1.0 Electrical Safety

Engaging with the power of electricity can be very dangerous. Engineers, electricians, and other trained professionals work directly with electricity as they deal with such equipment as overhead power lines and circuit assemblies. Other employees such as machine operators and office personnel usually work with electricity indirectly. Many employees are exposed to electricity during the performance of their jobs in one way or another, creating a recognized workplace hazard for most.

Approximately 350 electrical-related fatalities occur each year as reported by the Bureau of Labor Statistics, which makes electricity the fourth leading cause of injury-related occupational death. Another 30,000 non-fatal electrical-related accidents are estimated to occur each year in workplaces around the country.

While electricity, in one form or another, has become essential to modern business, it is generally accepted as a source of power without much thought to the hazards that it poses. With this familiarity, electricity is not often treated with the respect that it deserves. Approaches to the promotion of electrical safety recognize hazards associated with the use of electrical energy and take precautions so that hazards do not cause serious injury or death. Workplace safety programs should address the variety of ways electricity can become a hazard in the environment in order to reduce the rate and severity of any potential electrical incident that could result in injury or death.

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1.1 What is Electricity

In order to understand electricity, it helps to first understand atoms. Atoms are small particles that make up matter. Within the atom are electrons, protons, and neutrons. Electrons have a negative charge (-), and protons have a positive charge (+). The electrons spin around the outside of the atom nucleus, with the positive charge of the protons keeping them from leaving the atom.

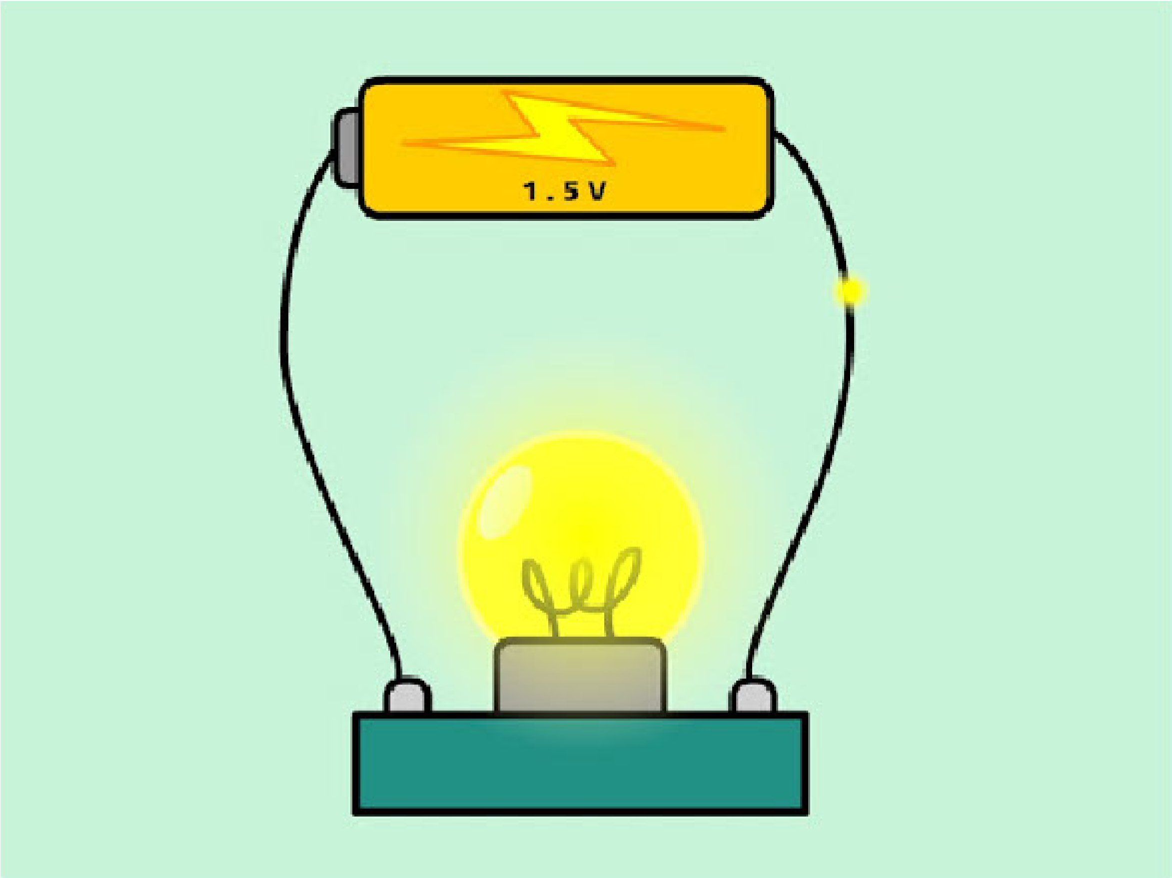
When a force is applied, electrons can break loose and move to another atom. When an atom loses electrons, it has more protons than neutrons and then becomes positively charged. Conversely, an atom that gains electrons has more negative particles and then becomes negatively charged. Electrons can be made to move from one atom to another, and when they do, a current of electricity is created. Simply defined, electricity is the “flow of electrons” as they move through a conductor.

Click play on the video to watch a short overview of what electricity is and how electrons flow through conductors.

Click Box

1.1.1 Electricity in Action

There are three basic rules regarding electricity in action which are important to understand in the prevention of injury in the workplace. First, an electric current will not flow until there is a *complete* loop, with the direction of the electrons flowing between a negatively charged point and a positively charged point, making a complete circuit. Secondly, electric current *always* tries to return to its source, that is, the transformer or other source that supplied it. And lastly, when current flows, electricity can help to accomplish work, but it also provides an opportunity for injury.



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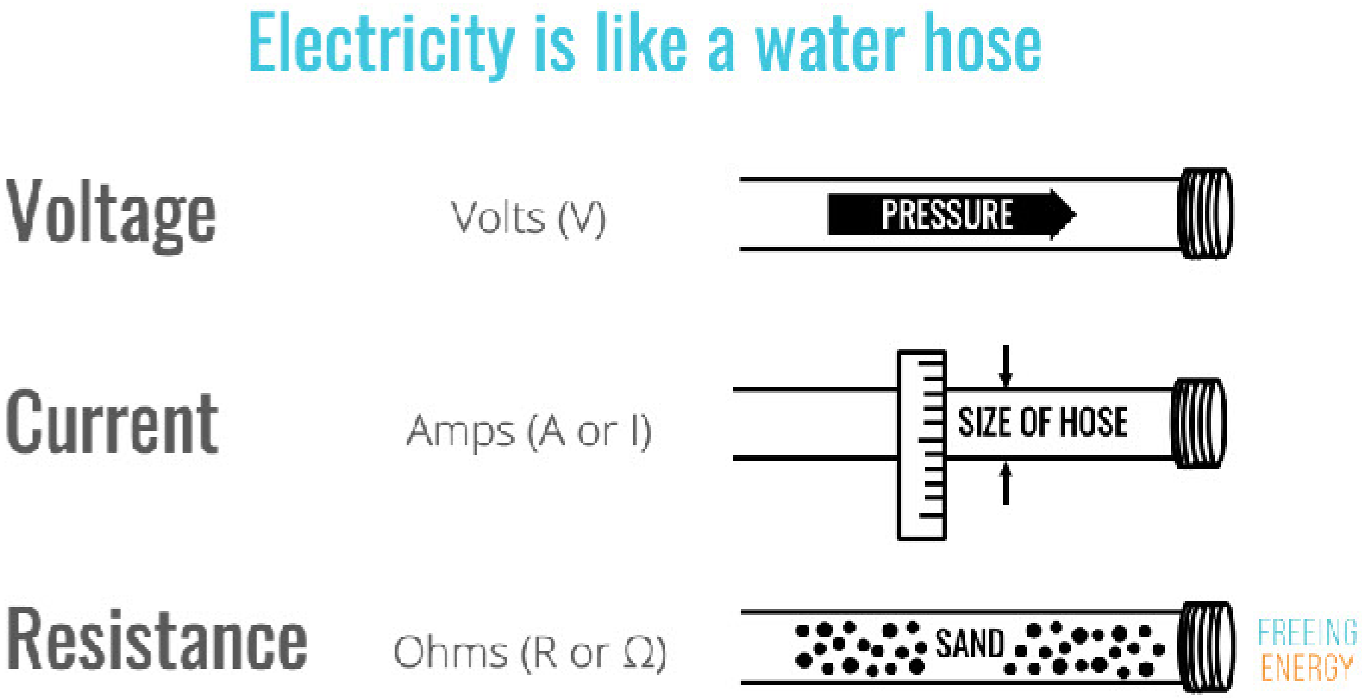
1.1.2 Electricity and Water Flow Comparison

Operating an electrical switch is much like turning on a water faucet. Behind the faucet, there is a source of water, a way to transport it, and pressure to make it flow. The faucet's water source is a reservoir or pumping station, and a pump provides enough pressure for the water to travel through the pipes.



For the electrical switch, the source is a power generating station. From this, a generator provides the pressure for the electrical current to travel through electrical conductors, or wires, to an actual switch that allows it to be energized. In the analogy of water flow, the voltage is the water pressure, the current is the amount of water flowing through the pipe, and the resistance is the size and length of the pipe. More water (current) will flow through the pipe the more pressure (voltage) is applied and the bigger the pipe is (lower the resistance).

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1.1.2 Electricity and Water Flow Comparison

Just as water flows, so do electrons, making electricity "electrons in motion." These electrons are measured in **current, force** and **resistance.** To understand these important terms, the following comparison of the flow of electricity to water is provided:

Term	Flow of Electricity (electrons)	Flow of Water (H_20)
Current	Measured in amps (I)	Measured in gallons/minute
Force	Measured in voltage (V)	Measured in pounds/square inch (psi)
Resistance	Measured in ohms (R)	Measured as friction/water-resistance

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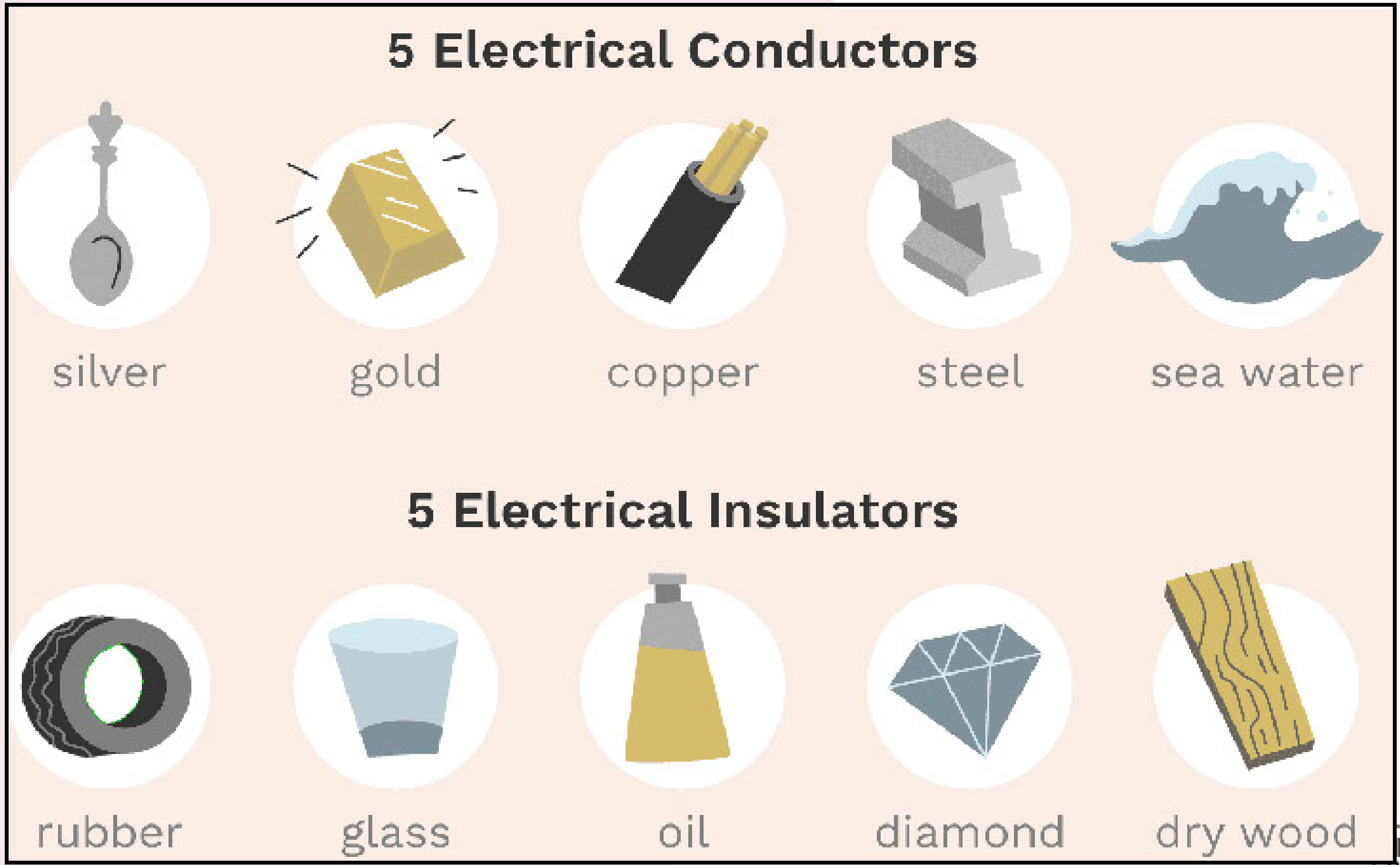
1.1.2 Electricity and Water Flow Comparison

Three factors determine the resistance of a substance to the flow of electricity: What it is made of, its size, and its temperature. Substances with very *little resistance* to the flow of electricity are called conductors, such as metals. Substances with a *high resistance* to the flow of electricity are called insulators such as glass, porcelain, plastic, and dry wood.

With this comparison, it is interesting to note that pure water is a poor conductor of electricity, but small amounts of impurities, such as salt and acid, make it a ready conductor. Moisture as perspiration contains both water, salts, and impurities. When the skin is dry, it is a poor conductor of electrical current. When it is moist, it readily conducts electricity. Extreme caution should be taken when working with electricity where there is water on the skin or in the environment. For example, this moisture concept applies to items such as wood. When wood is dry, it is a poor conductor; however, wet wood conducts electricity more readily.



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1.2 Ohm's Law

Ohm's Law is the most important and most often applied law in electricity. To understand electricity and how it works in the promotion of safety of the workplace, Ohm's Law should be thoroughly understood. The Law depicts the relationship that exists between the three basic quantities of electricity: current, voltage, and resistance. It describes the way current flows through a resistance when a different electric voltage is applied at each end of the resistance.

Ohm's Law is represented by this basic formula:

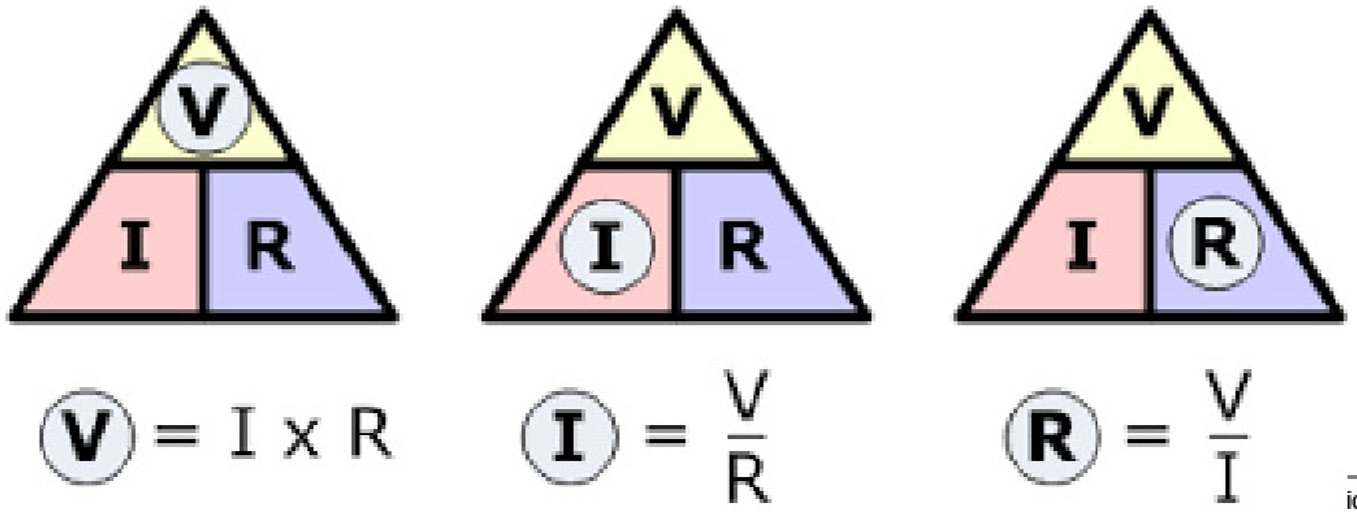
V (voltage) = **I** (amps) X **R** (resistance/ohms Ω)

This formula is used to find the voltage when the current and resistance are known. To derive the current when the voltage and resistance are known, the formula now becomes:

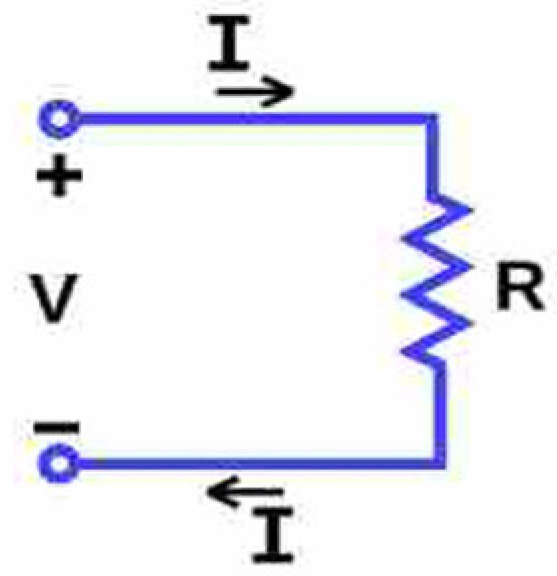
I=V/R

To find the resistance when the voltage and current are known, the formula then becomes:

R=V/I



1.2 Ohm's Law



An easy way to remember these formulas is to use the symbols in a triangle shape. To determine amps, cover the "I" in the figure. To determine resistance, cover the "R." To determine volts, cover the "V." When each of these equation factors in the triangle are covered, the unknown factor equation is revealed. It then becomes easier to see that voltage equals I times R, current or amps equals V divided by R, and resistance equals V divided by I. If two equation factors are known, the third can always be derived.

