TITAN UNIVERSITY

MSHA Part 46 New Miner Online 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
- Appendix: Recognition and Avoidance of Electrical Hazards Conclusion

Code of Federal Regulations Reference Material

This module covers important topics listed below from 30 CFR 56 Subpart K (Electricity):

- 56.12001 Circuit overload protection.
- 56.12002 Controls and switches.
- 56.12003 Trailing cable overload protection.
- 56.12004 Electrical conductors.
- 56.12005 Protection of power conductors from mobile equipment.
- 56.12006 Distribution boxes.
- 56.12007 Junction box connection procedures.
- 56.12008 Insulation and fittings for power wires and cables.
- 56.12010 Isolation or insulation of communication conductors.
- 56.12011 High-potential electrical conductors.
- 56.12012 Bare signal wires.
- 56.12013 Splices and repairs of power cables.
- 56.12014 Handling energized power cables.
- 56.12016 Work on electrically-powered equipment.
- 56.12017 Work on power circuits.
- 56.12018 Identification of power switches.
- 56.12019 Access to stationary electrical equipment or switchgear.
- 56.12020 Protection of persons at switchgear.
- 56.12021 Danger signs.
- 56.12022 Authorized persons at major electrical installations.
- 56.12023 Guarding electrical connections and resistor grids.
- 56.12025 Grounding circuit enclosures.
- 56.12026 Grounding transformer and switchgear enclosures.
- 56.12027 Grounding mobile equipment.
- 56.12028 Testing grounding systems.
- 56.12030 Correction of dangerous conditions.
- 56.12032 Inspection and cover plates.
- 56.12033 Hand-held electric tools.
- 56.12034 Guarding around lights.
- 56.12035 Weatherproof lamp sockets.
- 56.12036 Fuse removal or replacement.
- 56.12037 Fuses in high-potential circuits.
- 56.12038 Attachment of trailing cables.
- 56.12039 Protection of surplus trailing cables.
- 56.12040 Installation of operating controls.
- 56.12041 Design of switches and starting boxes.
- 56.12042 Track bonding.

- 56.12045 Overhead power lines.
- 56.12047 Guy wires.
- 56.12048 Communication conductors on power poles.
- 56.12050 Installation of trolley wires.
- 56.12053 Circuits powered from trolley wires.
- 56.12065 Short circuit and lightning protection.
- 56.12066 Guarding trolley wires and bare powerlines.
- 56.12067 Installation of transformers.
- 56.12068 Locking transformer enclosures.
- 56.12069 Lightning protection for telephone wires and ungrounded conductors.
- 56.12071 Movement or operation of equipment near high-voltage power lines

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.

Consider the following accidents reported by the MSHA that resulted from devastating electrical incidents at mine worksites. Notice the cause and consequence of each incident; think about what steps you might have personally taken to help prevent or respond to these incidents based on what you learn in this module.

Electrical Incident 1: On January 27, 2023, at approximately 6:25 a.m., a 23 year-old contract haul truck operator with 48 weeks of mining experience, and a 25 year-old contract haul truck operator with seven years of mining experience, were electrocuted. An energized high-voltage power line contacted their haul trucks, resulting in fatal electric shocks when they exited the cabs of their haul trucks.

The accident occurred because the mine operator and contractor:

- Did not install warning signs or barricades to warn miners of the hazard of the overhead high-voltage power lines where the hazard presented was not immediately obvious to miners working in the area
- Allowed the staging area to be located under, and equipment to be operated within ten feet of energized overhead high-voltage power lines
- Did not conduct workplace examinations

Electrical Incident 2: On the morning of November 23, 2020, a 39-year-old Maintenance Mechanic with 14 months of mining experience, was electrocuted at the Mill 1 Classifier disconnect enclosure. He was troubleshooting an overcurrent fault in the energized Mill 1 Classifier electrical circuit. He was not wearing any special personal protective equipment (PPE) and contacted an energized 480 Volts Alternating Current (VAC) conductor.

The accident occurred because the mine operator:

- Did not assure phase lead connections were adequate
- Did not assure that miners had proper PPE for troubleshooting energized electrical equipment

These incidents reported by the MSHA highlight the potential consequences of neglecting electrical safety protocols and regulations at mine worksites. By understanding key electrical concepts and hazards, you will be better able to avoid similar accidents and keep both yourself and your coworkers safe.

Key Terms

Let’s review some common electrical concepts and definitions.

- Component: Any material in a cable splice kit which becomes part of a splice.
- Conductor: A bare or insulated wire or combination of wires not insulated from one another, suitable for carrying an electric current.
- Electric cable: An assembly of one or more insulated conductors of electric current under a common or integral jacket. A cable may also contain one or more uninsulated conductors.
- Jacket: A nonmetallic abrasion-resistant outer covering of a cable or splice.
- Power conductor: An insulated conductor of a cable assembly through which the primary electric current or power is transmitted.
- Signaling cable: A fiber optic cable, or a cable containing electric conductors of a cross-sectional area less than #14 American Wire Grade (AWG) used where the circuit cannot deliver currents which would increase conductor temperatures beyond that established for the current carrying capacity of the conductors.
- Splice: The mechanical joining of one or more severed conductors in a single length of a cable including the replacement of insulation and jacket.

- Splice kit: A group of materials and related instructions which clearly identify all components and detail procedures used in safely making a flame-resistant splice in an electric cable.

Preparing for Electrical Hazards

Many of the federal regulations concerning electrical circuits and equipment may seem very technical in nature, especially if you are new to mining. While you may encounter electrical problems at a work site that require special electrical expertise, from people like electrical engineers or electrical inspectors, there are simple precautions you can take to better recognize and prevent electrical hazards.

When you visit a mine site for the first time, or begin your work for the day, it is smart to:

- Make sure you have all required PPE and verify that the PPE is in good working condition
- Identify the location of energized equipment and infrastructure
- Ask about the proper lock-out and tag-out equipment procedures, and ask to see an example of 'tagged' equipment
- Confirm there are no wet surfaces in your immediate and surrounding work area

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: 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.

What is the unit of measure for current?
Ampere or amp is the unit of measurement for current. For example, one could say that the maximum amount of current allowed in a particular cable is 100 amps.

What are the symbols for current?
The symbols for current may be the letter **I** or **a**. The letter **"I"** is commonly used to stand for current in equations such as Ohm's Law which we will review later in this section. The letter **"a"** is commonly used to represent a measurement or value of amps in a circuit or equation.

Resistance: 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).

What is the unit of measure for resistance?
Ohm is the unit of measurement for resistance. For example, we could say that the resistance of a heater is 10 ohms.

What are the symbols for resistance?
The symbols for resistance may be **R** or **Ω**. The letter **"R"** is commonly used to stand for resistance in equations such as Ohm's Law. The symbol **"Ω"** is commonly used to represent a measurement, or value of ohms in a circuit or equation.

Voltage: 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.

What is the unit of measure for voltage?
Volt is the unit of measurement for voltage. For example, the voltage output of a power center could be 440 volts.

What are the symbols for voltage?

The symbols for voltage may be **E** or **V**. The letter **"E"** is commonly used to stand for voltage in equations such as Ohm's Law. The letter **"V"** is commonly used to represent a measurement, or value of volts in a circuit or equation.

Power: 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.

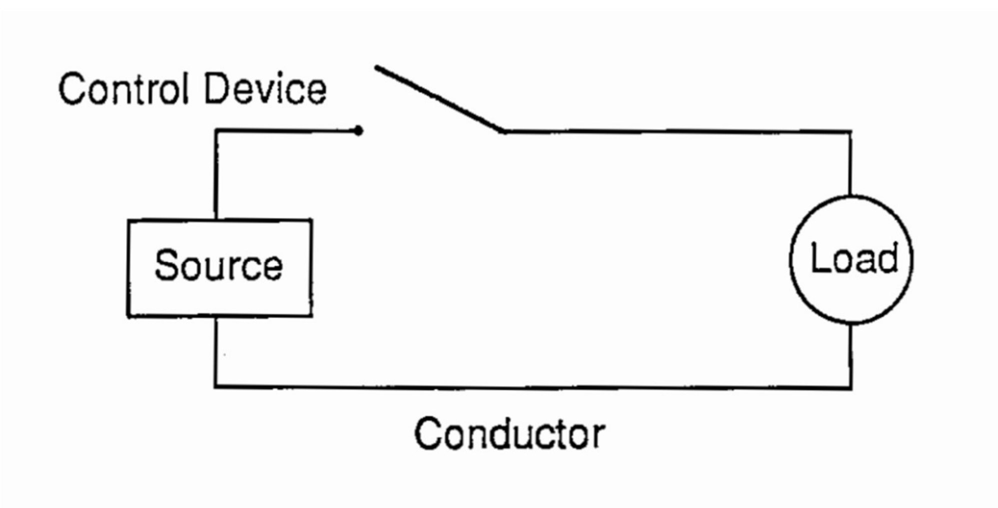
What is the unit of measure for power?
Watt is the unit of measurement for power. Since a watt is a small unit of power, kilowatt is more commonly used. A kilowatt is 1,000 watts. For example, one could say that a power center has 750 kilowatts of power available.

What are the symbols for power?
The symbols for power may be P or W. The letter "P" is commonly used to stand for power in equations such as the Power Formula. The letter "W" is used to represent a measurement, or value of watts in a circuit or equation.

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. Examples of a source are:

- Transformers
- Batteries
- Generators
- Rectifiers

Conductor: Provides a path for current to flow. Examples of a conductor are:

- Power Cables
- Trailing Cables
- Trolley Wire
- Mine Track
- Feeder Cable

Load: Uses the current flow to accomplish work. Examples of load are:

- Electric Motors
- Lights
- Resistors

Control Device: Permits or stops the current flow (manually or automatically) for service or protection purposes. Examples of a control device are:

- Circuit Breakers
- Fuses
- Switches
- Starters
- Contactors
- Relays
- Disconnects
- Control Device
- Conductor

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.

As previously discussed, the four fundamental units of electricity are current, resistance, voltage and power.

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

In most electrical mining circuits, electrical service is furnished with the voltage at certain values suitable for use. It is the resistance in the circuit that changes due to the changing loads. These resistance changes result in changes in the amount of current flowing in the circuit. Ohm's Law can be used to numerically describe this occurrence.

