VIRGINIA DEPARTMENT OF MINES, MINERALS & ENERGY

DIVISION OF MINES

ELECTRICAL REPAIRMAN

MAINTENANCE FOREMAN

&

CHIEF ELECTRICIAN

CERTIFICATION STUDY GUIDE

2011

Commonwealth of Virginia
Department of Mines, Minerals, and Energy
Division of Mines
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Repairman, Maintenance Foreman, and Chief Electrician
Certification Study Guide

INTRODUCTION

The purpose of the Electrical Repairman, Maintenance Foreman and Chief Electrician Certification Study Guide is to assist a qualified applicant in obtaining the Underground Electrical Repairman, Maintenance Foreman and/or Chief Electrician certification(s). The Board of Coal Mining Examiners (BCME) may require certification of persons who work in coal mines and persons whose duties and responsibilities in relation to coal mining require competency, skill or knowledge in order to perform consistently with the health and safety of persons and property.

The purpose of the electrical repairman's section is to assist an applicant who possesses one-year electrical experience in underground coal mining in obtaining an Underground Electrical Repairman certification in accordance with the regulations for the BCME's certification requirements. Applicants may be given six months credit for electrical educational training from a college, technical school, or vocational school. In addition, each applicant shall pass examinations in first aid and gas detection.

The purpose of the maintenance foreman's section is to assist the electrical repairman who possesses three years of electrical experience in underground coal mining in obtaining a Maintenance Foreman certification. Knowledge of the material in the repairman's and maintenance foreman's sections is needed to prepare for the examination.

The Maintenance Foreman applicant shall hold a valid electrical repairman's certification and shall meet the continuing education requirements prior to being eligible to take the Maintenance Foreman examination. An applicant shall possess three years electrical experience as applied to underground mining. An applicant may be given one-year credit for an electrical engineering degree or six months credit for electrical education training from a technical or vocational school. In addition, each applicant shall pass an examination in first aid.

The purpose of the chief electrician's section is to assist the Maintenance Foreman who possesses 5 years of electrical experience in underground coal mining in obtaining the Chief Electrician certification. Knowledge of the material in the repairman's, electrical maintenance foreman's and the chief electrician's sections is needed to prepare for the examination.

The Chief Electrician applicant shall hold a valid Electrical Repairman and Maintenance Foreman certification prior to being eligible to take the Chief Electrician examination. An applicant shall possess five years electrical experience as applied to underground mining or appropriately related work experience approved by the Chief of the Division of Mines and shall meet continuing education requirements. In addition, each applicant shall pass a first aid examination.

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DISCLAIMER

Article 3 of the **Coal Mine Safety Laws of Virginia** establishes requirements for certification of coal mine workers. The certification requirements are included in §45.1-161.24 through §45.1-161.41 in which the Board of Coal Mining Examiners is established for the purpose of administering the certification program. The Board has promulgated certification regulations 4 VAC 25-20, which set the minimum standards and procedures required for Virginia coal miner examinations and certifications.

The Virginia Department of Mines Minerals and Energy, Division of Mines developed this study guide to better train coal miners throughout the mining industry. The study guide material should be used to assist with the knowledge necessary for coal mining certifications. The material is not all-inclusive and should be used only as an aid in obtaining knowledge of the mining practices, conditions, laws and regulations. This material is based upon the Coal Mining Safety Laws of Virginia, Safety and Health Regulations for Coal Mines in Virginia, Title 30 Code of Federal Regulations (30 CFR), State and Federal Program Policy Manuals and other available publications. Nothing herein should be construed as recommending any manufacturer's products.

The study guide and materials are available at the Department of Mines, Minerals and Energy. Any questions concerning the study guide should be addressed to the Regulatory Boards Administrator at the Big Stone Gap Office.

Electrical Repairman, Maintenance Foreman, and Chief Electrician Certification Study Guide

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CHAPTER 1

INTRODUCTION TO ELECTRICITY
DIRECT CURRENT

Electricity was first introduced into coal mines before the beginning of the 20th century in the form of direct current for rail haulage. Direct Current (DC) generators provided power for most electrical power systems.

Batteries served as the first power source for rail haulage. Keeping the batteries charged was impossible, so trolley wires were soon introduced.

The first electrically driven coal mining equipment installed in the 1920's was the coal-cutting machine. Shuttle cars were introduced in the late 1930's. Electrically powered continuous mining machines were introduced in the late 1940's. From the 1950's and extending to present day mining, alternating current (AC) systems have replaced the vast majority of DC systems.

Most present day equipment operates in a wide range of voltages from 440 volts to 4,160 volts. The AC systems are more complicated but are more efficient than DC systems.

This brief review of the development of electrical systems in coal mines has shown that mines have gone from DC (trolley wire systems) rail haulage to very complicated AC systems.

A. ELECTRON THEORY

Everything around us, even the air we breathe, occupies space and has weight. Anything that meets this description is called matter. It is impossible to name a physical substance or object that is not matter. Coal, water, wood, and gas all are examples of matter.

What does matter consist of? Matter is made of very small units called molecules. The molecules are made of atoms. The atoms, in turn, are made of minute particles called protons, neutrons, and electrons.

Elements Not only does matter consists of the minute particles mentioned in the preceding paragraph, but also all matter is composed of elements. Elements are the so called "building blocks of nature." Elements cannot be divided or reduced to a simpler substance by chemical means. Examples of elements are pure iron, gold, silver, copper, hydrogen, and oxygen. There are some 90 naturally occurring elements known to man.

Elements may be combined in two different ways, in either compounds or mixtures. A compound is a combination of elements that can be separated only by chemical means. Examples of familiar compounds are pure water (which is composed of the elements hydrogen and oxygen) and salt (which is composed of the elements sodium and chlorine).

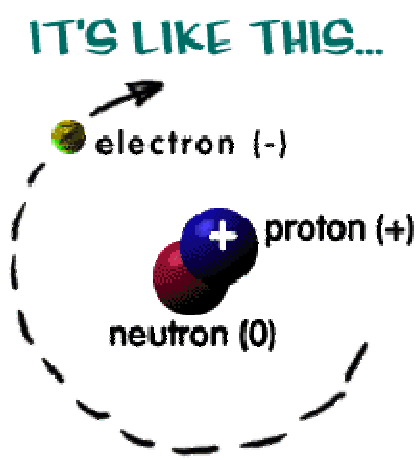
Molecules A drop of water can be divided into many small parts. In fact, it can be divided until the parts are no longer visible, yet each part retains the characteristics of the original drop. The smallest part of a substance that has all the characteristics of that substance is called a molecule. A single drop of water is made up of many millions of molecules, as are all other substances.

A molecule of water is expressed chemically as H_20, meaning that each molecule is composed of two distinct elements. H_20 stands for the combination of two parts of the element hydrogen (H) and one part of the element oxygen (0). The water molecule has a very simple structure, consisting of only two common elements. Molecules of other substances may be more complex, sometimes consisting of several elements.

Atoms The individual elements that combine to form molecules are made up of atoms. For a long time it was thought that, the atom was the smallest subdivision of matter. However, in recent years, the electron theory has been advanced; it helps to explain many electrical and chemical phenomena. According to the electron theory, atoms are composed of minute units called protons, neutrons, and electrons. Furthermore, all the atoms that make up a particular element are identical in their structure. The reason for the different types of elements, for example why iron differs from oxygen, is that the protons, neutrons, and electrons differ in number and is arranged differently within the atoms of each element.

Each proton and each electron carries an electrical charge (protons carry a positive charge, electrons carry a negative charge). The neutrons carry no charge. The electron theory explains that all atoms are similarly constructed of a central nucleus and orbiting electrons. The protons and neutrons are contained in a closely packed nucleus in the center of the atom. The electrons spin around the nucleus in much the same manner as the planets move around the sun.

The figure below shows the atomic structure of an atom. The structure of each atom is similar to and can be compared with the planet earth and its relationship with the sun. The hydrogen atom is the simplest of all atoms. It contains one electron revolving around one proton, which acts as a nucleus. Because the negative charge of the electron is equal to the positive charge of the proton, the atom is electrically balanced or neutral. The charged units (proton and electron) of the atom are shown in the illustration. Also, as previously discussed, the nucleus of all atoms contains neutrons as well as protons.



Common atoms illustrate the electron theory. The only difference in atoms of the various elements is in the number and arrangement of the protons, neutrons, and electrons. In some elements, the electrons in the outer paths are called free electrons because they can be dislodged from their regular path and be made to move from one atom to another. It is the movement or displacement of these free electrons that gives us electrical energy.

Electron Flow The discussion of protons and electrons is important. Electrons moving or flowing through a conductor (wire) is called an electric current. The electric current always flows from a point of negative potential (excess of electrons) to a point of positive potential (deficiency of electrons).

Current flowing through a conductor may be compared to water flowing through a pipe. If there is a pipe full of water and more water is pumped in at one end, water is forced out of the other end. If electrons are forced into one end of a copper wire containing billions of free electrons in the outer paths of the copper atoms, electrons are forced out of the other end. This electron flow principle is illustrated in the figure below.

