MSHA Annual Refresher Training

Module 2

Electrical Hazards and Safety Protections

MSHA Training Requirement:

Instruction on the recognition and avoidance of electrical hazards. [Section 46.5(b)(2)]

Learning Objectives:

1. Understand basic electrical properties and calculations.
2. Recognize common electrical hazards in surface mines and identify factors that contribute to electrical accidents.
3. Detail safety measures to protect workers from electrical hazards and securely handle electrical components and equipment.
4. Learn lock-out and tag-out procedures for safely working with electrical materials and equipment.

Module Sections

- 2.1 Introduction to Electrical Hazards
- 2.2 Electrical Terms and Calculations
- 2.3 Protection of Electrical Systems and Equipment
- 2.4 Major Causes of Electrical Accidents
- 2.5 Health Effects and Consequences of Electrical Accidents
- 2.6 Lock-Out and Tag-Out Procedures
- 2.7 Reporting Electrical Hazards

2.1 INTRODUCTION TO ELECTRICAL HAZARDS

Managing electrical hazards in the mining industry is critical to ensure the safety of workers and protect equipment. The rules outlined in 30 CFR Part 56 Subpart K (Electricity) outline specific guidelines to prevent accidents and maintain a secure work environment.

In this module you will review the key regulations that focus on managing electrical hazards in surface mines.

You will learn how to:

1. Understand basic electrical properties and calculations.
2. Recognize common electrical hazards in surface mines and identify factors that contribute to electrical accidents.
3. Detail safety measures to protect workers from electrical hazards and securely handle electrical components and equipment.
4. Execute lock-out and tag-out procedures for safely working with electrical materials and equipment.

Module Warmup

Why preventing electrical hazards matter?

Understanding how to identify and prevent electrical hazards at mine worksites is not only a procedural requirement but an invitation to take personal responsibility to learn and confidently follow safety regulations and procedures.

The rest of this module will help you further understand key electrical hazard concepts and why the topics listed above are important for preventing electrical hazards at a mine worksite.

2.2 ELECTRICAL TERMS AND CALCULATIONS

Let's review some common electrical definitions, their identifying symbols, and how they are measured. This will help you safely work with different electrical tools and equipment.

Current (I or a): Electrical current is the movement of electrical energy from one location to another. Current is sometimes considered as the flow of electrical charges through a conductor. The most common reference to current in the mining industry is to the amount of amperes in a given circuit. Current is measured in amperes (amps).

Resistance (R or Ω): Resistance is opposition to the flow of current. A common reference to resistance in the mining industry is to whether a circuit is open or closed (based on an ohmmeter reading). Resistance is measured in Ohms.

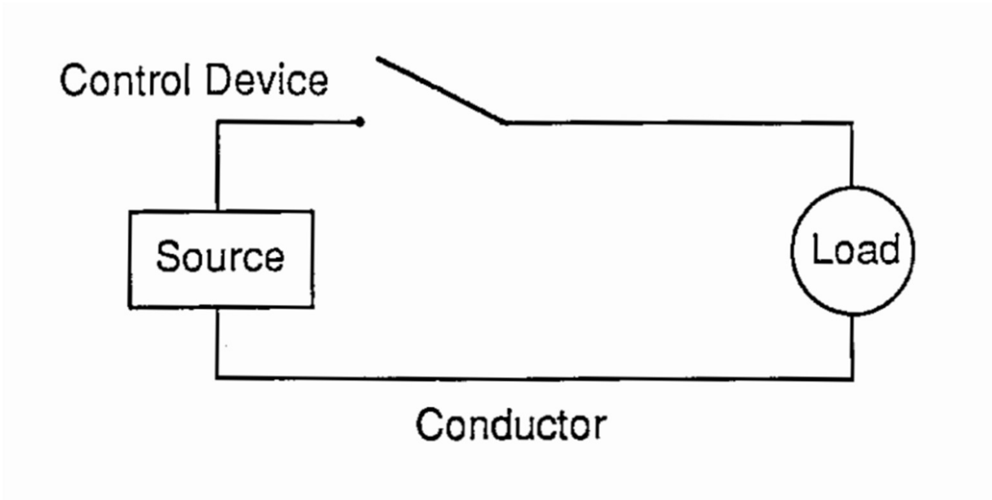
Voltage (E or V): Voltage is the electrical "pressure" which causes current to flow through a circuit. Voltage has also been called electromotive force, or potential difference. The most common reference to voltage in the mining industry is to the amount of volts in a given circuit. Voltage is measured in volts.

