This course describes the hazards of electrical work and basic approaches to working safely. You will learn skills to help you recognize, evaluate, and control electrical hazards. This information will prepare you for additional safety training such as hands-on exercises and more detailed reviews of regulations for electrical work.
OSHAcademy Course 615 Study Guide

Electrical Safety [Hazards and Controls]

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Contact OSHAcademy to arrange for use as a training document.

This study guide is designed to be reviewed off-line as a tool for preparation to successfully complete OSHAcademy Course 615.

Read each module, answer the quiz questions, and submit the quiz questions online through the course webpage. You can print the post-quiz response screen which will contain the correct answers to the questions.

The final exam will consist of questions developed from the course content and module quizzes.

We hope you enjoy the course and if you have any questions, feel free to email or call:

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Contents

Course Introduction ............................................................................................................................................... 1

Modules and Learning Objectives ................................................................................................................ 2
  Module 1 – The Basics .................................................................................................................................. 2
  Module 2 – Recognizing Hazards ................................................................................................................ 2
  Module 2 – Recognizing Hazards ................................................................................................................ 3

Module 1: The Basics ....................................................................................................................................... 4
  The First Step - Recognition ........................................................................................................................ 4
  Terms You Need to Know ............................................................................................................................ 6
  Severity of Electrical Shock ......................................................................................................................... 7
  Low Voltage Does Not Mean Low Hazard ................................................................................................... 8
  Electrical Burns ........................................................................................................................................... 9
  Arc Blast Hazards ....................................................................................................................................... 10
  The Electrical Safety Model ......................................................................................................................... 11
    1. Recognize Hazards ............................................................................................................................... 12
    2. Evaluate Risks ..................................................................................................................................... 12
    3. Control Hazards .................................................................................................................................. 13

Module 2: Recognizing Hazards .................................................................................................................... 15
  Inadequate Wiring Hazards ........................................................................................................................ 15
  Exposed Electrical Parts Hazards ............................................................................................................ 16
  Real-Life Scenario ..................................................................................................................................... 16
  Approach Boundaries ............................................................................................................................... 17
  Overload Hazards ...................................................................................................................................... 18
  Defective Insulation Hazards ..................................................................................................................... 19
Improper Grounding Hazards ................................................................. 19
Ground Fault Circuit Interrupters (GFCI) ............................................... 20
Overhead Powerline Hazards ................................................................ 21
Minimum Approach Distances .............................................................. 22
General Indicators of Electrical Hazards ............................................... 22
Module 3: Evaluating Risk and Controlling Hazards .............................. 24
Evaluating Risk ..................................................................................... 24
Controlling Hazards ............................................................................. 25
Creating a Safe Work Environment ...................................................... 25
Circuit Protection Devices ..................................................................... 26
Control Inadequate Wiring Hazards ....................................................... 27
Control Hazards of Fixed Wiring ......................................................... 27
Control Hazards of Flexible Wiring ...................................................... 28
Protection from Energized Parts ......................................................... 28
Protection Against Unexpected Startup ............................................... 29
Protection Around High Voltage Lines ................................................ 30
Electrical Protective Equipment ........................................................ 31
Tools ..................................................................................................... 32
Training Requirements ......................................................................... 32
Additional Resources .......................................................................... 34
Course Introduction

This course describes the hazards of electrical work and basic approaches to working safely. You will learn skills to help you recognize, evaluate, and control electrical hazards. This information will prepare you for additional safety training such as hands-on exercises and more detailed reviews of regulations for electrical work.

Your employer, co-workers, and community will depend on your expertise. Start your career off right by learning electrical safe practices and developing good safety habits while working with electricity. Safety is a very important part of any job. Do it right from the start.

The course will present many topics. There are four main types of electrical injuries: electrocution (death due to electrical shock), electrical shock, burns, and falls. The dangers of electricity, electrical shock, and the resulting injuries will be discussed. The various electrical hazards will be described. You will learn about the 3-STEP Electrical Safety Model, an important tool for recognizing, evaluating, and controlling hazards. Practices that will help keep you safe and free of injury are emphasized. To give you an idea of the hazards caused by electricity, case studies about real-life deaths will be described.
Modules and Learning Objectives

Module 1 – The Basics

Learning objectives in this module include:

- Give examples of electrical hazards in the workplace.
- Define "volt," "ampere," and "ohm."
- Discuss the difference between a series and parallel electrical circuit.
- Describe the factors that increase the severity of electrical shocks.
- Discuss the hazards associated with working around high voltage.
- Describe the three common types of electrical burns.
- Describe the dangers of arc flash and blast hazards.
- List the components of the Electrical Safety Model

Module 2 – Recognizing Hazards

Learning objectives in this module include:

- Identify two basic types of electrical wiring hazards.
- Describe the hazards of exposed electrical parts.
- Identify and describe the "Restricted Approach Boundary," "Limited Approach Boundary, and "Arc Flash Boundary."
- Discuss hazards associated with electrical overload conditions.
- Describe the importance of and types of electrical insulation.
- Describe methods for effectively guarding electrical equipment.
- Define the term, "grounding," and give examples.
- List and give examples of circuit protection devices including Ground Fault Circuit Interrupters (GFCIs).

- Discuss minimum approach distances when working around conductive objects.

- Describe general indicators of electrical hazards and give examples.

**Module 2 – Recognizing Hazards**

Learning objectives in this module include:

- Define and give examples for "risk," "probability," and "severity."

- Give examples of clues indicating high risk of injury.

- Describe the primary methods of controlling electrical hazards.

- List and give examples of circuit protection devices.

- Compare the hazards and controls for fixed and flexible electrical wiring.

- Describe general safe work practices when working around electrical circuits.

- Discuss how to protect against energized parts and unexpected startup.

- Describe protection while working around overhead power lines.