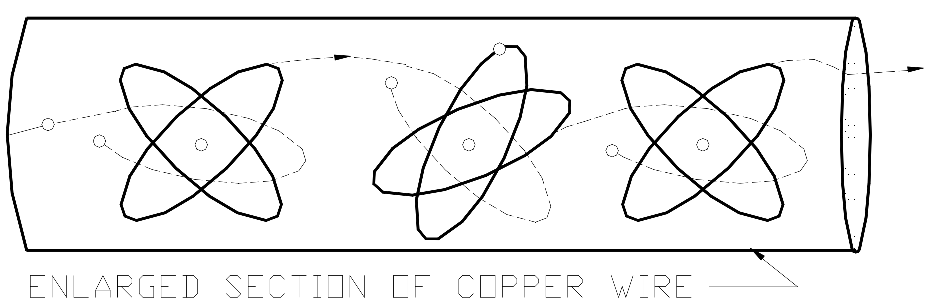


Figure: Electron Movement in a Conductor

B. ELECTRICAL UNITS

Electricity is closely related to magnetism. We can produce electricity with magnets. On the other hand, magnetism can be produced with electricity. Both electricity and magnetism are invisible.

There are three fundamental factors, which must be present for an operating electric circuit, which are voltage, current, and resistance. This section discusses electrical units and magnetism.

Voltage Electrical pressure is needed to make current flow through a conductor. A battery or an electrical generator produces pressure or a potential difference in an electrical circuit. Electrical pressure is measured in volts. One volt is the electrical pressure required to force 1 ampere of current through a resistance of 1 ohm. Ohm is defined below. Electrical pressure, electromotive force (emf), and potential difference are used interchangeably. The terms all represent voltage. The basic unit of measurement for voltage is the volt. An ordinary dry cell battery, such as a flashlight battery, has 1.5 volts. The voltage for most domestic electric service is approximately 120 volts. When voltage is applied to a circuit, a certain amount of current will flow through the circuit. If the voltage is increased, then the current flow will increase in direct proportion to the voltage.

Current: Current flow is simply the movement of electrons through a conductor. Ampere is the term used for the measurement of current flow.
To provide a standard method of indicating the direction of current flow, one terminal of the early chemical cell used as a source of electrical energy was marked positive (plus); the other terminal was labeled negative (minus). It was then assumed that when a circuit was connected to the cell terminals, a current would flow through the circuit from the negative terminal to the positive terminal (electron flow theory).

Heat, magnetism, chemical action, light and friction are five ways to produce electricity. Current always produces heat when it flows through a conductor. The amount of heat produced depends on the material of the conductor and on the amount of current flowing. For example, electric irons and toasters must have heating elements that produce enough heat to be practical. Current flowing through a threadlike conductor inside the lamp, called a filament, causes the light produced by an electric lamp. The filament must be heated so that it glows.

Magnetism is produced when current flows in a conductor. This is a very important effect, for it is the basis for millions of electrical machines, such as generators, motors, and electromagnets. Magnetism is a way to generate electricity cheaply and convert electrical energy to mechanical energy.

Current produces chemical action when it flows through certain liquids. Examples of this effect are the charging of a storage battery and the electroplating process.

Electric shock is the unpleasant and sometimes dangerous sensation caused by coming into contact with a source of electric energy. Voltage is often considered to cause shock. However, it is current flowing through the human body which produces the physical shock. The pain and the muscular contractions are due to the effect of current on the nerve centers and on the nerves themselves.

Current is measured in terms of the number of coulombs that pass by a given point in one second. When a conductor is connected across a source of voltage, and 6.28×10^{18} electrons (one coulomb) pass through the conductor for a period of 1 second, the one unit of current flow has occurred. This unit of current flow is called an ampere.

Resistance The definition of resistance is to oppose or retard. In electrical terms, resistance means the opposition to the movement of free electrons through a circuit or conductor. The amount of opposition offered by a conductor depends on the material of the conductor, its length, its cross sectional area, and its temperature. The ohm is the standard unit of measure for resistance.

Resistance to electric current is present in all matter, but one material may have much more resistance than another. Air, rubber, glass, and porcelain have so much resistance that they are called insulators and are used to confine electricity to its proper circuit.

The rubber covering on the wires to an electric lamp prevent the wires from touching each other and causing a short circuit. The rubber also protects a person using the lamp from receiving an electric shock. Air acts as an insulator whenever a light switch is opened. Air fills the gap between the open contacts of the switch, and no current flows because of the high resistance. However, even air may act as a conductor if the voltage is high enough. Such as a lightning strike is a discharge through air.

Metals are good conductors of electricity, but some are better than others. Copper and silver are good conductors of electricity because of their relatively low resistance. Aluminum is not as good of a conductor as copper, but is used for overhead power lines because of its lightweight and cost efficiency. Steel is a poor conductor, although it is sometimes used in combination with aluminum for added strength. Alloys of nickel and chromium are used in heater elements to provide a specific resistance, which passes enough current to heat the elements to a red glow. The alloy makes it possible to operate the elements at high temperatures without melting. Copper is a good conductor and relatively inexpensive. Therefore, copper is widely used in electrical circuits. However, copper is seldom used in its pure form. It is usually mixed with other metals to form a copper alloy.

C. ELECTROMAGNETISM

The theory of magnetism is based on knowledge of natural magnets, which the ancient scientists called lodestones. Modern man found that magnets could be made from iron and from metal alloys, which contained iron.

Magnetic field When iron filings are sprinkled over the entire area of a magnet, you notice filings which fall near the ends of the magnet is attracted to form bunches as shown in the figure below. Very few of the filings that fall near the center are so attracted. This experiment shows that the bar magnet has two distinct regions, or poles, indicating the areas where the magnetic force is greatest.

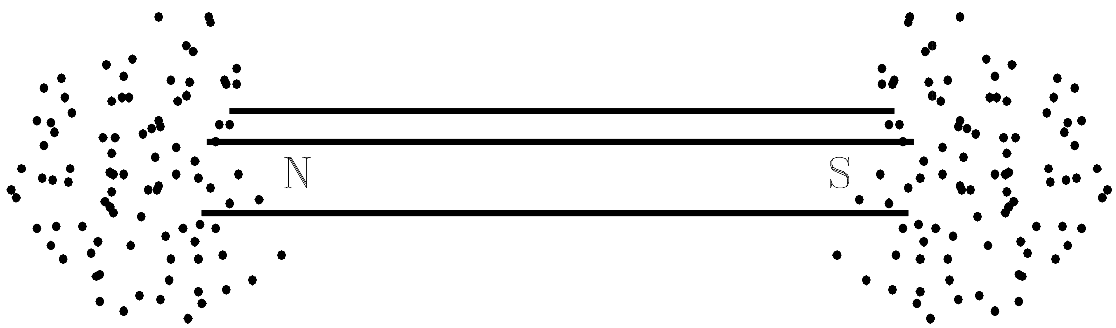


Figure: Concentration of Magnetic Field

The presence of a magnetic field surrounding a magnet can be demonstrated by sprinkling fine iron filings onto a sheet of paper or piece of glass held over a magnet. If the paper or glass is tapped gently, the filings will arrange themselves into a pattern of lines or loops, as shown in the next figure. This arrangement of the filings indicates the presence of a magnetic field, or flux. It is generally considered that these lines of force leave the magnet at the North Pole and reenter at the South Pole.

The explanation of why this pattern always forms is quite simple. The iron filings become magnetized by magnetic induction when they are brought into contact with a magnetic field. This causes them to line up with the field and to concentrate at the poles where the field is strongest.

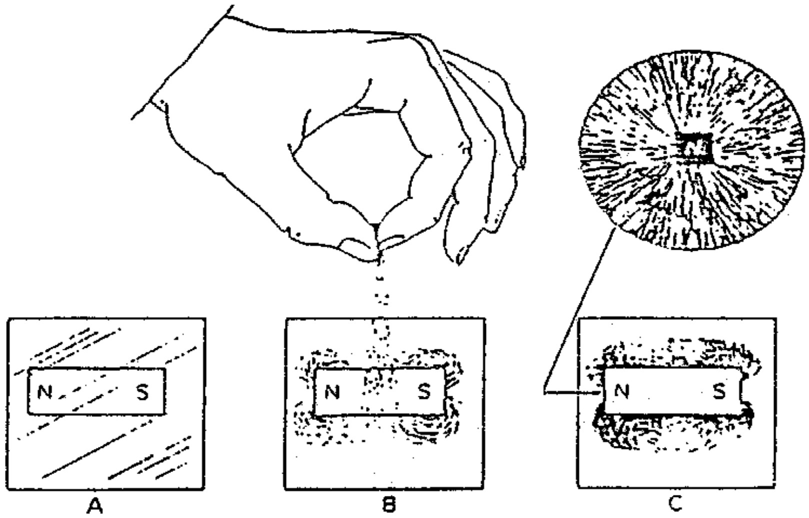


Figure: Pattern of Magnetic Field

Magnetic and Nonmagnetic Substances Iron and steel are referred to as magnetic substances because they are affected by the magnetic force. Most other substances are not affected and are defined as nonmagnetic. The ease with which magnetic flux concentrates within a substance is known as permeability. The indifference of a material to the concentration of a magnetic field is known as reluctance, or the opposite of permeability.