Power (P or W): Power is the rate at which work is done. Electrical power could be called the rate at which voltage and current get work done. A reference to power in the mining industry might be to the output of a given source. Power is measured in watts or kilowatts.

Basic Electrical Circuit

A *basic electrical circuit* normally consists of the following four parts:

- Source
- Conductor
- Load
- Control device



2.1: Parts of a basic electrical circuit

The purpose of each of these parts is below:

- **Source:** Supplies voltage or "pressure" to push current through the circuit
- **Conductor:** Provides a path for current to flow.
- **Load:** Uses the current flow to accomplish work.
- **Control Device:** Permits or stops the current flow (manually or automatically) for service or protection purposes.

Basic Electrical Calculations

While you may not always work directly with electrical tools or equipment, you might need to determine electrical information to share with coworkers or document in mine site reports.

Ohm's Law

Ohm's law describes the relationship of resistance, current, and voltage in a given circuit. It states that the current flowing in a given circuit is:

- *Proportional* to the applied voltage
- *Inversely proportional* to the resistance

Ohm's law variables:

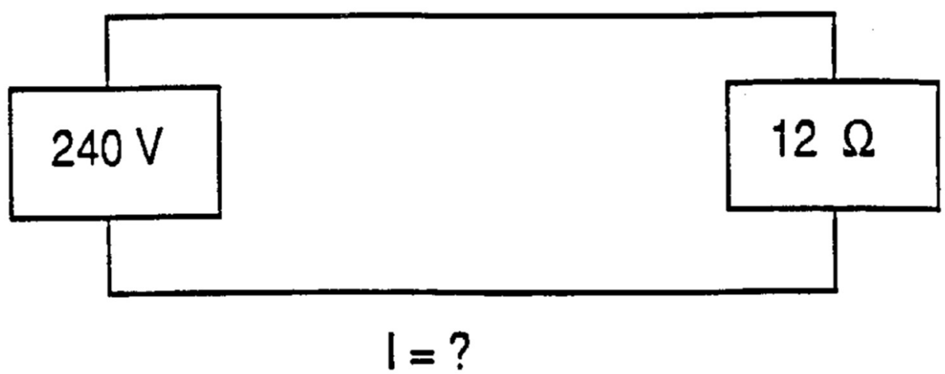
- I = current in amps
- E = voltages in volts

- R = resistance in ohms

Ohm's law calculations:

- I = E / R [amps = volts / ohms]
- E = I x R [volts = amps x ohms]
- R = E / I [ohms = volts / amps]

For example, Ohm's Law can be used to find the current in the following circuit.



2.2: Ohm's Law current calculation

Ohm's law calculations:

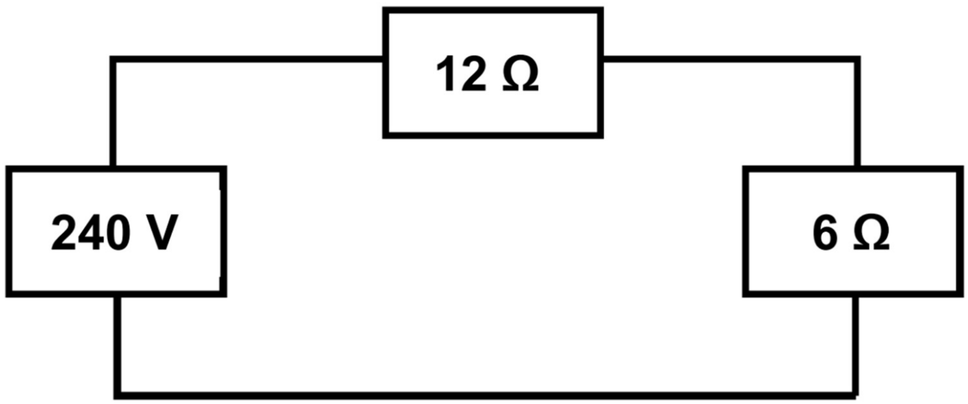
- I = E / R [amps = volts / ohms]
- I = 240 V/12 Ω
- I = 20 A