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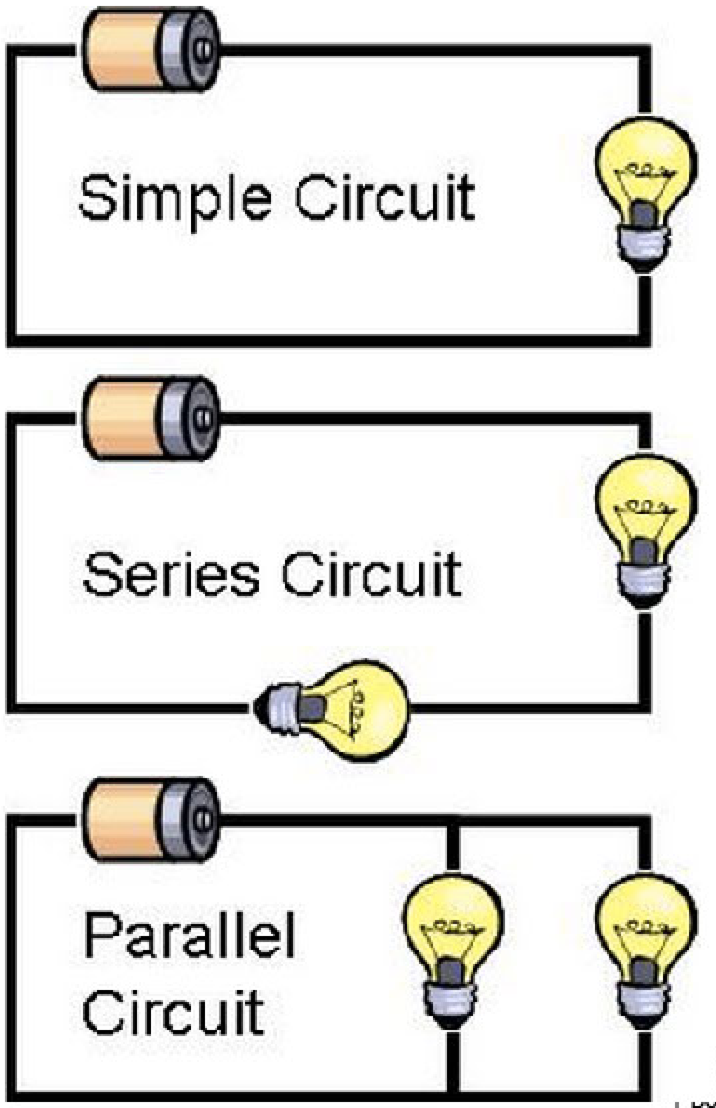
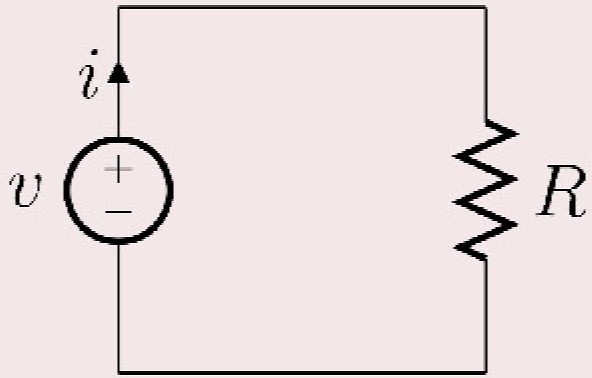
1.3 Definitions

With this basic knowledge, the following are several of the standard definitions of the terms and concepts used in the study of electricity:

- *Circuits:* Circuits provide a path for current to flow. To be a circuit, the path must start and end at the same point, forming a loop. Electrons with a negative charge connect with those that are positively charged in the circuit to flow depending on the resistance of the circuit material.
- *Conductors and Insulators:* Conductors are materials that allow electricity to flow easily as they contain many free electrons and are capable of carrying an electric current. Metals such as gold, silver, aluminum, and copper are all good conductors. Insulators are the opposite of conductors, as they do not carry electricity and, as such, are important in the protection against injury. Materials like rubber, plastic and paper are good insulators.
- *Voltage:* Voltage is the name for the electric force that causes electrons to flow and is the difference in electric potential energy between two points. Electrons flow through a conductor because a force called electromotive force (EMF) is exerted between the charged electrons.



1.3 Definitions



- ***Current:*** Current is the measure of continuous electron flow in a circuit. For electrons to move in a particular direction, it is necessary for a potential difference to exist between two points of the EMF source. Current is measured in amperes.

- ***Resistance:*** The movement of electrons along a conductor meets with some opposition. This opposition is known as resistance, and it measures just how well a material or object conducts electricity. Resistance makes it possible to generate heat, control current flow, and supply the correct voltage to a device. Low resistance means the object conducts electricity well; high resistance means the object does not conduct electricity well. Resistance is measured by a unit called the ohm. In general, resistance in a conductor depends on four factors: the material from which it is made, the length, the cross-sectional area, and the temperature of the material.

  - **Material.** Different materials have different resistances. Some, such as silver and copper, have a low resistance, while others, such as iron have a higher resistance.
  - **Length.** For a given material that has a constant cross-sectional area, the total resistance is proportional to the length. The longer the conductor, the greater the resistance.
  - **Cross-Sectional Area.** Resistance varies inversely with the cross-sectional area of the conductor. In other words, the resistance decreases as the cross-sectional area increases.
  - **Temperature.** Generally, in metals, the resistance increases as the temperature increases. For non-metals, the reverse is usually true.

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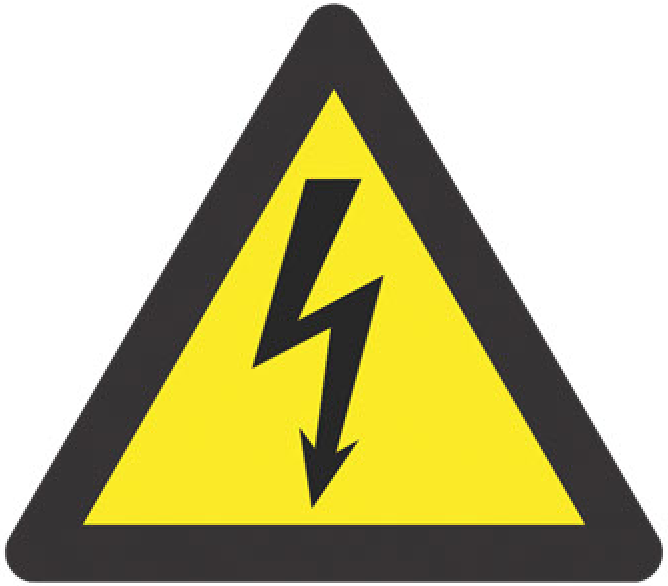
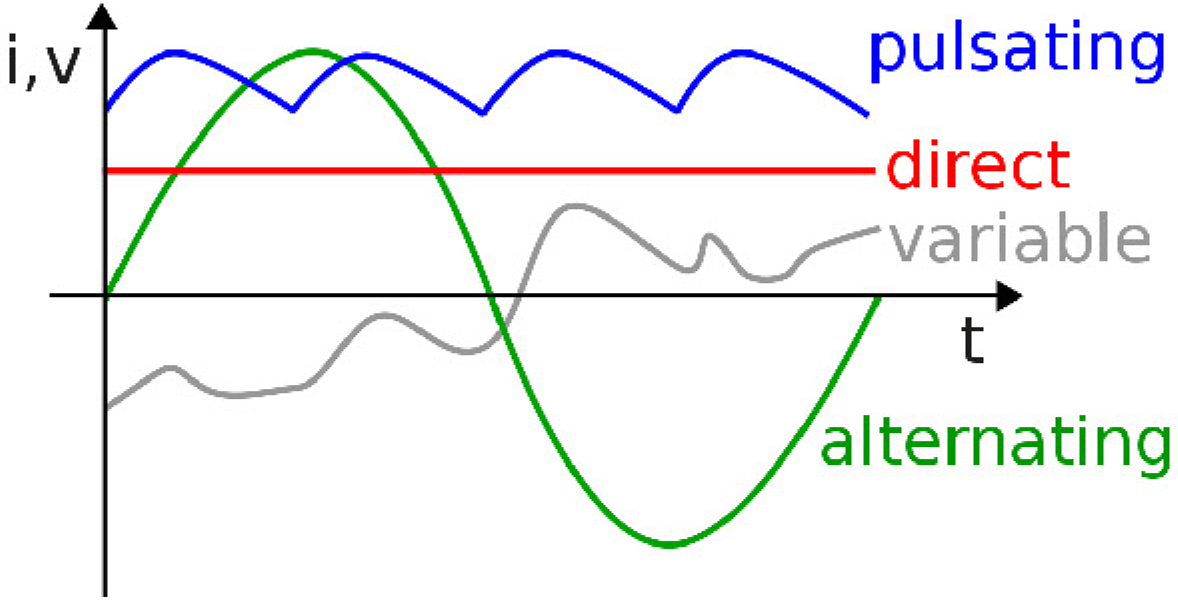
1.3 Definitions

- ***Energized/De-energized:*** While “energized” is being electrically connected to or is a source of voltage, “de-energized” is free from any electrical connection to a source of potential difference and from electrical charge.

- ***Alternating and Direct Current:*** Direct current (DC) flows continuously in one direction through a circuit because the polarity of the voltage source never changes, always flowing in one direction. Batteries and most electronics use direct current. On the other hand, alternating current (AC) changes rapidly in both direction and value. It reverses direction at regularly occurring intervals and has alternately positive and negative values. Electric power companies use alternating current in generators to produce electrical power by transforming the produced electrical energy into a high-voltage, but low-current, equivalent power. Conductors, or transmission lines, transport electrical power with some amount of resistance.





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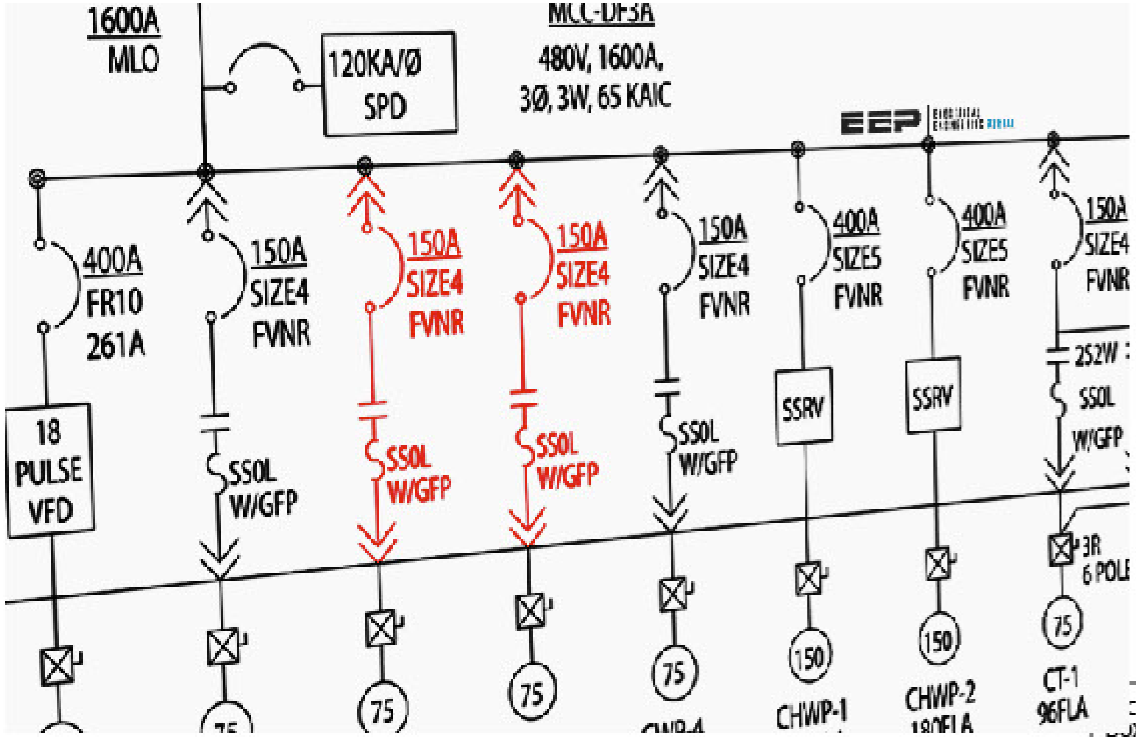
1.3 Definitions

- *Electromagnetism:* Electromagnetism is the magnetic effect created when an electric current flows in a conductor. It is created when the currents and magnetic fields interact. When current flows through a conductor, a magnetic field surrounds the conductor. The current direction determines the direction of the magnetic field. Electromotive force (EMF) is caused by a difference in potential between two points and is measured in volts.

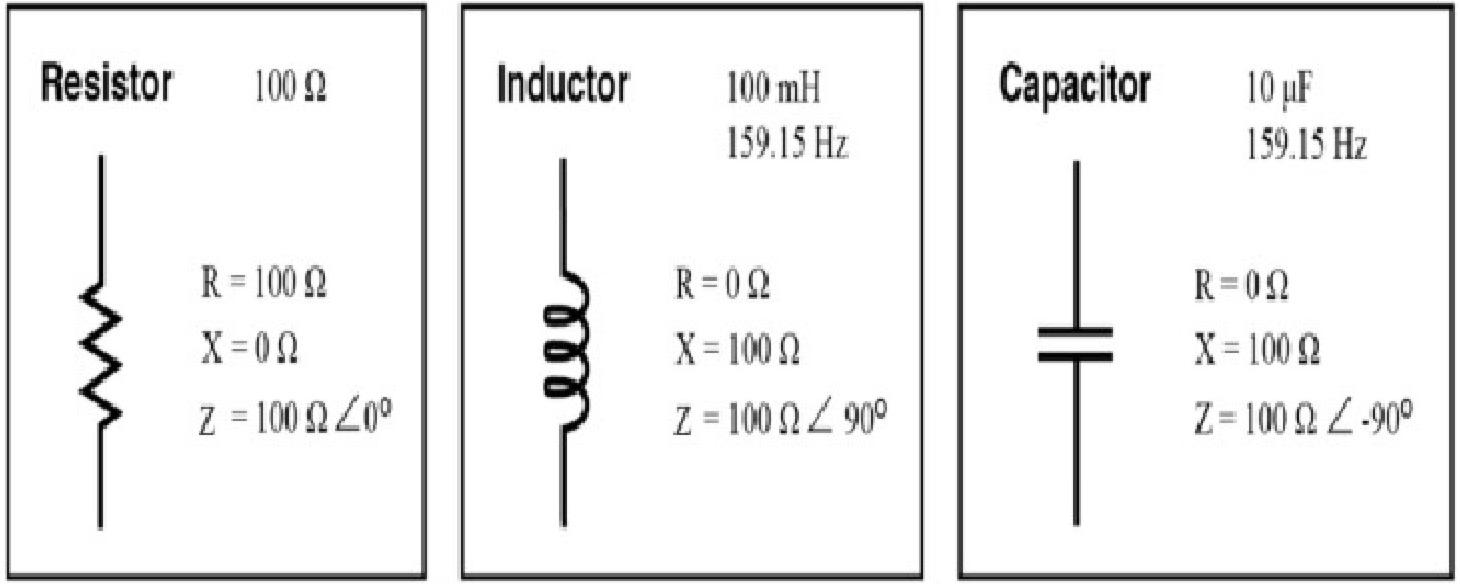
- *Single-Line Diagram:* A diagram that shows, by means of single lines and graphic symbols, the course of an electrical circuit or system of circuits and the component devices or parts used in the circuit or system.

- *Inductance:* Inductance is a property of an electric circuit by which an electromotive force is induced in it by a variation of current, either in the circuit itself or in a neighboring circuit. When the current in a circuit changes, the circuit may oppose the change due to inductance. Induction produces voltage by the relative motion of a conductor across a magnetic field.

- *Capacitance:* Capacitance is the ability to accumulate or release a charge. When the voltage across an electric circuit changes, the circuit opposes this change. While capacitance affects DC circuits only when they are turned off and on, it affects AC circuits continuously, since voltage is continuously changing.



1.3 Definitions



- *Reactance:* The opposition to current flow in a circuit due to capacitance or induction is called reactance. Reactance causes the current to lead or lag the voltage given the changing magnetic field outside of the conductor.