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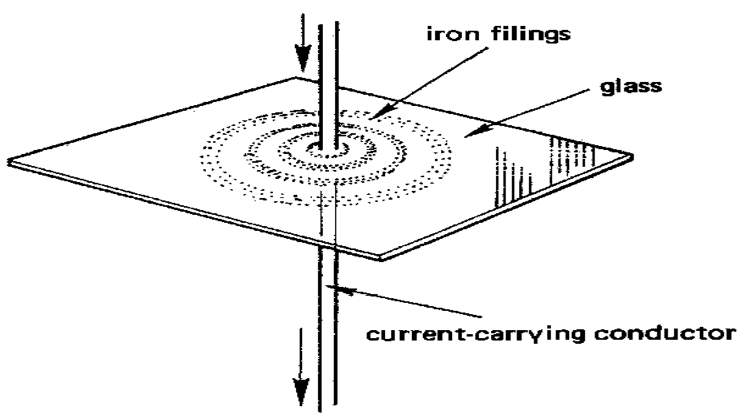


Figure: Magnetic Field around a Wire

Attraction and Repulsion of Magnetic Poles A properly suspended permanent magnet always aligns itself with the earth's magnetic field, with the **north pole** seeking to point toward the magnetic north pole of the earth. Now, if the north pole of a second bar magnet is brought close to the north pole of the suspended magnet, the suspended magnet is pushed away as shown in the figure below. Reverse the second magnet and bring the south pole close to the north pole of the suspended magnet, as illustrated in the figure below, and the two poles are pulled together. This illustrates a fundamental law of magnetism. Like poles repel and unlike poles attract. The behavior of magnetic poles is similar to that of electrical charges, where like charges repel and unlike charges attract.

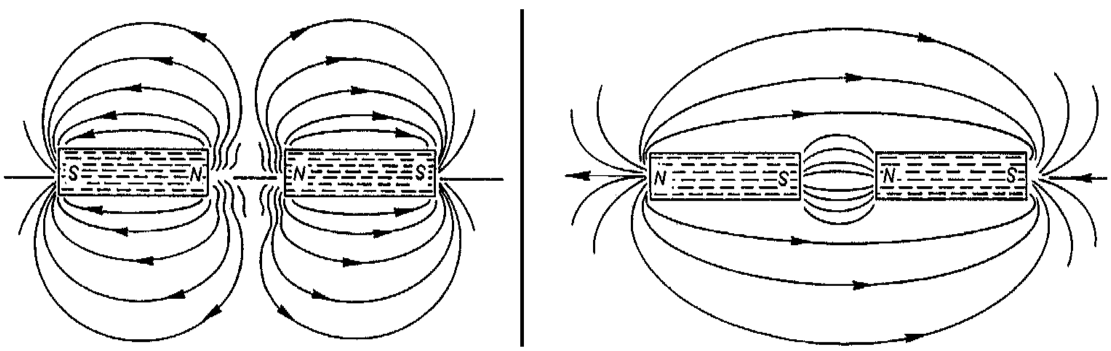


Figure: Repulsion and Attraction between Magnets

Permanent and Temporary Magnets: Magnets made from soft iron are called temporary magnets because they do not retain their magnetic qualities. Magnets, which retain their magnetic qualities, are called permanent magnets and are generally constructed of steel or a special alloy. Electromagnets possess magnetic qualities only when an electric current is present in the windings.

Electromagnetism: Electromagnetism is the most common method of generating electric power for the mining industry. An iron bar can be made into a magnet by placing it in a coil of wire and attaching the wire to the terminals of a battery. Since it is necessary to have an electric current in the coil of wire to magnetize the iron, there must be a close relationship between electric current and magnetism.

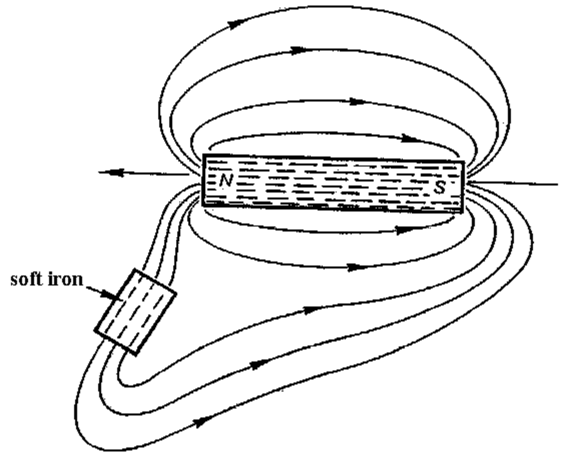


Figure: Distortion of a Magnetic Field

The figure above shows what happens when you place a piece of soft iron in the field of a permanent magnet. The field is distorted because of the difference in permeability of air and iron. Iron has a much greater permeability than air.

Electromagnets The field around a single conductor is not very strong, but when the conductor is formed into coil, as shown in the figure below, we are able to concentrate the magnetic lines of force. Further concentration can be achieved by placing a core of soft iron in the open coil, or solenoid. The coil of wire, or solenoid, containing an iron core is actually a simple electromagnet. The strength is determined by three factors the amount of current in the winding, the number of turns in the coil, and the material of which the core is made.

The direction of current flow through the coil of an electromagnet determines the poles of the magnetic field. This relationship is determined by the left hand rule, which states, "If the coil is grasped in the palm of the left hand with the fingers pointing in the direction of current flow, then the thumb points toward the North Pole of the coil."

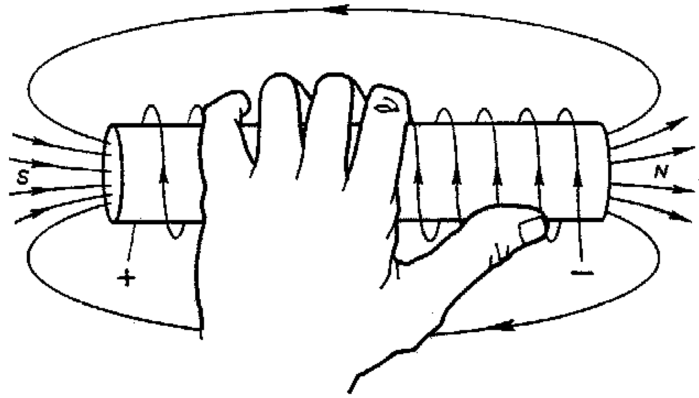


Figure: Magnetic Field Produced by a Coil

Electromagnetic Induction As previously, discussed, electric current flowing through a conductor creates a magnetic field around that conductor. The reverse is also true in that a magnetic field can cause a current flow in a conductor. This can be demonstrated using a strong horseshoe magnet, a length of copper wire, and a very sensitive current reading meter (galvanometer), connected as shown in the next figure. When the conductor is moved downward through the magnetic field, the galvanometer needle is deflected, indicating there is a current in the circuit. When the conductor is moved upward through the field, the needle is again deflected but this time in the opposite direction, indicating that electron flow in the wire is now reversed. Holding the wire still and moving the magnet up and down can achieve the same effect. When relative motion between the conductor and the magnetic field is not present, then current does not flow in the wire.

When the conductor is moved across the magnetic field, some of the magnetic energy is transferred to the conductor as voltage, or emf, forcing the free electrons to move at right angles to the magnetic field. This causes current flow in the circuit when the path is complete. The amount of current produced by moving the single conductor through the magnetic field is very small. We can increase the amount of current produced by increasing the speed of relative movement by forming the conductor in to a coil so that more wires are cutting across the magnetic field. A combination of these methods is used to create a practical electrical generator.

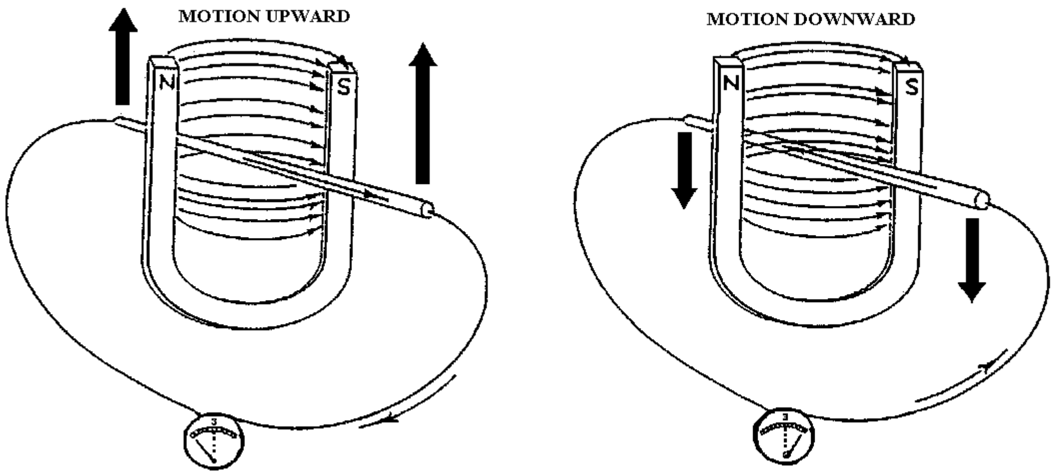


Figure: Producing Current by Electromagnetic Induction

D. TYPES AND SOURCES OF ELECTRICITY

As previously, discussed, current flow is simply the movement of electrons through a conductor. If the electrons move in one direction through the conductor, this is referred to as direct current (DC). If electrons move back and forth through the conductor at a specific interval, this is referred to as alternating current (AC). The two most common methods of producing electricity for the mining industry are electromagnetism and chemical (battery).

Direct Current. Direct current occurs when electrons flow from a negative potential to a positive potential, with a steady flow in one direction only. DC is suitable for battery charging, electroplating, and certain electronic circuits.

Certain electrical circuits make use of a particular type of direct current, called pulsating direct current. A pulsating direct current is obtained by using specially designed switches, which alternately turn a direct current off and on, causing the current to flow in pulses. The ignition coil circuit of an automobile is a good example of pulsating direct current. Each time the ignition points close, a short pulse of direct current flows through the ignition coil. The current pulses always flow in the same direction.