Resistance

How to calculate resistance depends on whether the resistances are:

- In a series
- In parallel

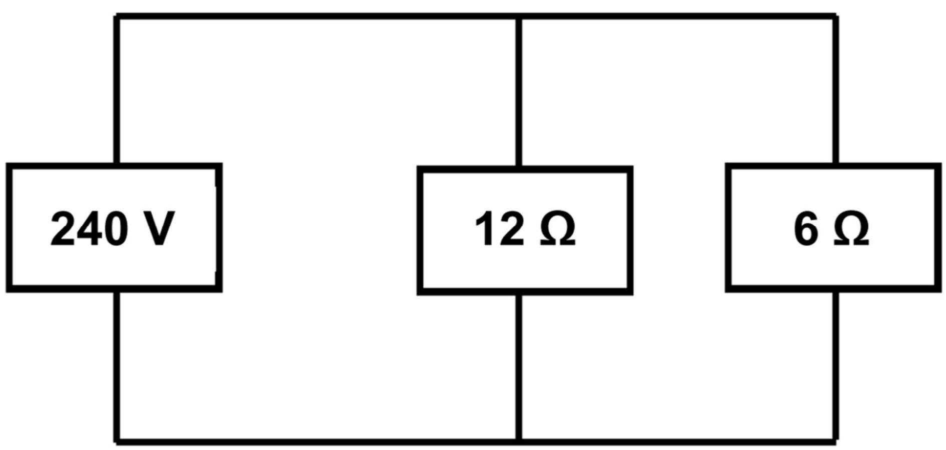
Resistances in series can be totaled by simply adding them.



2.3: Ohm's Law resistance calculation

R (total) = R1 + R2
R (total) = 12Ω + 6Ω
R (total) = 18Ω

However, resistances in parallel must be added differently.



2.4: Ohm's Law resistance in parallel calculation

- R(total) = R1 X R2 / R1+R2
- R(total) = 12Ω X 6Ω / 12Ω + 6Ω
- R(total) = 72Ω / 18Ω
- R(total) = 4Ω

Power

Power is defined as the rate at which work is done. Electrical power, then, would be the rate at which voltage and current get work done.

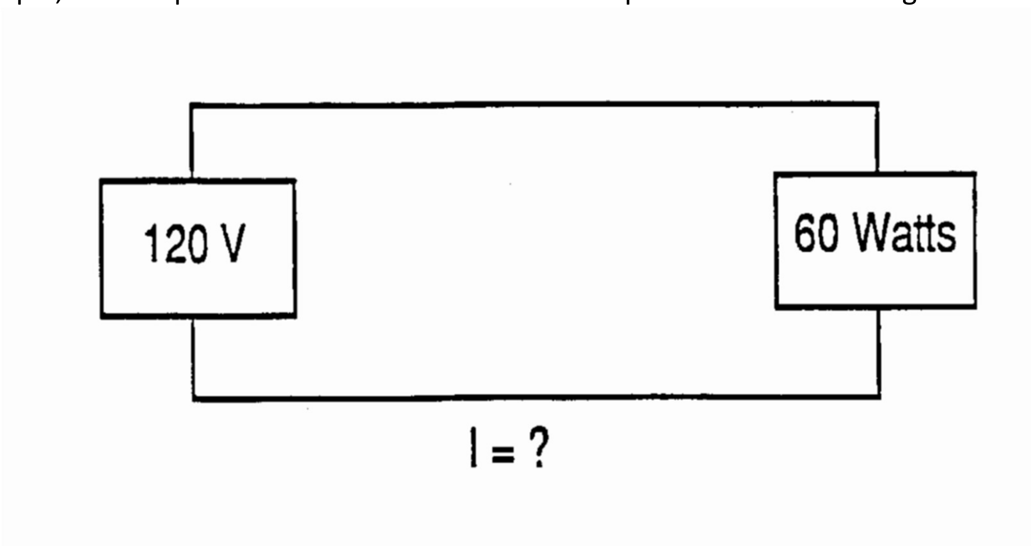
Power variables:

- P = power in watts
- E = voltages in volts
- I = current in amps

Power calculations:

- P = E x I [watts = volts / amps]
- E = P / I [volts = watts x amps]
- I = P / E [amps = watts / volts]

For example, use the power calculation to find the total power in the following circuit.



2.5: Power formula calculation

- I = P / E [amps = watts / volts]
- I = 60 watts / 120 volts
- I = 0.5 amps

Now, you know four primary basic electrical calculations that will help you communicate with coworkers or document data in mine site reports.

2.3 PROTECTION OF ELECTRICAL SYSTEMS AND EQUIPMENT

Equipment Controls and Switches

The basic electrical circuit parts (a source, conductor, load, and control device) will likely be present at every mine site in which you work. Therefore, you need to know the standards for switches and other controls for electrical systems and equipment at mine sites to help mitigate the risks of shocks, burns, fires, and other potentially hazardous consequences.

Switches and control devices are used for stopping and starting electrical equipment.
The purpose of a switch is to make or break the current to a load by means of a mechanical control. Arcing occurs when a switch or mechanical control is operated.

Electrical arcing occurs when electricity bridges or crosses a gap–or "jumps"–between two conductive surfaces. It often happens when there is a break or damage in an electrical circuit, causing a sudden release of electrical energy in the form of sparks or flashes.

What is an arc flash?
An arc flash is a sudden release of energy caused by an electrical fault or short circuit, resulting in an explosive discharge of intense heat, light, and pressure. This phenomenon occurs when electric current travels through the air between conductors or from a conductor to a ground, creating a highly luminous electric arc.

Electrical arcs produce tremendous amounts of heat! The temperature of an electric arc at currents of 2 amps to 20 amps can range from 3600°F to 7200°F at the starting and ending points of the arc.

Importantly, switches and starting boxes are designed for specific *ratings* and certain *environments*. These ratings, typically indicated on a nameplate inside the switchbox, include information about voltage, amperage, and horsepower, ensuring compatibility with the intended application.

Control devices: Control devices, including switches, must be fully enclosed to ensure the safety of personnel and equipment. Enclosures prevent exposure to bare conductors and energized parts, reducing the risk of electrical hazards. Improvised switches, such as plug and receptacle setups (i.e., "Miller Plugs"), trolley taps and trolley wire devices, often fail to meet compliance standards due to their inherent safety risks.

Switch boxes: Switch boxes should also be rated for the environmental conditions they are used in.

Switches should also be connected to the power correctly. Most switches have a line connection and load connection.

All switches, starting boxes, and other electrical controls should be designed and sized following accepted industry standards, particularly those set forth by organizations like the NEC (National Electrical Code) and IEEE (Institute of Electrical and Electronics Engineers).

Operating switches and starting boxes beyond their design can result in shock, burn, and explosion hazards!

Installation of Operating Controls

Proper installation of switches, control devices, and associated equipment is paramount for electrical safety and compliance at a mine site. This includes the following operating controls:

- Knife Throw Switches
- Boxes, Enclosures, Conduits, and Cables
- Cover Plate Installation

You must install operating controls in a way that they can be used safely without touching energized wires!

