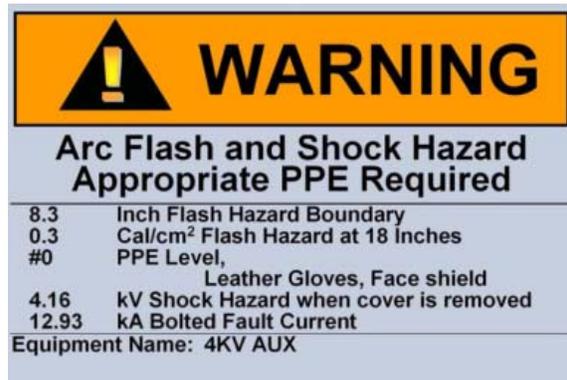
|  WARNING | |
|---|-------------------------------|
| Arc Flash and Shock Hazard Appropriate PPE Required | |
| Flash Hazard Boundary | 1 Ft 3 In |
| cal/cm ² Flash Hazard at 1 Ft 6 In | 0.91 |
| Category 0 | Untreated Cotton |
| Shock Hazard when cover is removed | 480 VAC |
| Glove Class | 00 |
| Limited Approach (Fixed Circuit) | 3 Ft 6 In |
| Restricted Approach | 12 In |
| Prohibited Approach | 1 In |
| Arc Flash Study Date IEEE 1584-2004a | 01/07/2008 |
| Equipment ID (Name): | MCC-1 (MCC-1) |
| Protective Device: | MCC 1 |
| Line Side of: | MCC 1 MAIN |
| Scenario: | 1 - Normal with UPS SS Closed |
| Study Performed By PowerStudies.com (253) 639-8535 | |

Sample Arc Flash Hazard Label

This third label is on a piece of energized electrical equipment with an 8.3 inch arc flash hazard boundary. When working this close, you would need level zero PPE.

The NFPA 70E 2009, which we will cover in a few minutes, requires that one of two specific pieces of information appear on all arc flash labels: the available incident energy or required level of PPE. This label has both.

More information is usually provided than the minimum.



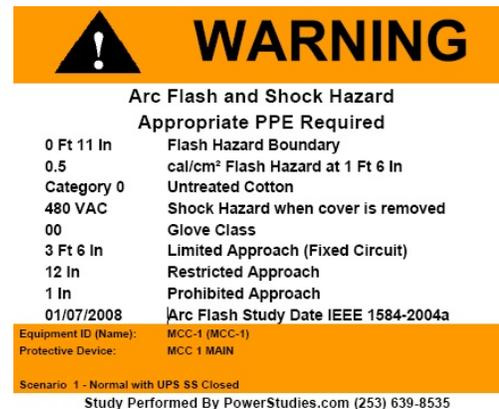
Answer the questions about the label to the right.

Where is the flash protection boundary? **11 inches away from the hazard**

What level of PPE is needed inside the flash protection boundary? **Level 0**

What is the voltage of the equipment? **480 volts AC**

How far could an affected employee get to the hazard without a qualified escort? **3 feet 6 inches**

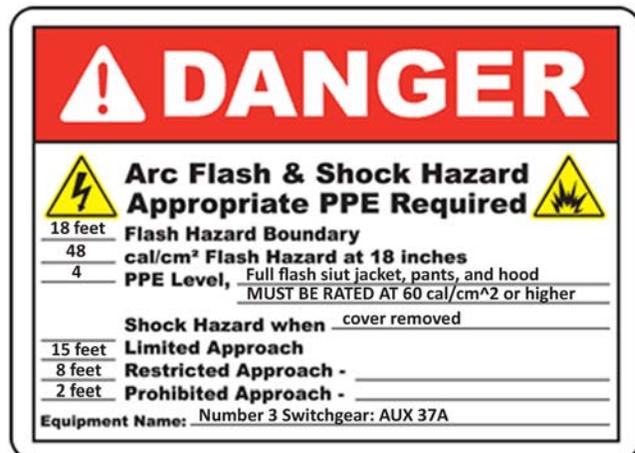


Warning Label or Danger Label

As you work near arc flash hazards, you may see two different kinds of labels. One is the orange warning label and the other is the red danger label.

Most often, the danger label is only used when arc flash energy levels can reach over 40 calories per square centimeter. Above these levels, the danger is so great that some employers do not have the PPE required for situation.

Although you should be careful around any arc flash hazard label, you should be especially careful around danger labels.



Answer the following questions about the danger label shown above.
What is the flash protection boundary? **18 feet**
When is a shock hazard present? **When the cover is removed**
What level of PPE is required? **Level 4**
Would 40 cal/cm² PPE be enough to work around this hazard? **No, at least 60 is needed**

Working Safely

Look for labels

Look for unlabeled hazards

Assume all equipment is live and energized

Look for lockouts and tagouts

Wear the right clothing to work

Use PPE when needed



Now that you have a good idea about what to look for when you see an arc flash hazard label, let's go through some tips to make sure you continue to work safely around these hazards.

Always be on the lookout for hazards, whether they are labeled or not.

Assume that all equipment is fully energized with electricity. Do not think that just because someone is working around an electrical hazard that they have deenergized the equipment.

Also be aware of any equipment that is locked out or tagged out. Locking out and tagging out a machine makes sure no one tries to energize a piece of equipment while someone else is working on it.

If you see a tag like the one shown in the picture, do not try to remove it. Only the person who locked out the machine has the authority to turn it back on.

Also, wear the right clothing to work. PPE will be provided by the employer, but you should wear your own non-melting clothing, work boots, and safety glasses.