- Describe the various types of electrical protective equipment and tools.
Module 1: The Basics

Electricity is Dangerous

Whenever you work with power tools or on electrical circuits, there is a risk of electrical hazards, especially electrical shock. Anyone can be exposed to these hazards at home or at work. Workers are exposed to more hazards because job sites can be cluttered with tools and materials, fast-paced, and open to the weather. Risk is also higher at work because many jobs involve electric power tools.

Electrical workers must pay special attention to electrical hazards because they work on electrical circuits, and contact can cause electrical current to flow through the body, resulting in shock and burns. Serious injury or even death may occur.

As a source of energy, electricity is used without much thought about the hazards it can cause. Because electricity is a familiar part of our lives, it often is not treated with enough caution. As a result, an average of one worker is electrocuted on the job every day of every year!

Quiz Instructions

Read the material in each section to discover the correct answer to questions. Circle the correct answer. When you’re finished go online to take the final exam. This exam is open book, so you can use this study guide.

1. Which of the following causes electrical burns and other injuries?
   a. Electrical resistance
   b. Electrical voltage
   c. Electrical current
   d. Electrical inductance

The First Step - Recognition

Electricity has long been recognized as a serious workplace hazard, exposing employees to electric shock, electrocution, burns, fires, and explosions. According to the Bureau of Labor Statistics, in 2016, 134 workers died from electrocutions, which represents a decrease from 174 in 2011. What makes these statistics tragic is that most of these fatalities could have been easily avoided.
The first step toward protecting yourself is recognizing the many hazards you face on the job. To do this, you must know which situations can place you in danger. Knowing where to look helps you to recognize hazards.

- Inadequate wiring is dangerous.
- Exposed electrical parts are dangerous.
- Overhead powerlines are dangerous.
- Wires with bad insulation can shock you.
- Electrical systems and tools that are not grounded or double-insulated are dangerous.
- Overloaded circuits are dangerous.
- Damaged power tools and equipment are electrical hazards.
- Using the wrong PPE is dangerous.
- Using the wrong tool is dangerous.
- Some on-site chemicals are harmful.
- Defective ladders and scaffolding are dangerous.
- Ladders that conduct electricity are dangerous.
- Electrical hazards can be made worse if the worker, location, or equipment is wet.

2. **What is the first step in protecting yourself against electrical burns, shock, and other injuries?**

   a. Recognizing hazards  
   b. Complying with OSHA  
   c. Knowing how to respond  
   d. Reporting accidents
Terms You Need to Know

What is a "volt?" A Volt is a measure of the electrical force that seems to push the current along. Think of voltage as a lot of water stored in a high water tank. Because the water tank is high, the water will have more force behind it as it flows down the water pipe to your home. If the same tank was placed at ground level, your water pressure would not be as great. The symbols commonly used for voltage are "E" or "V".

What is an "ampere?" An ampere is the unit used to measure the amount of electrical current. Amperage is often referred to as "current" by electrical workers and engineers. Let's go back to our water tank. If the diameter of your pipe coming from the water tank is large, a lot of water (amperage) will flow through the pipe. If the pipe's diameter is small, a smaller amount of water will flow through the pipe. If you need a lot of current (many amps) to operate your equipment, you'll need large wires to run the current or they'll burn up! The symbol for amperage is "I".

What is an "ohm?" Think of an ohm as "resistance". An ohm is the unit used to measure the opposition (a.k.a. resistance) to the flow of electrical current. Using our water analogy: A small water pipe is going to oppose a lot of water from flowing. Relatively little water will be able to flow through the pipe. So, the pipe offers a high resistance to the flow of water. You can see that a large pipe would offer little resistance to the flow of water. Big pipe: a lot of water! It's that simple. In an electrical circuit, components are usually sources of resistance. Any component that heats up due to electrical current is a source of resistance. The symbol for resistance is "R".

What is a "series" circuit? The current in a series circuit takes only one path. For example, water from high in the mountains may flow down one stream (series) into a river that flows to the ocean.

What is a "parallel" circuit? The current in a parallel circuit takes many paths. For example, the water flowing from a water tank up on a hill will flow through many different water pipes (parallel) before it reaches the ocean.
3. Which of the following is the unit used to measure the resistance to the flow of electrical current?

   a. Volt  
   b. Ampere  
   c. Ohm  
   d. Newton

**Severity of Electrical Shock**

The severity of injury from electrical shock depends on the amount of electrical amperage (current) and the length of time the current passes through the body. For example, 1/10 of an ampere (amp) of electricity going through the body for just 2 seconds is enough to cause death.

The amount of internal current a person can withstand and still be able to control the muscles of the arm and hand can be less than 10 milliamperes (milliamps or mA).

Currents above 10 mA can paralyze or "freeze" muscles. When this "freezing" happens, a person is no longer able to release a tool, wire, or other object. In fact, the electrified object may be held even more tightly, resulting in longer exposure to the shocking current. For this reason, hand-held tools that give a shock can be very dangerous.

If you can't let go of the tool, current continues through your body for a longer time, which can lead to respiratory paralysis (the muscles that control breathing cannot move) and you may stop breathing.

People have stopped breathing when shocked with currents from voltages as low as 49 volts. Usually, it takes about 30 mA of current to cause respiratory paralysis.

Currents greater than 75 mA may cause ventricular fibrillation (very rapid, ineffective heartbeat). This condition will cause death within a few minutes unless a special device called a defibrillator is used to save the victim. Heart paralysis occurs at 4 amps, which means the heart does not pump at all. Tissue is burned with currents greater than 5 amps.