Distribution and Junction Box Protection

Connecting or Disconnecting Trailing Cables and Power Cables to Junction Boxes

A trailing cable is a flexible electrical cable that is used to provide power to mobile machinery or equipment at a worksite. Trailing cables are often used at mine sites. When connecting or disconnecting trailing cables and power cables to junction boxes, you must do so *without* any electrical load. This means ensuring that there is *no* power running through the cables before making or breaking connections. Working without electrical load minimizes the risk of electrical shocks or damage to equipment.

What is electrical load?
Electrical load refers to the amount of power that is drawn from and active in an electrical system at any given time. Although some may interpret "under load" as equipment being in operation, the safest practice is always to remove power entirely before disconnecting cables. Any violation of this standard, such as disconnecting cable plugs while they are energized, poses significant risks.

If there is any doubt about the availability of means to de-energize circuits, discuss your concern with the mine operator or designated electrician to ensure safe disconnecting practices are followed. Remember, electrical arc flash hazards are a real concern when energized circuits are disconnected while still carrying a load!

2.4 MAJOR CAUSES OF ELECTRICAL ACCIDENTS

What factors contribute to electrical accidents at mines?

Electrical accidents at mines are often attributed to six common causes:

- Faulty insulation, connections, splices, and grounding
- Working on energized equipment
- Operating equipment near energized infrastructure
- Allowing unauthorized work on electrical equipment
- Ignoring or not identifying water hazards
- Not wearing proper Personal Protective Equipment (PPE)

Let's review each of these causes of electrical accidents so you know how to avoid them. We will also review the corresponding safety regulations that help prevent these types of accidents.

Faulty Insulation, Connections, Splices, and Grounding

Faulty insulation, connections, splices, and grounding can lead to electrical hazards because they create opportunities for electricity to escape, or arc, potentially causing shocks, fires, or explosions.

Faulty Insulation

In electrical terms, insulated means that something is separated from other surfaces that conduct electricity by a special substance called a dielectric. This substance stops electricity from passing through easily and prevents sudden discharges of electricity. The outer "jacket" of a cable then helps protect the internal conductors from cuts, abrasion, moisture, and other potentially dangerous hazards. Therefore, the outer jacket of a cable must be intact for the cable to be fully protected.

Faulty Connections

An electrical conductor is any material, usually in the form of a wire, cable, or bus bar, capable of carrying an electric current. In electrical systems, conductors typically form the pathways through which electricity travels, such as wires, cables, or traces on circuit boards.

Sometimes, an electrical connection refers to the point where two or more conductors are joined together to allow the flow of electricity between them. These connections can be made using various methods such as soldering, crimping, or using connectors. The quality of an electrical connection is crucial for ensuring proper resistance and safe transmission of electricity between the conductors.

Additionally, electrical conductors exposed to mechanical damage must be protected. You must also keep inspection and cover plates on all electrical equipment and junction boxes in place at all times, except during testing or repairs. You must also guard electrical connections and resistor grids that are hard to insulate, unless they are already protected by where they are located.

Circuit and Trailing Cable Overload Protection

If you are working with electrical tools or equipment, it is possible that a particular circuit seems to be carrying more electricity than it should.

You should always make sure that circuits have the right fuses or circuit breakers to prevent them from being overloaded. You can refer to the Insulated Power Conductor Engineers Association Handbook (IPCEA) or the cable manufacturer data for more information.

What About Trailing Cables?

Trailing cables are cables that are used to supply power to mobile or portable equipment. They must have protection from overloads or short circuits.

Fuse Removal or Replacement

In addition to circuit and trailing cable overload protection, you should follow proper fuse removal and replacements procedures to mitigate faulty electrical connections.

You should never remove or replace fuses by hand in an energized circuit. Instead of removing fuses by hand, which can be dangerous, use specialized equipment and techniques designed to prevent electrical shock for these tasks. Preventing faulty electrical connections helps electrical systems run smoothly and minimizes the risk of accidents, whether it is preventing circuit or trailing cable overloads or safely removing or replacing fuses.