- *Impedance:* Resistance is a characteristic of electrical conductors, which tends to hold back or impede the flow of current. This effect can be visualized as friction inside of the conductor. Friction requires force to overcome it, just as friction makes it difficult to push a heavy box along a concrete floor. In each case, the friction produces heat.

Click Box

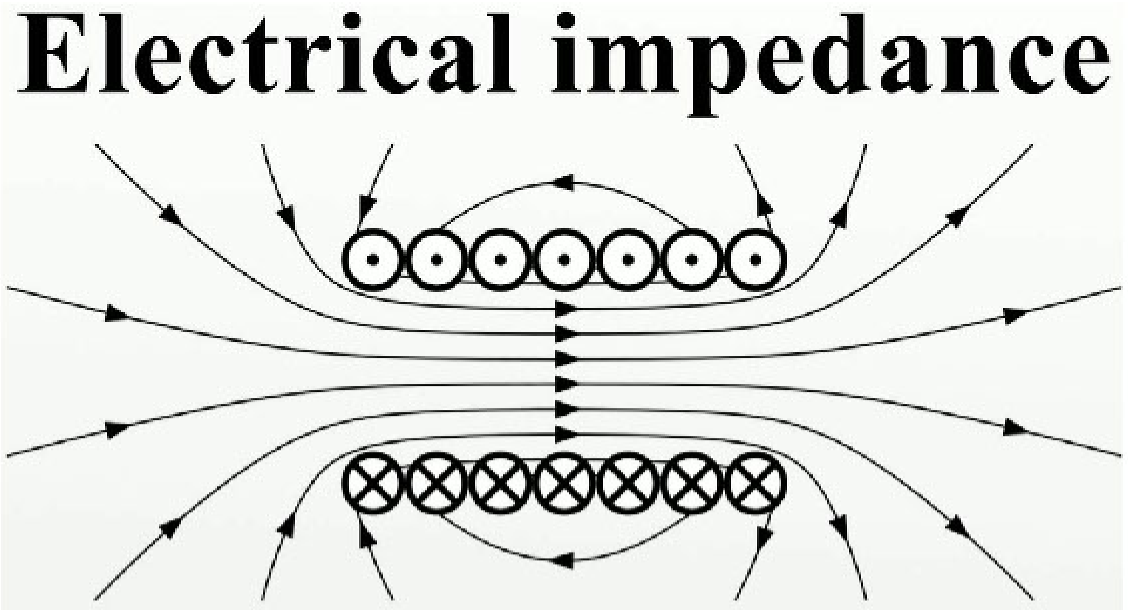
1.3 Definitions

In addition to overcoming resistance inside of a conductor, the current may also encounter some impedance caused by something outside of the conductor. That something is called "magnetic reactance," because it is a magnetic effect reacting against the current which caused it. Alternating current is constantly forcing this magnetic field to change, and this is a burden imposed on the current. Inductive reactance and capacitive reactance can be combined to yield the total "magnetic reactance". Resistance and reactance combine to form the total opposition to current flow, known as impedance.

The table provided offers a summary of the meaning and use of some of these electrical terms:

Summary of Electrical Terms

Function	Term	Symbol	Unit of Measure	Abbreviation
Force	Voltage	E	Voltage	V
Result of Force	Current	I	Ampere	A
Resists Current Flow Due to Physical Properties	Resistance	R	Ohm	Ω
Resists Current Flow Due to Magnetic Effect	Reactance	X	Ohm	Ω
Total Opposition to Current Flow in ac Systems	Impedance	Z	Ohm	Ω



1.4 Electrical Safety Regulations

OSHA's electrical standards address the government's concern that electricity has long been recognized as a serious workplace hazard, exposing employees to such dangers as electric shock, electrocution, fires and explosions. The objective of the standards is to minimize such potential hazards by specifying design characteristics of safety in use of electrical equipment and systems. OSHA's electrical standards were carefully developed to cover only those parts of any electrical system that an employee would normally use or contact. The exposed and/or operating elements of an electrical installation such as lighting equipment, motors, machines, appliances, switches, controls, and enclosures, must be constructed and installed so as to minimize electrical dangers to employees in any workplace.

The OSHA electrical standards were based on the National Fire Protection Association's standard NFPA 70E, Electrical Safety Requirements for Employee Workplaces, and the National Electrical Code (NEC). The standards extracted from the NEC were those considered to most directly apply to employee safety and are primarily performance-oriented.

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1.4 Electrical Safety Regulations

Electrical safety is addressed in the following specific OSHA standards for general industry:

- **Subpart I:** Personal Protective Equipment (1910.137 Electrical Protective Equipment)
- **Subpart R:** Special industries (1910.269 Electric Power Generation, Transmission and Distribution)
- **Subpart S:** Electrical, providing for practical safeguarding of employees in their workplaces. This Subpart is divided into 4 sections:
  - Design safety standards for electrical systems (1910.302-308)
  - Safety-related work practices (1910.331-335)
  - Safety-related maintenance requirements (1910.361)
  - Safety requirements for special equipment (1910.381)
- **Subpart J:** General Environmental Controls (1910. 147/133 Lockout/Tagout)

1.4.1 National Fire Protection Association

NFPA 70 E is the “Standard for Electrical Safety Requirements for Employee Workplaces.” While not considered OSHA regulations, this standard provides guidance related to employee protections for electrical safety. The standard was first developed by the National Fire Protection Association in 1976 and applies to all employees who work on or near exposed energized electrical conductors or circuit parts. It also applies to employees who face a risk from electrical shock, thermal heat, or arc flash or blast. The standard primarily addresses the following electrical hazards:

- Shock
- Arc flash/arc blast
- Fire ignition

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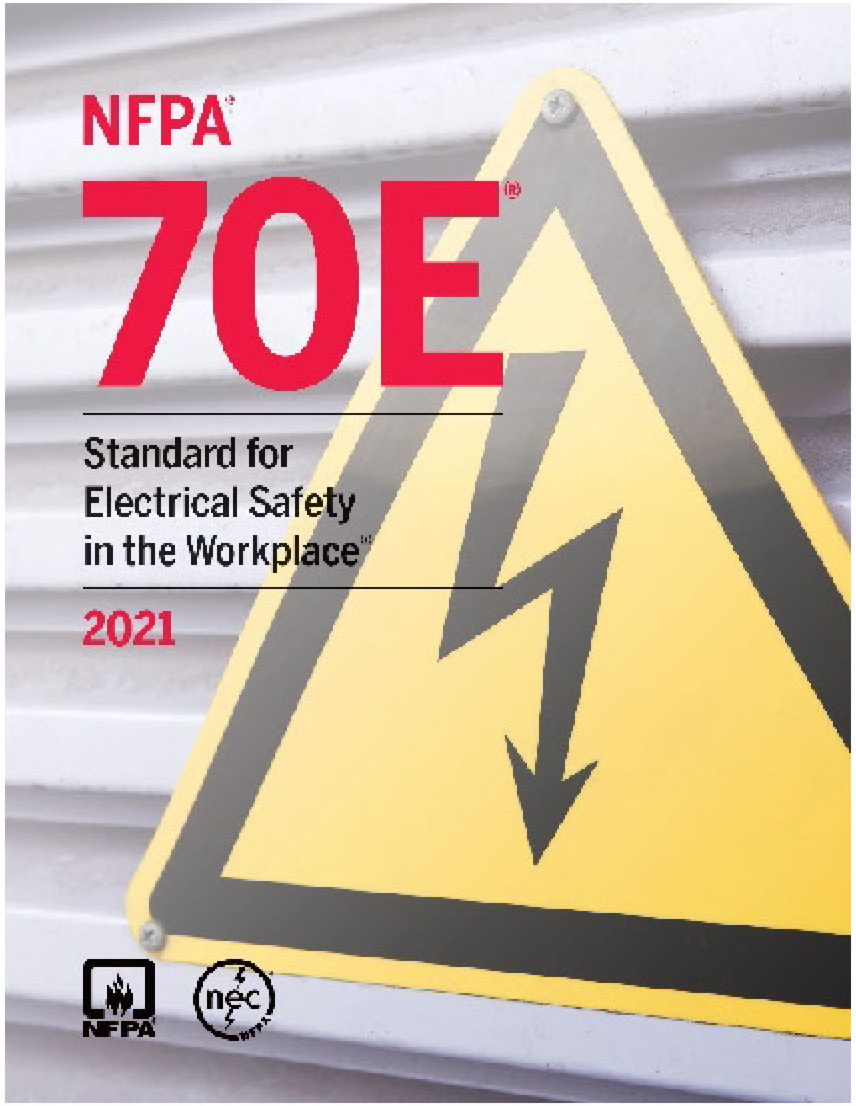
1.4.1 National Fire Protection Association



The original and primary mission of the NFPA is fire protection; therefore, fire ignition from arc flash is a major emphasis of the NFPA standard. The incidence of fire ignition has dropped dramatically since the advent of not only the NFPA standard, but also the development of the National Electric Code and its acceptance of installation requirements within the industry. The NFPA and NEC do not address all hazards of electricity; for example, the NEC protects individuals from shock hazards under normal conditions, but it is not designed to protect employees from abnormal conditions.

Requirements for safe work practices in NFPA 70E include requirements for shock and arc flash boundaries, requirements for personal protective equipment, training requirements to be considered "Qualified," and energized electrical work permits. Given its importance in the safety of employees, this course has dedicated an entire section to the topic of arc flash and arc blast, utilizing numerous components of the NFPA standard in its summary of the topic.

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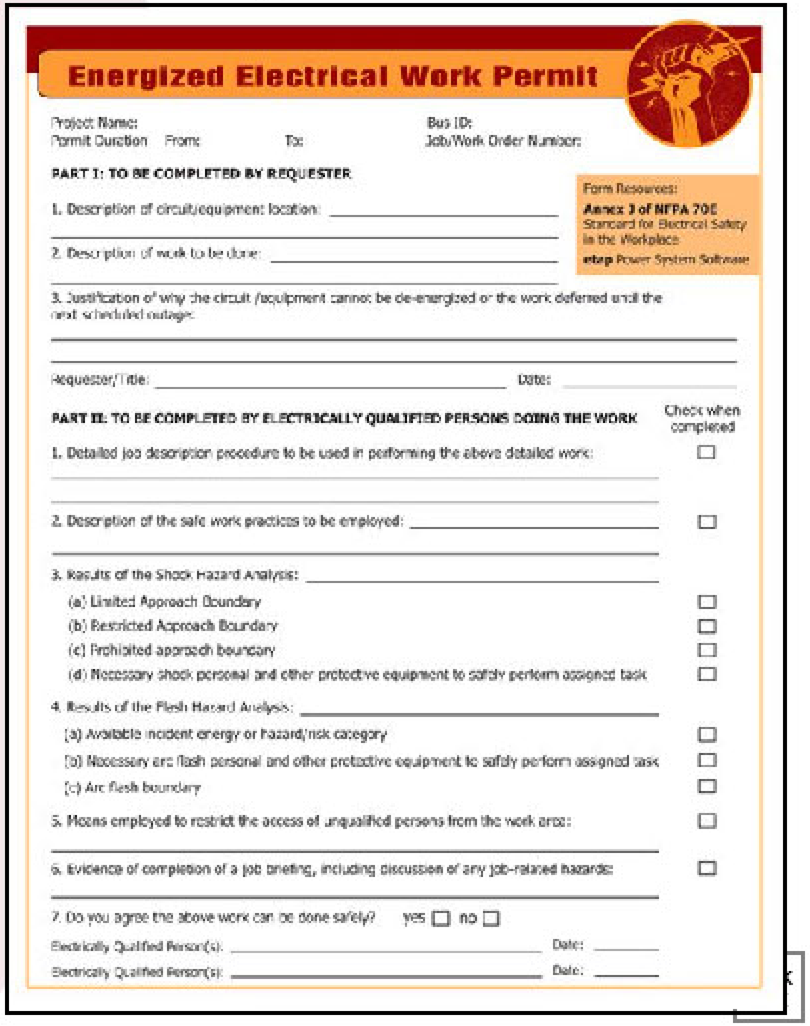
1.4.2 Energized Electrical Work Permit

The overall purpose of an energized electrical work permit (EEWP) is to ensure that the hazards of working on or near exposed live parts are properly considered. It also serves as a notice to equipment operators, managers and employees that work on energized equipment is going to be performed for their protection.



Energized Electrical Work Permit

Project Name: Bus ID:
Permit Duration From: To: Job/Work Order Number:

PART I: TO BE COMPLETED BY REQUESTER

Form Resources:
Annex J of NFPA 70E
Standard for Electrical Safety in the Workplace
etap Power System Software

1. Description of circuit/equipment location:
2. Description of work to be done:
3. Justification of why the circuit /equipment cannot be de-energized or the work deferred until the next scheduled outage:

Requester/Title: Date:

PART II: TO BE COMPLETED BY ELECTRICALLY QUALIFIED PERSONS DOING THE WORK Check when completed

1. Detailed job description procedure to be used in performing the above detailed work: ☐
2. Description of the safe work practices to be employed: ☐
3. Results of the Shock Hazard Analysis:
(a) Limited Approach Boundary ☐
(b) Restricted Approach Boundary ☐
(c) Prohibited approach boundary ☐
(d) Necessary shock personal and other protective equipment to safely perform assigned task ☐
4. Results of the Flash Hazard Analysis:
(a) Available incident energy or hazard/risk category ☐
(b) Necessary arc flash personal and other protective equipment to safely perform assigned task ☐
(c) Arc flash boundary ☐
5. Means employed to restrict the access of unqualified persons from the work area: ☐
6. Evidence of completion of a job briefing, including discussion of any job-related hazards: ☐
7. Do you agree the above work can be done safely? yes ☐ no ☐
Electrically Qualified Person(s): Date:
Electrically Qualified Person(s): Date:

The permit is required under the following conditions:

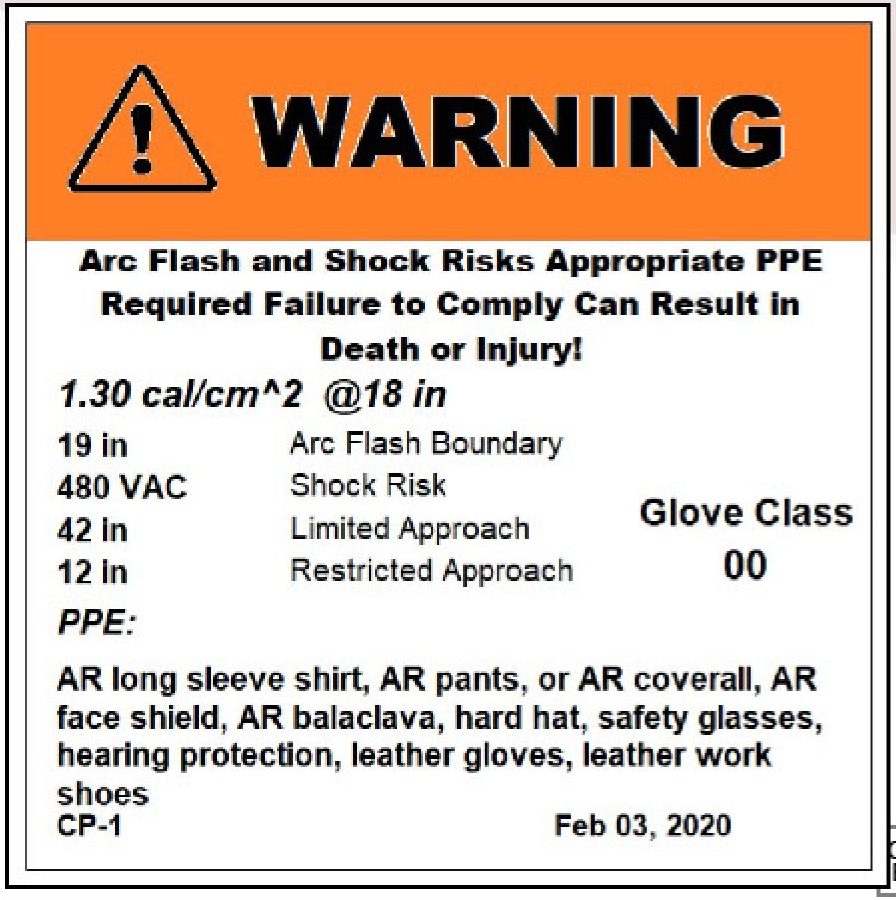
- When work is performed within the restricted approach boundary, or
- When the employee interacts with the equipment when conductors or circuit parts are not exposed but an increased likelihood of injury from an exposure to an arc flash exists.

To develop an EEWP, the first step is to conduct an Arc Flash and Shock Hazard Analysis to determine the category of PPE required, approach boundary information, max fault current and more. The development of the work permit document should then include the following elements:

- The circuit, equipment, and location of the job/task at hand.
- The work that is to be done.
- Justification of why the circuit or equipment cannot be de-energized, or the work deferred until the next scheduled outage.

1.4.2 Energized Electrical Work Permit

- A section for the Electrically Qualified Person to complete an assessment of the task at hand and determine if the job can be done safely. To accomplish this, they need to provide the following information:
  - A detailed job description procedure to be used when performing the job/task at hand.
  - A description of the safe work practices to be employed.
  - Results of the Arc Flash Hazard Analysis and Shock Hazard Analysis which include the exposure voltage.
  - Shock Protection Boundaries.
  - Necessary PPE.
  - Means employed to restrict the access of unqualified persons from the work area.
  - Evidence of completion of a "Job Briefing" including discussion of any job-related hazards.



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1.4.2 Energized Electrical Work Permit

Once completed, the EEWP is not only signed by the Electrically Qualified Person, but also members of the management team, including the safety manager and maintenance manager. Any employee who will be performing tasks under the permit should be fully trained on the NFPA Standard and the permit requirements.