The muscle structure of the person also makes a difference. People with less muscle tissue are typically affected at lower current levels. Even low voltages can be extremely dangerous because the degree of injury depends not only on the amount of current but also on the length of time the body is in contact with the circuit.
4. Which of the following determines the severity of an electrical shock?

   a. The amount and duration of current flow
   b. The type of electrical current
   c. The degree and speed of electrical decay
   d. They prevent the need for reactive processes

**Low Voltage Does Not Mean Low Hazard**

This table shows what usually happens for a range of currents (lasting one second) at typical household voltages. Longer exposure times increase the danger to the shock victim. For example, a current of 100 mA applied for 3 seconds is as dangerous as a current of 900 mA applied for a fraction of a second (0.03 seconds).

<table>
<thead>
<tr>
<th>Current</th>
<th>Reaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 milliamp</td>
<td>Just a faint tingle.</td>
</tr>
<tr>
<td>5 milliamps</td>
<td>Slight shock felt. Disturbing, but not painful. Most people can &quot;let go.&quot; However, strong involuntary movements can cause injuries.</td>
</tr>
<tr>
<td>6-25 milliamps (women)†</td>
<td>Painful shock. Muscular control is lost. This is the range where &quot;freezing currents&quot; start. It may not be possible to &quot;let go.&quot;</td>
</tr>
<tr>
<td>9-30 milliamps (men)</td>
<td></td>
</tr>
<tr>
<td>50-150 milliamps</td>
<td>Extremely painful shock, respiratory arrest (breathing stops), severe muscle contractions. Flexor muscles may cause holding on; extensor muscles may cause intense pushing away. Heart fibrillation possible. Death is possible.</td>
</tr>
</tbody>
</table>
5,000 milliamps (5 amps)  

Rhythmic pumping action of the heart ceases. Muscular contraction and nerve damage occur; death likely.

10,000 milliamps (10 amps)  

Cardiac arrest and severe burns occur. Death is probable.

15,000 milliamps (15 amps)  

Lowest overcurrent at which a typical fuse or circuit breaker opens a circuit!

*Effects are for voltages less than about 600 volts. Higher voltages also cause severe burns. Differences in muscle and fat content affect the severity of shock.

5. Which of the following is the lowest level of electrical current that can cause heart fibrillation and death?

   a. 5-10 milliamps  
   b. 50-150 milliamps  
   c. 10 amps  
   d. 15 amps

Electrical Burns

The most common shock-related, nonfatal injury is a burn. Burns caused by electricity may be of three types:

- electrical burns,
- arc burns, and
- thermal contact burns.

Electrical burns can result when a person touches electrical wiring or equipment that is used or maintained improperly. They are one of the most serious injuries you can receive and usually require immediate attention.
**Arc burns**: Arcing is the luminous electrical discharge that occurs when high voltage exists across a gap between conductors and current travels through the air. Temperatures as high as 35,000°F have been reached in arc-blasts. Arc-blasts occur when powerful, high-amperage currents (1) arc in a distribution box or a motor control center (Confined Flash), or (2) arc in an open space with the energy escaping 360° in all directions (Open Flash).

**Thermal burns** occur when electricity starts a fire or explosion. Clothing may catch fire and thermal burns may result from the heat of the fire. Extremely high-energy arcs can also damage equipment, causing fragmented metal to fly in all directions.

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**6. What are the most common injuries due to electrical hazards?**

- a. Falls
- b. Impact
- c. Shocks
- d. Burns

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**Arc Blast Hazards**

There are three primary hazards associated with an arc-blast.

1. Arcing during an arc blast gives off thermal radiation (heat) and intense light, which can cause burns. Several factors affect the degree of injury, including skin color, area of skin exposed, and type of clothing worn. Proper clothing, work distances, and overcurrent protection can reduce the risk of such a burn.

2. A high-voltage arc can produce a considerable pressure wave blast. A person who is 2 feet away from a 25,000-amp arc feels a force of about 480 pounds on the front of the body. In addition, such an explosion can cause serious ear damage and memory loss due to concussion. Sometimes the pressure wave throws the victim away from the arc-blast. While this may reduce further exposure to the thermal energy, serious physical injury may result. The pressure wave can propel large objects over great distances. In some cases, the pressure wave has enough force to snap off the heads of steel bolts and knock over walls.
3. **Metal burns:** A high-temperature (5,000-35,000 deg F.) high-voltage arc can also cause many of the copper and aluminum components in electrical equipment to melt. These droplets of molten metal can be blasted great distances by the pressure wave. Although these droplets harden rapidly, they can still be hot enough to cause serious burns or cause ordinary clothing to catch fire, even if you are 10 feet or more away.

7. **Skin color, area of exposed skin, and type of clothing worn can affect _____ arc blast hazards.**
   
   a. metal burn  
   b. acceleration  
   c. pressure wave blast  
   d. radiation

**The Electrical Safety Model**

To make sure all employees are safe before, during and after electrical work is performed, electrical workers should follow the three-step process of the Electrical Safety Model:

1. recognize hazards  
2. evaluate risk  
3. control hazards

To be safe, you must think about your job and plan for hazards. To avoid injury or death, you must understand and recognize hazards. You need to evaluate the situation you are in and assess your risks. You need to control hazards by creating a safe work environment, by using safe work practices, and by reporting hazards to a supervisor or trainer.

If you do not recognize, evaluate, and control hazards, you may be injured or killed by the electricity itself, electrical fires, or falls. If you use the safety model to recognize, evaluate, and control hazards, you will be much safer at work.

Use the safety model to:

- Recognize, evaluate, and control hazards.
- Identify electrical hazards.
• Don't listen to reckless, dangerous people.

• Evaluate your risk.

• Take steps to control hazards.

8. **What are the three components of the Electrical Safety Model?**

   a. Eliminate, engineer, or administrate hazards
   b. Locate, redesign, or remove hazards
   c. Recognize, evaluate, and control hazards
   d. Analyze, evaluate, and prosecute hazards

1. **Recognize Hazards**

   The first step of the Electrical Safety Model is recognizing the electrical hazards around you. Only then can you avoid or control the hazards. It is best to discuss and plan hazard recognition tasks with your co-workers.