Faulty Splices

In electrical terms, a splice refers to the joining together of two or more electrical conductors to create a continuous electrical path.

Splicing is a common practice in electrical installations, repairs, and maintenance to connect wires or cables securely and safely at mine work sites.

MSHA-assigned approval markings must be legible and permanently marked for approved splices. The marking must appear at least once on the assembled splice.

If indications of a poor splice connection are apparent you should de-energize, lock-out and tag-out the circuit prior examination by an electrical inspector. The inspector should evaluate whether the splice should be removed from service and repaired.

Faulty Grounding

You will often work with various types of electrical systems and equipment at mine worksites. Depending on system type, an additional conduction connection may be required. Therefore, it is essential to understand the importance of grounding in electrical systems. Grounding helps prevent electrical hazards and ensures the safety of everyone on the site.

Electrical Grounding

Electrical grounding is present when an electrical circuit or electrical equipment is connected to earth or to some conducting body in place of the earth.

Electrical grounding helps to:

- Minimize the risk of electric shocks and other hazards
- Limit voltage differences between noncurrent-carrying parts and the earth

If there is a fault, relying solely on the earth as a conductor might not be fast enough to prevent serious damage or injury!

Equipment Grounding and System Grounding

The federal regulations regarding grounding requirements relate to both equipment grounding and system grounding at mine sites.

Electrical equipment grounding refers to the process of connecting metal parts of electrical equipment to the ground.

The purpose of equipment grounding is to provide a safe path for fault currents to travel in case of a fault or electrical leakage. If there is a fault in the electrical equipment, such as a short circuit or a ground fault, the equipment grounding conductor directs the fault current safely to the ground, preventing it from passing through a person's body or causing a fire.

System grounding refers to the way that current carrying conductors in the distribution system are intentionally connected (or not connected) to the earth.

The main purpose of electrical system grounding is to ensure the stability of the electrical system and to provide a reference point for voltage levels. It helps to stabilize voltage levels and ensures that the electrical system operates within safe limits. It also helps to dissipate lightning strikes and other electrical surges safely into the ground.

Equipment grounding protects individuals and property from electrical hazards, while system grounding ensures the stability and safety of the electrical system itself.

Working on Energized Equipment

Working on energized equipment poses a significant risk to mine workers as it increases the likelihood of accidental contact with live wires or components, potentially resulting in severe shocks or electrocution.

Without proper precautions, such as lock-out or tag-out procedures that clearly mark equipment status, identification of power switches, or additional precautions near switchgear, you face increased danger when performing maintenance or repairs on powered machinery.

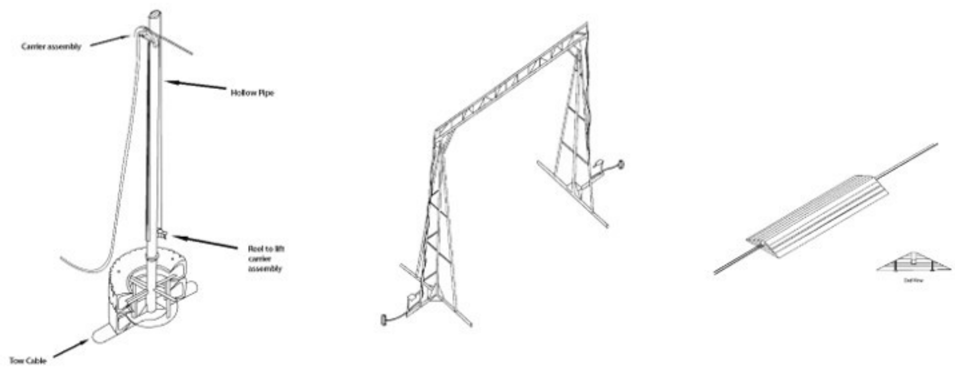
If you are in doubt about electrical equipment status, do not proceed to work on it!

Remember, you should put up suitable danger signs at all major electrical installations and fix any dangerous conditions before turning on equipment or wiring!