There are several exemptions to the work permit requirement:

- Testing, troubleshooting and voltage measuring
- Thermography and visual inspection if the restricted approach boundary (RAB) is not crossed
- Access/egress from an area with energized electrical equipment with no electrical work and the RAB is not crossed
- General housekeeping and miscellaneous nonelectrical tasks if the RAB is not crossed

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1.5 Electrical Injuries and their Effects on Employees

Electricity is widely recognized as a serious workplace hazard, exposing employees to Injuries such as electric shock and burns. These injuries can range from minor to very serious, given a number of different factors and conditions in the workplace. The following are the most common types of electrical workplace injuries:

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1.5.1 Electric Shock

Electric shock is a reflex response possibly involving trauma which occurs when electrical current passes over or through an employee's body. It usually involves burns and abnormal heart rhythm and unconsciousness. An electrical shock incident occurs when the body becomes part of the electrical circuit as current enters the body at one point and leaves at another. Typically, shock occurs when a person contacts:

- One wire of an energized circuit and the ground.
- A metallic part in contact with an energized wire while the person is also in contact with the ground.

Metallic parts of electric tools and machines can become energized if there is a break in the insulation of their wiring. A low-resistance wire between the metallic case of the tool/machine and the ground- an equipment grounding conductor- provides a path for the unwanted current to pass directly to the ground. This greatly reduces the amount of current passing through the body of the person in contact with the tool or machine. Properly installed, the grounding conductor provides protection from electric shock.

Electrocution occurs when electrical current passes over or through an employee's body resulting in a fatality.

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1.5.2 Falls

Fall injuries of a secondary or indirect nature can occur as a result of an electric shock, which may cause muscles to contract causing an employee to lose his or her balance. An explosion from an electrical incident can also cause a fall to occur. Falls can result in bruises, bone fractures and even death. For example, a fall from a ladder after receiving a small shock can result in a very serious injury.

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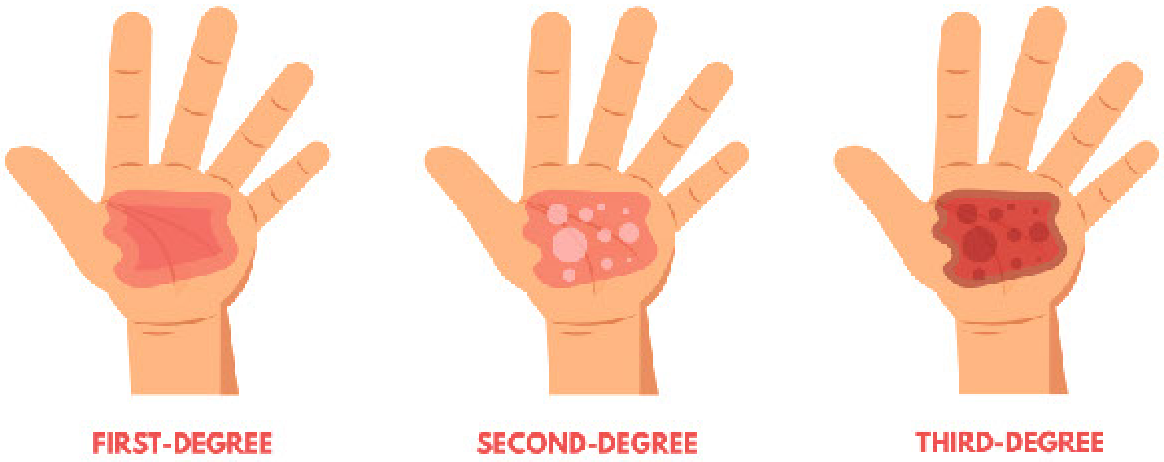
1.5.3 Burns

Burns are the most common shock-related, nonfatal injury. They occur when an employee contacts energized electrical wiring or equipment. Although electrical burns can occur anywhere on the body, they most often occur on the hands and feet.

Human skin provides great protection from normal elements; however, human skin provides poor protection from extreme heat which is a byproduct of exposure to electricity. Typically, there are three types of burns:



It should be noted that, in some circumstances, all three types of burns may be produced simultaneously.

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1.5.4 Electricity and the Human Body

It is well known that the human body will conduct electricity. If direct body contact is made with an electrically-energized part while a similar contact is made simultaneously with another conductive surface that is maintained at a different electrical potential, a current will flow, entering the body at one contact point, traversing the body, and then exiting at the other contact point, usually the ground.

It is important to know just how much electricity is dangerous to the human body. The chart on this slide demonstrates the effects that can range from a barely perceptible tingle to severe burns and immediate cardiac arrest. Although it is not known the exact injuries that result from any given amperage, the provided table demonstrates a general relationship for a shock of only one second's duration.

Electrical Shock Effects on Human Body

Current Levels (Milliamps)	Probable Effect on Human Body
1mA	Slight tingling sensation. (Still dangerous under some conditions.)
5mA	Slight shock felt. Disturbing but not painful. Average person can let go.
6mA – 16mA	Painful shock causing some loss of muscle control. Commonly termed "let go" range or freezing current.
17mA- 99mA	Extreme pain, respiratory arrest, severe muscle contractions, individual cannot let go. Death is possible.
100mA – 2000mA	Ventricular fibrillation, muscular contraction and nerve damage. Death is likely.
Over 2000mA	Cardiac arrest. Internal organ damage and severe burns. Death is probable.

1.5.4 Electricity and the Human Body

The effects of electric shock on the human body depend on several factors, some of which are:

- **General health of the employee.** When the incident occurs, the heart health and muscular structure of the body will affect the significance of the injury incurred.
- **Path of the current.** For example, a small current that passes from one extremity through the heart to the other extremity is capable of causing severe injury or electrocution.
- **Resistance.** The body has resistance to current flow. More than 99% of the body's resistance to electric current flow is at the skin. Studies have shown that the electrical resistance of the human body varies with the presence of moisture, as well as the pressure applied to the contact point and the contact area itself.
- **Amount of current or voltage through the body.** Although high voltage often produces massive destruction of tissue at contact locations, it is generally believed that the detrimental effects of electric shock are due to the current actually flowing through the body. Even though Ohm's law (I=E/R) applies, it is often difficult to correlate voltage with damage to the body because of the large variations in contact resistance usually present in accidents. Any electrical device used on a house wiring circuit can, under certain conditions, transmit a fatal current.

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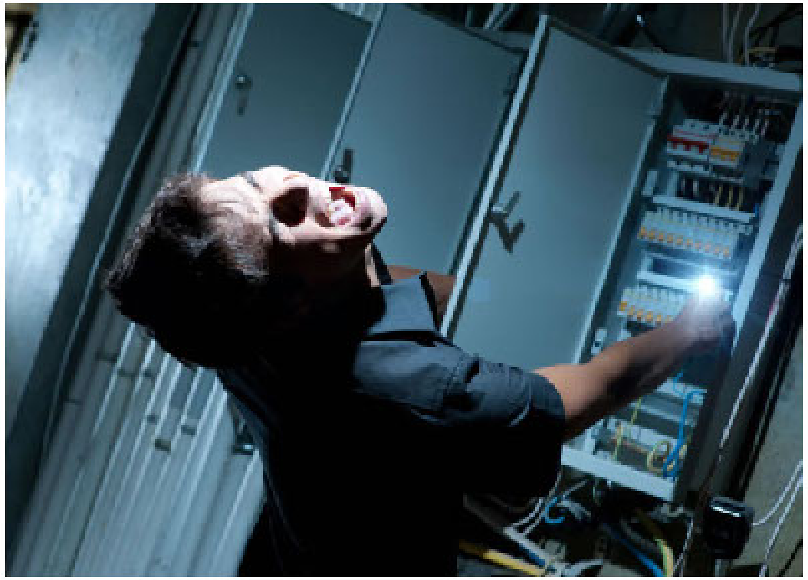
1.5.4 Electricity and the Human Body



- With increasing alternating current, the sensations of tingling give way to contractions of the muscles. The muscular contractions and accompanying sensations of heat increase as the current is increased. Sensations of pain develop, and voluntary control of the muscles that lie in the current pathway becomes increasingly difficult. As current approaches 15 mA, the victim cannot let go of the conductive surface being grasped and is said to "freeze" to the circuit, referred to as the "let-go" threshold. As current approaches 100 mA, ventricular fibrillation of the heart occurs, defined as "very rapid uncoordinated contractions of the ventricles of the heart resulting in loss of synchronization between heartbeat and pulse beat." Once it occurs, it will continue until death ensues within a few minutes.

- **Duration of the shock.** The length of time the body is in the circuit has a significant bearing on the final outcome. If the shock is of short duration, it may only be a painful experience for the person and the heart may stop during current passage, only to restart normally on current interruption, improving the victim's chances for survival.

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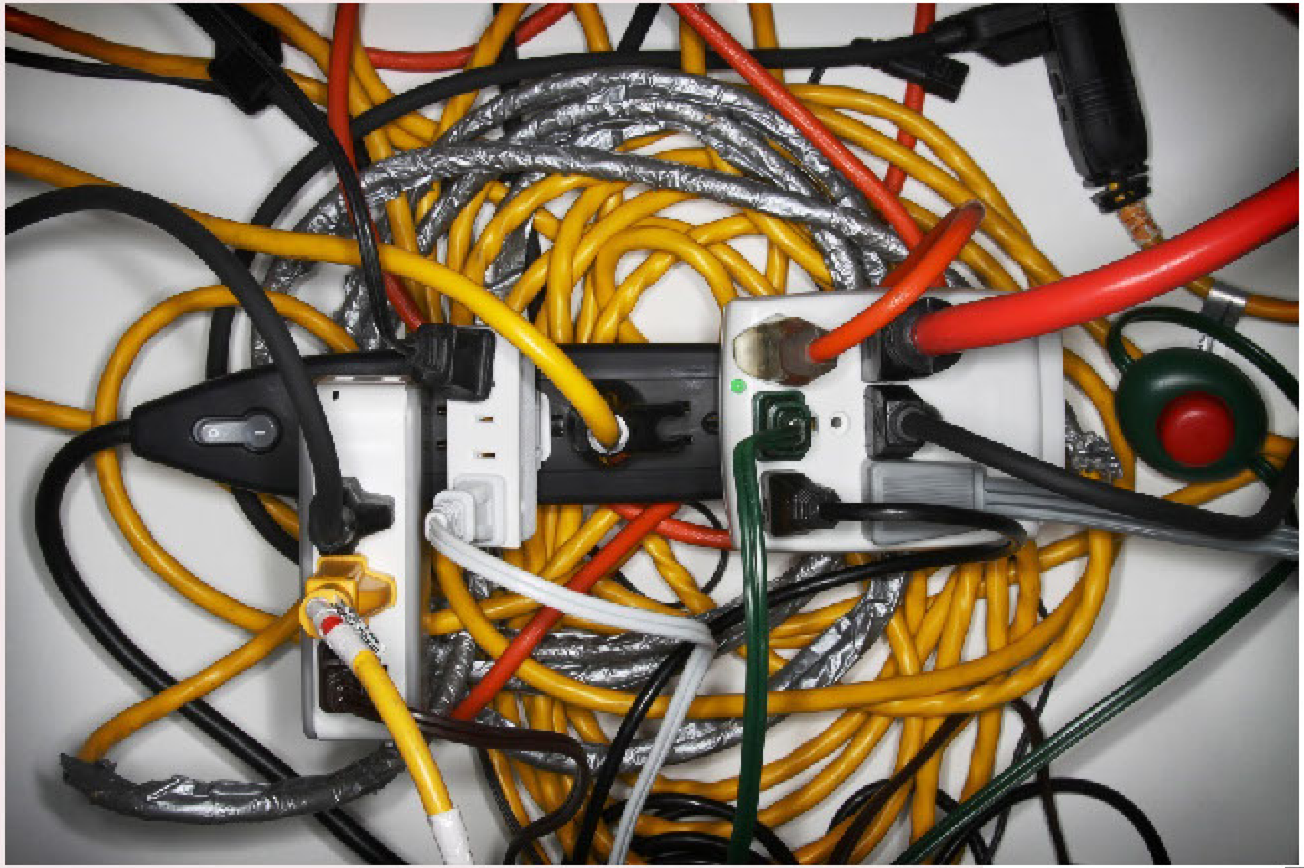
2.0 Electrical Hazards and Control Measures

The identification of electrical hazards and control measures that address them is a critical step in the process of ensuring the protection and safety of employees at the workplace. An electrical hazard is defined as a dangerous source of possible injury or damage to health such that making contact or equipment failure can result in electrical shock, arc-flash burn, thermal burn, or blast. Many employees are unaware of the potential electrical hazards present in their work environment, which makes them much more vulnerable to the risks of injury or damage to their health.



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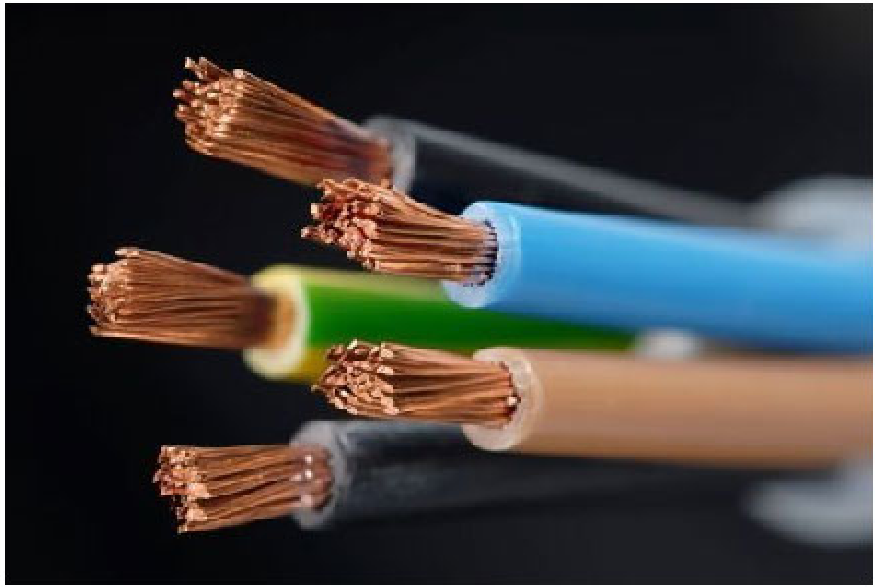
2.2 Electrical Control Measures



Electrical incidents are caused by many different events; however, the underlying root cause can be a combination of three possible factors for just about any electrical incident:

- Work on unsafe equipment and installations
- Unsafe workplace environments, such as the presence of moisture of flammable vapors
- Unsafe work practices, such as the failure to de-energize or work performed in close proximity to energized parts

There are a number of ways to protect employees from the threat of electrical hazards. Some methods are for the protection of qualified employees doing work on electrical circuits, while other methods are geared towards nonqualified employees who work near energized equipment.

Click Box

2.2 Electrical Control Measures

The NFPA standard depicts several control measures that can be taken to address these root causes, of which the following are just a few:

- Consider every electrical conductor or circuit part energized until proven otherwise
- De-energize an electrical conductor or circuit part and make it safe to work, which is itself, a potentially hazardous task
- Identify and categorize tasks to be performed on or near exposed energized electrical conductors and circuit parts
- Utilize appropriate equipment and tools to prevent an electrical incident from occurring
- Use procedures as “tools” to identify the hazards and develop plans to eliminate or control the hazards
- Identify and use precautions appropriate to the working environment

Some of the many ways to prevent incidents and protect against electrical hazards are through the use of electrical protective devices, grounding, guarding, insulation, enclosures, warnings or labels, and safe de-energizing practices. Also reviewed in this section are hazardous locations and the control measures to be taken to ensure that hazards are eliminated or reduced for work to be performed in or around them.

2.2.1 Electrical Protective Devices

As a power source, electricity can create conditions almost certain to result in bodily harm, property damage, or both. It is important that employees understand the availability and use of electrical protective devices such as fuses, circuit breakers, and ground-fault circuit-interrupters (GFCIs). These devices are considered circuit protectors and are critically important to electrical safety as they limit or stop the flow of current automatically should a ground fault, overload or short circuit occur in a wiring system. The following are examples of such devices:

Click Box

2.2.1 Electrical Protective Devices

Fuses

A fuse is an electrical device that opens a circuit when the current flowing through it exceeds the rating of the fuse. Fuses are designed to protect equipment and conductors from excessive current. The "heart" of a fuse is a special metal strip (or wire) designed to melt and blow out when its rated amperage is exceeded.

Circuit Breaker

Circuit breakers provide protection for equipment and conductors from excessive current without the inconvenience of changing fuses. Circuit breakers trip (open the circuit) when the current flow is excessive.

Ground-Fault Circuit-Interrupter

GFCIs are used in wet locations and other high-risk areas, as they interrupt the flow of electricity with as little as 1/40 of a second to prevent electrocution. They compare the amount of current going into electric equipment with the amount of current returning from it along the circuit conductors. If the difference exceeds 5 milliamperes, the device automatically shuts off the electric power.