   The most frequent causes of electrical injury/death are:

   • contact with power lines
   • lack of ground-fault protection
   • path to ground missing or discontinuous
   • equipment not used in manner prescribed
   • improper use of extension and flexible cords

2. **Evaluate Risks**

   Evaluation is a judgment call, and it's based on the perceived level of risk of injury. Risk is determined by analyzing the probability of an injury occurring and the severity of the injury if it occurs. The greater the probability and higher the severity, the greater the risk.
When evaluating risk, it is best to identify all possible hazards first, then evaluate the risk of injury from each hazard. Do not assume the risk is low until you evaluate the hazard. It is dangerous to overlook hazards.

9. What must you do first, before you can avoid or control electrical hazards?

   a. Recognize them
   b. Use personal protective equipment
   c. Eliminate them
   d. Ask OSHA to inspect

3. Control Hazards

Once electrical hazards have been recognized and evaluated, they must be controlled. You control electrical hazards in two main ways:

1. create a safe work environment and

2. use safe work practices.

One way to implement this safety model is to conduct a job hazard analysis (JHA). Below is a simple JHA using three columns:

- Column 1. Break down the job into its separate steps.
- Column 2. Evaluate the hazard(s) inherent in each step.
- Column 3. Develop a hazard control to eliminate or mitigate hazards.

<table>
<thead>
<tr>
<th>Task</th>
<th>Hazards</th>
<th>Precautions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Removing the cover</td>
<td>Electric shock from exposed live wires</td>
<td>De-energize by opening circuit breaker or removing fuse</td>
</tr>
</tbody>
</table>
Removing the GFCI  |  Possible other live wires in opening  |  Test wires with appropriate voltmeter to ensure all wires are de-energized
--- | --- | ---
Installing the GFCI  |  Possible connecting wires incorrectly  |  Check wiring diagrams to ensure proper connects
Replace cover and re-energize  |  Possible defective GFCI  |  Test GFCI

Once the JHA is completed, use it to train employees who are not familiar with the job, for retraining if employees demonstrate a lack of knowledge, skills, or ability (SKAs). Make sure the JHA is reviewed each time an employee must perform a hazardous procedure.

10. According to the Electrical Safety Model, what action is required after evaluating hazards?
   a. Reporting hazards
   b. Controlling hazards
   c. Recognizing hazards
   d. Categorizing hazards
Module 2: Recognizing Hazards

Inadequate Wiring Hazards

Inadequate or improper electrical wiring was one of OSHA’s top 10 most commonly cited violations during 2016. An electrical wiring hazard exists when:

- the wire is too small for the current it will carry: could cause a fire, or
- is not connected properly: could cause a shock hazard.

Normally, the circuit breaker in a circuit is matched to the wire size. However, in older wiring, branch lines to permanent ceiling light fixtures could be wired with a smaller gauge than the supply cable. Let’s say a light fixture is replaced with another device that uses more current. The current capacity (ampacity) of the branch wire could be exceeded. When a wire is too small for the current it is supposed to carry, the wire will heat up and could cause a fire.

When you use an extension cord, the size of the wire you are placing into the circuit may be too small for the equipment. The circuit breaker could be the right size for the circuit but not right for the smaller-gauge extension cord. A tool plugged into the extension cord may use more current than the cord can handle without tripping the circuit breaker. The wire will overheat and could cause a fire.

The kind of metal used as a conductor can cause an electrical hazard. Special care needs to be taken with aluminum wire. Since it is more brittle than copper, aluminum wire can crack and break more easily. Connections with aluminum wire can become loose and oxidize if not made properly, creating heat or arcing.

You must recognize that inadequate wiring is a hazard.

1. In which situation below may an electrical wiring fire hazard exist?
   a. When the wire is not rated for the voltage it will carry
   b. When the wire is not the proper length for the current it will carry
   c. When the wire is too small for the current it will carry
   d. When the wire is too large and is inherently too resistant
Exposed Electrical Parts Hazards

Being "exposed" to electrical parts occurs when a person can inadvertently make contact with an energized conductor or circuit part.

- Wires and parts can be exposed if a cover is removed from a wiring or breaker box.
- The overhead wires coming into a home may be exposed.
- Electrical terminals in motors, appliances, and electronic equipment may be exposed.
- Older equipment, or equipment that is being service, may have exposed electrical parts.
- If you contact exposed live electrical parts, you will be shocked.

You must recognize that an exposed electrical component is a hazard.

Real-Life Scenario

Five workers were constructing a chain-link fence in front of a house, directly below a 7,200-volt energized power line. As they prepared to install 21-foot sections of metal top rail on the fence, one of the workers picked up a section of rail and held it up vertically. The rail contacted the 7,200-volt line, and the worker was electrocuted. Following inspection, OSHA determined that the employee who was killed never received any safety training from his employer and no specific instruction on how to avoid the hazards associated with overhead power lines. In this case, the company failed to obey these regulations:

- Employers must train their workers to recognize and avoid unsafe conditions on the job.
- Employers must not allow their workers to work near any part of an electrical circuit UNLESS the circuit is de-energized (shut off) and grounded, guarded in such a way that it cannot be contacted.
- Ground-fault protection must be provided at construction sites to guard against electrical shock.
2. What precautions should you take when working around old motors, appliances, and electrical equipment to eliminate or reduce exposure to live electrical parts?

   a. First, turn off the power
   b. Test high voltage with a meter
   c. Post warning sign
   d. Use the spark test for voltage

Approach Boundaries

The risk from exposed live parts depends on your distance from the parts. Three "boundaries" are key to protecting yourself from electric shock and one to protect you from arc flashes or blasts. These boundaries are set by the National Fire Protection Association (NFPA 70E-2015).