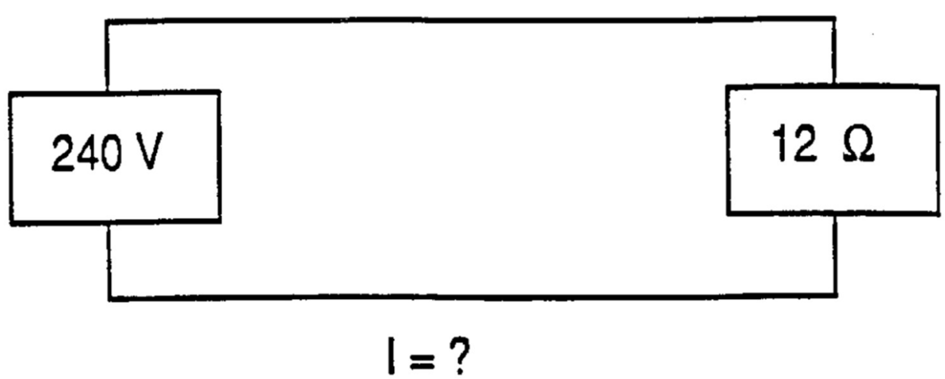
Ohm's law variables:

- 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]

Let's practice! 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:

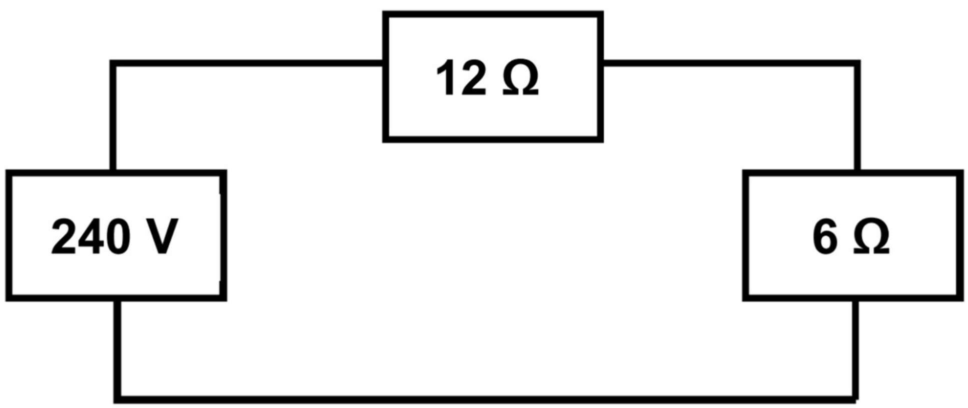
- I = E / R [amps = volts / ohms]
- I = 240 V/12 Ω
- I = 20 A

Resistance

How to calculate resistance depends on whether the resistances are:

- In a series
- In parallel

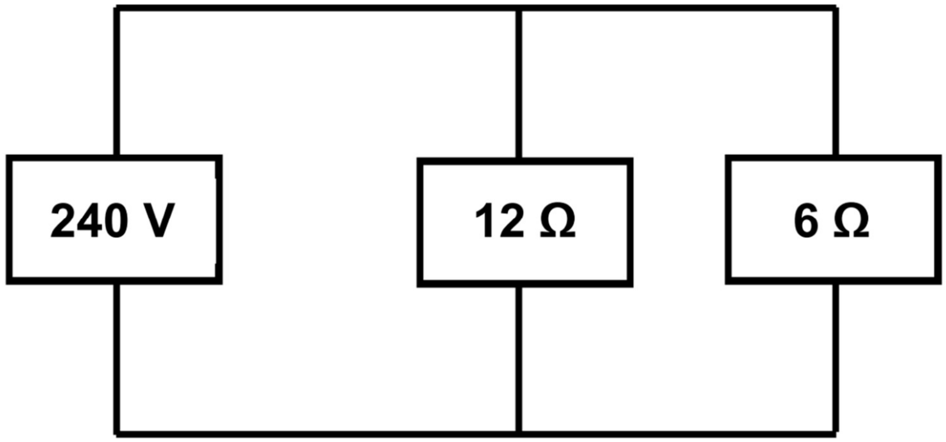
Resistances in series can be totaled by simply adding them.



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.

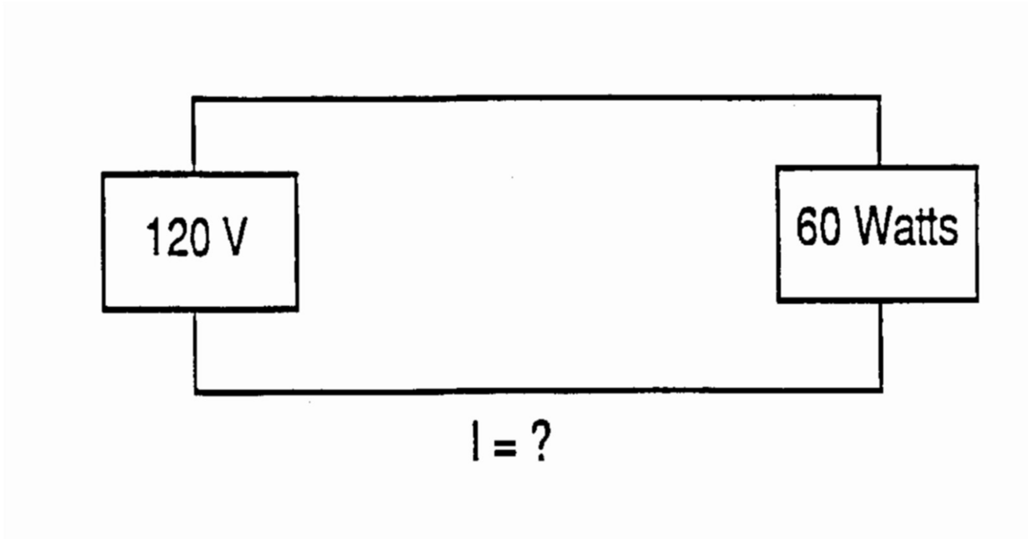
Power variables:

- 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]

Let's practice! 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

Good work. 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. For example, dust-proof or explosion-proof enclosures are necessary for hazardous locations, while weatherproof enclosures are suitable for wet or damp environments.

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

- **Line connection:** The line connection is commonly found at the top of the switch and is connected to the source of power.
- **Load connection:** The load connection is at the bottom of the switch and is connected to the equipment that the switch serves.

Do the rules for switches and controls depend on where and how you use them?
No. 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).

The rules regarding switches and controls apply across all electrical installations within mining operations, irrespective of:

- Work location (surface or underground)
- Electrical voltage (high or low)
- Type of current (alternating or direct)
- Whether you are operating stationary or portable equipment

Regardless of the factors listed above, equipment and circuits must be equipped with switches or other controls that are of an approved design and construction and installed correctly. Operating switches and starting boxes beyond their design can result in shock, burn, and explosion hazards!

How to Spot Improper Switches and Starting Boxes

- Switches and starter boxes that are not properly rated (voltage, current, horsepower) for the circuit for which they control.
- Switches and starter boxes not approved or accepted for the purpose they are being used (an interior box used outdoors).
- Control devices that create a hazard by their design and use.

Installation of Operating Controls

Proper installation of switches, control devices, and associated equipment is paramount for electrical safety and compliance at a mine site.

Consider the following regulations regarding proper installation of operating controls:

- **Knife Throw Switches:** A knife switch is a manual disconnecting device consisting of a metal blade that can be moved to make or break the electrical connection in a circuit. When the blade is in the open position, the circuit is disconnected, and when it is closed, the circuit is complete, allowing electricity to flow.
    - Knife throw switches, whether single or double throw, should be mounted to prevent gravity from inadvertently closing the switch when opened. Additionally, the wiring configuration should ensure that switch blades are de-energized when in the open position, reducing the risk of electrical accidents.
- **Boxes, Enclosures, Conduits, and Cables:** All boxes, enclosures, conduits, and cables must be securely fastened to mounting surfaces according to NEC regulations. The Code mandates that boxes be firmly attached to the surface they are mounted on, with alternative support methods only permissible if the surface cannot adequately support the box. Hanging boxes by wire is not considered an acceptable method of installation!
- **Cover Plate Installation:** In certain conditions, cover plates may be required to protect energized connections or parts. Failure to install these plates where necessary could result in noncompliance with safety standards.

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

Check for These Common Causes of Unapproved or Improper Installation of Controls and Switches:

- Breaker or fuse box that is not secured in place
- Controls installed that allow for exposed energized connections (such as a breaker or fuse and block installed without an enclosure, or stop or start controls without proper covers)
- Circuits without a switch such as: Motor circuits hooked directly to power without any switch/control, 110-volt light circuits without switches, or bare wires pushed into receptacles
- Overloads installed improperly (bypassed, shunted, etc.)

Distribution and Junction Box Protection

In simplified terms, a **distribution box** is a component of an electrical system that serves to distribute electrical power from a main power source to various branch circuits or loads within a building or construction site.

A distribution box typically contains multiple circuit breakers or fuses, each connected to a specific branch circuit, allowing for individual control and protection of electrical circuits.

Distribution boxes must have a **disconnecting device** for each branch circuit. This device serves as a safety measure, allowing workers to cut off power to specific circuits when needed. When turned off, the disconnecting device should be visible, indicating that the circuit is *not* powered.

Additionally, circuit breakers and disconnecting devices, such as a knife switch, on distribution boxes must be **labeled** to show which circuits each device controls. This labeling helps workers identify the correct circuit and prevents accidental power shutdowns.

Junction Box Connection Procedures

In electrical terms, a junction box is a protective enclosure used to contain electrical connections, such as wires, cables, or electrical devices.

At a mine site, a junction box might be used to connect trailing cables and power cables, facilitating the flow of electricity between different parts of the worksite. In short, a junction box provides a secure location for joining electrical wires or cables together, allowing for the extension or branching of electrical circuits.

What safety measures do junction boxes provide?

Junction boxes:

- Help protect electrical connections from environmental factors such as dust, moisture, and accidental damage
- Contain any sparks or heat generated by electrical connections, reducing the risk of ignition in combustible surroundings
- Typically feature removable covers or access points, allowing electricians to easily access and inspect the connections within for maintenance or troubleshooting purposes

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.

For example, worn-out insulation can expose you to live wires, while improper grounding can fail to divert dangerous currents away from equipment and personnel.

Let's look at an example of each of these factors that contribute to electrical accidents at mines.

Faulty Insulation

When we say something is "insulated," it means it has a protective substance around it. If it does *not* have this protection, it is considered uninsulated. Putting a cover on something, for example, is one way to make sure it is insulated properly.

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.

To avoid faulty insulation of electrical systems, equipment, or tools, you should make sure that you have the proper protection for each of the following types of cables:

- Communication conductors
- High-voltage wires
- Uncovered signal wires

Review and compare each of the following safety standards to avoid electrical hazards from faulty insulation.

Safety Standards for Communication Conductors

You will likely work near telephone or other signal wires at mine sites. Telephone and "Low-Potential" (low-voltage) signal wires need to be shielded or insulated, or both, to avoid touching live power wires or any other power source.

What is a Low-Potential signal wire?
A Low-Potential signal wire means that the wire can transmit 650 volts or *less*. A shock and fire hazard could exist if the higher voltage were to get onto the lesser insulated system!

Safety Standards for High-voltage, "High-Potential", Wires

High-potential (high-voltage) wires must be covered, insulated, or positioned to prevent contact with low-voltage wires.

What is a High-Potential signal wire?
A High-Potential signal wire means that the wire can transmit more than 650 volts.

You should also not use hand-held electrical tools at high-voltage levels! Hand-held electrical tools designed for lower voltages may not be adequately insulated or rated to handle higher voltage levels. High voltages can also increase the likelihood of losing control over the tool, especially if the voltage causes unexpected reactions or behaviors in the equipment.

Safety Standards for Uncovered, "Bare", Signal Wires

Bare (uncovered) signal wires are wires *without* any insulation.

Signal wires without insulation that people can touch should have a voltage of *no more than* 48 volts. A shock hazard would exist if bare conductors at more than 48 volts were accessible to people!

Cable Insulation and Environmental Factors

Mine worksites can be in all sorts of natural environments. Therefore, electrical cables must have outer jackets that are suitable for the environment in which they are used. For example, they must have the appropriate rating for the application (i.e., “outdoor” for outdoor use; “W” for wet locations and sunlight resistant; and “SUN, RES” or “SR” for sunlight resistant only).

How to Check that Wires and Cables Are Suitable for the Environment They Are Used:

- Cables exposed to direct sunlight should have an outer jacket that is resistant to the damaging effects of ultraviolet light.
- Cables installed or used outdoors should always be of a type suited for wet locations.
- Cables supplying power to dredges, floating pond pumps, and similar equipment must be suitable for submersion in water.

Insulation and Fittings for Power Wires and Cables

Power wires and cables must be also insulated adequately where they pass into or out of electrical compartments. Cables must enter metal frames of motors, splice boxes, and electrical compartments only through proper fittings.