Cables and Wires Near Energized Infrastructure

Operating equipment near overhead power lines, guy wires, and energized trailing cables introduces the risk of accidental contact or proximity to high-voltage sources. This contact or increased proximity can lead to electric shocks, burns, or equipment damage.

Different methods to protect cables near energized infrastructure or other mine worksite equipment include the usage of cable towers, cable bridges, and cable crossovers.



Cable Tower **Cable Bridge** **Cable Crossover**

2.6: Cable Tower, Cable Bridge, and Cable Crossover

Make sure to maintain a safe distance and be aware of your surroundings to prevent inadvertent contact with energized infrastructure!

Allowing Unauthorized Work on Electrical Equipment

While you may consistently operate electrical systems or equipment at mine sites, you must make sure that you do not work on electrical equipment unless you are authorized to do so. Untrained or inexperienced personnel may inadvertently create unsafe conditions or fail to follow proper procedures, leading to equipment damage, electrical malfunctions, or personal injury. Lack of expertise and oversight increase the likelihood of electrical accidents occurring.

Only “Authorized Persons” should enter or work on or in areas where major electrical installations are located.

What is an “Authorized Person”?
Authorized Persons means a person approved or assigned by mine management to perform a specific type of duty or duties or to be at a specific location or locations in the mine.

If there is an electrical component to the mining task you are working on, do not go into electrical switchgear. That’s a job for the electrician!

Ignoring or Not Identifying Water Hazards

Water hazards create an increased risk of electrical accidents at mines by facilitating the conduction of electricity through wet surfaces or equipment. When water comes into contact with exposed electrical components or circuits, it can create short circuits, electrical arcing, or equipment malfunction, posing dangers to workers and equipment alike.

Always ensure dry and insulated conditions when working at mine sites!

Not Wearing Proper Personal Protective Equipment (PPE)

Not wearing proper Personal Protective Equipment (PPE) such as insulated gloves, boots, or adequate eye protection can increase the risk of electrical hazards by leaving workers vulnerable to electric shocks, burns, or other injuries.

PPE acts as a crucial barrier between you and electrical hazards. It provides insulation and protection against direct contact or exposure to electrical currents and heat.

2.5 HEALTH EFFECTS AND CONSEQUENCES OF ELECTRICAL ACCIDENTS

Now, we will consider some of the common health effects and consequences of electrical accidents. This will help you better prevent and respond to accidents from:

- Electrical fires
- Burns
- Shock and electrocution

Electrical Fires at Mine Sites

To have a fire, you only need a few components. There must be:

- Heat
- Fuel or a combustible material
- Oxygen

In most of the locations where electricity is used in the mining industry, a combustible material and oxygen will be readily available. In fact, it is hard to think of a location where these two items are not present!

Let's briefly consider how one of these individual fire components, heat, can contribute to electrical fires.

Burns and Heat from Electrical Arcs

Electrical arcing occurs when electricity bridges or crosses a gap–or "jumps"–between two conductive surfaces. It often happens when there is a break or damage in an electrical circuit, causing a sudden release of electrical energy in the form of sparks or flashes.

What is an arc flash?
An arc flash is a sudden release of energy caused by an electrical fault or short circuit, resulting in an explosive discharge of intense heat, light, and pressure. This phenomenon occurs when electric current travels through the air between conductors or from a conductor to a ground, creating a highly luminous electric arc.

Electrical arcs produce tremendous amounts of heat! The temperature of an electric arc at currents of 2 amps to 20 amps can range from 3600°F to 7200°F at the starting and ending points of the arc.

There is no way that a human can withstand the heat from uncontrolled arcing. The injury could be a very serious burn, a permanent disability, or even death.

Actions to Help Prevent Electrical Fires at Mine Sites

The primary ways to help prevent fires at mine sites are preventing excessive current flow from an overload or short circuit, or an arc that may occur from normal circuit operation or from fault conditions.

Being vigilant about the safeguards and regulations that you learned about in this module will help you prevent electrical fires at mine sites.