1. The Restricted Approach Boundary. This is the closest boundary to exposed live parts. Only a Qualified Person wearing appropriate PPE, as determined by the Shock Risk Assessment, may enter. The Qualified Person must also have an Energized Electrical Work Permit (EEWP). When you're this close, if you move the wrong way, you and your tools could touch live parts.

2. The Limited Approach Boundary. An Unqualified Person may enter this area, but only if continuously supervised and escorted by a Qualified Person and advised of potential hazards. Both persons must wear appropriate PPE as determined by the Shock Risk Assessment. A qualified person is someone who has demonstrated the skills and knowledge on the hazards and on the construction and operation of equipment involved in a task.

3. The Arc Flash Boundary. Only Persons wearing appropriate PPE for the Arc Flash Boundary, as determined by an Arc Flash Risk Assessment, may enter.
3. Only an electrical Qualified Person wearing appropriate PPE, as determined by the Shock Risk Assessment, may enter _____.
   a. the Arc Blast Zone
   b. the Arc Flash Boundary
   c. the Limited Approach Boundary
   d. the Restricted Approach Boundary

**Overload Hazards**

Overloads in an electrical system are hazardous because they can produce heat or arcing. Wires and other components in an electrical system or circuit have a maximum amount of current they can carry safely. If too many devices are plugged into a circuit, the electrical current will heat the wires to a very high temperature. If a tool uses too much current, the wires will heat up.

The temperature of the wires can be high enough to cause a fire. If their insulation melts, arcing may occur. Arcing can cause a fire in the area where the overload exists, even inside a wall.

To prevent too much current in a circuit, a circuit breaker or fuse is placed in the circuit. If there is too much current in the circuit, the breaker "trips" and opens like a switch. If an overloaded circuit is equipped with a fuse, an internal part of the fuse melts, opening the circuit. Both breakers and fuses do the same thing: open the circuit to shut off the electrical current.

If the breakers or fuses are too big for the wires they are supposed to protect, an overload in the circuit will not be detected and the current will not be shut off. Overloading leads to overheating of circuit components (including wires) and may cause a fire.

*You must recognize a circuit with improper overcurrent protection devices - or one with no overcurrent protection devices at all - is a hazard.*

Overcurrent protection devices are built into the wiring of some electric motors, tools, and electronic devices. For example, if a tool draws too much current or if it overheats, the current will be shut off from within the device itself. Damaged tools can overheat and cause a fire.

*You must recognize that a damaged tool is a hazard.*
4. Which of the following is TRUE about circuit breakers and fuses?
   a. Circuit breakers are more reliable than fuses
   b. Circuit breakers will melt and fuses will open
   c. Both circuit breakers and fuses open the circuit
   d. Fuses must always be located near a circuit breaker

Defective Insulation Hazards

Insulation that is defective or inadequate is an electrical hazard. Usually, a plastic or rubber covering insulates wires. Insulation prevents conductors from coming in contact with each other and with people.

Extension cords: Extension cords may have damaged insulation. Sometimes the insulation inside an electrical tool or appliance is damaged. When insulation is damaged, exposed metal parts may become energized if a live wire inside touches them.

Tools: Electric hand tools that are old, damaged, or misused may have damaged insulation inside. If you touch damaged power tools or other equipment, you will receive a shock. You are more likely to receive a shock if the tool is not grounded or double-insulated. Double-insulated tools have two insulation barriers and no exposed metal parts.

You must recognize that defective insulation is a hazard.

5. While working with electric hand tools, when are you more likely to receive a shock?
   a. If the tool is not grounded or double-insulated
   b. If the tool was made prior to 1989
   c. When the tool has synthetic insulation
   d. When a tool is used while wearing leather gloves

Improper Grounding Hazards

When an electrical system is not grounded properly, a hazard exists because unwanted voltage cannot be safely eliminated. The most common OSHA electrical violation is improper grounding of equipment and circuitry. The metal parts of an electrical wiring system that we touch (switch plates, ceiling light fixtures, conduit, etc.) should be grounded and at 0 volts. If the system is not grounded properly, these parts may become energized. Metal parts of motors, appliances, or
electronics that are plugged into improperly grounded circuits may be energized. If there is no safe path to ground for fault currents, exposed metal parts in damaged appliances can become energized.

Extension cords may not provide a continuous path to ground because of a broken ground wire or plug. If you contact a defective electrical device that is not grounded (or grounded improperly), you will be shocked.

You must recognize an improperly grounded electrical system is a hazard.

6. What is the most common OSHA electrical violation?
   a. Defective power tools
   b. Failure to use GFCIs on worksites
   c. Use of three-prong plugs with power tools
   d. Improper grounding of equipment and circuitry

Ground Fault Circuit Interrupters (GFCI)

A ground fault circuit interrupter, or GFCI, is an inexpensive life-saver. GFCIs detect any difference in current between the two circuit wires (the black wires and white wires). This difference in current could happen when electrical equipment is not working correctly, causing leakage current. If leakage current (a ground fault) is detected in a GFCI-protected circuit, the GFCI switches off the current in the circuit, protecting you from a dangerous shock.

More important points to remember:

- GFCIs are set at about 5 mA and are designed to protect workers from electrocution.
- GFCIs detect the loss of current resulting from leakage through a person who is beginning to be shocked. If this situation occurs, the GFCI switches off the current in the circuit.
- GFCIs are different from circuit breakers because they detect leakage currents rather than overloads.

Circuits with missing, damaged, or improperly wired GFCIs may allow you to be shocked.