<u>Direct Current Generator</u> A simplified diagram of a DC generator is illustrated in the next figure. A wire loop represents the conductor, which rotates in the magnetic field. The ends of the loop terminate in two copper

half rings, which are insulated from each other. Fixed brushes make contact with the copper rings to conduct electricity to the external circuit. The loop is rotated in clockwise direction. In position A, the conductors of the loop are moving parallel with the field; and since the conductor is not cutting the lines of force, there is no voltage. At position B, the loop is moving at right angles to the field, and voltage is at a maximum. Note that the sides of the loop will reverse themselves, but voltage to the external circuit, the galvanometer, will remain flowing in the same direction. Since the brushes are stationary, they deliver direct current because either conductor in contact with a particular brush will have the same direction of motion across the field.

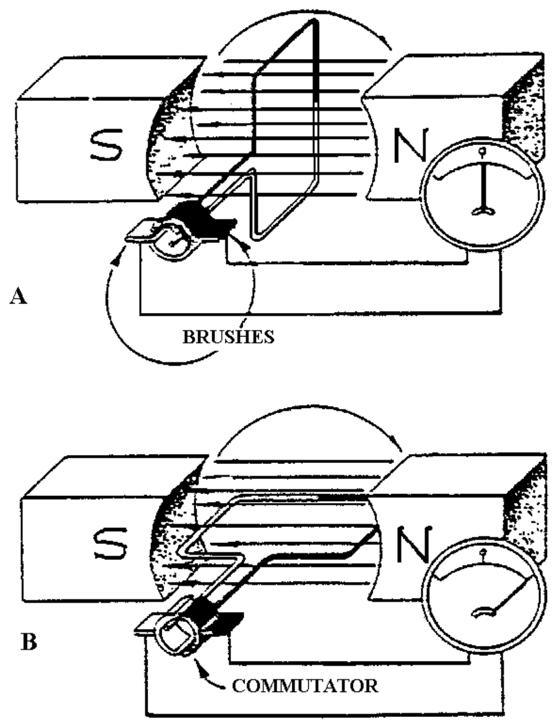


Figure: DC Generator

A direct current generator is quite different from the working model shown in the previous figure. Instead of permanent magnets, strong electromagnets are used. Controlling the amount of current flow through the field coils can control the strength of the field circuit. A variable resistance (rheostat) in the field circuit makes it possible to control the voltage output of the generator. Instead of a single loop, there are many coils of wire in the rotor/armature. The ends of each coil terminate in opposite copper segments. These copper segments are formed in a ring called a commutator. The rotor assembly illustrated in the next figure is an armature for a DC generator.

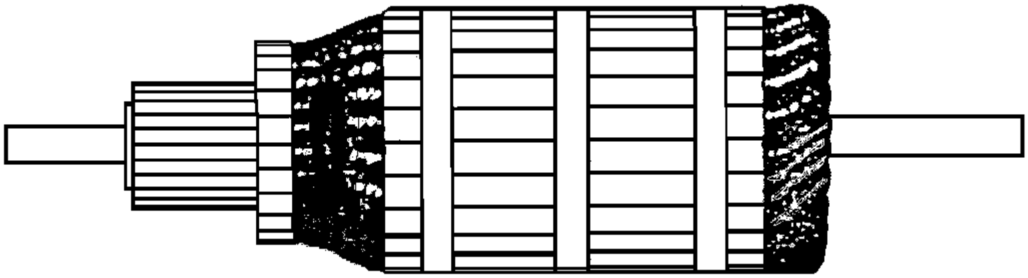


Figure: Armature for a DC Generator

The ends of the armature shaft ride on bearings. The three main parts of a generator are the stator, the rotor/armature, and the end bells. The main frame of the generator holds the stator, or field; this frame supports the end bells, which carry the bearings. One end bell contains the brush rig, which holds the brushes. The voltage generated is controlled by a rheostat in the field circuits, which changes the strength of the electromagnets. A change in speed will also change the voltage, but it is much simpler to control by resistance.

E. OHM'S LAW AND BASIC ELECTRICAL CIRCUITS

Voltage, current, and resistance have a definite relationship in electrical circuits and parts of an electrical circuit. If the voltage is increased, the current increases proportionately, and if the resistance is increased, the current decreases proportionately. This section will discuss the basic law on which this relation is based. The law is used to compute quantities of voltage, current, and resistance in the three basic electrical circuits.

<u>Ohm's Law</u> A German scientist, Ohm, developed a law for the quantities of a circuit as follows: One volt is the pressure required to force 1 ampere of current through a resistance of 1 ohm. This law can be reduced to a simple formula where E stands for volts, I stand for current, and R stands for resistance, as shown by the Ohm's law circle in the following figure. Simple division or multiplication solves this formula. Where two of the quantities are known, the third can always be determined. Block out the unknown in the formula and the remaining portion tells how to solve the problem.

Suppose the voltage and current for a circuit are known but the resistance for the circuit is not. Place a finger over the R and the remaining part is E over I. This can be written as

$$R = \frac{E}{I}$$

Dividing E by I solves the problem. Given a voltage pressure of 120 volts and a current of 5-amps, what is the resistance? 120-volts divided by 5-amps equals 24, so the answer is 24 ohms of resistance.
If you know the resistance of a circuit and the voltage applied to the circuit, how much current will flow through the circuit? Use the following figures to determine quantities. Cover the I and you have volts divided by the resistance. If a 4-ohm resistor is connected to a 120-volt source, how much current will flow through the resistor? Divide 120 volts by 4 ohms and 30 amperes of current will flow. Why is it important to know this? Fuses or circuit breakers protect branch circuits. If a 30-ampere load is in a branch circuit, which is protected by a 20-ampere fuse, the fuse will open "blow" and current will not flow in an open circuit.

To find the voltage in a circuit cover the E and the solution is I times R. It is sometimes important to know the amount of voltage present in part of an electrical circuit. When the resistance is known and the current is measured with an ammeter, then the voltage drop can be calculated. If there is a resistance of 8-ohms and 10-amperes in the circuit, what is the voltage across the resistor? Using the formula, I X R (10 times 8) equals 80 volts, which is the voltage drop across the resistor. The different types of circuits are explained along with the use of meters to determine voltage and current.

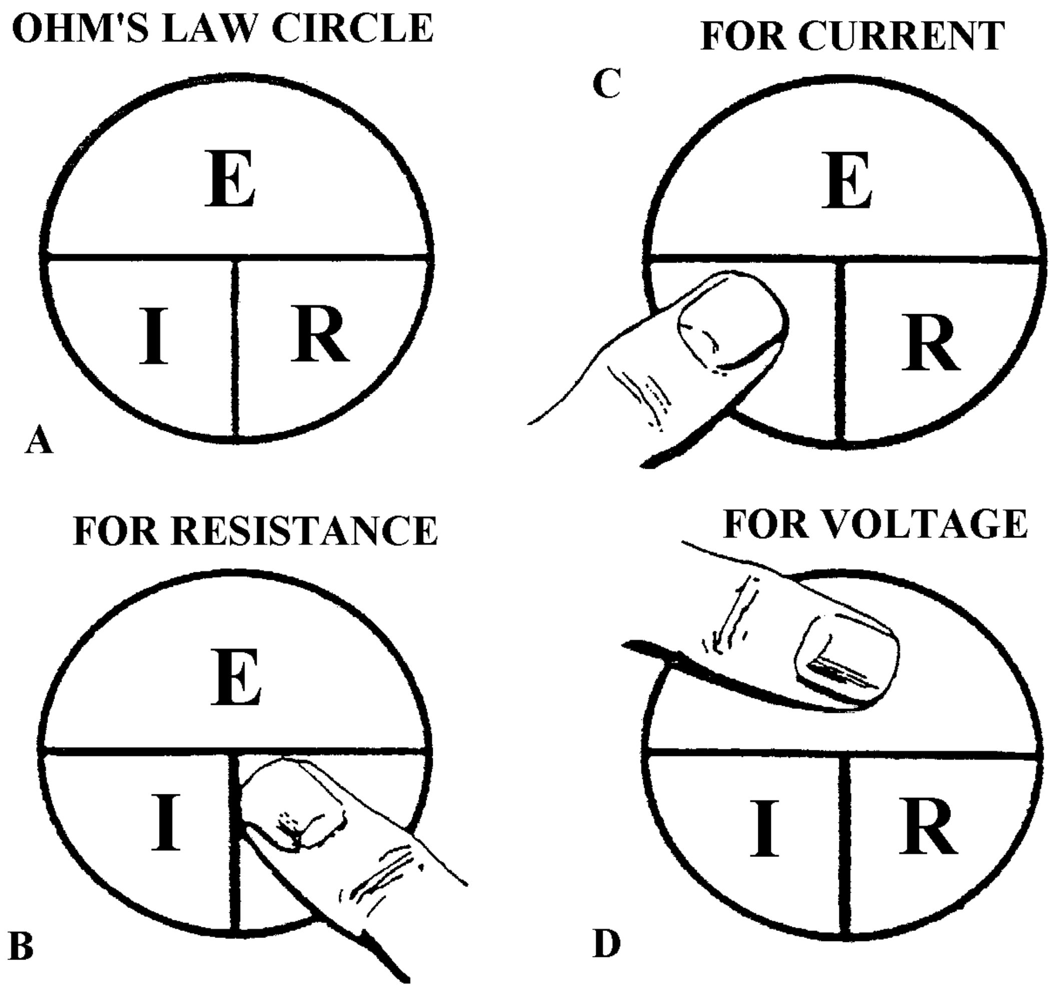


Figure: Ohm's Law Formulas

<u>Basic Circuits</u> A series circuit is the simplest; the parallel is a little more complicated; the series/parallel circuit is the most complicated electrical circuit. Each is governed by its own set of rules. The following paragraphs explain their basic rules, laws, and operation.