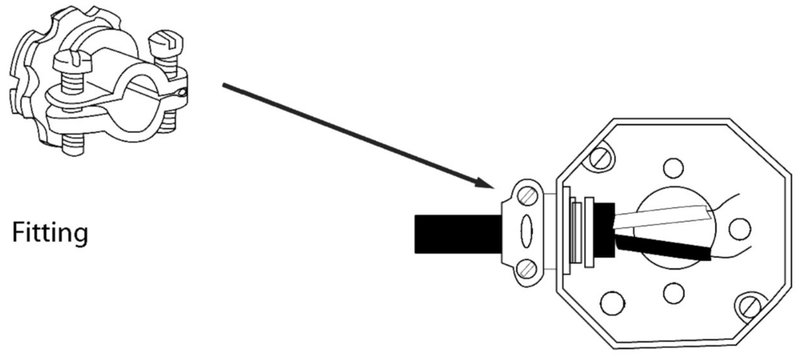
Let’s review some key concepts to better understand insulation and fittings for power wires and cables.

A **wire** is a conductor with only electrical insulation surrounding the conductor.

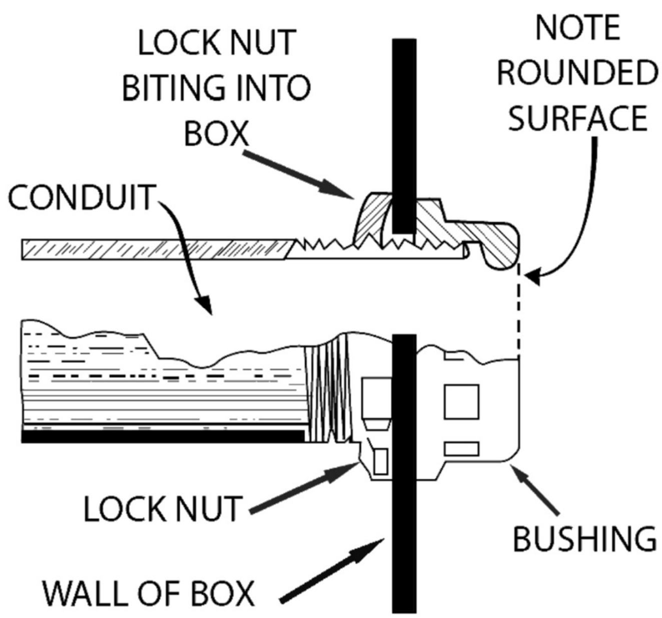
A **cable** is a conductor with electrical insulation immediately surrounding the conductor *and* mechanical insulation or covering surrounding the entire assembly.

A **fitting** or **insulated bushing:**

- Provides strain relief for the conductors
- Provides additional insulation for insulated wires not enclosed in a jacket. (**Note:** a jacketed cable does not require this additional insulation)
- Protects the insulation of wires and cable jackets from physical damage



2.6: Fitting



2.7: Insulated bushing

A **fitting** performs only a mechanical function because the cable already has adequate electrical insulation and a protective outer jacket. The connector securely fastens the cable to the outlet box to prevent movement that would put strain on the electrical connections inside the electrical enclosure. Most connectors are designed for specific sizes and types of cable.

An **insulated bushing** is used to protect the wires from abrasion by its smoothly rounded insulated surface. The rounded surface of a bushing is provided by an insulating sleeve, lining, or plastic bushing. Wires installed in conduit require protection at the end of the conduit where the conduit enters a metal enclosure.

Whenever an insulated wire, other than a cable, passes into enclosures, splice boxes, and, or junction boxes, additional mechanical protection is required. Additionally, when insulated wires, other than cables, pass through metal frames, the holes must be substantially bushed with insulated bushings.

What are indicators of poor insulation and fittings for power wires and cables?

- Wires or cables entering metal enclosures or holes without any fitting
- Wires or cables loose in a fitting allowing strain on the electrical connections
- Damaged cable jacket or conductor insulation at entrance point of enclosures
- Cable jacket removed or conductor insulation removed to allow entrance of conductors into enclosure holes

Causes of Outer Jacket and Insulation Damage in Cables

Common problems that contribute to outer jacket and insulation damage in cables can be attributed to one of the following conditions:

- The insulation is not adequate (i.e., the insulation on the conductor is either damaged or missing).
- The cable is not fully protected (i.e., the outer jacket on the cable is either damaged or missing).
- The insulation is not adequate, and the cable is not fully protected.

If you observe damaged outer jackets or conductor insulation in cable splices you should not continue working until the cable is properly repaired!

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. You might be familiar with the metals such as copper and aluminum, and know that they are commonly used as conductors due to their high conductivity. 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.

Recall that in mining, *all* electrical circuits or installations–regardless of, for example, surface or underground, high or low voltage, alternating or direct current, stationary or portable equipment–must be of a sufficient size and current-carrying capacity to ensure that a rise in temperature resulting from normal operations will not damage the insulating materials.

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.

What causes faulty connections?
Faulty connections in electrical systems, tools, and equipment are often due to lack of proper overload and fuse protection measures. There are specific ways to protect circuits and electrical equipment to mitigate faulty connections, which include:

- Circuit and trailing cable overload protection
- Proper fuse removal or replacement

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.

For example, an electrical system could be powering too many tools at once, or maybe there is a fault in the system causing an excessive load. This is where circuit overload protection becomes essential.

You should always make sure that circuits have the right fuses or circuit breakers to prevent them from being overloaded.

How do you know if you are using the right fuse and circuit breaker?
You can use the following references to determine proper fuse or breaker size:

- Insulated Power Conductor Engineers Association Handbook (IPCEA): This handbook is commonly used and provides ampacity tables that can be used provided you know certain information about the cable, such as the size of the conductor(s), the number of conductors, the configuration of the cable, voltage and temperature rating of insulation, and whether it is shielded or not.

- Cable manufacturer data: The manufacturer's data will provide special or particular information on application or use of the cable, construction of the cable, and other related identification information.

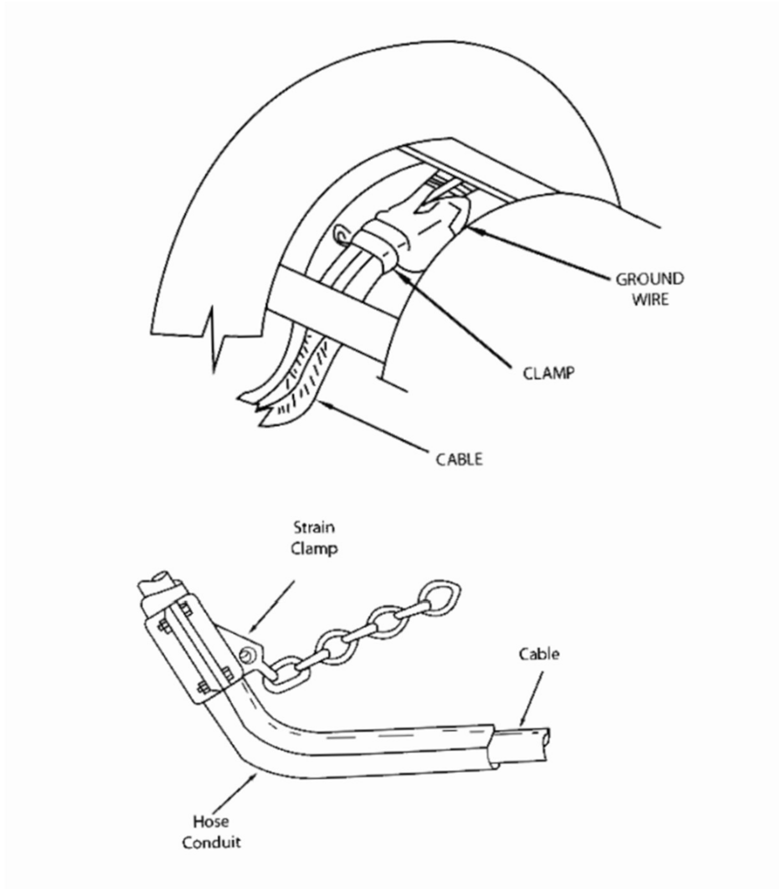
What About Trailing Cables?

Trailing cables are cables that are used to supply power to mobile or portable equipment. For example, if you are operating a piece of mobile equipment like a crane or a forklift at a mine worksite, these machines often rely on trailing cables to supply them with power. Therefore, trailing cables must also have protection from overloads or short circuits. They should be placed where they will not be run over by vehicles or other equipment at the mine site.

Trailing cables are subject to strain and wear from being pulled by mobile equipment and dragged across the mine floor. The 25-feet next to the machine is usually subjected to more damage due to machine movement. Temporary splices typically do not have the strength or durability to withstand this abuse, and this greater stress, strain, and wear causes a higher degree of hazard to persons who might have to handle the cable or work in the area.

You can help prevent damage and strain on trailing cables by hanging cables with suitable hangers, storing them in cable boats, on reels mounted on the equipment, or covering cables with substantial bridges where equipment crossing is unavoidable.

Additionally, trailing cables should be attached to equipment in a way that prevents strain on the electrical connections. For example, if you were using a training cable with a crane, you might use cable restraints or clamps strategically placed along the crane's structure. These restraints would support the trailing cable at different intervals, preventing it from sagging or dragging on the ground, which could lead to strain on the electrical connections.



2.8: Strain connection on cables

Where can you check for trailing cable problems?

- **Distribution Centers:** Inspect trailing cable connections at distribution centers to ensure each cable is adequately protected against overload or short circuits.
- **Power Centers:** Check the integrity of trailing cable protection mechanisms at power centers to prevent electrical incidents.
- **Cable Boxes:** Thoroughly examine cable boxes to verify that protective devices are in place and functioning correctly.
- **Attachment to Mobile Equipment:** Confirm that trailing cables are attached to machines in a way that protects them from damage and prevents strain on the electrical connections.
- **Proximity to Mobile Equipment:** Do not let mobile equipment run over power conductors or drag loads over them without proper protection.
- **Placement of Surplus Trailing Cables:** Check that surplus trailing cables to shovels, cranes, and similar equipment are stored in cable boats, on reels mounted on the equipment, or protected in other suitable ways.

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.

If you are conducting maintenance on an electrical circuit, for example, you will more than likely need to remove or replace a fuse at some point. When you remove or replace a fuse you are dealing with an *energized* circuit; this means there is a risk of electrical shock!

How Do You Safely Remove or Replace a Fuse?

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. It's a small step that can make a big difference in keeping you safe on the job!

What About Removing or Replacing a Fuse With High-Voltage?

High-voltage circuits come with their own set of risks and challenges. When it comes time to remove or replace fuses in these circuits, it is essential to use the right tools for the job. For fuses in high-potential circuits you must use fuse tongs or hot line tools when removing or replacing fuses in high-voltage circuits. These specialized tools allow you to work safely in high-voltage environments, minimizing the risk of electrical accidents.

Identifying Faulty Electrical Connections

In summary, preventing faculty 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, remember to keep the following considerations in mind to help identify faulty electrical connections:

- Damaged, burned, or brittle insulation on cables and wires
- Cables and wires that are smoking or appear hot
- Cables and wires that show visible damage such as cuts, abrasions, or kinking
- Conductors that are not protected from mechanical damage by a proper conduit, raceway, cable, tray, or location
- Cables or conductors without proper physical support

Faulty Splices

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

- **Splice:** The mechanical joining of one or more severed conductors in a single length of a cable including the replacement of insulation and jacket.