You need to recognize that a circuit improperly protected by a GFCI is a hazard.
7. Ground Fault Circuit Interrupters (GFCIs) detect the loss of current resulting from _____.
   a. a disconnected ground wire in the circuit
   b. leakage through a person who is beginning to be shocked
   c. short circuits directly to ground
   d. an open circuit due to a person not properly grounded

Overhead Powerline Hazards

Most people do not realize that overhead powerlines are usually not insulated. More than half of all electrocutions are caused by direct worker contact with energized powerlines. Powerline workers must be especially aware of the dangers of overhead lines.

In the past, 80% of all lineman deaths were caused by contacting a live wire with a bare hand. Due to such incidents, all linemen now wear special rubber gloves that protect them up to 34,500 volts. Today, most electrocutions involving overhead powerlines are caused by failure to maintain proper work distances.

Shocks and electrocutions occur where physical barriers are not in place to prevent contact with the wires. When dump trucks, cranes, work platforms, or other conductive materials (such as pipes and ladders) contact overhead wires, the equipment operator or other workers can be killed.

If you do not maintain required clearance distances from powerlines, you can be shocked and killed. (The minimum distance for voltages up to 50kV is 10 feet. For voltages over 50kV, the minimum distance is 10 feet plus 4 inches for every 10 kV over 50kV.) Never store materials and equipment under or near over-head powerlines. We'll talk more about this topic in the next section.

8. In the past, what has been the major cause of all lineman deaths due to electrocution?
   a. Touching the live wire with a bare hand
   b. Falling across a live wire at elevation
   c. Unintentionally contacting some part of the body with a live wire
   d. Completing the circuit between two live wires
Minimum Approach Distances

Altitude Correction Factor for Minimum Approach Distances. Minimum approach distances ensure that workers do not approach or take any conductive object closer to the energized parts. If the work is performed at elevations greater than 3,000 ft (900m) above mean sea level, the minimum approach distance must be determined by multiplying the distances by the correction factor corresponding to the altitude at which the work is performed.

Depending on the voltage of the line, a worker or a conductive object, must keep the minimum distance specified below between them and any energized part of the power line.

For more information on minimum approach distances and evaluating work zones, see Oregon OSHA's Fact Sheet on Power Line Safety.

See 29 CFR 1910.269 Tables R-3 through R-9 for more information on calculating approach distances.

9. Which of the factors below will increase the safe distance (phase to ground exposure) from a high voltage line?
   a. Decrease in humidity
   b. Increase in humidity
   c. Decrease in altitude
   d. Increase in altitude

General Indicators of Electrical Hazards

There are a number of general situations and conditions in the workplace that indicate electrical hazards:

- Tripped circuit breakers and blown fuses show that too much current is flowing in a circuit. This condition could be due to several factors, such as malfunctioning equipment or a short between conductors. You need to determine the cause in order to control the hazard.

- An electrical tool, appliance, wire, or connection that feels warm may indicate too much current in the circuit or equipment. You need to evaluate the situation and determine your risk.
• An extension cord that feels warm may indicate too much current for the wire size of the cord. You must decide when action needs to be taken.

• A cable, fuse box, or junction box that feels warm may indicate too much current in the circuits.

• A burning odor may indicate overheated insulation.

• Worn, frayed, or damaged insulation around any wire or other conductor is an electrical hazard because the conductors could be exposed. Contact with an exposed wire could cause a shock. Damaged insulation could cause a short, leading to arcing or a fire. Inspect all insulation for scrapes and breaks. You need to evaluate the seriousness of any damage you find and decide how to deal with the hazard.

• A GFCI that trips indicate there is current leakage from the circuit. First, you must decide the probable cause of the leakage by recognizing any contributing hazards. Then, you must decide what action needs to be taken.

10. **Tripped circuit breakers and blown fuses show that _____.**

   a. the speed of the current in the circuit is too fast
   b. the resistance in the circuit has increased
   c. there has been a spike in voltage
   d. too much current is flowing in a circuit
Module 3: Evaluating Risk and Controlling Hazards

Evaluating Risk

After you recognize a hazard, your next step in the Electrical Safety Model is to evaluate your risk from the hazard. The closer you work to the "danger zone," the more likely you'll be exposed to the electrical hazard.

Risk = Probability + Severity. To analyze and evaluate risk we must determine both probability and severity. Probability is the likelihood that an injury will occur. Severity is the degree of harm to the injured worker. You can estimate probability; however, severity is nothing more than a matter of luck.

For instance, exposed wires should be recognized as a hazard. If the exposed wires are 15 feet off the ground, you're not close to the danger zone so the probability of an injury is low. However, if you are going to be working on a roof near those same wires, the probability would be high. In either situation, contact with the exposed wire could be fatal. But if the employee is working at elevation and could fall, the severity is more likely going to be fatal.

Another factor increasing your risk of injury is working around combinations of hazards. Improper grounding and a damaged tool greatly increase your risk. Wet conditions combined with other hazards also increase your risk. You will need to make decisions about the nature of hazards to evaluate your risk and do the right thing to remain safe.

1. What must be determined when evaluating the risk of an electrical hazard?
   a. Probability and risk
   b. Severity and compliance
   c. Probability and severity
   d. Risk level and magnitude

Clues Indicating Risk

There may be important clues that electrical hazards exist. For example, if a GFCI keeps tripping while you are using a power tool, that's a clue that there is a problem. Don't keep resetting the GFCI and continue to work. You must evaluate the "clue" and decide what action should be taken to control the hazard.
Any of these conditions, or "clues," tells you something important: there is a risk of fire and electrical shock. The equipment or tools involved must be avoided. You will frequently be caught in situations where you need to decide if these clues are present. A maintenance electrician, supervisor, or instructor needs to be called if there are signs of overload and you are not sure of the degree of risk. Ask for help whenever you are not sure what to do. By asking for help, you will protect yourself and others.