<u>Series Circuits</u> The simplest circuit consists of a resistance (load), a source of power, and the wires, which connect the load to the source. A complete electrical circuit means one with a continuous path for current to follow from the source of power, through the load, and back to the source, as

illustrated in the figure on this page. The figure indicates a practical circuit that is protected by a fuse and controlled by a switch. The switch makes it possible to turn the circuit on and off as desired. This schematic could represent the circuit for an emergency light supplied by a battery. The long line in the battery symbol represents the positive side and the short line indicates the negative side. Polarity markings must be observed when measurements are made with DC meters.

The positive lead of a voltmeter must be connected to the positive side of the DC circuit and the negative lead to the negative. An ammeter could be connected in series in the circuit on either side of the resistor, but polarity markings must be observed as indicated.

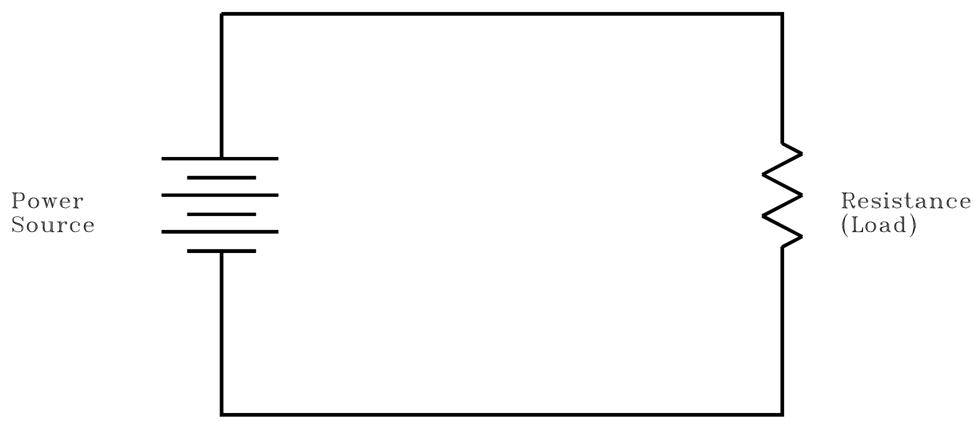


Figure: Simple Circuit

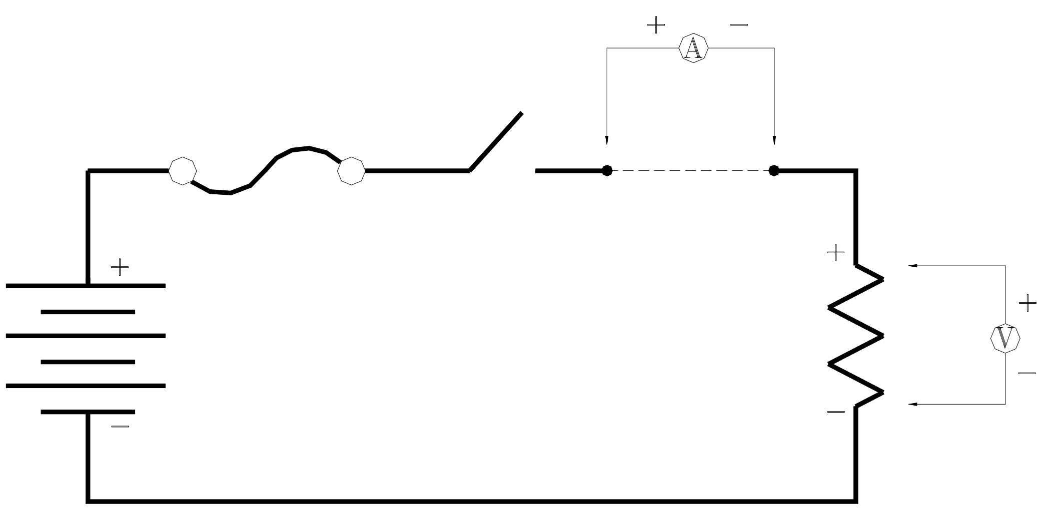


Figure: A Practical Series Circuit

The fuse, the switch, and the resistor are all in series with each other. A definition of a series circuit is a circuit in which there is only one path for the current to flow. The voltage across the resistor is the applied voltage from the battery. The current in the circuit is the same at all places, because there is only one path for the current to follow.

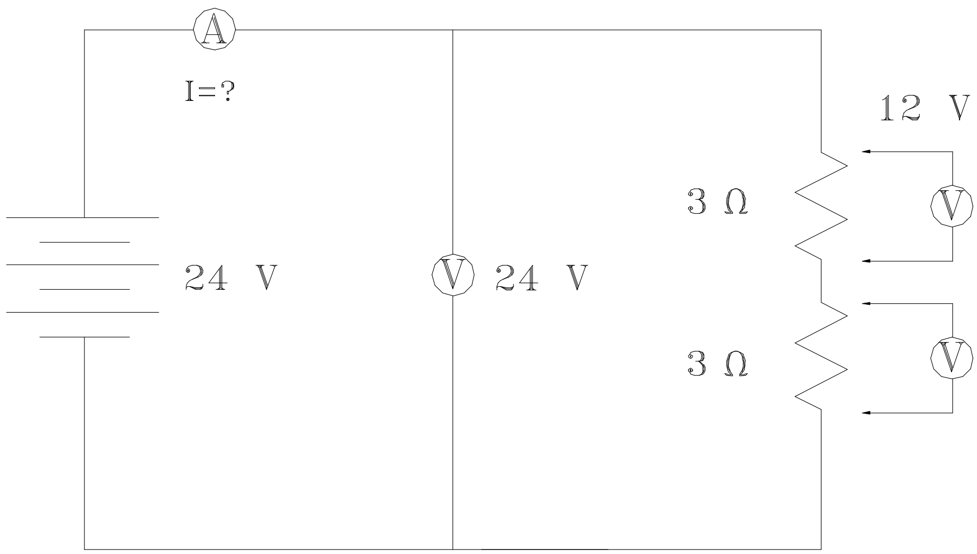


Figure: Equal Resistance in Series

In the figure above figure there are two resistors connected in series to show what the term "voltage drop" means. Ohms represent the resistance value; each resistor has 3 ohms of resistance. A voltmeter connected across the battery reads the full battery voltage of 24 volts. The voltage across both resistors is 24 volts. The reading across either resistor is 12 volts. Half of the applied voltage drops across each resistor because they are of equal value. Voltage drop may be explained by comparing it to a water system. At a water pumping station, the pressure may be 100 pounds per square inch (PSI). Homes located close to the station have about the same pressure. At some distance away from the station, the pressure may have dropped to 80 pounds, while those located at the farthest end of the system may receive only 60 pounds. Resistance causes this drop in pressure in the system. A similar situation exists in a circuit due to a drop in voltage as the electrical pressure meets resistance. The voltage drop occurs in the resistance. What is the current flow in the circuit in the figure above? The answer is found by applying Ohm's law; but in this case the separate resistances must be added together to first find the total resistance, 3 plus 3 equals 6 ohms total, and when divided into 24 volts equals 4 amperes of current flow.

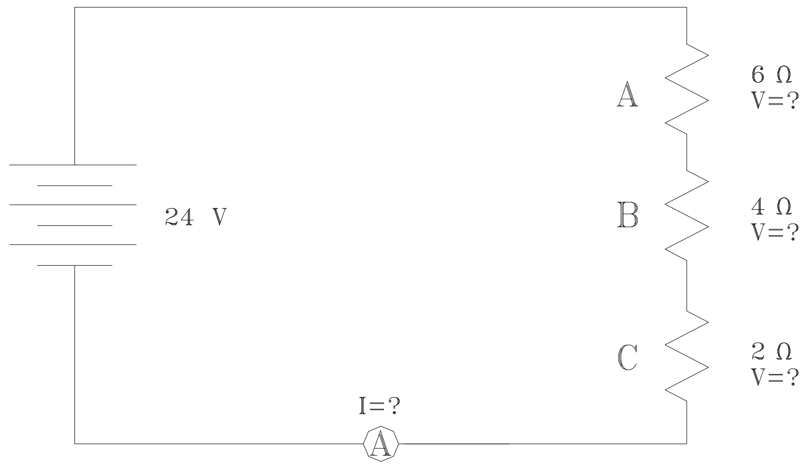


Figure: Resistance in Series

The above figure is a series circuit, which shows three unequal resistors. The voltage drop across each resistor is found by first finding the total resistance and then the current. The total resistance is R_T = 6 ohms + 4 ohms + 2 ohms = 12 ohms. Twenty-four volts divided by 12 ohms equals 2 amperes. The current through a resistor multiplied by the resistance in ohms is the voltage drop across that resistor. Two amperes times six ohms equals 12 volts, which is the drop across resistor A. The drop across resistor B is 8 volts (2 X 4), while C drops 4 volts (2 X 2). The sum of the voltage drops is 12 + 8 + 4, which is equal to the applied voltage, or 24 volts.

The following rules apply to a series circuit:

a. Only one path for current flow exists.

b. The current is equal in all parts of a series circuit.

$I_T = I_A = I_B = I_C$

c. The total resistance is the sum of the individual resistances.

$R_T = R_A + R_B + R_C$

d. The sum of the voltage drops in a series circuit equals the applied voltage.