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

There are several methods for splicing wires, including:

- **Twist and ape:** This is a basic method where the stripped ends of the wires are twisted together and then covered with electrical tape for insulation.
- **Wire Nut or Twist-On Connector:** A wire nut is a connector with a threaded metal insert that screws onto the twisted ends of wires, securing them together.
- **Soldering:** Soldering involves melting a metal alloy (solder) onto the stripped ends of wires to fuse them together.
- **Crimping:** Crimping involves using a specialized tool to compress a metal sleeve (crimp) onto the stripped ends of wires, creating a secure connection.
- **Compression Splice:** This involves using a mechanical device or connector to join the wires together, typically by compressing them within a metal housing.

Whichever type of splice method is used, the splice must be performed correctly to ensure electrical safety and reliability!

You should visually examine splices and repairs to ensure:

- Mechanical strength
- Electrical efficiency
- Moisture exclusion
- A good bond with the outer jacket
- Equality to or improvement over the original levels of insulation and damage protection

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. Remember, electrical specialists or supervisors should be contacted for assistance if there is any indication of a faulty splice!

Common Factors that Result in Faulty Splices

You should routinely check the integrity of the splice to ensure that it is clean, undamaged, and properly bonded.

Consider how these three common problems contribute to faulty splices:

- **Dirty cables:** If cables are not well cleaned, the splice's outer jacket will have a tendency to slip on the cable and fray at the ends. These frayed ends can catch on protruding objects and cause further damage to the cable.
- **Damaged cables:** Damaged cables can create space for water and other environmental hazards to degrade the integrity of the cable.
- **Improper bonding:** Splices that have an outer jacket that is not bonded in its entirety to the original cable.

If you are repairing power cables with a splice you must follow the following practices to avoid a faulty splice. Make sure the repair is strong and conducts electricity well, and insulate the repair as well as the original and seal it to keep out moisture. Importantly, you must provide similar damage protection to the original, including good bonding to the outer covering.

Faulty Grounding

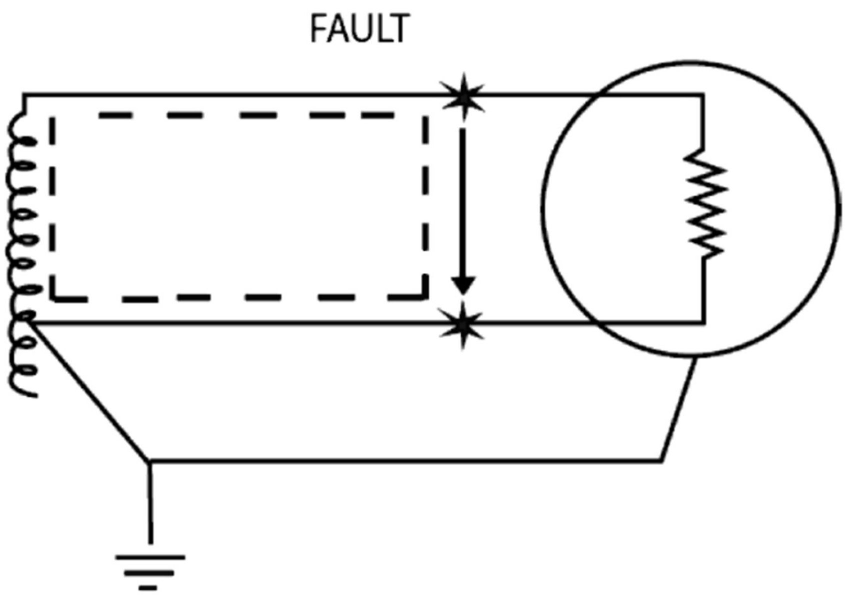
You will often work with various types of electrical systems and equipment at mine worksites. Depending on system type, an additional conduction connection may be required. Therefore, it is essential to understand the importance of grounding in electrical systems. Grounding helps prevent electrical hazards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

But what exactly is grounding, and why is it critical in mining operations?

Electrical Ground and Grounding

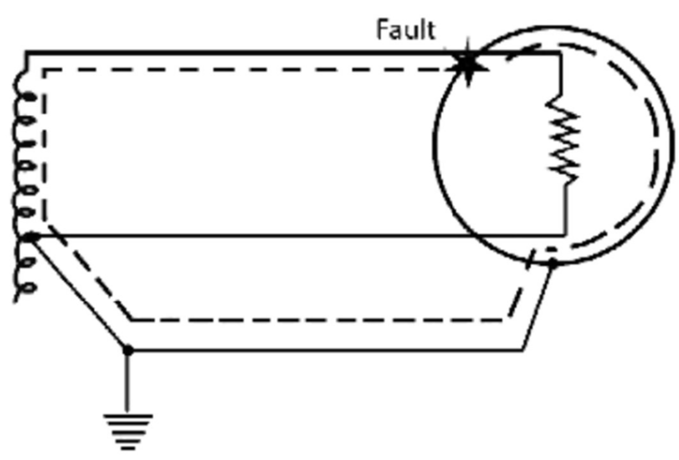
Let's review some important definitions and actions regarding electrical grounding and learn how you can avoid hazards created by faulty electrical grounding at mine worksites.

- **Electrical Ground:** An electrical ground is a conducting connection, whether intentional or accidental, between an electrical circuit or electrical equipment and the earth or to some conducting body in place of the earth.
- **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 Fault:** An electrical fault refers to any abnormal condition in an electrical circuit that disrupts or interferes with the normal flow of electrical current. Depending on the nature and severity of the fault, current may still flow, but can be erratic or continue in unintended paths which can pose significant safety risks.



2.9: Electrical fault

- **Ground Fault Condition:** A ground fault condition occurs when an unintended electrical connection is made between an energized conductor and the earth or ground. This can happen when insulation breaks down or when a live wire comes into contact with a grounded surface or a conductive path that leads to the ground. When a ground fault occurs, it can lead to excessive current flowing through the unintended path, potentially causing electrical hazards such as shocks, fires, or damage to equipment.



2.10: Ground fault condition

You must ground the following electrical equipment, tools, and systems at mine sites:

- **Circuit Enclosures:** You must ground or provide equivalent protection for all metal enclosures around electrical circuits, except for battery-operated equipment.
- **Transformer and Switchgear Enclosures:** You must ground metal fencing and buildings enclosing transformers and switchgear.
- **Mobile Equipment:** You must make sure that mobile equipment powered by trailing cables has frame grounding or similar protection.

Let’s take a closer look at electrical grounding and why it is important.

Why is Electrical Grounding Important?

Electrical grounding helps to:

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

Additionally, there are four general, basic purposes for electrical grounding:

- To ensure that noncurrent-carrying metal parts, such as equipment frames, are always safe at ground potential even if the insulation should fail
- To ensure that circuit protective devices will operate to remove a fault quickly
- To ensure that feeders or equipment are positively discharged and de-energized before maintenance is performed
- To dissipate lightning to earth ground

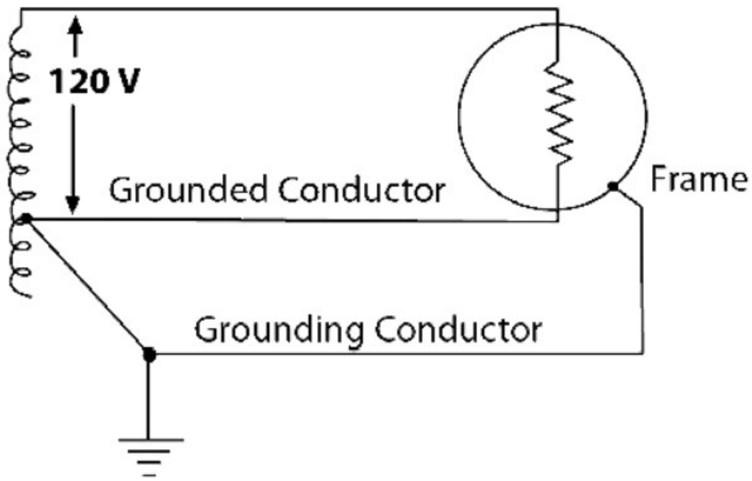
How to Determine Effective Grounding

In simplified terms, equipment grounding must meet two primary conditions:

- **Condition 1: Connected metal parts.** All metal parts of electrical equipment are linked together.

  AND

- **Condition 2: Connected to the earth.** The connected metal parts of electrical equipment are then linked to the earth.



2.11: Single phase 120 circuit

The National Electrical Code (NEC), Article 100, defines "grounded effectively" as when an electrical circuit or electrical equipment is intentionally connected to earth through a ground connection or connections of sufficiently low impedance and having sufficient current-carrying capacity to prevent the buildup of voltages which may result in an undue hazard to connected equipment or to persons.

Essentially, this means that the ground connection should have low impedance (resistance) and be able to carry enough current to prevent dangerous voltage build-ups that could harm equipment or people.

An effective grounding path from circuits, equipment, and metal enclosures for conductors, then, must:

- Be permanent and continuous
- Have capacity to conduct safely any fault current likely to be imposed on it
- Have sufficiently low impedance to limit the voltage to ground and to facilitate the operation of the circuit protective devices in the circuit

You must test the continuity and resistance of grounding systems right after installing, repairing, or modifying them, and then annually. You must also keep records of the resistance measurements and make them available upon request!

Can the Earth be the Sole Equipment Grounding Conductor?

The earth must *not* be used as the sole equipment grounding conductor! Remember that 'grounding equipment' means that you create a safe path for electrical faults to travel back to their source. While it might seem logical to use the earth as a conductor, it's not reliable.

Why isn't the earth a good grounding conductor?
The earth is not a good grounding conductor because it has high electrical resistance (impedance). This means it does not let electricity flow through it easily. So, if there is a fault in equipment and electricity tries to travel through the ground back to its source, it will face a lot of resistance. Recall that proper equipment grounding conductors provide a reliable path for fault currents to travel back to the source quickly and safely, reducing the risk of accidents from electrical hazards. Because the earth cannot handle large amounts of fault currents efficiently, it has limited capacity to carry these currents back to the source quickly. This slows down the process and might not be effective in preventing accidents.

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 vs. System Grounding: The Regulations Still Apply!

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

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

The metal parts of all equipment that can become energized due to insulation failure must be grounded. For example, all metal conduits, metal raceway, metal armor of cables, outlet boxes, cabinets, switch boxes, mining machine frames, power center enclosures, motor frames, transformer cases, and other frames and metallic cases of electric equipment that could become energized through insulation failure, must be connected to the earth. This helps prevent dangerous voltage differences between these parts and the earth, especially during equipment operation.

What is the purpose of equipment grounding?
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.

How do you complete electrical equipment grounding?

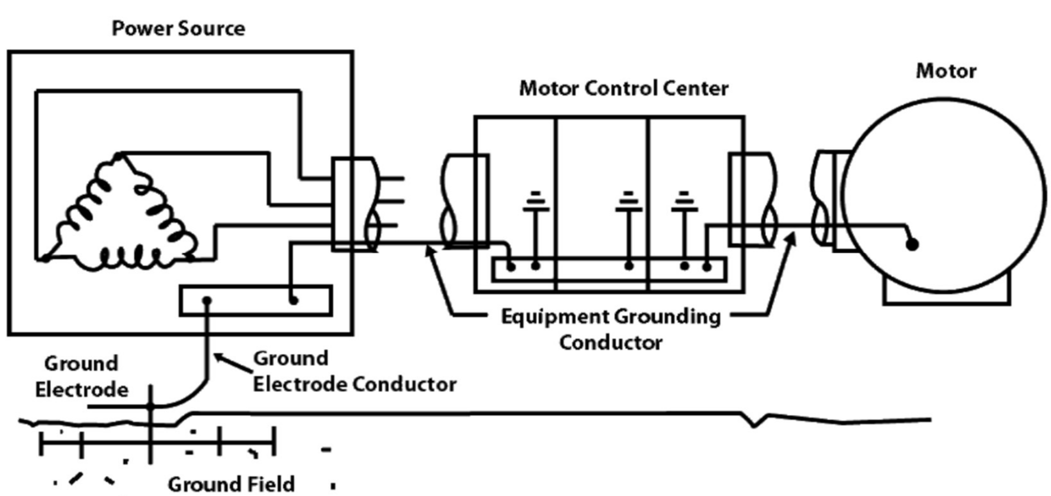
Electrical equipment grounding is done using a separate conductor, typically a green or bare copper wire, which is connected to the grounding terminal of the equipment and then to a grounding electrode, like a grounding rod buried in the earth.