2. What should you do if a Ground Fault Circuit Interrupter (GFCI) keeps tripping while you are using a power tool?
   a. Keep resetting the GFCI until it works right
   b. Recognize it as a clue that there is a problem
   c. Take the GFCI out of service and continue work
   d. Attempt three resets to see if it will work

Controlling Hazards

To control hazards, you must first create a safe work environment, then work in a safe manner. Generally, it is best to remove the hazards altogether and create an environment that is truly safe. When OSHA regulations and the NEC are followed, safe work environments are created.

But, you never know when materials or equipment might fail. Prepare yourself for the unexpected by using safe work practices. Use as many safeguards as possible. If one fails, another may protect you from injury or death.

Creating a Safe Work Environment

A safe work environment is created by controlling contact with electrical voltages and the currents they can cause. Electrical currents need to be controlled so they do not pass through the body. Make your environment safer by doing the following:

- Treat all conductors - even de-energized ones - as if they are energized until they are locked out and tagged.
- Lock out and tag out circuits and machines.
- Prevent overloaded wiring by using the right size and type of wire.
- Prevent exposure to live electrical parts by isolating them.
• Prevent exposure to live wires and parts by using insulation.

• Prevent shocking currents from electrical systems and tools by grounding them.

• Prevent shocking currents by using GFCIs.

• Prevent too much current in circuits by using overcurrent protection devices.

3. Treat all electrical conductors as if they are ______.
   a. de-energized and safe to work with
   b. de-energized and not properly grounded
   c. energized with high voltage dc current
   d. energized until they are locked out and tagged

Circuit Protection Devices

Circuit protection devices limit or stop the flow of current automatically in the event of a ground fault, overload, or short circuit in the wiring system. Well-known examples of these devices are fuses, circuit breakers, ground-fault circuit interrupters (GFCI), and arc-fault circuit interrupters.

**Fuses** and circuit breakers open or break the circuit automatically when too much current flows through them. When that happens, fuses melt and circuit breakers trip the circuit open. Fuses and circuit breakers are designed to protect conductors and equipment. They prevent wires and other components from overheating and open the circuit when there is a risk of a ground fault.

**Ground-fault circuit interrupters**, or GFCIs, are used in wet locations, construction sites, and other high-risk areas. These devices interrupt the flow of electricity within as little as 1/40 of a second to prevent electrocution. GFCIs 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.

**Arc-fault devices** provide protection from the effects of arc-faults by recognizing characteristics unique to arcing and by functioning to deenergize the circuit when an arc-fault is detected.
4. Which device interrupts the flow of electricity within as little as 1/40 of a second to prevent electrocution?

a. Capacitor  
b. GFCI  
c. Circuit breaker  
d. Fuse

Control Inadequate Wiring Hazards

Electrical hazards result from using the wrong size or type of wire. You must control such hazards to create a safe work environment. You must choose the right size wire for the current expected in a circuit. The wire must be able to handle the current safely. The wire’s insulation must be appropriate for the voltage and tough enough for the environment. Connections need to be reliable and protected.

Fixed, permanent wiring is better than extension cords, which can be misused and damaged more easily. A variety of materials can be used in wiring applications, including non-metallic sheathed cable (Romex®), armored cable, and metal and plastic conduit.

Control Hazards of Fixed Wiring

The wiring methods and size of conductors used in a system depend on several factors:

- intended use of the circuit system
- building materials
- size and distribution of electrical load
- location of equipment (such as underground burial)
- environmental conditions (such as dampness)
- presence of corrosives
- temperature extremes
Control Hazards of Flexible Wiring

Flexible wiring can be used for extension cords or power supply cords. DO NOT use flexible wiring as a substitute for fixed wiring or in situations where:

- frequent inspection would be difficult,
- damage would be likely, or
- long-term electrical supply is needed.

Flexible cords must not be:

- run through or hidden in holes in walls, ceilings, or floors;
- run through doorways, windows, or similar openings (unless physically protected); or
- attached to building surfaces (except with a tension take-up device within 6 feet of the supply end)

5. Do not use flexible wiring as a substitute for fixed wiring or in situations where _____.
   a. damage would be likely
   b. short-term supply is needed
   c. inspections are infrequent
   d. line length exceeds 25 feet

Protection from Energized Parts

A break in an electric tool's or machine's insulation can cause its metal parts to become "hot" or energized, meaning that they conduct electricity. Touching these energized parts can result in an electrical shock, burn, or electrocution.

The best way to protect yourself when using electrical tools or machines is to establish a low-resistance path from the device's metallic case to the ground. This requires an equipment grounding conductor, a low-resistance wire that directs unwanted current directly to the ground.
A properly installed grounding conductor has a low resistance to ground and greatly reduces the amount of current that passes through your body. Cord and plug equipment with a three-prong plug is a common example of equipment incorporating this ground conductor. Never use a three-prong plug if the center ground prong is missing.

Another form of protection is to use listed or labeled portable tools and appliances protected by an approved system of double insulation or its equivalent. Where such a system is employed, it must be marked distinctively to indicate that the tool or appliance uses an approved double insulation system.

For more information, check out OSHAcademy course [710 Energy Control Program (Lockout/Tagout)].

6. What should be done if you see a power tool's plug with a missing center ground prong?
   
   a. Use the tool because the plug is still safe
   
   b. Be careful and use common sense
   
   c. Tag the tool before use
   
   d. Do not use it

**Protection Against Unexpected Startup**

**Lockout/Tagout.** Proper lockout/tagout procedures protect you from the dangers of the accidental or unexpected startup of electrical equipment and are required for general industry by OSHA Standard 1910.333, Selection and Use of Work Practices. Requirements for construction applications are in 29 CFR 1926.417, Lockout and Tagging of Circuits. These procedures ensure that electrical equipment is deenergized before it is repaired or inspected and protects you against electrocution or shock.