2.2.2 Grounding

The requirement for effective grounding is one of the most frequently cited violations of OSHA's electrical standards. Grounding must be considered wherever electrical current flows. Proper grounding and bonding must be correctly applied if the system, the equipment, and the people that come in contact with them are to be protected. To be effective, the path to ground must:

- Be permanent and continuous
- Have ample current-carrying capacity to safely conduct any currents imposed on it
- Have impedance sufficiently low to limit the potential above ground and to facilitate the operation of the overcurrent devices in the circuit

2.2.3 Guarding of Live Parts

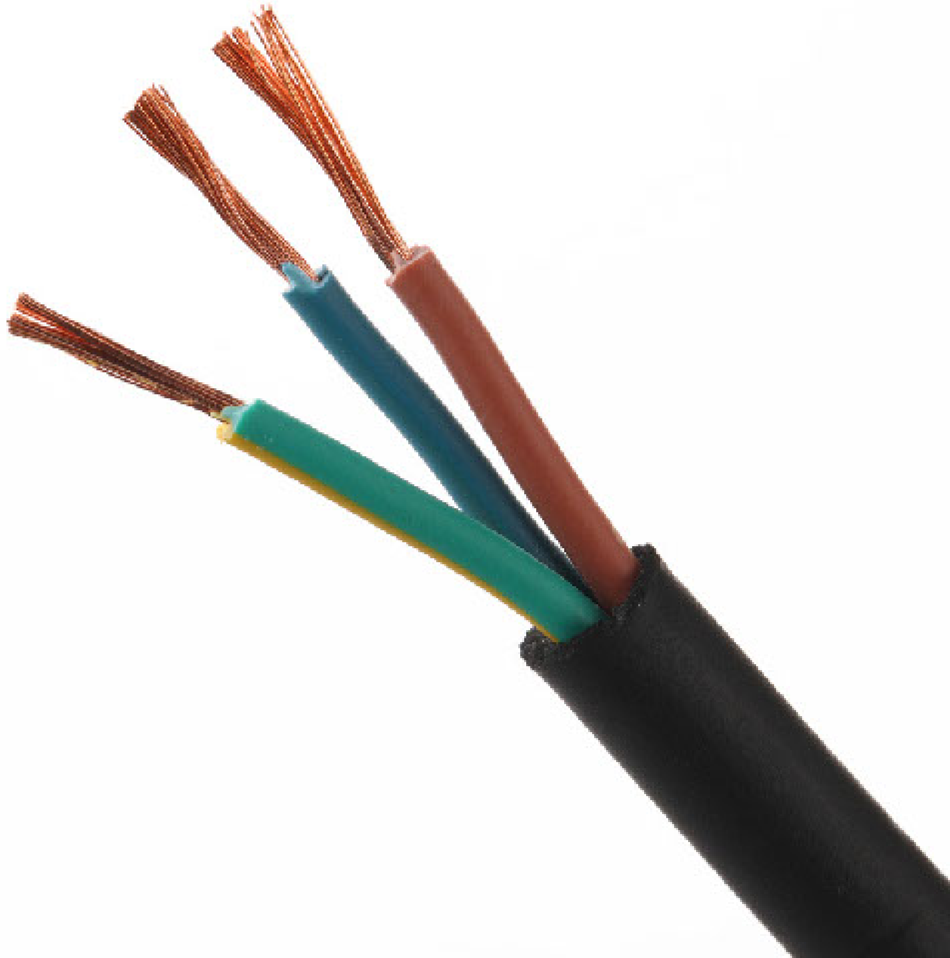
Live parts of electric equipment operating at 50 volts or more must be guarded against accidental contact by approved cabinets, enclosures, or partitions making them accessible only to qualified persons or elevation of 8 ft. or more above the floor or working surface. Entrances to guarded locations must be marked with conspicuous warning signs. An employer must also enclose or guard electric equipment in locations where it could potentially be exposed to physical damage.

Click Box

2.2.4 Insulation

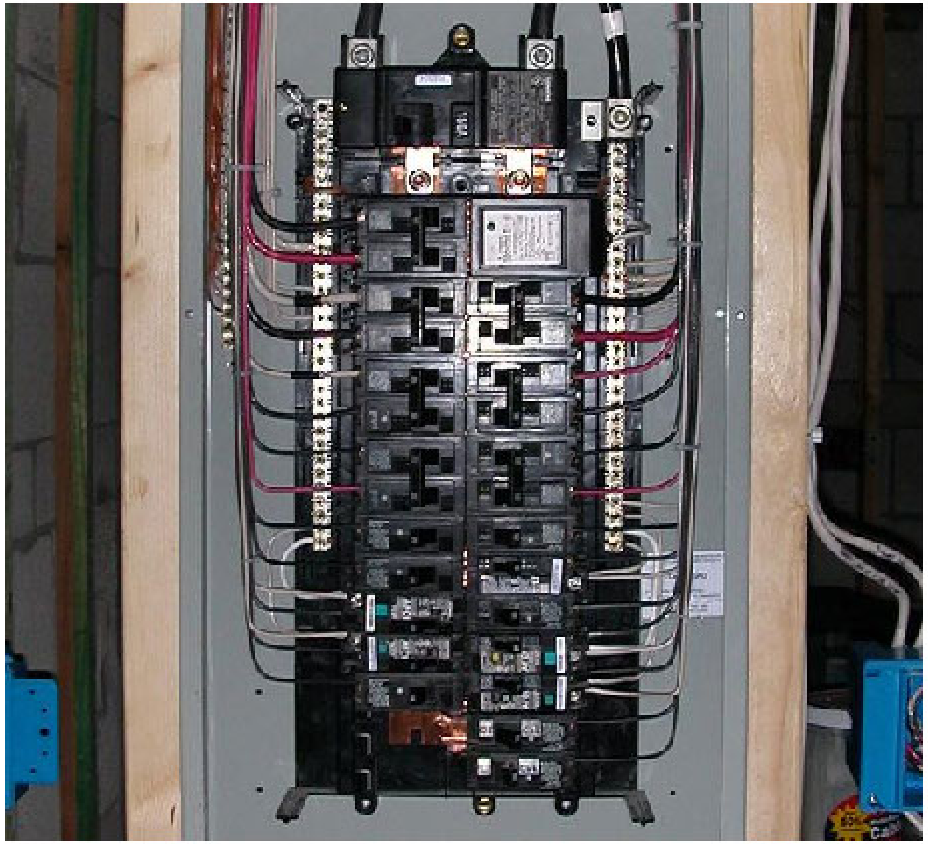
Electrical insulation plays an important role in product safety and the resulting employee safety for those who work with electrical equipment or components. Insulation is typically composed of a unique combination of materials that have been verified for chemical compatibility when used at certain maximum temperatures. These combinations are arranged to form insulation systems for applications such as motors and transformers.

As temperatures rise, the chemicals react with each other and deteriorate insulation properties, such as flame resistance in the insulation coating of conductor wires. This deterioration of insulation performance will result in not only product failure but also an electrical fire hazard. As a result, it is important that an employer consider the protective measures that insulation can provide upon purchase of new equipment and electrical components.



2.2.5 Cabinets, Boxes, and Other Enclosures

Conductors entering boxes, cabinets, or fittings can be damaged if they rub against the sharp edges of cabinets, boxes, or fittings. Therefore, they must be protected from damage at the point of entrance. To protect the conductors, some type of clamp or rubber grommet must be used. The device used must close the hole through which the conductor passes as well as provide protection from abrasion. If the conductor is in a conduit and the conduit fits tightly in the opening, additional sealing may not be required.



The knockouts in cabinets, boxes, and fittings should be removed only if conductors are to be run through them. However, if a knockout is missing or if there is another hole in the box, the hole or opening should be closed.

All pull boxes, junction boxes, and fittings should be provided with covers approved for the purpose. If metal covers are used, they should be grounded. In completed installations, each outlet box should have a cover, faceplate, or fixture canopy. Covers of outlet boxes having holes through which flexible cord pendants pass should be provided with bushings designed for the purpose or have smooth, well-rounded surfaces on which the cords can rest.

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2.2.5 Cabinets, Boxes, and Other Enclosures

Exposed live parts of motors and controllers operating at 50 volts or more between terminals should be guarded against accidental contact by any of the following:

- By installation in a room or enclosure that is accessible only to qualified persons
- By installation behind substantial partitions or screens that is accessible only by qualified persons. Any openings in the partitions or screens should be designed and located so that unqualified persons are not likely to accidentally come in contact with live electrical parts
- By installation on a balcony or platform elevated as to prevent access by unqualified persons, or
- By installation at an elevation of 8 ft. or more above the working surface

2.2.5 Cabinets, Boxes, and Other Enclosures

Blocking electrical panels that house circuit breakers is a violation of both OSHA regulations and NFPA codes. These regulations require accessibility to the front of electrical panels to have a minimum of three feet of clearance and a minimum width to be the width of the equipment or 2.5 feet, whichever is greater. This assures that in case of an electrical emergency, there is a clear working space in front for quick access to the circuit breakers.

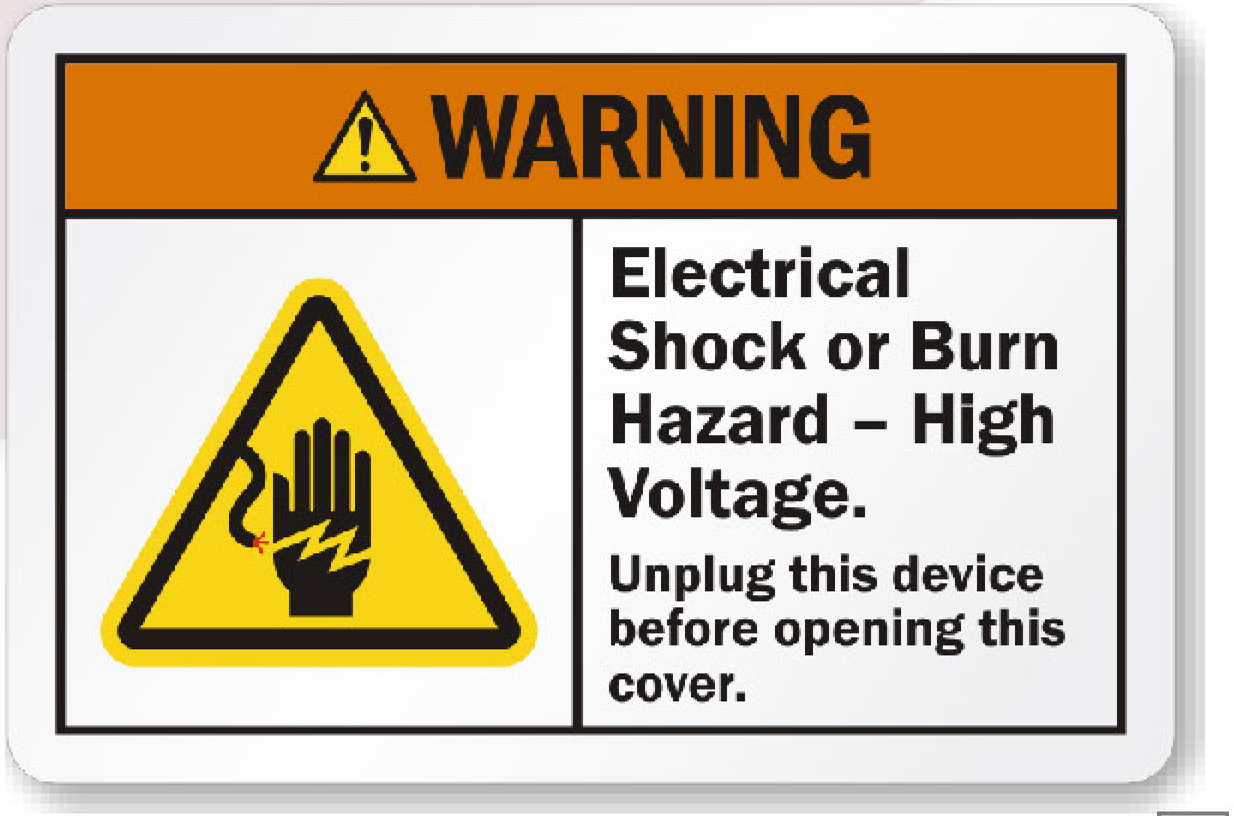
Pull and junction boxes for systems over 600 volts should be provided a complete enclosure for the containment of conductors or cables. Boxes should be closed by suitable covers securely fastened in place. Underground box covers that weigh over 100 pounds meet this requirement. Covers for boxes should be permanently marked "HIGH VOLTAGE." The marking should be on the outside of the box cover and be readily visible and legible. Also required is the securing of panel doors to prevent them from swinging into an employee.

Click Box

2.2.6 Warnings and Labels

The use of alerting techniques are effective ways to warn employees (especially non-qualified employees) of the dangers present. Alerting techniques might include safety signs, safety symbols, or accident prevention tags. Oftentimes, the use of such signs alone is not adequate as an employee (especially a non-qualified employee) may accidentally come in direct contact with an energized circuit. In these instances, a barricade should be used in conjunction with safety signs.

A barricade is an effective way to prevent or limit employee access to work areas exposing employees to uninsulated energized conductors or circuit parts. Conductive barricades may not be used where they might cause an electrical contact hazard. If signs and barricades do not provide sufficient warning and protection from electrical hazards, an attendant should be stationed to warn and protect employees.



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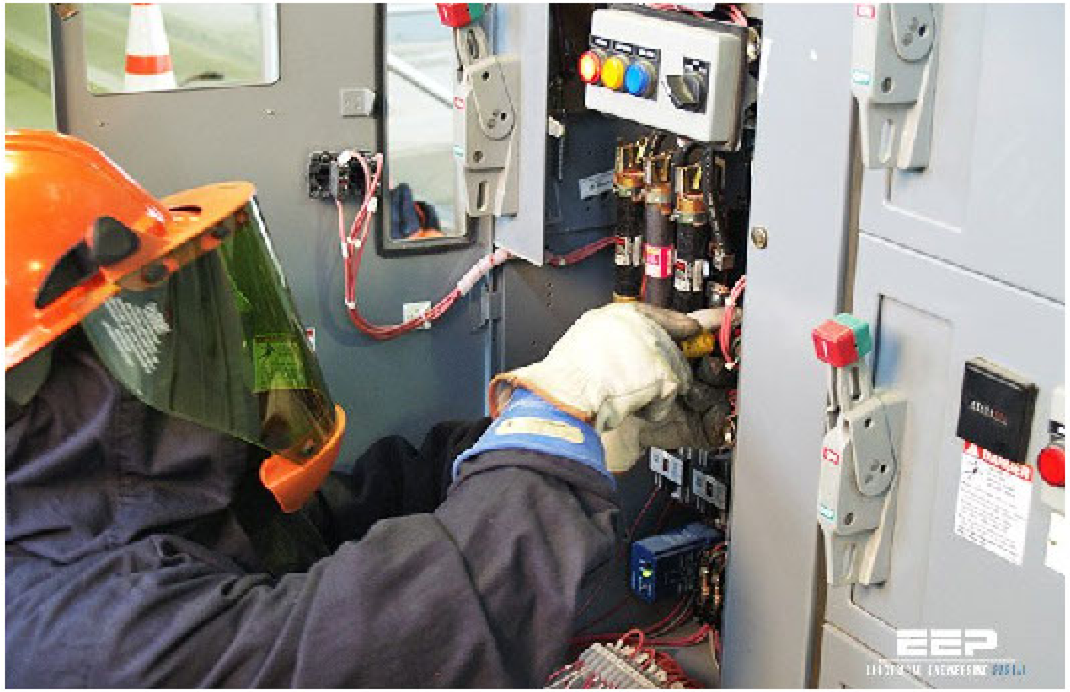
2.2.7 Safe De-Energizing Practices



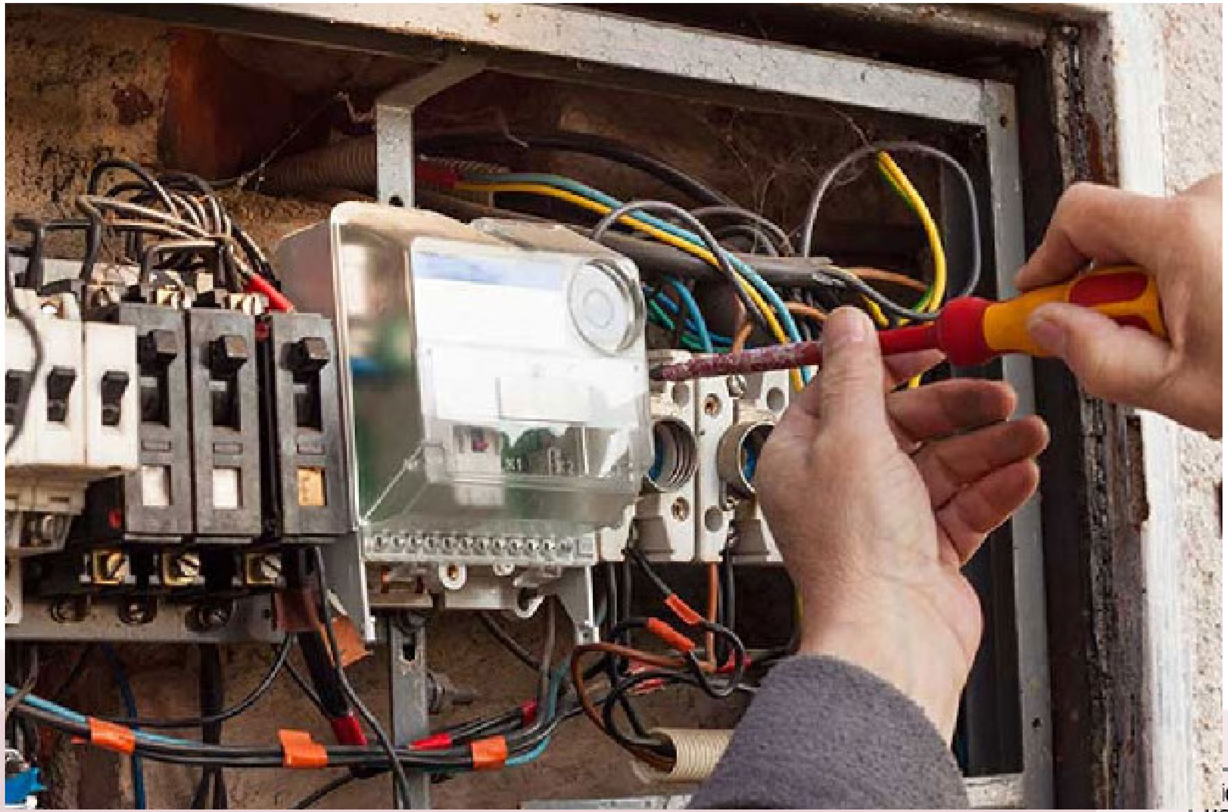
Many electrical lines, circuits, and systems are worked on while energized. This is often because the system loading or its configuration, or both, makes it impossible to de-energize the system, or because continuity of customer service must be maintained. However, some work can only be done with the system de-energized, such as splicing underground cable or work inside a boiler.