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

What is the purpose of electrical system grounding?
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.

How do you complete electrical system grounding?
Electrical system grounding involves connecting the electrical system, including transformers, generators, and service panels, to the earth. This is typically done by connecting one of the conductors of the electrical system to a grounding electrode, such as a grounding rod or metal water pipe, using a grounding conductor.

In the diagrams below, you can see how electrical equipment is grounded. Notice how all the frames of the equipment are interconnected and then linked to the earth. This setup effectively prevents hazardous voltage levels between different pieces of equipment and the earth.



2.12: Electrical equipment that is equipment grounded in an ungrounded system

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

Remember, the federal safety regulations require equipment grounding regardless of the system grounding that exists!

Ground Electrode Measurement

When grounding electrical systems or equipment it is important to establish and maintain a good connection to earth to ensure safe operating conditions. However, the characteristics of the earth as a conducting medium are generally *variable* and *unpredictable*.

Therefore, you must test the earth connection or ground electrode to determine the integrity of the earth connection.

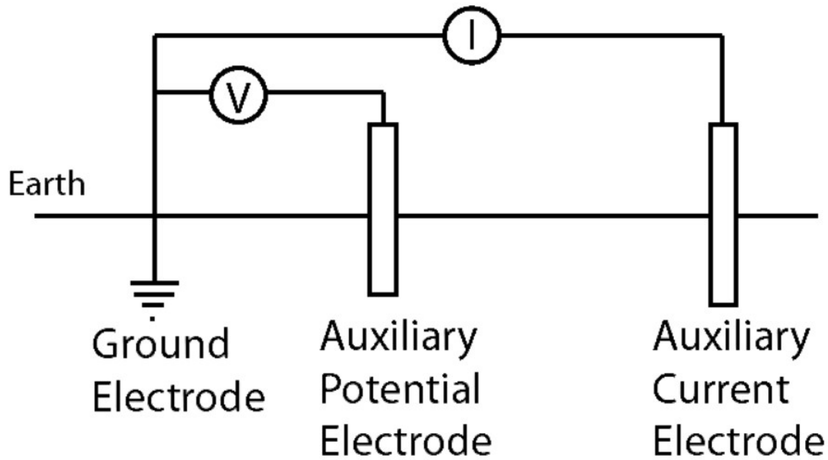
Ground electrodes are established for three primary reasons:

- To maintain equipment frames at ground potential
- To provide an efficient ground connection so that feeders and electrical equipment can be positively discharged and de-energized before maintenance is performed
- To dissipate lightning to earth ground

How can you test a ground electrode?
The "Fall of Potential Method" for testing has been determined as a reliable and accurate method for measuring ground electrode resistance. Instruments made specifically for this test are available although other current sources may be used along with good voltmeter and ammeter.

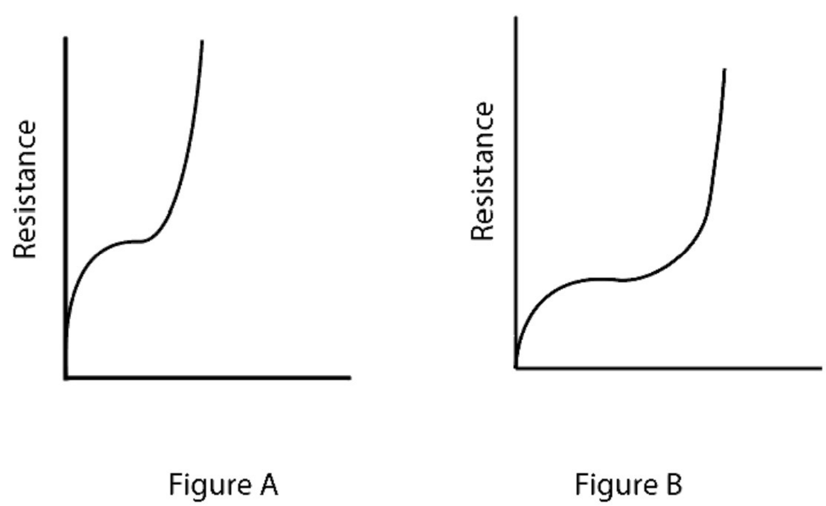
The following is a general description of this test.

A known current **"I"** is passed between the auxiliary current electrode and the safety ground bed. The potential difference **(E)** is measured between the auxiliary potential electrode and the safety ground bed. The ratio **(E/I)** will give a resistance which, with proper spacing of electrodes, results in the required resistance of the ground bed.



2.13: Ground electrode measurement

The value of resistance of the electrode to the earth is found on the flat portion of the curve (at 62% of the distance from the ground electrode to the current probe).



2.14: Ground electrode resistance

Grounding Electrodes and Ground Fields

Periodic testing of grounding electrodes and ground fields must demonstrate that a low resistance connection to earth is established and maintained.

The Code of Federal Regulations does not specify a maximum acceptable value for resistance to earth, but there are several consensus publications that can provide guidance on acceptable values.

The National Electrical Code, for example, specifies a maximum value of 25 ohms for a single driven rod electrode, and IEEE Standard 142-1972 recommends a value of 5 ohms for a typical substation ground field.

Grounding of Generators

There are different rules for grounding generators depending on whether they are portable or vehicle mounted.

What's considered a portable generator?
"Portable" is defined as capable of being carried in the hand or on the person, or easily carried or conveyed. Portable generators are therefore usually small wattage designs and serve electrical equipment by cord and plug through receptacles fixed on the generator assembly. Grounding of the generator frame is therefore not required.

Portable Generators: The frame of a portable generator does not have to be grounded and can serve as the grounding electrode for a system supplied by the generator, so long as the following conditions are met:

- **Condition 1:** The generator supplies only equipment mounted on the generator and/or cord-and plug-connected equipment through receptacles mounted on the generator.

  AND

- **Condition 2:** The noncurrent-carrying metal parts of equipment and the equipment grounding conductor terminals of the receptacles are bonded to the generator frame.

Vehicle-Mounted Generators: The frame of a vehicle can serve as the grounding electrode for a system supplied by a generator located on the vehicle, so long as the following conditions are met:

- **Condition 1:** The frame of the generator is bonded to the vehicle frame.

  AND

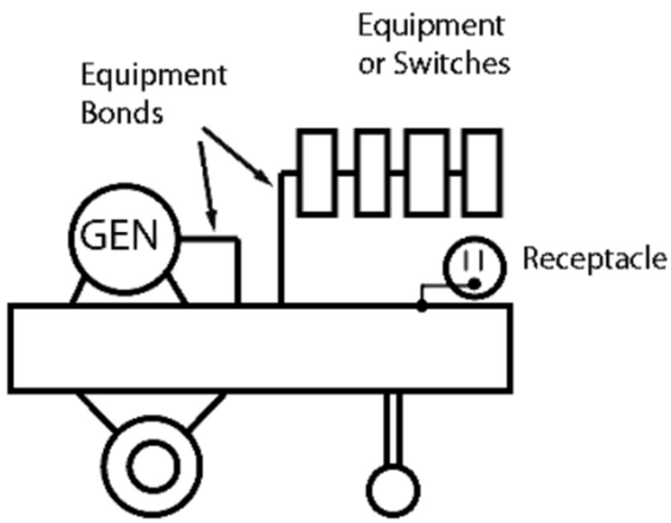
- **Condition 2:** The generator supplies only equipment located on the vehicle and/or cord- and plug-connected equipment through receptacles mounted on the vehicle or on the generator.

AND

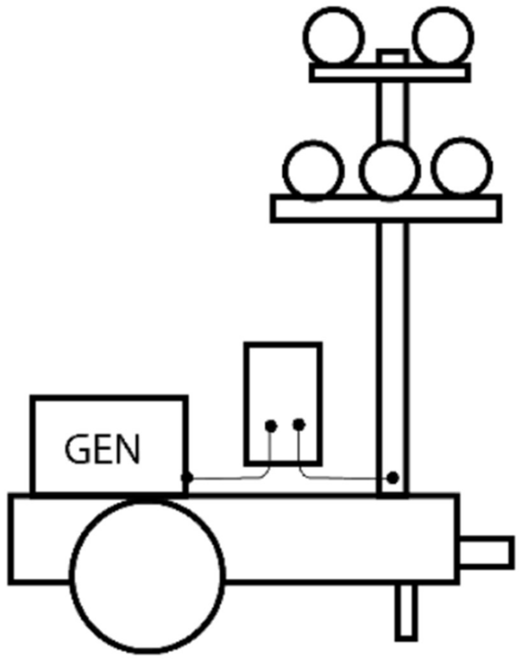
- **Condition 3:** The noncurrent-carrying metal parts of equipment and the equipment grounding conductor terminals of the receptacles are bonded to the generator frame.

AND

- **Condition 4:** The system complies with all other provisions of effectively grounding a generator. No grounding electrode is required for generator installations in which the assembly meets the requirements for portable and vehicle-mounted generators.



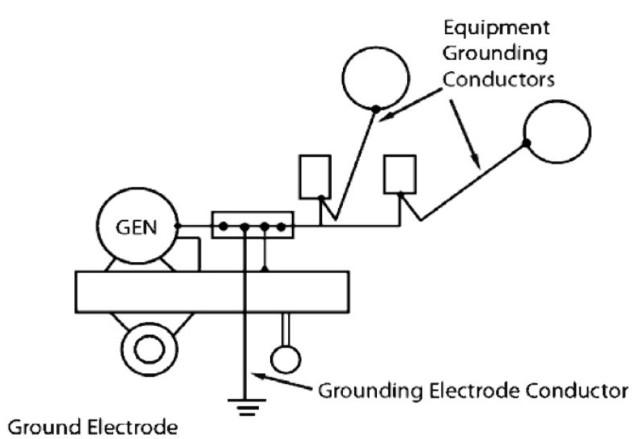
2.15: Vehicle mounted generator



2.16: Vehicle mounted generator and light plant

In instances where the vehicle mounted generators do not meet the above requirements, grounding of the electrical equipment through a ground electrode is required!

The following diagram shows the major components of such a system.



2.17: Vehicle mounted generator grounding requirements

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!

Consider the following regulations when working on energized equipment:

Handling Energized Power Cables

- Use insulated hooks, tongs, ropes, or slings when moving power cables manually.
- Only pull or drag the cable with the equipment it powers if it is attached properly and insulated according to standards.

Working on Electrically-Powered Equipment and Power Circuits

- Turn off the equipment before working on it.
- Lock the equipment or take other steps to ensure it cannot be turned on accidentally.
- Put up warning signs that indicate a system is turned off and have them signed by the workers doing the job.
- Only remove locks or safety devices if you installed them or if you're authorized.

Working Near Switchgear

- Keep dry wooden platforms, insulating mats, or other materials that do not conduct electricity in place at switchboards and power-control switches where there is a risk of electric shock. (Metal plates that a person stands on and are at the same voltage as the grounded parts of the switches can also be used).
- Label main power switches to show what they control.
- Make sure that there is enough space around stationary electrical equipment or switchgear for safe access.
- Guard electrical connections and resistor grids that are hard to insulate, unless they are already protected by where they are located.