The first step before beginning any inspection or repair job is to turn the current off at the switch box and padlock the switch in the OFF position. This applies even on so-called low-voltage circuits. Securely tagging the switch or controls of the machine or equipment being locked out of service clarifies to everyone in the area which equipment or circuits are being inspected or repaired.

Only qualified electricians who have been trained in safe lockout procedures should maintain electrical equipment. No two of the locks used should match, and each key should fit just one lock. In addition, one individual lock and key should be issued to each maintenance worker authorized to lock out and tag the equipment. All employees who repair a given piece of
equipment should lock out its switch with an individual lock. Only authorized workers should be permitted to remove it.

7. Which of the following procedures protects the electrician from accidental or unexpected equipment startup?
   a. Electrical release procedures  
   b. Lockout/tagout procedures  
   c. Continual monitoring of equipment status  
   d. Using a "buddy system" during maintenance

**Protection Around High Voltage Lines**

Before working under or near overhead power lines, ensure that you maintain a safe distance to the lines and, for very high-voltage lines, ground any equipment such as cranes that can become energized. If working on power lines, ensure that the lines have been deenergized and grounded by the owner or operator of the lines. Other protective measures like guarding or insulating the lines help prevent accidental contact.

Employees unqualified to work with electricity, as well as mechanical equipment, should remain at least 10 feet away from overhead power lines. If the voltage is more than 50,000 volts, the clearance increases by 4 inches for each additional 10,000 volts.

When mechanical equipment is operated near overhead lines, employees standing on the ground should avoid contact with the equipment unless it is located outside the danger zone. When factoring the safe standoff distance, be sure to consider the equipment's maximum reach.

Safe practices that will save your life:

- Do NOT assume a downed conductor is safe simply because it is on the ground or it is not sparking.

- Do NOT assume that all coated, weatherproof or insulated wire is just telephone, television or fiber-optic cable.

- Low-hanging wires still have voltage potential even if they are not touching the ground. So, “don’t touch them.” Everything is energized until tested to be de-energized.
• Never go near a downed or fallen electric power line. Always assume that it is energized. Touching it could be fatal.

• Electricity can spread outward through the ground in a circular shape from the point of contact. As you move away from the center, large differences in voltages can be created.

• Never drive over downed power lines. Assume that they are energized. And, even if they are not, downed lines can become entangled in your equipment or vehicle.

• If contact is made with an energized power line while you are in a vehicle, remain calm and do not get out unless the vehicle is on fire. If possible, call for help.

• If you must exit any equipment because of fire or other safety reasons, try to jump completely clear, making sure that you do not touch the equipment and the ground at the same time. Land with both feet together and shuffle away in small steps to minimize the path of electric current and avoid electrical shock. Be careful to maintain your balance.

8. If contact is made with an energized power line while you are in a vehicle, be sure to _____.
   a. get out and slowly walk away from the vehicle
   b. stay in the car unless the vehicle is on fire
   c. jump away and land on one foot
   d. ask someone to open the door for you

**Electrical Protective Equipment**

Employees who work directly with electricity should use the personal protective equipment required for the jobs they perform. This equipment may include rubber insulating gloves, hoods, sleeves, matting, blankets, line hose, and industrial protective helmets designed to reduce electric shock hazard. All help reduce the risk of electrical accidents. General safe practices include:

• Electrical protective equipment must be periodically tested in accord with the test tables found in the standard(s).
• Insulating equipment must be inspected for damage before each day's use. Equipment found defective must be taken out of service until repaired and retested.

• The arc-rated protective clothing and other protective equipment generally must cover the worker's entire body, except for hands, feet, head and face, which may be protected by other PPE.

Tools

Appropriate and properly maintained tools help protect workers against electric hazards. It's important to maintain tools regularly because it prevents them from deteriorating and becoming dangerous. Check each tool before using it. If you find a defect, immediately remove it from service and tag it so no one will use it until it has been repaired or replaced.

When using a tool to handle energized conductors, check to make sure it is designed and constructed to withstand the voltages and stresses to which it has been exposed.

9. Insulating equipment, such as electrical protective gloves, found defective must be

   a. thrown away and never used again
   b. taken out of service until repaired and retested
   c. checked and used carefully
   d. exchanged for other protective equipment the next day

Training Requirements

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. When working on electrical equipment, for example, some basic procedures to follow are to:

• Assume all overhead wires are energized at lethal voltages. Never assume that a wire is safe to touch even if it is down or appears to be insulated.

• Never touch a fallen overhead power line. Call the electric utility company to report fallen electrical lines.
• Stay at least 10 feet away from overhead wires during cleanup and other activities. If working at heights or handling long objects, survey the area before starting work for the presence of overhead wires.

• If an overhead wire falls across your vehicle while you are driving, stay inside the vehicle and continue to drive away from the line. If the engine stalls, do not leave your vehicle. Warn people not to touch the vehicle or the wire. Call or ask someone to call the local electric utility company and emergency services.

• Never operate electrical equipment while you are standing in water.

• Never repair electrical cords or equipment unless qualified and authorized.

• Have a qualified electrician inspect electrical equipment that has gotten wet before energizing it.

• If working in damp locations, inspect electric cords and equipment to ensure that they are in good condition and free of defects, and use a ground-fault circuit interrupter (GFCI).

• Always use caution when working near electricity.

10. How far should workers, or their equipment, stay away from overhead wires during cleanup and other activities?

   a. No less than 3 feet
   b. Between 3 and 5 feet
   c. At least 10 feet
   d. Between 5 and 15 feet
Additional Resources


2. OSHA Safety and Health Topics - Electrical

3. Electrical Safety Glossary

4. Napo's Films, Via Storia

5. Electrical Safety Video