$V_T = V_A + V_B + V_C$

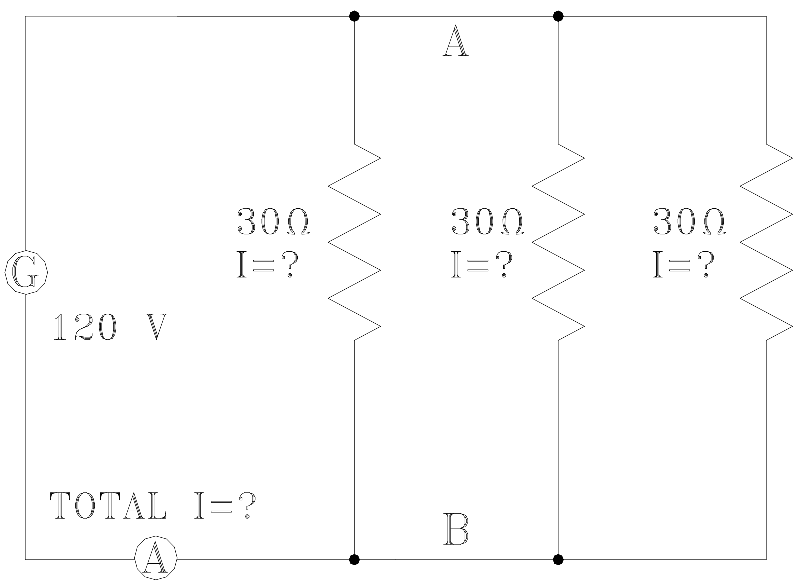


Figure: Resistors in Parallel

Parallel Circuits A parallel circuit exists when there are two or more paths for the current to follow. The lighting circuits in a building are connected in parallel. The first rule for a parallel circuit is that each component in the parallel circuit receives the voltage that is applied to the parallel circuit. The previous figure gives an illustration of this rule. A voltmeter connected anywhere on line A to line B reads the applied voltage of 120 volts. Each resistor receives the same voltage, so the voltage drop is the same for all resistors in parallel. Another rule for a parallel circuit is that the total current is the sum of the current in the branches. Find the current in each branch to get the total current. The resistance and the voltage are known, so V divided by R, or 120 divided by 30, equals 4 amperes for the current in one branch. Since the three branches have the same value of resistance, each one has a current of 4 amperes, or a total of 12 amperes for the whole circuit. What is the equivalent resistance of this circuit? The voltage and the total current are known, therefore, 120 divided by 12, equals 10 ohms. Therefore, one 10-ohm resistor will draw the same current as the three equal resistors in parallel. Thus, the total effective resistance in a parallel circuit is less than the smallest individual resistor.

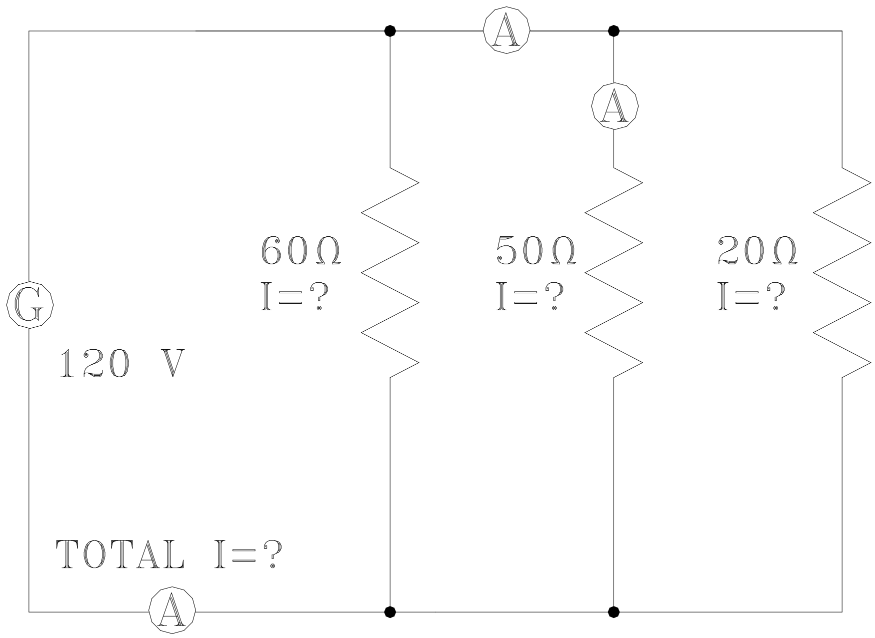


Figure: Unequal Resistors in Parallel

Another example is given in the figure above, where there are unequal resistors in a parallel circuit. The method of solution is the same as in the preceding problem. The applied voltage is the same across each resistor. Note the ammeter is connected is series with the 50-ohm resistor to read the current in the 50-ohm resistor. By applying Ohm's law, (120 volts/50 ohms) current in the 50-ohm resistor is 2.4 amperes. Current in the 20-ohm resistor is 6 amperes. Two amperes flow through the 60-ohm resistor. How much current will the meter read at the top of the circuit (A)? At this place in the circuit, the ammeter reads the current through the 50 and 20-ohm resistors, which is 8.4 amperes. The total current for all three resistors is 10.4 amperes. What is the equivalent resistance of the circuit? Divide 120 by 10.4, and the answer is approximately 11.5 ohms.

Following is a summary of the rules, which apply to a parallel circuit:

a. The same voltage is applied to each resistor connected in parallel.

$V_T = V_A = V_B = V_C$

b. More than one path for current flow exists.

c. Current in a parallel circuit divides according to the resistance of each path.

d. The total current is the sum of the current in the individual branches.

$I_T = I_A + I_B + I_C$

e. The total resistance of a parallel circuit is always less than the smallest resistor in the parallel circuit.

Series-Parallel Circuits. The circuit in the following figure shows a combination of resistors in series and parallel. This circuit demands a new method for solution. The parallel part of the circuit must be solved first. To find the combination for the parallel resistors use the "product divided by sum" method as follows:

$$R = \frac{R_1 \times R_2}{R_1 + R_2} \quad \frac{10 \times 10}{10 + 10} = \frac{100}{20} = 5 \text{ ohms}$$

One hundred divided by 20 equals 5 ohms as the equivalent resistance. The parallel branch is in series with the 15-ohm resistor, so the series-parallel combination has a total resistance of 20 ohms. The total current for the circuit is 6 amperes. This is also the current through the 15-ohm resistor. The voltage drop across the 15-ohm resistor is 90 volts (15 X 6). The current divides equally in the parallel part because the resistors are equal. Each 10-ohm resistor has a current flow of 3 amperes, which results in a voltage drop of 30 volts across the parallel branches. Total voltage drop is 30 plus 90, or 120, which is the applied voltage.

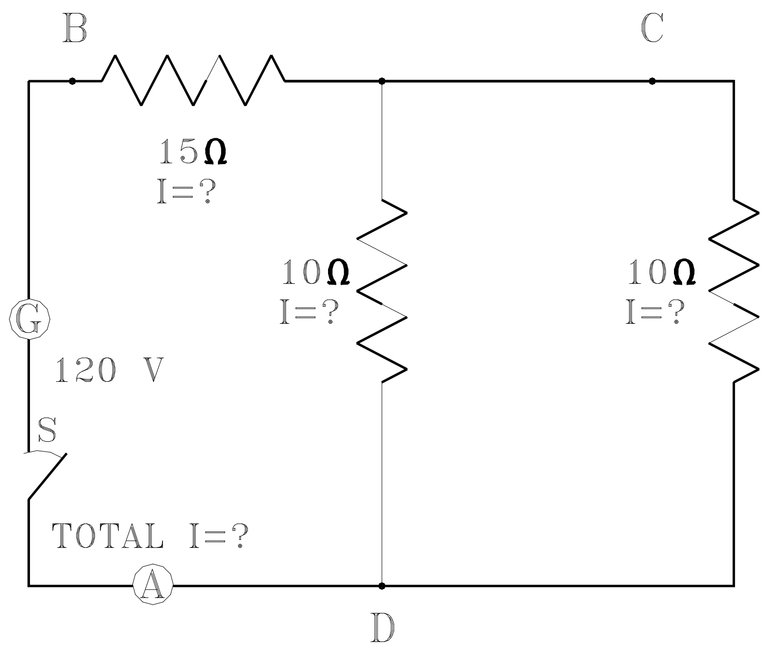


Figure: Resistors in Series Parallel

How would a voltmeter be used to measure the voltage drops in the figure above? Between points B and C, the meter measures the voltage drop across the 15-ohm resistor (90 Volts). From C to D, the meter reads the drop of 30 volts for the resistors in parallel. The applied voltage/generator (G) is read between B and D (120 Volts). Note that the voltage drop is the same for all the resistors in the parallel section.

<u>Power in Electric Circuits</u> Electric power is measured in watts just as mechanical power is measured in horsepower. One horsepower (1 hp) is equal to 746 watts. Electric power is usually expressed in kilowatts. A kilowatt equals 1000 watts; therefore, a kilowatt is equal to approximately 1.3 horsepower.

<u>Direct Current Circuits</u> The electrical power (P = watts) in a DC circuit can be determined by either one of three formulas:

$P = (E \text{ X } I)$ $P = (I^2 \text{ X } R)$ $P = \frac{E^2}{R}$

When the voltage and current are known, the power is determined by simple multiplication. As an example, a 120-volt circuit drawing 10 amperes consumes 1200 watts, or 1.2 kilowatts.