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.

Consider the following regulations when working with cables or wires near energized infrastructure:

Cable or Wire Type	*Safety Regulation*
Track Bonding	Bond or weld both rails together at every joint, and crossbond rails at least every 200 feet if the track is used for the trolley circuit. If rails are moved or replaced, or if broken bonds are found, they must be rebonded within *three* shifts.
Overhead Powerlines	Install overhead high-voltage powerlines according to the National Electrical Code.
Guy Wires	Guy wires for poles supporting high-voltage transmission lines must meet the grounding or insulator protection requirements of the National Electrical Safety Code.
Communication Conductors on Power Poles	Telegraph, telephone, or signal wires should not be installed on the same crossarm with power wires on poles. If they are on poles supporting powerlines, install them according to the National Electrical Code.
Installation of Trolley Wires	Install trolley wires at least seven feet above rails, aligned and supported to control sway and sag.
Circuits Powered from Trolley Wires	Ground wires for lighting circuits powered from trolley wires must be securely

	connected to the ground-return circuit.
Lightning Protection for Telephone Wires and Ungrounded Conductors	Equip each ungrounded power conductor or telephone wire leading underground and exposed to lightning with approved lightning arrestors within 100 feet of where the circuit enters the mine. Connect lightning arrestors to a low-resistance grounding medium on the surface and keep them at least 25 feet away from neutral grounds.
Movement or Operation of Equipment near High-Voltage Powerlines	When equipment needs to be moved or operated near energized high-voltage powerlines (excluding trolley lines) with clearance less than 10 feet, de-energize the lines or take other precautionary measures.
Short Circuit and Lightning Protection	Protect powerlines, including trolley wires, and telephone circuits from short circuits and lightning.

Trailing Cables

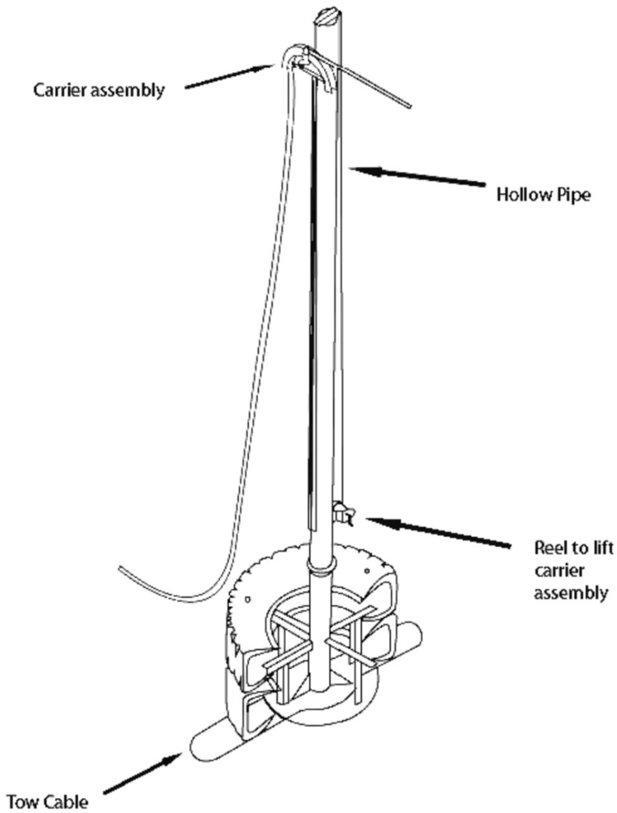
Trailing cables must be attached to machines in a suitable manner to protect the cable from damage and to prevent strain on the electrical connections. To reduce potential hazards from working near energized equipment, you should secure surplus trailing cables as follows:

Surplus trailing cables to shovels, cranes and similar equipment must be:

- Stored in cable boats
- Stored on reels mounted on the equipment
- Otherwise protected from mechanical damage

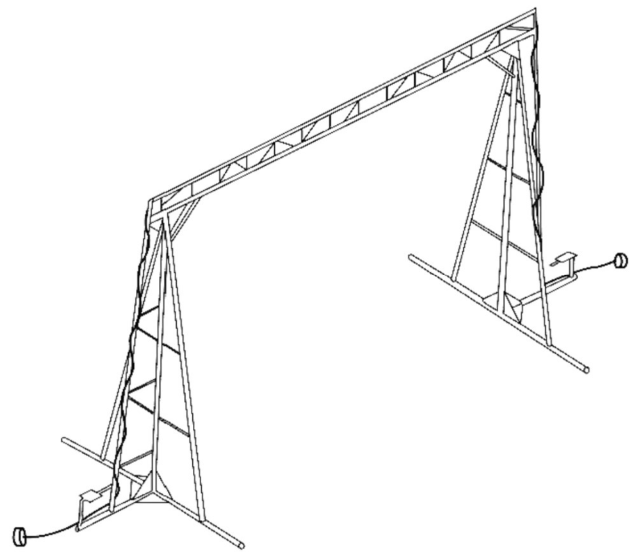
Different methods to protect cables near energized infrastructure or other mine worksite equipment include:

- **Cable Towers:** Cable towers are widely used in suspending cable to protect it from damage. A tower is made of two basic components, a support base and upright standards. The support base is generally made of steel skids or rubber tires filled with concrete. The upright standard is made of steel beams or pipe with a radius sling or saddle on the tip to support the cable. A well-designed tower will have a small hand winch to hoist or lower the cable.



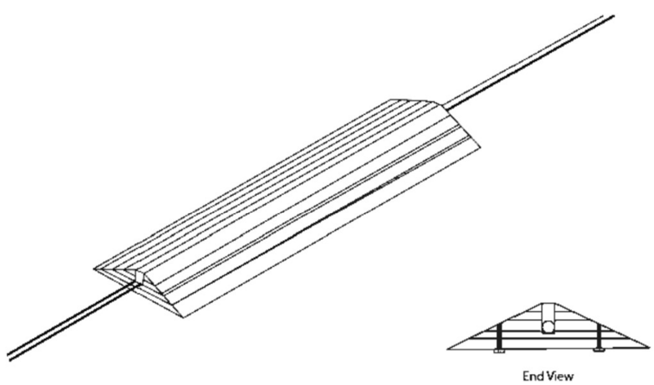
2.18: Cable tower

- **Cable Bridges:** A cable bridge is more substantial than a tower supporting cable above haulage and service roads. A cable bridge is an all-steel arch which is designed to span the haul road with sufficient clearance for haul trucks to go under. A bridge is used generally in semi-permanent locations.



2.19: Cable bridge

- **Cable Crossovers**: Cable crossovers of rubber or metal “mats” with a center groove are generally used where there is less, or lighter, traffic. Belting that is bolted together can be used to make these crossover mats.



2.20: 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!

What is a major electrical installation?
Major electrical installation means an assemblage of stationary electrical equipment for the generation, transmission, distribution, or conversion of electrical power.

Major electrical work and installations would include, but are not limited to, high-voltage substations, transformer rooms or vaults, and other restricted areas containing energized connection or other contact points.

Look out for these common mistakes that can easily result in electrical accidents:

- Persons inside controlled areas of electrical installations that are not authorized by the operator to be conducting work
- Persons inside controlled areas of electrical installations that are not aware of the associated hazards

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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.

Remember these easy ways to help prevent electrical problems from water hazards:

- Use only grounded or double insulated electrical tools and equipment
- Use GFCI (Ground Fault Circuit Interrupter) receptacles or pigtails in damp or wet locations at mines or when in confined spaces
- Use weather-proof lamp sockets where they might be exposed to weather or wet conditions that could affect illumination or create a shock hazard

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 special 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.

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2.5 HEALTH EFFECTS AND CONSEQUENCES OF ELECTRICAL ACCIDENTS

You now know that electrical accidents in mining are often caused by six common factors:

- 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)

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.

Consider these examples of how heat from electrical arcs resulted in burns and injuries to miners:

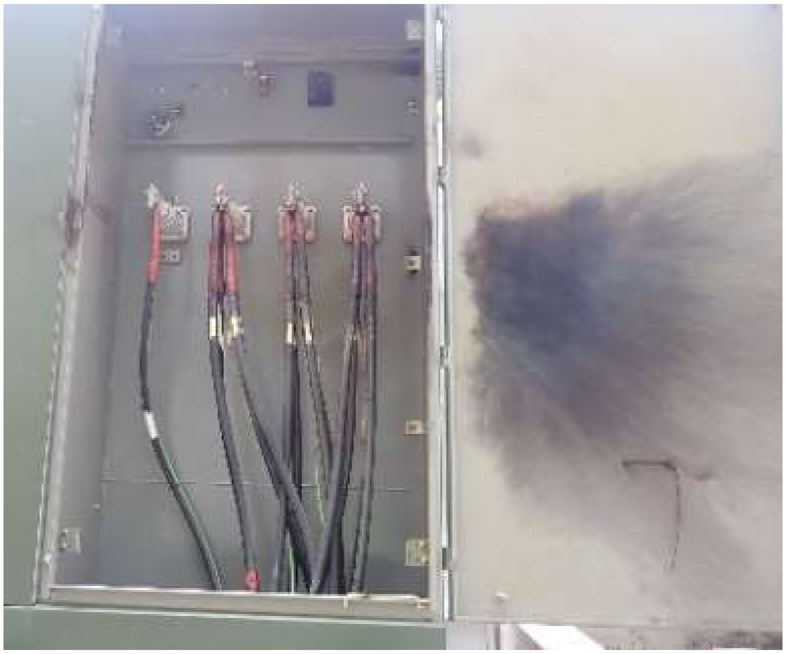
- An electrician received burns from an arc flash when he cut an energized power line.

2.21: Burn marks on gloves, evidence of arc flash hazards

- An electrician and trainee electrician were injured by an arc flash after the electrician re-entered a grounded cable into a cathead and energized the breaker.

2.22: Aftermath of burnout breaker after arc flash accident

- Two contract miners received burns from an arc flash while checking the rotation on a transformer.



2.23: Damage upon transformer due to arc flash accident

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 through several key practices:

- Prevention of overcurrent conditions such as short circuits or overload protection for circuits and equipment.
- Installation methods to protect conductors and equipment from damage or contact that might result in an arc or overcurrent condition or shock.
- Equipment design to prevent arcing during normal operation which could cause an explosion.
- Equipment protection and guarding due to where and how they are placed. For example, you should guard portable extension lights and other lights that could cause potential hazards based on where and how they are placed in proximity to where work is being performed or where other equipment is located.

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.

Several factors contribute to the severity of electrical shock:

- The amount of current
- Duration of exposure and
- The path the current takes through the body

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.

The table below illustrates how different currents impact the human body.

Current Values (through body trunk)	Effect
Generally Safe Current Values	
1 Milliampere, or less	Causes no sensation – not felt. Is at the threshold of perception.
1 to 8 Milliamperes	Sensation of shock. Not painful. Individual can let go at will, as muscular control is not lost (5mA is accepted as maximum harmless current intensity.
Unsafe Current Value	
8 to 15 Milliamperes	Painful shock. Individual can let go at will, as muscular control is not lost.
15 to 20 Milliamperes	Painful shock. Muscular control of adjacent muscles lost. Cannot let go.