At-Risk Behaviors:

Accidents are usually preventable



Remember that over 95 percent of all industrial injuries are caused by unsafe behaviors. That means that the injuries are preventable.

When working around electricity, even as an affected worker who will not be working on live electrical equipment, you still need to be careful.

Don't wear conductive jewelry to work, including rings, necklaces, and metal watches. Don't use damaged equipment, including power tools themselves or their cords, and don't carry anything conductive near electrical hazards, including aluminum ladders and non-insulated hand tools.

Select the four safe working practices

Stay away from hazardous situations

Wear the proper protective clothing to work

Wear the right PPE when needed

Don't try to remove locks on locked out equipment

Touch live exposed wires if you need to

Use damaged equipment if you are in a hurry

Carry conductive aluminum ladders near arc flash hazards

Enter the prohibited shock approach boundary when you need to

Specific Hazards for Company

This will be company specific

Q over company specific hazards

What To Do If An Arc Flash Occurs

To someone else

Stay away from the explosion

Get help

Stay calm

To you

Get away from the explosion

Get help

Stay calm

If you are near an arc flash accident and see someone who is injured, don't follow your instincts to rush in and save them. You might set off another arc flash and be killed. You will not be able to help if you are dead.

What you should do is get help right away. The time it takes for a critically injured person to get help is crucial in helping them survive the accident.

Let other workers know about the accident and get someone to call 911. If you are not trained in giving medical attention, do not try. Wait until someone who is trained shows up to help.

If you are the one who is injured in an arc flash accident, try to get away and get help immediately. What will most likely happen is that you will automatically try to get away if you are still conscious and will probably not remember much.

Also, stay calm. Hopefully you will be wearing the right protective clothing and the proper PPE.

If not, you might be in the 95 percent of all accidents that could have been prevented by working safety and wearing the right protection.

Arc Flash Survivor Video

Here is an interview with some arc flash survivors and how they really did not remember much about the actual event just to show you how devastating the blast can be.



<http://www.youtube.com/watch?v=6H6lLBikuq&feature=related>

What are some of the things you should do if you see someone get injured by an arc flash? Select three.

Stay calm

Get help

Call 911

Rush in and try to get them away from the hazard

Walk away and don't tell anyone

Four Industry Standards Associated Arc Flash

OSHA 29 Code of Federal Regulations Part 1910 Subpart S

NFPA 70E-2009 Standard for Electrical Safety Requirements for Employee Workplaces

NFPA 70-2008 National Electrical Code

IEEE Standard 1584-2002 Guide for Performing Arc Flash Hazard Calculations

Four common industry standards are associated with arc flash. Let's go over how they affect you.

The OSHA 29 Code of Federal Regulations Part 1910 Subpart S covers electrical safety requirements that are necessary for the keeping employees safe.

It includes design standards for electrical systems, safety-related work practices and maintenance requirements as well as safety requirements for special equipment.

The NFPA 70E goes over workplace safety requirements concerning electrical equipment.

It also covers safety-related work practices, maintenance requirements, and safety requirements for special equipment.

The national electric code, or NEC is a substantial book of electricity-related regulations that covers wiring, communication systems, general use equipment, safety standards, and power systems, just to name a few.

Lastly, the IEEE standard 1584-2002 provides a guide to correctly perform arc flash hazard calculations.

When software programs calculate arc flash boundaries, they will use the regulations specified in the IEEE standard.

Summary

Electrocution is a shock that kills

Pure water is an insulator, sweat is a conductor

Arc flashes are short circuits with low resistance and high current

Arc flash labels will help you stay away and wear the right PPE

Thanks for being so attentive today. To quickly summarize some of the things you have learned today, let's go through a few final points.

Electricity is powerful and can be dangerous. Be careful around it.

Electrocutions are shocks that kill you. Stay away from shock hazards, especially when you are sweating, since sweat is a conductor of electricity even though pure water is not.

Arc flashes are short circuits that happen when no load or resistance is in a circuit and the circuit is completed through the air, causing an explosion. The explosion is bright, loud, and hot.

Since an arc flash's intensity is determined by the available current and how long it lasts, arc flash hazard studies are done to figure out safety boundaries and PPE levels for each hazard.

The labels will be placed where you can see them so you can stay away or wear the right PPE so that the PPE is destroyed in an arc flash instead of your skin.

PRE/POST TEST

1. Which of the following is an insulator of electricity?

Gold

Copper

Sweat

Pure water

2. Which of the following would increase the amount of current in a circuit?

Heating up the conductors

Decreasing the voltage

Decreasing the work distance

Decreasing resistance

3. What makes a short circuit dangerous?

A larger load on the circuit

Little-to-no resistance

Less voltage

Decreased current

4. What is electrocution?

An electric shock that kills someone

A light shock

An arc flash that injures a worker

Electricity that resides in capacitors

5. All of the following about arc flash are true except:

Hot temperatures

Loud noises

Bright lights

Low currents

6. What determines the intensity of an arc flash?

The available current and how long it lasts

The voltage and humidity level

Air pressure and voltage level in the sensors

Energy and fault lines

7. What must be on all equipment that has an arc flash hazard?

An arc flash warning or danger label

A shock protection sign

A blue arc flash label with a yellow warning triangle

A green arc flash hazard stamp

8. What normally happens to PPE during an arc flash?

It sounds an alarm

It is destroyed instead of your skin

It burns cleanly and without much heat

It shrinks and fits better

9. What would a qualified worker look like with Level 4 PPE on?

Someone wearing a space suit

Someone wearing a suit of armor

Someone wearing a scuba diving outfit

Someone getting ready to run outside

10. What will an arc flash label usually have on it?

Panel destination and source current

PPE level required and flash protection boundary