Using the I squared R formula, let us suppose the current is 10 amps and the resistance is 10 ohms. The current squared is 10 X 10, or 100 amps, which multiplied by the resistance, 10 ohms, gives 1000 watts, or 1 kilowatt.

The third formula uses the voltage squared divided by the resistance to find power in watts.

This last formula may prove useful in knowing a certain resistance. Simply transpose the formula to: $R = \frac{E^2}{P}$

For example, most electrical space heaters are rated for volts and watts on the nameplate, but the resistance of the heating element is not given. A 1500-watt heater designed for 120-volt operation will make a suitable problem. The voltage squared (120 X 120) is 14,400, and when divided by 1500 gives a resistance of 9.6 ohms.

In using the power formulas, P represents the power in watts. To use this formula for a piece of equipment rated 2.5 kilowatts, it would have to be converted to watts (2500).

F. BATTERIES

Other than generators, chemical action is the most important source of electrical energy. A battery is a device used to convert chemical energy into electrical energy.

A battery is made up of units called cells. However, the term "cell" and "battery" are used interchangeably. All cells are divided into two general types primary and secondary. Once the primary cell is exhausted, it is useless. On the other hand, the secondary cell may be recharged. In the following paragraphs, we discuss the primary cells and the storage battery. The storage battery consists of two or more secondary cells.

<u>The Primary Cell</u> The most common primary cell is the dry cell, the type used in an ordinary flashlight. A cross-sectional view of a dry cell is shown in the following figure. The two terminals are connected to plates in the cell and are called electrodes. The zinc can serve as the negative electrode as well as the container for the cell, and the carbon rod serves as the positive electrode. The electrolyte consists of a chemical dissolved in water and mixed with a thick paste. The paste prevents the electrolyte from spilling. The top of the cell is sealed to prevent evaporation of moisture and to keep the contents of the can from spilling. Connections to the cell are made by terminal posts, which are connected to the zinc and carbon electrodes.

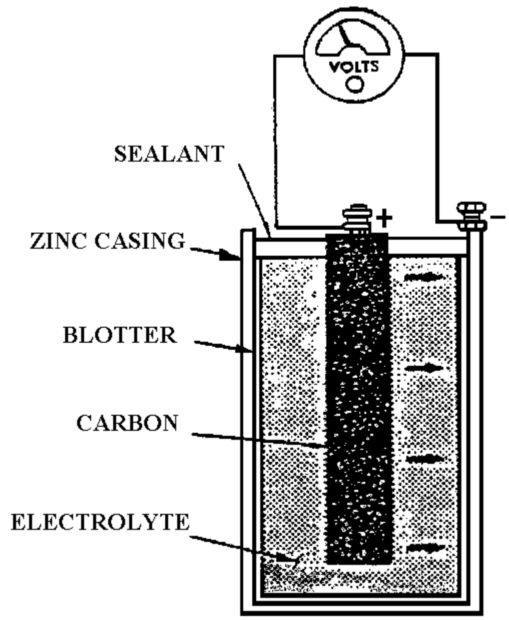


Figure: A Primary (Dry) Cell

When the cell is connected to a circuit, a chemical reaction takes place between the electrolyte and the negative electrode. This reaction creates voltage between the positive and the negative electrodes, which results in an electron flow from the negative terminal through the external circuit and back to the positive terminal.

A single primary cell of the type shown in the figure above develops a voltage of 1.5 volts. The size of the cell has nothing to do with the voltage that it can develop. The voltage depends on two factors only-- the type of electrolyte and the electrode material. The amount of current that a cell can furnish, however, is dependent upon the area of the plates exposed to the electrolyte; or, the amount of current is directly dependent on the cell size. This is why flashlight batteries are quite small, whereas batteries designed for heavier current flow are much larger.

As mentioned, 1.5 volts are developed by a primary cell. This is referred to as the open circuit or no-load voltage. When a cell is supplying current to a circuit, the voltage is somewhat lower. The voltage under a load is called terminal voltage. Terminal voltage is the open circuit voltage minus the current flow times the internal resistance of the battery. It is often necessary to furnish voltage higher than that provided by a single cell. When this is the case, two or more cells are connected to the negative terminal of the next cell. A diagram of four cells connected in series is shown in the following figure. A combination of cells connected in this manner is called a battery. When cells are connected in series, the individual cell voltages add together to form a higher voltage. Notice in "A" that the four cells produce a total of 5.2 volts or a nominal voltage of 6volts. Remember this rule: when cells are connected in series, the voltage is increased, but the current capacity remains the same as for a single cell.

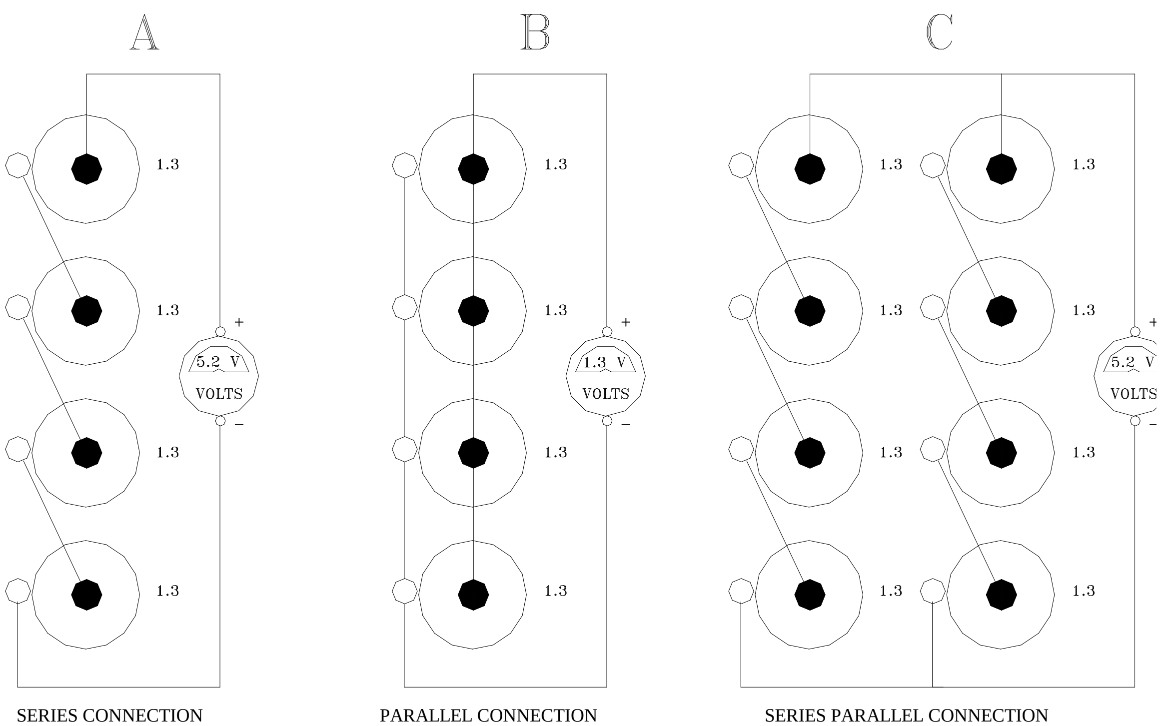


Figure: Cell Connections

To increase the current capacity, connect the cells in parallel. The positive terminal of one cell is connected to the positive terminal of the next cell, and the negative terminals are connected similarly. A parallel connection is shown in "B" above. When cells are connected in parallel, the total current is equal to the sum of the individual currents produced by each cell, but the output voltage remains the same as that for a single cell.

To increase both the voltage and current capacity, the cells are connected in series and in parallel. This combination is called a series/parallel connection. A diagram of eight primary cells connected in series/parallel is shown in "C" in the previous figure.

The Storage Battery The most common storage battery is the lead acid type, so called because the plates are made of lead and the electrolyte is acid. Probably, the most common storage battery is the 12-volt DC battery that is used in automobiles.

As previously described, a battery is made up of two or more cells. The exact number of cells depends on the desired voltage. The automobile battery consists of six cells (2 volts each) connected in series. The battery is contained in a case, which is divided into compartments, one compartment for each cell. Groups of positive and negative plates are assembled to form an element, and each element makes up one cell. The elements are immersed in a sulfuric acid and water solution called electrolyte. Thin sheets of wood, porous rubber, or glass fiber, (called separators) are placed between the plates to prevent them from touching and causing a short circuit.

The battery plates are made in the form of a grid, which is filled with a soft lead paste, the active material in the plates. Several plates are put together to form a positive group and a negative group. The plates of each group are connected together and then connected to the external terminal or connecting post.

When a storage battery is charged and in operating condition, the active material on the positive plates is lead peroxide, and spongy lead on the negative plates. When the battery is discharging, the plates undergo a chemical change. The acid from the electrolyte unites with the active plate material, and lead sulfate is formed on both the positive and negative plates. During discharge, the acid content of the electrolyte is decreased. If the battery is allowed to continue discharging, the sulfate deposit on the plates increases until no further chemical action can take place. In this condition, the battery is completely discharged. A battery in which the plates have been allowed to accumulate a heavy deposit of lead sulfate is practically useless, as it is almost impossible to recharge a battery in this condition.

When a battery is being charged, the chemical action is reversed. The lead sulfate is then removed from the plates, and sulfuric acid is formed. Thus during charging, the acid content of the electrolyte is increased.

The number of cells connected in series determines the voltage of a battery. Although the open circuit voltage of a lead acid cell is approximately 2.2 volts, the cell is normally rated at only 2 volts because it drops to that value under load. A battery rated at 12 volts consists of six lead acid cells connected in series, while a battery rated at 24 volts has twelve cells.