Shock and Electrocution

Many people have experienced a small or fleeting electrical shock sometime in their lives. A small shock from plugging in or unplugging an electrical cord for an appliance, for example, is a common experience. While you may not have experienced a serious health problem from this type of shock, even a small amount of current under specific conditions can lead to electrocution.

What About Voltage and Electrical Shock?

Voltage, known as electrical pressure, drives current through the body. Unfortunately, our bodies are effective conductors of electricity.

According to Ohm's Law, the level of current passing through the body is directly influenced by the voltage applied. Higher voltages result in increased current flow, potentially causing significant harm to organs and vital bodily functions. Violent muscular contractions can occur, often propelling a person away from the electrical source.

Is contact with low voltage electrical current still dangerous?
Even at lower voltages, the effects of electrical currents can be hazardous. Muscle contractions may not be as forceful, but proximity of the electrical current flow to the heart region can induce fibrillation or hinder muscle response, making it challenging to break free from an electrical shock.

Let’s look at how each electrical current amount, duration, and path contribute to the severity of electrical shock.

Current Amount: How Electrical Current Effects the Human Body

The human body is a proficient conductor of electricity. The intensity of an electrical shock and the resultant injuries are therefore directly influenced by the level of current passing through the body.

Current Duration: Exposure and Contact Time

In general, the *longer* an electrical current flows through the body, the *more* serious the shock. Studies indicate that the time for fibrillation to start varies according to the voltage contacted. Higher voltages need less time for fibrillation of the heart to start.

Current Path: Electrical Current Flow

When you come into contact with an electrical source, the current can enter your body and follow a path through your tissues, nerves, and organs.

Ohm's Law (Current (I) = Voltage (V) / Resistance (R)) helps us understand how electrical current flows through the body.

Skin Moisture and Electrical Current

A person's resistance to electrical current flow can also be impacted by skin moisture.

In almost all mines, wet conditions can be encountered which would increase the current flow during shock!

What should I do if a co-worker is getting or has been shocked?

The danger from an electrical shock depends on the type of current, how high the voltage is, how the current travels through the body, the person's overall health, and how quickly the person is treated.

Any person who has been shocked should be seen by a health care provider!

2.6 LOCK-OUT AND TAG-OUT PROCEDURES

Lock-out and tag-out procedures are safety measures implemented to protect miners from hazards associated with the unexpected energization or startup of machinery or equipment, or the release of stored energy.

These procedures involve specific steps to ensure that machinery and equipment are:

- Properly shut down
- Isolated from energy sources
- Tagged to indicate that they should not be operated

Lock-out and tag-out procedures help prevent accidents and injuries and ensure that machinery and equipment cannot be inadvertently started or operated during maintenance or servicing activities. It is essential for miners to be trained in and follow site-specific lock-out and tag-out procedures in the appropriate *order* to maintain a safe work environment in surface mines.

2.7 REPORTING ELECTRICAL HAZARDS

You Have the Right to Report Electrical Hazards

As a mining worker you have the right to report unsafe work conditions and electrical hazards. You can take both local and federal action until your concern is addressed and an unsafe electrical condition is fixed.

Local Action

If you identify or are asked to work in situations where electrical hazards exist, you can:

- Report the problem to your immediate supervisor
- Outline and document the nature of the problem with as much information as possible
- Request assistance from electrical specialists and inspectors

Federal Action

You can also utilize federal resources to report electrical hazards.

Congress included provisions in the Mine Act for miners and representatives of miners to formally complain to MSHA regarding safety or health conditions or practices at mines confidentially and *without* reprisal. Miners or their representatives filing complaints also have the right to appeal enforcement decisions made by MSHA regarding their complaint.

There are three types of complaints classified by MSHA:

1. Section 103(g) Complaint
2. Non-Miner and/or Anonymous Complaints
3. Other Complaints

Section 103(g) Complaints and Non-Miner and/or Anonymous Complaints are "hazardous condition complaints." Other complaints are not "hazardous condition complaints."