20 to 50 Milliamperes	Painful. Severe muscular contractions. Breathing is difficult.
100 to 200 Milliamperes	Ventricular Fibrillation (A heart condition that results in death, no known remedy.)
200 & Over Milliamperes	Severe burns. Severe muscular contractions, so severe that chest muscles clamp heart and stop it during duration of shock. (This prevents ventricular fibrillation).
** Milliampere = one thousandth of an ampere.*	

Current Duration: Exposure and Contact Time

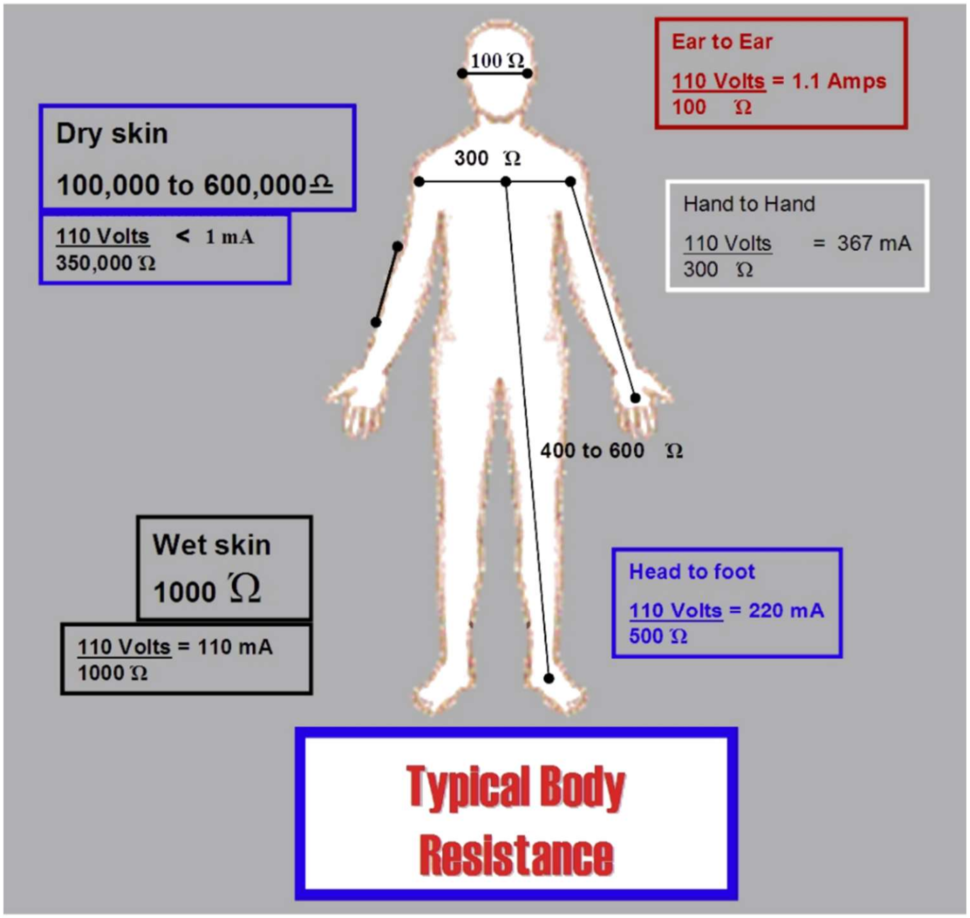
In general, the *longer* an electrical current flows through the body, the *more* serious the shock. Studies indicate that the time for fibrillation to start varies according to the voltage contacted. Higher voltages need less time for fibrillation of the heart to start.

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.

The flow of electrical current through the body is illustrated in the example diagram below. It shows how the distance the electrical current travels in your body. It also illustrates the difference between typical body resistance and wet and dry skin.



2.24: Resistance against volts per specific body part

Body Pathways and Resistance

The diagram shows the relationship between different body pathways and resistance to electrical current:

- **Ear to Ear:** When current flows from ear to ear, with a typical resistance of about 100 ohms, 110 volts can generate a current of 1.1 amperes (A). This high current can be fatal as it passes through the brain.
- **Hand to Hand:** If the current passes from one hand to the other, the resistance is around 300 ohms. At 110 volts, the resultant current is approximately 367 milliamperes (mA), which can severely harm or even be fatal due to the proximity to the heart.
- **Head to Foot:** The resistance between the head and foot is about 500 ohms. Under 110 volts, this distance will induce a current of 220 mA, which can travel through crucial organs and systems, posing severe health risks.

Skin Moisture and Electrical Current

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

For example, callous or dry skin can have a fairly high resistance, but moist skin will have a lower resistance. However, skin resistance should *not* be a consideration in limiting current flow since contact with an electrical current may easily destroy the skin. Once the skin resistance to electrical current is lowered, current flow is then limited by only the internal resistance, which is much lower.

The table below highlights the differences between skin resistance of electrical current on dry and wet skin. It references the sample calculations of electrical pathways in the body pathways and resistance diagram shown earlier.

Skin Moisture	Effect
Dry Skin	The resistance of dry skin to electrical current ranges from 100,000 to 600,000 ohms (Ω). For example, with 110 volts applied, the current that passes through the body is less than 1 milliampere (mA) if the skin resistance is 350,000 ohms.
Wet Skin	Wet skin significantly *lowers* the body's resistance to electrical current. In the sample calculations on the diagram above, we can see that wet skin lowers the body's resistance to electrical current by approximately 1,000 ohms. In other words, applying the same 110 volts across wet skin results in a current of about 110 milliamperes (mA), which is much higher and dangerously significant.
**** Skin resistance should not be a consideration in limiting current flow since contact with an electrical current may easily destroy the skin.***	

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.

Follow these guidelines for what to do if a co-worker has been injured by contact with electricity:

- Do not touch an injured person who is still in contact with an electrical current.
- Do not get near high-voltage wires until the power is turned off.
- Stay at least 20 feet (about 6 meters) away — farther if wires are jumping and sparking.
- Do not move a person with an electrical injury unless there is immediate or ongoing danger.
- Call 911 if the injured person experiences: severe burns, confusion, difficulty breathing, heart rhythm problems, cardiac arrest, muscle pain and contractions, seizures, or loss of consciousness.

When it is safe to do so:

- Turn off the source of electricity. Use a dry, nonconducting object made of cardboard, plastic or wood to move the source away from you and the injured person.
- Begin CPR if the person shows no signs of circulation, such as breathing, coughing or movement.
- Cover any burned areas with a sterile gauze bandage, if available, or a clean cloth. Do not use a blanket or towel, because loose fibers can stick to the burns!
- Prevent the injured person from becoming chilled.

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

Key Takeaways from Electrical Current Amount, Duration, and Path

Knowing how electrical current amount, duration, and path impacts electrical accidents is critical for your safety and that of your coworkers. By recognizing the relationship between current intensity and the severity of potential injuries, you can take proactive measures to prevent accidents and promote a secure working environment.

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

The general steps for lock-out and tag-out procedures typically include the following processes and actions in the table below:

Process	*Actions*
Identification	Identify the machinery or equipment to be serviced or maintained and understand its energy sources.
Notification	Inform all affected workers about the planned shutdown and lock-out and tag-out procedures.
Shutdown	Turn off the machinery or equipment using the appropriate controls or switches.
Isolation	Physically isolate the machinery or equipment from its energy sources. This may involve disconnecting power sources, blocking valves, or other means to prevent energy flow.
Lock-out	Securely lock the machinery or equipment using padlocks or similar devices to prevent its operation.
Tag-out	Attach a tag or label to the locked-out machinery or equipment to provide additional warning and information. The tag typically includes details such as the reason for the lock-out/tag-out, the name of the

	authorized person performing the lock-out/tag-out, and the expected duration of the lock-out/tag-out.
Verification	Verify that the machinery or equipment is properly shut down, isolated, locked, and tagged before starting any work.
Work Completion	Complete the necessary servicing, maintenance, or repairs on the machinery or equipment.
Removal of lock-out/tag-out devices	Only "authorized personnel" should remove the lock-out/tag-out devices (label and locks) once the work is complete and the machinery or equipment is safe to operate.
Restoration of energy	Gradually restore energy to the machinery or equipment following established procedures, ensuring that all workers are clear of danger zones.

These 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

You will encounter many different work processes, environmental conditions, and company safety rules at your mine worksite. The MSHA and Code of Federal Regulations require implementation of the electrical safety standards outlined in this training section.

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**: A "Section 103(g) complaint Is a reasonable belief that an imminent danger, a violation of a mandatory safety or health standard, **OR** a violation of the Mine Act exists, and is communicated to MSHA by a person identifiable as a miner or a representative of miners. In addition to the name of the miner or representative of miners, for MSHA administrative purposes, the complaint should include at least one type of contact information, such as an e-mail address or a telephone number. If the complainant does not provide a name or contact information, see next paragraph ("Non-Miner and/or Anonymous Complaints").
2. **Non-Miner and/or Anonymous Complaints:** A "Non-Miner and/or Anonymous" complaint is an assertion that an imminent danger, a violation of a mandatory safety or health standard, or a violation of the Mine Act exists, and is communicated to MSHA by

someone other than a miner or a miners' representative, **OR** Communicated to MSHA by someone who has elected not to provide their name or any contact information.

3. **Other Complaints:** An "Other" complaint is communicated to MSHA and does not allege an imminent danger, a violation of a mandatory safety or health standard, or a violation of the Mine Act at a mine.

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

Appendix: RECOGNITION AND AVOIDANCE OF ELECTRICAL HAZARDS CONCLUSION

Reflect on Your Personal Responsibility to Identify and Prevent Electrical Hazards

At the beginning of this module you read about two fatal mine worksite incidents due to electrical hazards. These incidents were a result of multiple failures in hazard identification and mitigation:

- **Lack of Warning Signs and Barricades:** Failure to install warning signs or barricades around overhead high-voltage power lines left miners unaware of the potential danger.
- **Unsafe Location of Staging Area and Equipment:** Allowing the staging area to be situated beneath energized power lines and operating equipment within ten feet of these lines significantly increased the risk of electrical accidents.
- **Neglect of Workplace Examinations:** Failing to conduct regular workplace examinations meant potential hazards went unnoticed and unaddressed, exacerbating the risk to workers' safety.
- **Inadequate Phase Lead Connections:** Lack of assurance regarding the adequacy of phase lead connections compromised the integrity of the electrical system, increasing the likelihood of accidents.
- **Insufficient Personal Protective Equipment (PPE):** Workers were not provided with proper PPE for troubleshooting energized electrical equipment, leaving them vulnerable to potential hazards.

Before you move on to the module assessment, consider how you will personally uphold the following standards at mine worksites to protect yourself and your co-workers:

- Stay alert to potential electrical hazards in your work environment and report any concerns promptly to your supervisor.
- Follow established safety procedures, including lock-out and tag-out protocols, when working with or near electrical equipment.
- Ensure you are equipped with, and use, the appropriate PPE for the tasks you are performing, and never attempt to troubleshoot energized equipment without the necessary gear.

Let’s Review What You’ve Learned!

You learned a lot[1] of new information in this module. Some concepts might be completely new to you, or, you might have been familiar with some of the concepts or terms.

Either way, take a minute to review what you should now be able to do after completing this module.

You can now:

- Name and give an example of the four parts of an electrical circuit.
- Calculate the current, resistance, voltage and power in a circuit.
- Name the six major causes of electrical accidents.
- Explain how fires or explosions can occur from the use of electricity.
- Explain why burns and death can result from exposure to the heat from an electrical arc.
- Explain the effects of current on the average human body.
- Identify and apply key terminology related to equipment grounding.
- Apply the electrical regulations to mining equipment and related activities.

If you are confident that you can accomplish these tasks above, proceed to the Quiz.

If you want more time to review and reflect on these tasks, return to the specific pages you want to review. You can also review additional expanded content in the Module Resource Materials.