Click Box

2.2.7 Safe De-Energizing Practices

OSHA requires that live electrical parts be de-energized before the employee works on or near them, unless the employer can demonstrate that de-energizing introduces additional or increased hazards or is infeasible due to equipment design or operational limitations. OSHA regulations do acknowledge that sometimes it is infeasible to de-energize electrical equipment and allowances have been made for this. Such allowances include the testing of electric circuits that can only be performed with the circuit energized or when de-energizing would increase current hazards or create additional hazards, including such times as:

- Interruption of life support equipment
- Deactivation of emergency alarm systems
- Shutdown of hazardous location ventilation equipment
- Removal of illumination for an area



2.2.7 Safe De-Energizing Practices

If it has been determined that de-energizing a circuit is not feasible, and the employee must work "hot," the employer should develop and enforce safety-related work practices to prevent electric shock or other injuries resulting from either direct or indirect electrical contacts. The specific safety-related work practices should be consistent with the nature and extent of the associated electrical hazards, some of which could include:

- Energized Electrical Work Permit
- Personal Protective Equipment
- Insulated Tools
- Written Safety Program

To perform energized work, employees must first be thoroughly trained and proficient in the work practices adopted, utilizing the appropriate personal protective equipment. Any employee who has not been trained and has not demonstrated proficiency is considered unqualified under OSHA regulations and cannot get closer to energized parts than the minimum approach distances specified in the standard for the voltages involved.

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2.2.8 Lockout and Tagout

Because a deenergized circuit can easily be energized while an employee is working on it, the circuits energizing the parts should be locked and tagged out. Electric equipment that has been deenergized but has not been locked or tagged out should always be treated as energized parts. The employer should develop and maintain a written copy of the lockout/tagout procedures established and make it available to all employees. Lockout tagout procedures should be followed in accordance with an employer's written electrical safety program. Lockout/tagout is an integral step in the establishment of a safe condition as described in the last section of this course, Electrical Safety Program.

Click Box

2.2.8 Lockout and Tagout

Only qualified persons may work on electric circuit parts or equipment that have not been deenergized. Such persons should be capable of working safely on energized circuits and be familiar with the proper use of special precautionary techniques, personal protective equipment, insulating and shielding materials, and insulated tools. A more detailed definition of a "qualified person" appears in the last section of this course entitled, Electrical Safety Program."

It is important to understand the distinction between the OSHA and NFPA electrical standards and OSHA standard, "Control of Hazardous Energy" (Lockout/Tagout). The lockout/tagout standard helps safeguard employees from hazardous energy while they are performing servicing or maintenance on machines and equipment. The standard covers electrical energy sources, but it specifically excludes "exposure to electrical hazards from work on, near, or with conductors or equipment in electrical utilization installations." Thus, the lockout/tagout standard does not cover electrical hazards associated with conductors and equipment but only covers that electrical equipment which relates to general machinery and equipment.

Click Box

2.2.8 Lockout and Tagout

Disconnecting Motors

When disconnecting motors, a disconnecting means should be located in sight from the controller. The means should disconnect the motor and the controller from all ungrounded supply conductors and should be designed such that no pole can be operated independently. If a motor and the driven machinery are not in sight from the controller location, the installation should comply with one of the following conditions:

- The controller disconnecting means should be capable of being locked in the open position.
- A manually operable switch that will disconnect the motor from its source of supply should be placed in sight from the motor location.

The disconnecting means should plainly indicate whether it is in the open (off) or closed (on) position and be readily accessible. If more than one disconnect is provided for the same equipment, only one need be readily accessible. Additionally, motors, motor-control apparatus, and motor branch-circuit conductors should be protected against overheating due to motor overloads or failure to start, and against short-circuits or ground faults.

2.2.9 Hazardous (Classified) Locations

Hazardous (classified) locations are those areas where a potential for explosion and fire exist because of flammable gases, vapors, or finely pulverized dusts in the atmosphere, or because of the presence of easily ignitable fibers or flyings. Hazardous locations may result from the normal processing of certain volatile chemicals, gases, and grains, or it may result from accidental failure of storage systems for these materials. It is also possible that a hazardous location may be created when volatile solvents or fluids, used in a normal maintenance routine, vaporize to form an explosive atmosphere.

Hazardous locations can be found in occupancies such as aircraft hangars, gasoline dispensing and service stations, bulk storage plants for gasoline or other volatile flammable liquids, paint-finishing process plants, health care facilities, agricultural or other facilities where excessive combustible dusts may be present, marinas, boat yards, and petroleum and chemical processing plants.

Substance	Substance Class	Area Classification NEC500	NEC505	Hazardous Location Characteristics
Gases/ Vapors	Class I (NEC 501)	Division 1	Zone 0	Explosion hazard present continuously or occasionally under normal operating conditions
			Zone 1	
		Division 2	Zone 2	Ignitable concentrations of flammable gases or vapors are not normally present, but could be present in the case of a fault
Dusts	Class II (NEC 502)	Division 1	Zone 20	Combustible dusts are present in quantities sufficient to produce explosive and ignitable
			Zone 21	
		Division 2	Zone 22	Combustible dust due to abnormal operations may be present in quantities sufficient to produce explosive or ignitable mixtures
Fibers	Class III (NEC 503)	Division 1	Not equivalent	Easily ignitable fibers/flyings are handled or manufactured
		Division 2		Easily ignitable fibers/flyings are stored or handled

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2.2.9 Hazardous (Classified) Locations

To determine the proper classification, each room, section, or area should be considered individually. Regardless of the cause of a hazardous location, it is necessary that every precaution be taken to guard against ignition of the atmosphere. Obviously, no open flames should be permitted in these locations. However, there are other potential sources of ignition, including electrical equipment.

The normal operation of switches, circuit breakers, motor starters, contactors and plugs and receptacles release energy in the form of arcs and sparks as contacts open and close, making, and breaking circuits. Electrical equipment such as lighting fixtures and motors are classified as "heat-producing," and can become a source of ignition if they reach a surface temperature which exceeds the ignition temperature of the particular gas, vapor, or dust in the atmosphere. It is also possible that an abnormality or failure in an electrical system could provide a source of ignition. The failure of insulation from cuts, nicks or aging can also act as an ignition source again from sparking, arcing and heat.

There are several OSHA standards that regulate the installation of electrical wiring and equipment in hazardous (classified) locations which provide the necessary control measures to ensure a safe and protected working environment for employees required to work in these locations.

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3.0 Arc Flash and Arc Blast

Both an arc flash and an arc blast pose serious hazards in an electrical or industrial workplace. However, it is possible to prevent these by following proper safety practices and utilizing the right equipment for the best protection.

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3.0 Arc Flash and Arc Blast

Both an arc flash and an arc blast pose serious hazards in an electrical or industrial workplace. However, it is possible to prevent these by following proper safety practices and utilizing the right equipment for the best protection.

An arc flash is the light and heat produced from an electric arc supplied with sufficient electrical energy to cause substantial damage, fire, or injury. Electrical arcs experience negative incremental resistance, which causes the electrical resistance to decrease as the arc temperature increases. Therefore, as the arc develops and gets hotter, the resistance drops, drawing more and more current (runaway) until some part of the system melts, trips, or evaporates, providing enough distance to break the circuit and extinguish the arc. Click the play button on the bottom image to see the power of both an arc flash and blast when completed at a testing facility.

Electrical arcs, when well-controlled and fed by limited energy, produce very bright light, and are typically used in arc lamps for welding, plasma cutting, and other industrial applications. Welding arcs can easily turn steel into a liquid with an average of only 24 DC volts. When an uncontrolled arc forms at high voltages, and especially where large supply-wires or high-amperage conductors are used, arc flashes can produce deafening noises, supersonic concussive-forces, super-heated shrapnel, temperatures far greater than the Sun's surface, and intense, high-energy radiation capable of vaporizing nearby materials.

3.0 Arc Flash and Arc Blast

A typical arc flash incident may be inconsequential; however, it could easily produce a more severe explosion, called an arc blast. As the arc flash explosion emits heat and light, a pressure wave present creates the arc blast. The arc blast releases radiant energy that is about four times hotter than the surface of the sun's surface into the air. This energy is enough to melt metals within its range. The result of the violent event can cause destruction of equipment, fire, and injury to employees working in the area and at a far distance. In addition to the arc blast, destruction also arises from the intense radiant heat produced by the arc, which produces tremendous amounts of light energy from infrared to ultraviolet. Surfaces of nearby objects, including people, absorb this energy and are instantly heated to vaporizing temperatures.

While the arc flash is distinctly different from the arc blast, both are part of the same arc fault, and are often referred to as simply an arc flash. From a safety standpoint, they should be treated separately. For example, personal protective equipment can be used to effectively shield an employee from the radiation of an arc flash; however, that same PPE may likely be ineffective against the flying objects, molten metal, and violent concussion that the arc blast can produce. For this reason, other safety precautions need to be taken in addition to wearing PPE, to help prevent serious injury.

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3.1 Injuries Caused by an Arc Flash and Arc Blast

Any individual within the area of an arc flash incident may suffer from serious injuries and even death. An arc flash is very hot, which can cause massive burns to employee's skin. Even if the employee is several feet away from the incident, they still may be at risk for burns. Unprotected clothing ignites right away upon exposure to an arc flash. While there is a treatment for burns caused by an arc flash, there still may be years of recovery with survival rates being lower the higher the percentage of the body is burned.

Eye damage also arises from arc flash incidents. If an employee does not wear the required eye protection, they may be hit in the eyes with molten debris and projectiles. Damages to the retina often result from the harsh UV radiation that accompanies the arc flash.

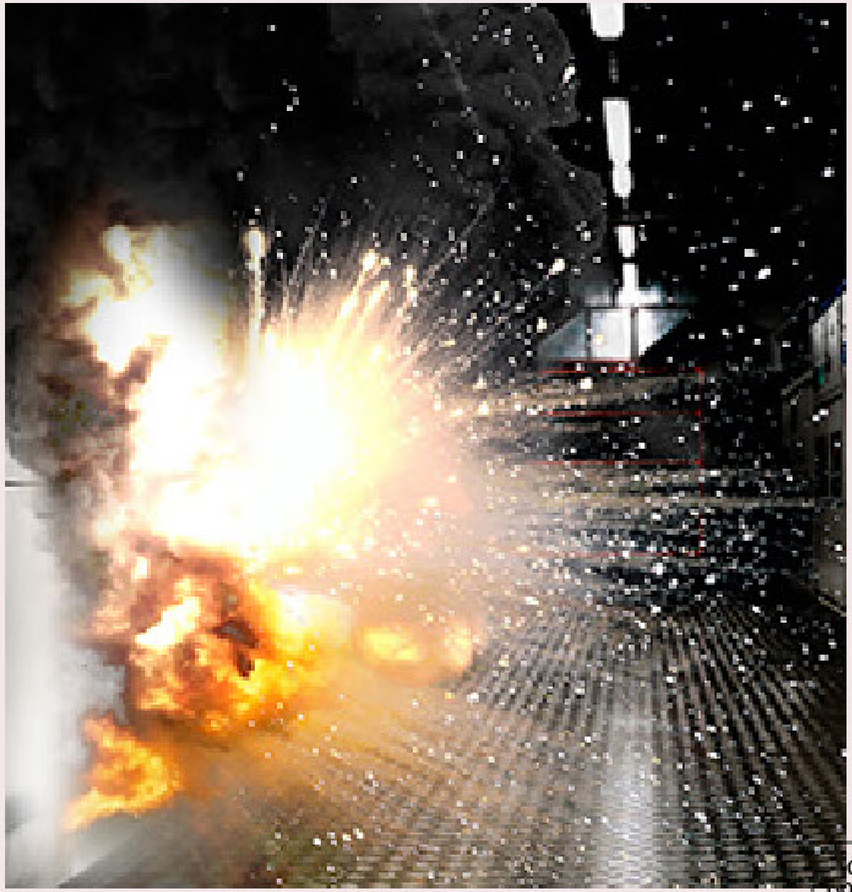
Click Box

3.1 Injuries Caused by an Arc Flash and Arc Blast

Respiratory problems, such as breathing impairment and lung injury, impacts an individual near an arc flash. Massive heated vapors make it difficult to breathe, which leads to serious lung damage. Other internal organs may also be susceptible to injuries because of the thermoacoustic blast. The powerful blast can knock people off their feet, increasing the chances of a fatality from falls or electrocution.

Additional types of serious injuries that result from an arc blast may include:

- Memory loss due to a concussion
- Shock hazard from touching an energized conductor
- Hearing loss due to the loud sound that is created with the pressure wave
- Shrapnel wounds resulting from flying debris
- Inhalation of toxic gases from vaporized metals
- Trauma from the blast pressure



3.2 Arc Flash Hazards

Spikes or voltage transients often cause arc flashes and resulting arc blasts. When lightning strikes, or upon switching reactive loads, such voltage transients occur. Although it takes only a few microseconds for the transient to last, it is accompanied by thousands of enormous amps of energy and plasma arcs.

In addition to spikes, there are several other hazards that can contribute to an arc flash incident. They include:

- Exposed energized electrical conductors or circuit parts
- Broken conductor insulation
- Static electricity
- Blocked disconnect panels
- Resistance heating due to corrosion and dust

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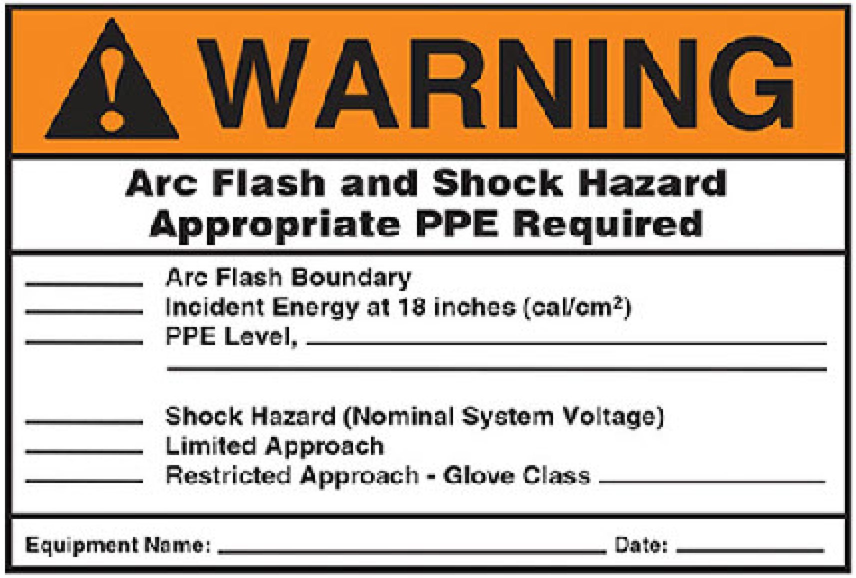
3.2 Arc Flash Hazards

- Worn connections
- Equipment not properly installed or maintained, such as circuit breakers
- Faulty or damaged electrical equipment
- High voltage cables

Lastly, and most importantly, is the hazard generated by the human element. For the most part, carelessness, a lack of compliance with safety guidelines, and poor safety work practices result in arc flashes and blasts. While employees may be well-trained, there is always the chance that their inability to perform safety procedures or maintain focus on their tasks can created hazards in the workplace.

3.3 Arc Flash Risk Assessment



A risk assessment for the potential of an arc flash incident is an overall process that identifies hazards, estimates the potential severity of injury or damage to health, estimates the likelihood of occurrence of injury or damage to health, and determines if protective measures are required. The results of the assessment will determine flash protection boundaries and the PPE requirements as a function of location and work activity. Arc flash boundaries vary with the type of equipment and configuration, available short circuit current, the voltage, the predicted fault duration protective devices upstream on the arcing fault and their settings.

Integral in this assessment is the determination of the "incident energy" of an arc flash event. This is the amount of thermal energy impressed on a surface, a certain distance from the source, generated during an electrical arc event. There are several methods used to determine the incident energy of an arc flash event and the arc flash boundary equations, each with their own benefit and potential cost. It is recommended for smaller companies that a professional consultant is utilized to develop the assessment. For larger organizations, the NFPA Standard provides tables and equations that can be utilized, or the employer can purchase appropriate software programs to help in the running of the assessment. Whatever approach is taken to complete the assessment should result in the posting of these boundaries and the training of employees to understand and respect them.

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3.4 Arc Flash Control Measures

Three key factors determine the intensity of an arc flash: the quantity of fault current available in a system, the time until an arc flash fault is cleared, and the distance an individual is from a fault arc. Various design and equipment configuration choices can be made to affect these factors and, in turn, reduce the arc flash hazard.