MODULE RESOURCE MATERIALS

List of Common Electrical Concepts and Definitions

- **Component:** Any material in a cable splice kit which becomes part of a splice.
- **Conductor:** A bare or insulated wire or combination of wires not insulated from one another, suitable for carrying an electric current.
- **Electric Cable:** An assembly of one or more insulated conductors of electric current under a common or integral jacket. A cable may also contain one or more uninsulated conductors.
- **Jacket:** A nonmetallic abrasion-resistant outer covering of a cable or splice.
- **Power Conductor:** An insulated conductor of a cable assembly through which the primary electric current or power is transmitted.
- **Signaling Cable:** A fiber optic cable, or a cable containing electric conductors of a cross-sectional area less than #14 AWG used where the circuit cannot deliver currents which would increase conductor temperatures beyond that established for the current carrying capacity of the conductors.
- **Splice:** The mechanical joining of one or more severed conductors in a single length of a cable including the replacement of insulation and jacket.
- **Splice Kit:** A group of materials and related instructions which clearly identify all components and detail procedures used in safely making a flame-resistant splice in an electric cable.

Recommended Safety Procedures for Ground Check Monitor Testing

There is an increased risk of electrical shock hazards while testing electrical equipment and systems. Therefore, you should follow the recommended safety procedures below, particularly when testing ground check circuit in underground mines:

- During routine electrical inspections, the ground check circuits should be tested by opening the ground check conductor at the extreme (load) end of each branch circuit.
- When there is reason to believe that breaking the grounding conductor will not open the circuit breaker, a representative number of ground check circuits should be tested using the following procedures:
    - At least two MSHA electrical inspectors shall participate in the testing.
    - Open the ground check conductor at the extreme (load) end of the circuit. If the circuit breaker opens, reconnect the ground check conductor and proceed.
    - If the breaker does not open, disconnect and ground the high-voltage conductors.
    - Open the grounding conductor immediately inby the origin of the ground check circuit.
    - When frames of equipment are connected in series by the grounding conductor, open the grounding conductor between any two units of electric equipment whose frames are connected to the grounding conductor.
- Open the grounding conductor at the frame of the most distant load that the grounding conductor being monitored by the ground check circuit is intended to protect.

Recommended Equipment and Supplies for Mining Electrical Specialists

In addition to the basic safety equipment and supplies required for all miner and electrical inspectors, the following equipment and supplies are recommended for electrical specialists:

- Electrically-rated safety shoes and safety rubber boots
- 100% cotton or fire-resistant (FR) rated coveralls
- Class 2 high-voltage gloves with leather protectors
- Class 0 low-voltage gloves with leather protectors
- Padlock, hasp extender, and suitable tags for lockout/tagout
- Non-contact AC voltage detector appropriately rated for the circuits, equipment, and environmental conditions encountered during electrical inspections
- Multimeter(s) for measuring voltage, current, and resistance. Meters must be appropriately rated for the circuits, equipment, and environmental conditions encountered during electrical inspections
- Earth-resistance tester
- Insulation resistance tester appropriately rated for the circuits, equipment, and environmental conditions encountered during electrical inspections

- Safety Circuit Tester, Becker/SMC Model C-3100 or equivalent (used to verify compliance with 30 CFR 75.900 and 75.902)
- Set of flat feeler gauges (0.003, 0.004, 0.005, 0.007 and 0.009 inch)
- Set of round feeler gauges (0.007, 0.009 and 0.011 inch)
- Caliper ruler
- Binoculars

Simplified Electrical Rules and Corresponding Code of Federal Regulations Listing

- **Circuit Overload Protection:** Make sure circuits have the right fuses or circuit breakers to prevent them from being overloaded. [56.12001]
- **Controls and Switches:** All electrical equipment and circuits need approved switches or controls that are installed correctly. [56.12002]
- **Trailing Cable Overload Protection:** Mobile equipment's trailing cables must have protection from overloads or short circuits. [56.12003]
- **Electrical Conductors:** Use electrical conductors that are big enough and can handle the current without getting too hot and damaging the insulation. Protect conductors from mechanical damage. [56.12004]
- **Protection of Power Conductors from Mobile Equipment:** Do not let mobile equipment run over power conductors or drag loads over them without proper protection. [56.12005]
- **Distribution Boxes:** Each branch circuit in distribution boxes must have a disconnecting device. This device should be visible when turned off to show the circuit is not powered. Each device should be labeled to show which circuit it controls. [56.12006]
- **Junction Box Connection Procedures:** When connecting or disconnecting trailing cables and power cables to junction boxes, make sure to do it without any electrical load. [56.12007]
- **Insulation and Fittings for Power Wires and Cables**: Make sure power wires and cables are properly insulated where they go into or out of electrical compartments. Only use proper fittings when cables enter metal frames, motors, splice boxes, or electrical compartments. If insulated wires pass through metal frames, use insulated bushings to protect them. [56.12008]
- **Isolation or Insulation of Communication Conductors:** Keep telephone and low-voltage signal wires protected from touching energized power wires or any other power source. [56.12010]
- **High-Potential Electrical Conductors:** Cover, insulate, or position high-voltage electrical wires to prevent them from touching low-voltage wires. [56.12011]
- **Bare Signal Wires:** Bare signal wires that people might touch shouldn't have a voltage higher than 48 volts. [56.12012]

- **Splices and Repairs of Power Cables:** When repairing power cables make sure the repair is strong and conducts electricity well, insulate the repair as well as the original and seal it to keep out moisture, and provide similar damage protection to the original, including good bonding to the outer covering. [56.12013]
- **Handling Energized Power Cables:** Do not move power cables with equipment unless you use insulated sleds or slings. When moving them manually, use insulated hooks, tongs, ropes, or slings unless there are other safety measures in place. You can pull or drag the cable with the equipment it powers if it is attached properly and insulated according to standards. [56.12014]
- **Work on Electrically-Powered Equipment:** Before working on electrically powered equipment, make sure it is turned off. Lock the power switches or take other steps to ensure the equipment can't be turned on accidentally. Put up warning signs and have them signed by the workers doing the job. Only remove locks or safety devices if you installed them or if you're authorized. [56.12016]
- **Work on Power Circuits:** Turn off power circuits before working on them unless you're using special tools designed for working on live circuits. Put up warning signs and lock the switches to prevent the circuits from being turned on while you're working on them. Only remove locks or safety devices if you installed them or if you're authorized. [56.12017]
- **Identification of Power Switches:** Label main power switches to show what they control, unless it is obvious from where they are located. [56.12018]
- **Access to Stationary Electrical Equipment or Switchgear:** Make sure there's enough space around stationary electrical equipment or switchgear for safe access. [56.12019]
- **Protection of Persons at Switchgear:** Keep dry wooden platforms, insulating mats, or other materials that do not conduct electricity in place at switchboards and power-control switches where there's a risk of electric shock. Metal plates that a person stands on and are at the same voltage as the grounded parts of the switches can also be used. [56.12020]
- **Danger Signs:** Put up suitable danger signs at all major electrical installations. [56.12021]
- **Authorized Persons at Major Electrical Installations:** Only authorized people should enter areas with major electrical installations. [56.12022]
- **Guarding Electrical Connections and Resistor Grids:** Guard electrical connections and resistor grids that are hard to insulate, unless they are already protected by where they are located. [56.12023]
- **Grounding Circuit Enclosures:** Ground or provide equivalent protection for all metal enclosures around electrical circuits, except for battery-operated equipment. [56.12025]
- **Grounding Transformer and Switchgear Enclosures:** Ground metal fencing and buildings enclosing transformers and switchgear. [56.12026]
- **Grounding Mobile Equipment:** Make sure mobile equipment powered by trailing cables has frame grounding or similar protection. [56.12027]

- **Testing Grounding Systems:** Test the continuity and resistance of grounding systems right after installing, repairing, or modifying them, and then annually. Keep records of the resistance measurements available upon request. [56.12028]
- **Correction of Dangerous Conditions:** Fix any dangerous conditions before turning on equipment or wiring. [56.12030]
- **Inspection and Cover Plates:** Keep inspection and cover plates on electrical equipment and junction boxes in place at all times, except during testing or repairs. [56.12032]
- **Hand-Held Electric Tools:** Do not use hand-held electric tools at high voltage levels. [56.12033]
- **Guarding Around Lights:** Guard portable extension lights and other lights that could cause shock or burns because of where they are placed. [56.12034]
- **Weatherproof Lamp Sockets:** Use weather-proof lamp sockets where they might be exposed to weather or wet conditions that could affect illumination or create a shock hazard. [56.12035]
- **Fuse Removal or Replacement:** Do not remove or replace fuses by hand in an energized circuit. Use equipment and techniques designed to prevent electrical shock for these tasks. [56.12036]
- **Fuses in High-Potential Circuits:** Use fuse tongs or hot line tools when removing or replacing fuses in high-voltage circuits. [56.12037]
- **Attachment of Trailing Cables:** Attach trailing cables to machines in a way that protects them from damage and prevents strain on the electrical connections. [56.12038]
- **Protection of Surplus Trailing Cables:** Store surplus trailing cables to shovels, cranes, and similar equipment in cable boats, on reels mounted on the equipment, or protect them from mechanical damage in other suitable ways. [56.12039]
- **Installation of Operating Controls:** Install operating controls in a way that they can be used safely without touching energized wires. [56.12040]
- **Design of Switches and Starting Boxes:** Switches and starting boxes should be designed and sized to be safe. [56.12041]
- **Track Bonding:** Bond or weld both rails together at every joint, and crossbond rails at least every 200 feet if the track is used for the trolley circuit. If rails are moved or replaced, or if broken bonds are found, they must be rebonded within three shifts. [56.12042]
- **Overhead Powerlines:** Install overhead high-voltage powerlines according to the National Electrical Code. [56.12045]
- **Guy Wires:** Guy wires for poles supporting high-voltage transmission lines must meet the grounding or insulator protection requirements of the National Electrical Safety Code. [56.12047]
- **Communication Conductors on Power Poles:** Telegraph, telephone, or signal wires should not be installed on the same crossarm with power wires on poles. If they are on poles supporting powerlines, install them according to the National Electrical Code. [56.12048]

- **Installation of Trolley Wires:** Install trolley wires at least seven feet above rails, aligned and supported to control sway and sag. [56.12050]
- **Circuits Powered from Trolley Wires:** Ground wires for lighting circuits powered from trolley wires must be securely connected to the ground-return circuit. [56.12053]
- Short Circuit and Lightning Protection: Protect powerlines, including trolley wires, and telephone circuits from short circuits and lightning. [56.12065]
- **Guarding Trolley Wires and Bare Powerlines:** Guard or deenergize trolley wires and bare powerlines where metallic tools or equipment might touch them. [56.12066]
- **Installation of Transformers:** Transformers should be enclosed, placed at least 8 feet above the ground, installed in a transformer house, or surrounded by a substantial fence at least 6 feet high and 3 feet from any energized parts, casings, or wiring. [56.12067]
- **Locking Transformer Enclosures:** Keep transformer enclosures locked against unauthorized entry. [56.12068]
- **Lightning Protection for Telephone Wires and Ungrounded Conductors:** Equip each ungrounded power conductor or telephone wire leading underground and exposed to lightning with approved lightning arrestors within 100 feet of where the circuit enters the mine. Connect lightning arrestors to a low-resistance grounding medium on the surface and keep them at least 25 feet away from neutral grounds. [56.12069]
- **Movement or Operation of Equipment near High-Voltage Powerlines:** When equipment needs to be moved or operated near energized high-voltage powerlines (excluding trolley lines) with clearance less than 10 feet, deenergize the lines or take other precautionary measures. [56.12071]