- *Fault current* can be limited by using current-limiting devices such as breakers, grounding resistors or fuses.

- *Arcing time* can be reduced by temporarily setting upstream protective devices to lower setpoints during maintenance periods, allowing for faults in the circuit to be cleared by the breaker nearest to the fault, minimizing the effect on the entire system. It can also be reduced by protection based on detection of arc-flash light. One of the most efficient means to reduce arcing time is the use of an arc eliminator which extinguishes the arc within a few milliseconds by creating a short-circuit on another part of the system, diverting the arc flash to another location. Lastly, another way to mitigate arc flash is to use a triggered current limiter which inserts a low-rated continuous current-limiting fuse that melts and interrupts the arc flash, eliminatingthe arc flash at the source.

- *Distance* poses a challenge in the implementation of control measures. The radiant energy released by an electric arc is capable of permanently injuring or killing a human being at distances of up to 20 feet. The distance from an arc flash source within which an unprotected person has a 50% chance of receiving a second-degree burn is referred to as the "approach boundary."

Beyond those listed, there are a number of other engineering, administrative and personal protective equipment control measures that should be considered in a workplace which has identified potential arc flash hazards during the risk assessment process.

3.5 Limits of Approach Boundaries

Observing a safe approach distance from exposed energized electrical conductors or circuit parts is an effective means of maintaining electrical safety. As the linear distance between a person and the exposed energized conductors or circuit parts decreases, the potential for electrical incidents increases.

When an arc-flash hazard exists, boundaries are determined as an approach limit at a distance from a prospective arc source within which a person could receive a second-degree burn if an electrical arc flash were to occur. A second-degree burn is possible by an exposure of unprotected skin to an electric arc flash above a certain incident energy level as established in the risk assessment.

It is important to understand that staying outside the arc-flash boundary does not guarantee that an employee will not be burned by an arc-flash incident. It just means that the employee could receive a curable burn, rather than a more serious or fatal burn.

Skin Temperature	Duration	Damage Caused
110 F	6 hours	Cell breakdown begins
158 F	1 second	Total cell destruction
176 F	.01	Curable (2nd Degree) burn
205 F	.01 second	Incurable (3rd Degree) burn

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3.5 Limits of Approach Boundaries

The OSHA electrical standards also identify required minimum approach distances (MAD) that must be maintained, based on the voltage involved, by unprotected qualified employees when exposed to energized parts. While these distances are based on shock protection and not arc flash protection, they are incorporated within the arc flash boundaries, as depicted at the bottom of the above diagram. Included in the various requirements are proper work techniques, equipment, and PPE for each distance, with additional standard tables providing guidance for adjusting MADs for alternative conditions and situations. An employer is advised to review the MAD values and incorporate them into their workplace procedures should they be applicable to their workplace.

Table R-6—Alternative Minimum Approach Distances for Voltages of 72.5 kV and Less[1]

Nominal voltage (kV) phase-to-phase	Distance			
	Phase-to-ground exposure		Phase-to-phase exposure	
	m	ft	m	ft
0.050 to 0.300[2]	Avoid Contact		Avoid Contact	
0.301 to 0.750[2]	0.33	1.09	0.33	1.09
0.751 to 5.0	0.63	2.07	0.63	2.07
5.1 to 15.0	0.65	2.14	0.68	2.24
15.1 to 36.0	0.77	2.53	0.89	2.92
36.1 to 46.0	0.84	2.76	0.98	3.22
46.1 to 72.5	1.00	3.29	1.20	3.94

[1] Employers may use the minimum approach distances in this table provided the worksite is at an elevation of 900 meters (3,000 feet) or less. If employees will be working at elevations greater than 900 meters (3,000 feet) above mean sea level, the employer shall determine minimum approach distances by multiplying the distances in this table by the correction factor in Table R-5 corresponding to the altitude of the work.

[2] For single-phase systems, use voltage-to-ground

Click Box

3.5.1 Arc-resistant Switchgear and Controls

Arc-resistant switchgear equipment is designed to withstand the effects of an internal arcing fault and directs the internally-released energy away from the employee. Arc-resistant switchgear is just one design available to minimize energy levels where employees are exposed to electrical hazards. Other equipment and designs include, but are not limited to, remote racking (insertion or removal), remote opening and closing of switching devices, high-resistance grounding of low-voltage systems, current limitation, and specification of covered conductors within equipment.

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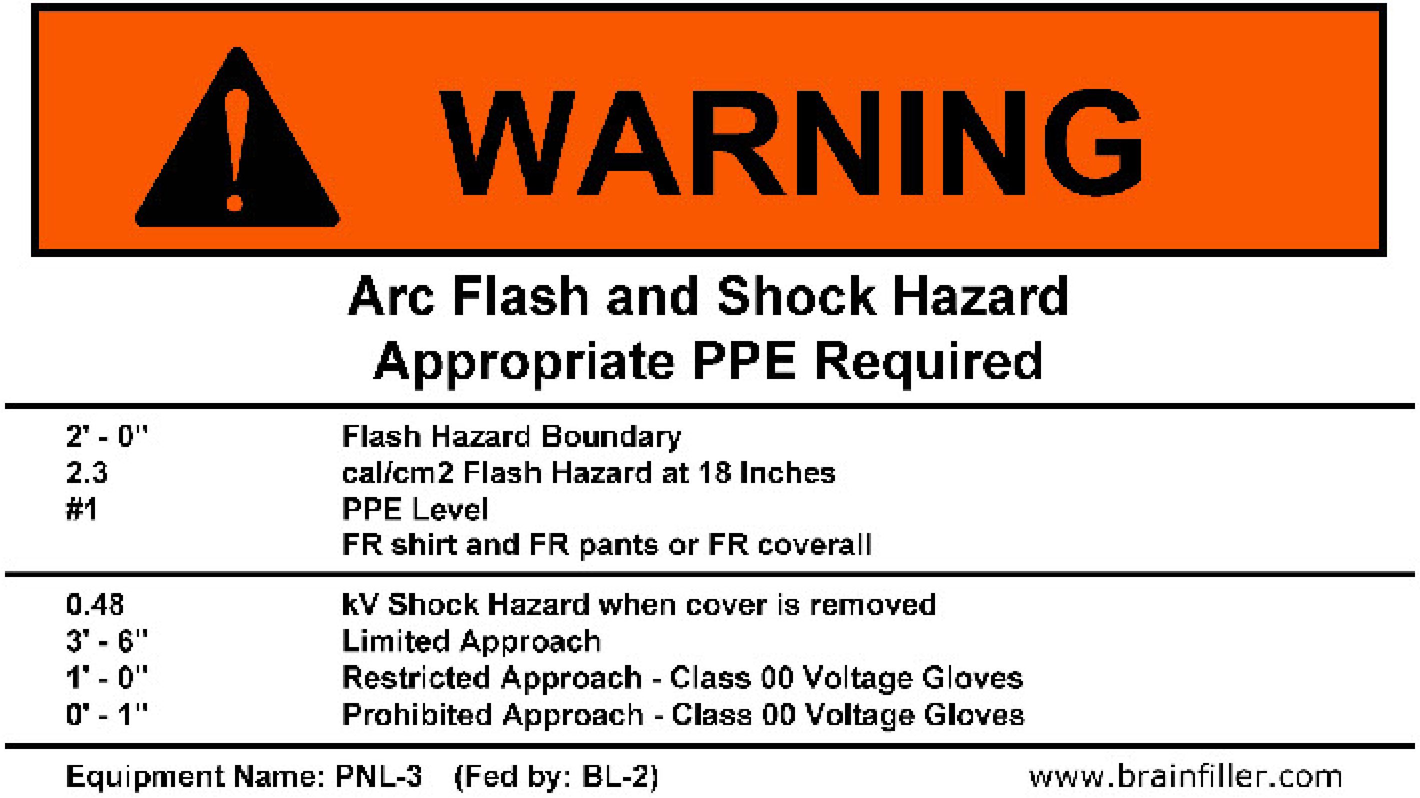
3.5.2 Labeling



Labels are designed to warn of potential arc flash hazards for those employees responsible for working in and around these hazardous areas. They also can identify the personal protective equipment that is to be worn to protect them against the risk of injury. An employer is to identify the type of equipment requiring labeling and to document the method and information required on label.

Click Box

3.5.3 Personal Protective Equipment

It is important to understand that just because there is an electrical shock hazard present, it doesn't mean there won't be an arc flash hazard present as well. That is the reason that it is very important to complete an arc flash hazard assessment in the workplace. Electric arcs pose some of the most serious safety hazards for employees. Arc flash or blast hazards include high temperatures over short periods of time, hot gases, an intense pressure wave from the explosion, and shrapnel from vaporized and molten metal particles. When an employee is exposed to an arc, the clothing they wear may play a large role in the severity of the potential injury. An Arc Flash Suit is considered a complete arc-rated clothing and equipment system that covers the entire body, except for the hands and feet. Rated arc flash face shields are designed to protect the face from very high thermal heat produced during an arc flash event. Voltage-rated rubber insulated gloves must be worn with leather covers to provide the appropriate arc flash and shock protection.

Since there may be a lot of confusion on arc flash protection, it's very important to spell out in detail how to select the appropriate arc flash PPE and how to determine arc flash boundaries in an electrical safety program. The employer is responsible for providing arc flash protection gear, and the employee is responsible for wearing and maintaining that arc flash protection. The selection of the appropriate arc flash protection is important, requiring training for the qualified persons helping in that decision-making process.

3.5.3 Personal Protective Equipment

The NFPA Standard requires that the protective clothing selected for the corresponding hazard/risk category number to have an arc rating of at least the minimum value listed on the chart depicted in the following slides.

PPE Category 1 Minimum arc rating between 4 and 8 cal/cm^2	• Arc rated, flame-resistant long sleeve shirt and pants or coveralls • Arc rated face shield with wrap-around guarding or hood • Arc rated jacket, parka, rain wear or hard hat liner (as needed) • Flame-resistant hard hat • Flame-resistant safety glasses or goggles • Hearing protection (ear canal inserts) • Heavy duty leather gloves (optional leather gloves protectors with insulating rubber gloves) • Leather work shoes (as needed)
PPE Category 2 Minimum arc rating between 8 and 25 cal/cm^2	• Arc rated, flame-resistant long sleeve shirt and pants or coveralls • Arc rated, face shield with wrap-around guarding or flash suit hood, with balaclava • Arc rated jacket, parka, rain wear or hard hat liner (as needed) • Flame-resistant hard hat • Flame-resistant safety glasses or goggles • Hearing protection (ear canal inserts) • Heavy duty leather gloves (optional leather gloves protectors with insulating rubber gloves) • Leather work shoes (footwear)

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3.5.3 Personal Protective Equipment

PPE Category 3 Minimum arc rating between 25 and 40 cal/cm^2	• Arc rated, flame-resistant long sleeve shirt and pants and coveralls (selected so that the system arc rating meets the required minimum) • Arc rated arc flash suit including jacket, pants, hood (rating level as required) • Arc rated gloves (rating level as required) • Arc rated jacket, parka, rain wear or hard hat liner (as needed) • Flame-resistant hard hat • Flame-resistant safety glasses or goggles • Hearing protection (ear canal inserts) • Heavy duty leather gloves (optional leather gloves protectors with insulating rubber gloves) • Leather work shoes (footwear)
PPE Category 4 Minimum arc rating 40 cal/cm^2	• Arc rated, flame-resistant long sleeve shirt and pants and coveralls (selected so that the system arc rating meets the required minimum) • Arc rated multi-layered flash suit jacket (selected so that the system arc rating meets the required minimum) • Arc rated flash suit pants (rating level as required) • Arc rated flash suit hood (rating level as required) • Arc rated gloves (rating level as required) (optional leather gloves protectors with insulating rubber gloves) • Arc rated jacket, parka, rain wear or hard hat liner (as needed) • Flame-resistant hard hat • Flame-resistant safety glasses or goggles • Hearing protection (ear canal inserts) • Leather work shoes (footwear)

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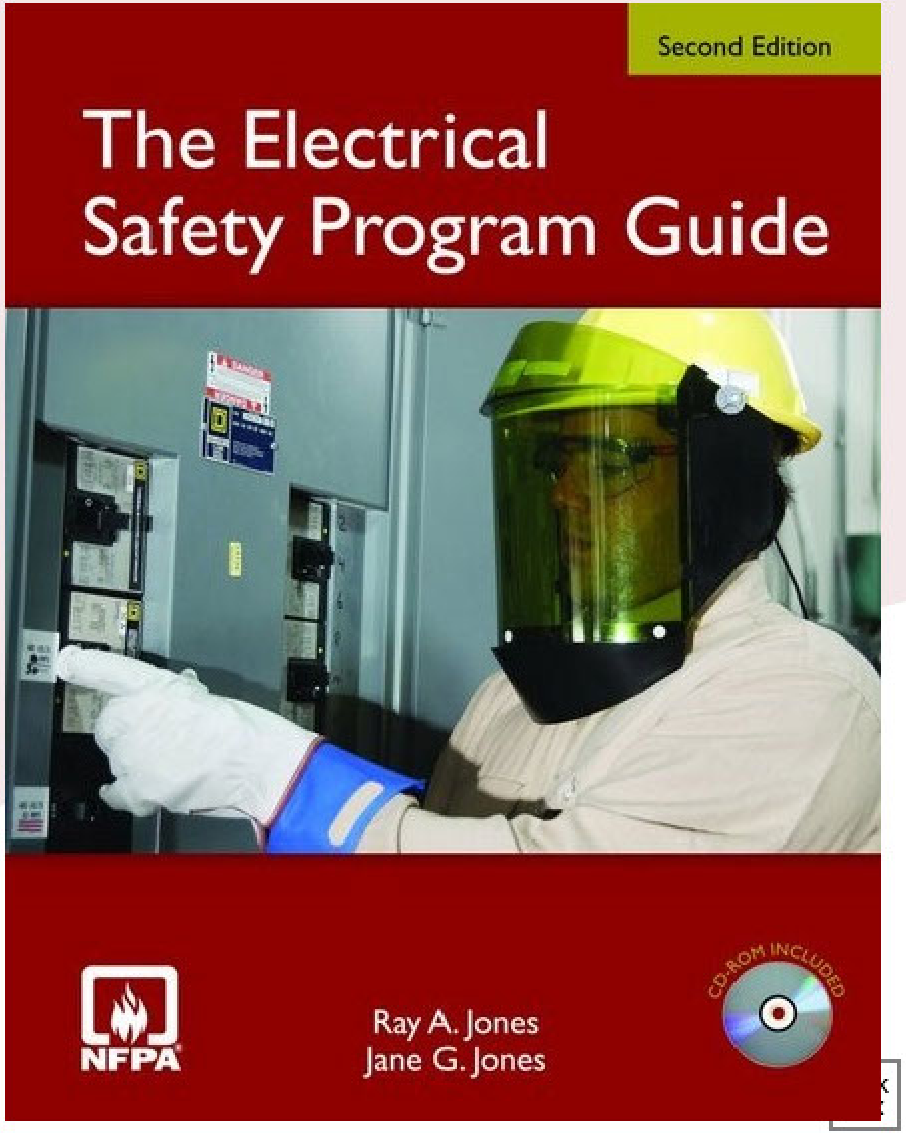
4.0 Electrical Safety Program

The NFPA standard recommends that an employer have an Electrical Safety Program which is described as a written document that guides and directs employee activity when working around electricity. The program should reflect and be appropriate for the voltage, energy level and circuit conditions that exist at the workplace. As with any safety program introduced, it should be implemented as part of an employer's overall occupational health and safety management system. This section incorporates the key elements to be included in an Electrical Safety Program.



4.1 Basic Principles

Electrical safety principles are the guiding rules of electrical safety in an organization. The NFPA standard does not require specific safety principles, given the variety and types of industries that exist; however, Annex E of the standard contains recommended principles, some of which appear below:

- Inspection, evaluation, and maintenance of electrical equipment to manufacturer's specifications
- The process for establishing an electrically safe work condition
- Safe work practices
- Utilization of proper tools for each job
- Identification, evaluation, and control of hazards
- Personal protective equipment
- Training and work plans for every job
- Auditing procedures

The principles not previously reviewed in this course are described in further detail in the remaining parts of this section.

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4.2 Electrically Safe Work Condition

Per the NFPA standard, an "Electrically Safe Work Condition" is a state in which an electrical conductor or circuit part to be worked on or near has been disconnected from energized parts, locked/tagged in accordance with established standards, tested to ensure the absence of voltage, and grounded if determined necessary. The process of turning off the electricity, verifying that it is off, and ensuring that it stays off while work is performed is called "establishing" an electrically safe work condition.

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4.2 Electrically Safe Work Condition

Until these six steps have been executed, some exposure to an electrical hazard still exists and proper personal protective equipment is required.

The following are important considerations when establishing a safe condition:

- Only qualified persons can establish an electrically safe work condition.
- The process of establishing an electrically safe work condition is inherently hazardous because it requires qualified persons to work around live conductors. Appropriate personal protective equipment must be worn and used when performing some of the steps.
- Per one of the basic principles of an electrical safety program, electrical conductors and equipment are considered energized until the process of establishing an electrically safe work condition is complete.

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4.2 Electrically Safe Work Condition

Once these six steps have been completed, electrical energy has been removed from all conductors and equipment, it cannot reappear unexpectedly, and an electrically safe condition has been established. It is interesting to note that many people think of this electrical safety precaution as a lockout/tagout procedure. Although lockout/tagout is an important part of the process, it is only one of the six steps in establishing an electrically safe work condition.

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4.3 Safe Work Practices

The NFPA standard specifies that an organization should develop and enforce procedures for working on or near electricity, particularly if live parts of 50 volts or more are present. The standard includes two specific procedures that an employer is required to adopt:

- Hazard/risk evaluation procedures
- Job briefing procedures

The NFPA standard requires that job briefings be held by the supervisor to ensure an understanding of the safe work practices to be conducted prior to the beginning of each job. The briefing should cover such subjects as hazards associated with the job, work procedures involved, special precautions, energy source controls, PPE requirements, and the information on the energized electrical work permit, if required. Additional job briefings shall be held if changes that might affect the safety of employees occur during the work.

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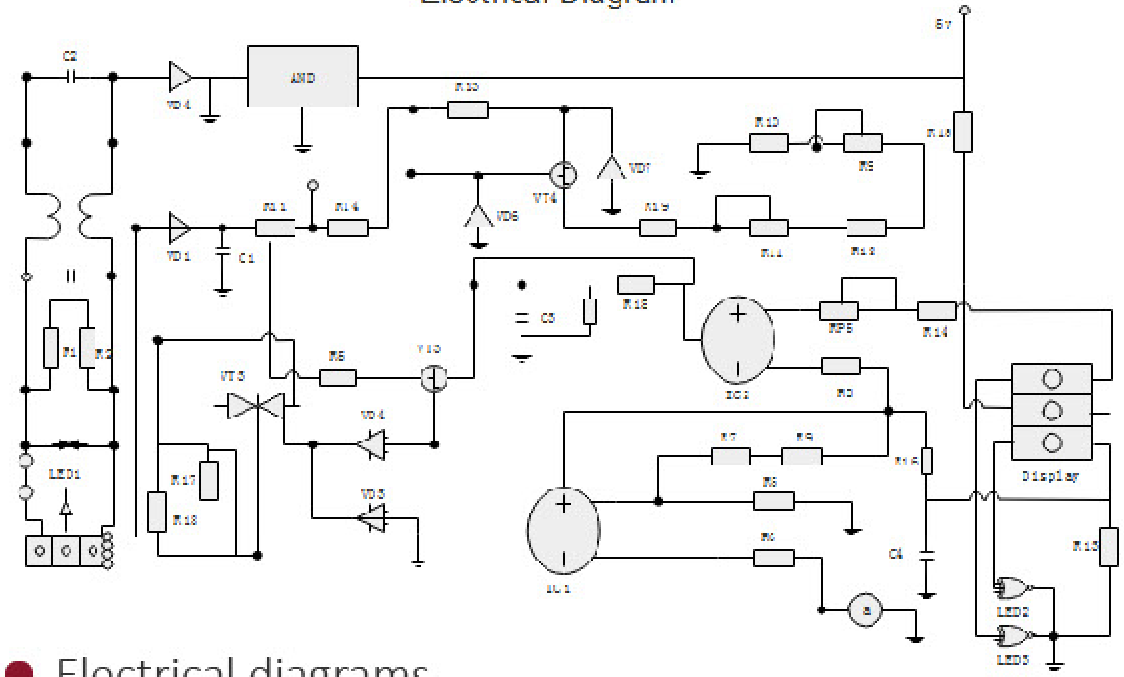
4.3 Safe Work Practices

In addition to these two procedures, an employer should consider developing a procedure for every electrical-related task that is performed in the workplace. The standard recommends that program procedures include, but are not limited to, the following items:

- Purpose of task
- Qualifications and number of employees to be involved
- Hazardous nature and extent of task
- Limits of approach
- Safe work practices to be utilized
- Personal protective equipment involved
- Insulating materials and tools involved
- Special precautionary techniques

Electrical Diagram



- Electrical diagrams
- Equipment details
- Sketches/pictures of unique features
- Reference data

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4.3 Safe Work Practices

OSHA's safety-related work practice standards for general industry are performance-oriented regulations that complement the existing NFPA electrical standard. These work practice standards include requirements for work performed on or near exposed energized and de-energized parts of electric equipment; use of electrical protective equipment; and the safe use of electric equipment. These regulations are intended to protect employees from the electrical hazards that they may be exposed to when employees are working with electric equipment. Such safety-related work practices include keeping a prescribed distance from exposed energized lines, avoiding the use of electric equipment when the employee or the equipment is wet, the use of electrical protective devices such as rubber gloves and mats, as well as locking-out and tagging equipment which is de-energized for maintenance.

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4.4 Qualified Person

In an effort to limit electrical injuries in the workplace, OSHA has only allowed a “Qualified Person” to perform work on or around energized circuits or equipment. Per OSHA, a qualified person is one who has demonstrated skills and knowledge to identify and avoid hazards related to the construction and operation of electrical equipment and installations and has received safety training to identify and avoid the hazards involved.

Whether an employee is considered to be a "qualified person" will depend upon various circumstances in the workplace. For example, it is possible and, in fact, likely for an individual to be considered "qualified" with regard to certain equipment in the workplace but "unqualified" as to other equipment.

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4.4 Qualified Person

An employee who is undergoing on the-job training and who, in the course of such training, has demonstrated an ability to perform duties safely at his or her level of training and who is under the direct supervision of a qualified person, is considered to be a qualified person for the performance of those duties.

It is also important to note that OSHA states that qualified electrical employees should not be requested to work on equipment that is "hot" or "live" except for two reasons:

- De-energizing introduces additional or increased hazards, such as cutting ventilation to a hazardous location.
- It is not feasible due to equipment design or operational limitations, such as performing voltage testing for diagnostics.

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4.4.1 Qualified Person Training

A qualified person is required to have demonstrated skills and knowledge about the equipment, safety policies and procedures of the facility. This demonstration is to be documented, verifying that the qualified person has received electrical safety training and can identify electrical hazards involved with electrical equipment. The training required should be classroom or on-the-job training. The degree of training provided should be determined by the risk to the employee for injury. It is the employer's responsibility to determine the training required and to ensure that the employee is adequately trained for the tasks undertaken.

Specific training requirements of a qualified person to recognize the hazards present include at least a familiarity with each of the following:

- The use of the precautionary techniques
- Personal protective equipment
- Insulated tools and test equipment
- Electrical policies and procedures
- Insulating and shielding materials

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4.4.1 Qualified Person Training

In addition, to be permitted to work within the limited approach of exposed energized conductors and circuit parts greater than 50 volts, a qualified person should be trained in all the following:

- The skills and techniques necessary to distinguish exposed live parts from other parts of electric equipment
- The skills and techniques necessary to determine the nominal voltage of exposed live parts
- The minimum approach distances to the voltages to which the qualified employee will be exposed
- The decision-making process necessary to be able to:
  - Perform the job safety-related plans and procedures
  - Identify electrical hazards
  - Assess the associated risk
  - Select the appropriate risk control methods from the hierarchy of controls, including the proper personal protective equipment

4.5 Personal Protective Equipment

Personal protective equipment is an integral part of any employer's safety program. OSHA has determined that PPE, although a good way to protect employees, should be used as a last line of defense. Prior to using PPE, the employer should determine if other means of protection, utilizing the hierarchy of controls, are available since the use of PPE in the workplace has its limitations.

Depending on the job task to be performed, PPE for the those that work with electricity includes safety glasses, face shields, nonconductive head protection, safety shoes, insulating gloves with leather protectors, insulating sleeves, and arc rated (AR) clothing. Additional PPE, such as fall protection equipment, respirators, chemical-resistant or cut-resistant gloves, and chaps, may be required, depending on the results of the hazard assessment. All PPE should provide an excellent means of protecting the employees from accidental electrical contact and to be effective, it should be comfortable, durable, and flexible.

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4.5 Personal Protective Equipment

In addition to PPE, those that work with electric power often use insulating protective equipment (IPE), such as line hoses, rubber hoods, rubber blankets, and insulating live-line tools for protection. However, since IPE is not worn by the employee, it is technically not considered as PPE.

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4.5 Personal Protective Equipment

The PPE requirements as depicted in the Section 3, Arc Flash and Arc Blast have already been reviewed. Whenever there is a risk of electric shock, there may be a risk for an arc flash. Understanding this concept, there are general industry requirements for which every employer must comply. These appear in the OSHA PPE standard, 1910.137, “Electrical Protective Equipment.” The guidelines include provisions for:

- The design requirements for specific types of electrical protective equipment:
  - Manufacture and marking of rubber insulating equipment
  - Electrical requirements, including the capability of withstanding voltage testing, and specific test requirements for AC and DC
  - Workmanship and finish, to include the requirement to meet the nation’s consensus standards as published by the American Society for Testing and Materials (ASTM)
  - Equipment current
- In-service care and use of electrical protective equipment, including repair requirements

4.5 Personal Protective Equipment

Prior to requiring employees to wear PPE, employers should:

- Perform hazard assessments, as required, and determine the PPE needed to protect employees
- Provide training on the proper use of PPE for working on or near exposed energized parts
- Discuss PPE needs during required job briefings
- Inspect and test certain PPE such as insulating (rubber) gloves and sleeves to ensure that they are not damaged or defective and will provide the needed protection

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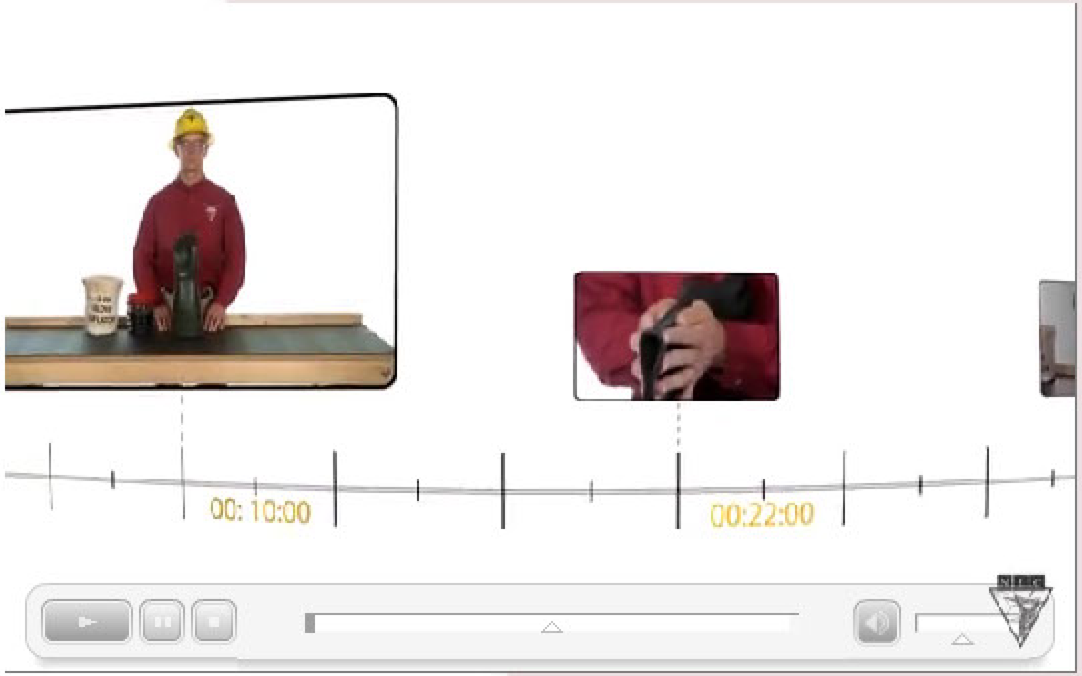
4.5 Personal Protective Equipment

Protective equipment must be maintained in a safe, reliable condition and should be inspected before each daily use and anytime damage is suspected. Proper storage extends the service life of gloves. Folds and creases strain natural rubber and cause it to cut from ozone prematurely. Storing rubber gloves in the right size bag and never forcing more than one pair into each bag will help equipment last longer.

Typical damage and their causes to personal protective equipment might include the following:

- Embedded foreign objects (metal slivers, splinters)
- Product deterioration due to temperature and ozone damage
- Foreign materials (oils, petroleum products, hand lotion, baby powder)
- Holes, punctures, tears, or cuts
- Swelling, softening, sticky or hardening

The employer should provide training to each employee who is required to use PPE for electrical hazards. As with any type of PPE, the employee must be trained to know when PPE is necessary, what PPE is necessary, how to properly don, doff, adjust, and wear PPE, the limitations of the PPE, and its proper care and maintenance.



Glove Inspection Prior to Use.

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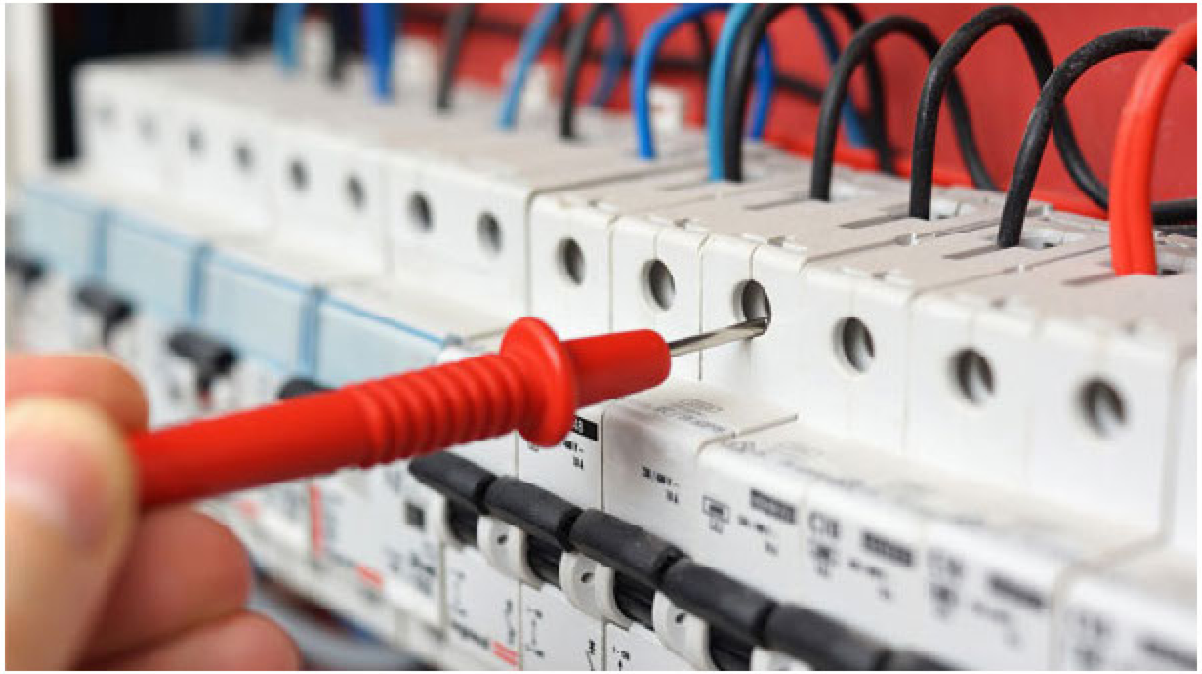
4.6 Training

When employees are trained to work safely when exposed to electrical hazards, they should be able to anticipate and avoid injury while working with electricity. All employees should be trained to be thoroughly familiar with the safety procedures for their particular jobs. Moreover, good judgment and common sense are integral to preventing electrical accidents.



The type and extent of the training provided should be determined by the risk to the employee when performing their tasks. An employer is to verify and document, at least annually, that required training is current, based on the provisions of the Electrical Safety Program. The intent of the training is to ensure that all affected personnel are able to understand when and how hazardous situations can arise and how to best reduce the risk associated with those situations.

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4.6 Training

Any employee who faces a risk of electrical hazards when the risk associated with that hazard is not reduced to a safe level should be trained to understand:

- Basic electrical concepts and definitions
- Specific electrical hazards in the workplace, their relationship to possible injury, and the control measures in place
- Safety-related work practices associated with their respective job tasks/assignments, such as de-energizing equipment and maintaining a safe distance from energized parts
- Personal protective equipment requirements
- Emergency response training:
  - Safe release of victims from contact with exposed energized parts (annual refresher)
  - First aid, CPR and AED (annual refresher)

4.6 Training

The training should be classroom, on-the-job, or a combination of the two. This type of training generally will be provided by a trainer who has an in-depth understanding of electrical system design and be acquainted with the electrical systems utilized in the workplace.

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4.6 Training

The training requirements for "qualified persons" was reviewed in the previous section. For unqualified employees, less technical training content may be appropriate in situations in which only awareness of electrical hazards is needed to ensure they do not interact with the electrical systems and are trained in general electrical safety precautions. The following general electrical safety rules apply to unqualified employees and should be incorporated into any training provided:

- Do not conduct any electrical repairs
- Report all electrical hazards to the supervisor
- Do not operate equipment if there is a chance there is an electrical hazard
- Do not allow electrical equipment or components to contact water
- Remember that even low-voltage electricity can be physically harmful
- Do not use cords or plugs that are missing the 'ground' prong
- Do not overload electrical receptacles

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4.7 Auditing

The electrical safety program should be audited to verify that the principles and procedures of the electrical safety program follow the standards and regulations. The documented audit should include a review of any field work and an evaluation of approach boundaries. When the auditing determines that the principles and procedures of the electrical safety program are not being followed, the appropriate revisions to the training program or revisions to the procedures should be made. Audits are to be performed at intervals not to exceed 1 year.

Additionally, an audit should take place prior to commencement of work on electrical systems. Each audit process might need to be specific to the properties of the electrical system, to the task to be performed, or to both. For each activity that has been assessed, it may be necessary to audit the risk reduction strategy that is applicable. A sample audit checklist may include a column depicting the electrical hazard identified, the risk reduction strategy implemented and a check whether the strategy is in place and operational.

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