Storage battery capacity (size) is expressed in terms of ampere hours. An ampere-hour is the amount of electrical charge that moves past a particular point in a circuit when unvarying current of 1 ampere is maintained for 1 hour. This rating indicates how long the battery may be used at a given rate before it is discharged. Theoretically, a 100-ampere-hour battery will furnish 100 amperes for 1 hour, 50 amperes for 2 hours, or 20 amperes for 5 hours. Storage batteries, like ordinary primary cells, may be grouped together and connected in series, parallel, or series parallel to give any voltage or current capacity desired.

G. DIRECT CURRENT MOTORS AND GENERATORS

Direct Current (DC) motors and generators are similar in construction. The DC generator is a device that converts mechanical energy to electrical energy while a DC motor is a device that converts electrical energy to mechanical energy.

The mining industry uses three different types of DC motors. Each has characteristics that are advantageous under given conditions. They are series, compound and shunt motors. The series motor has the field coils connected in series with the armature circuit. This type of motor, with constant potential applied, develops variable torque. The speed also varies with load. In fact, if a series motor does not have any load, the speed will keep increasing until it destroys itself.

The compound motor has one set of field coils in series with the armature circuit and another set of field coils in parallel with the armature and series field coils. This type is simply a series motor with the additional shunt field. The shunt field is used to keep the motor from speeding up and destroying itself under no load conditions. This type of motor is found on belt drives and motors for hydraulic systems.
The shunt motor has field coils connected in parallel with the armature. This type of motor, with constant potential applied, develops variable torque at an essentially constant speed, even under no load conditions. These motors are found on lathes, drills and planers.

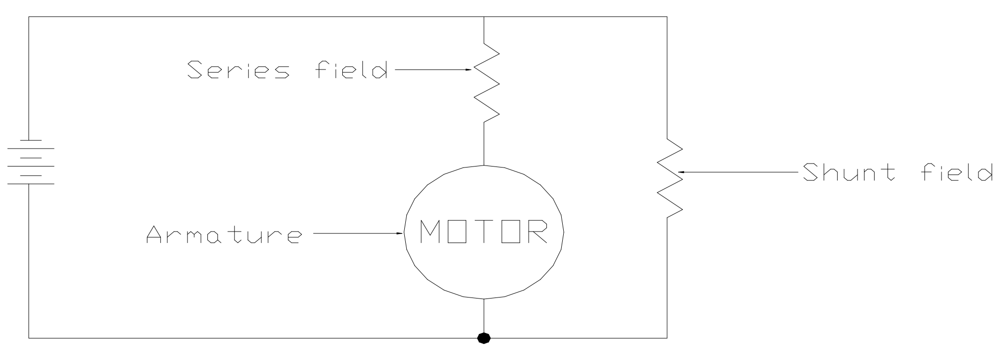


Figure: Schematic Diagram of DC Compound Motor

H. ELECTRICAL METERS

A good understanding of the functional design and operation of electrical meters is important.

Electricians shall always use meters with extreme caution to avoid direct contact with energized circuits and improper usage, which could result in severe burns or electrocution.

Ammeters are used to measure current.

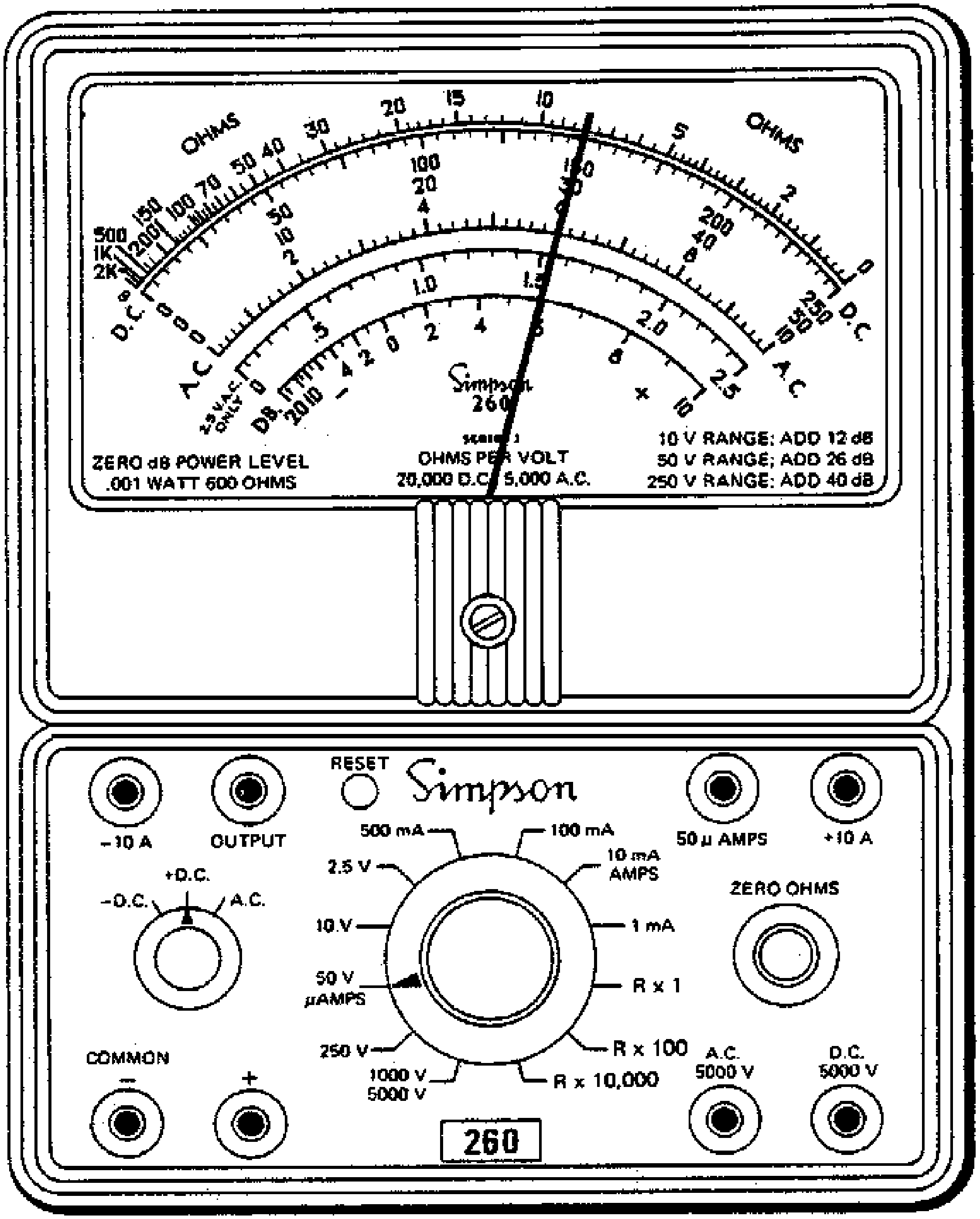
Voltmeters are used to measure voltage.

Ohmmeters are used to measure circuit continuity and total or partial circuit resistance.

Wattmeters are used to measure watts which is the total power consumed by electrical equipment.

Meggers or megometers are used to measure insulation resistance for cables and transformers.

The most commonly used meter in the mining industry is the multimeter. The multimeter is a multipurpose instrument that can measure resistance, voltage, or current. The face of the instrument has separate scales to indicate the three units to be measured. "All meters shall always be used in accordance with the manufacturer's specifications and recommendations."



When a multimeter is used as an ammeter or a voltmeter, the meter movement receives the current necessary for its operation from the circuit being measured. Resistance can be measured only in a de-energized circuit. When measuring resistance, the ohmmeter must provide the power source that operates the meter. The power source is usually a small battery, which is enclosed in the meter case.

The zero ohms set knob on the meter is really a small potentiometer for adjusting the meter's internal circuit current to make the needle read zero resistance. This adjustment is necessary because the characteristics of the internal battery will change slightly with usage.

In using the ohmmeter, always take your readings from a position directly in front of the meter. The meter should be "zeroed" each time the range switch is changed. To avoid endangering anyone or the equipment, an ohmmeter should only be connected to a circuit that has been de-energized, locked-out and tagged.
All resistances are read from resistance scale of the meter, the ohms scale. However, the range selector switch on the control panel provides for resistance readings in three separate ranges (R X 1, R X 100, and R X 10,000). When the range switch is set on (R X 1), the resistance values are read directly from the scale. (Note that on the resistance scale these numbers run from right to left, not left to right) When the switch is turned to (R X 100), the values read from this scale must be multiplied by 100. For the (R X 10,000) range, the values must be multiplied by 10,000 (add four zeros). The three range settings allow for more accurate readings for very small and very large resistance values.

To take any reading from the multimeter, you must read from directly in front of the meter face. If you try to read the meter from an angle, the pointer will appear either higher or lower than it actually is, and you will read an incorrect value.

All meters utilize current flow in making a measurement, since work is done in a circuit only when current is flowing. Current flow through the meter causes the pointer to move. The voltmeter scale on a multimeter is calibrated so that it indicates the amount of voltage that causes current to flow through a multiplier resistance inside the meter. This internal multiplier resistance determines the maximum voltage the meter can handle at that setting and limits the meter current to a safe value. The range switch determines the multiplier resistance for each meter range.

The voltmeter is connected in parallel with a circuit element so that it measures the potential difference across the element. To measure DC voltages the multimeter is also connected across the element. The first step, and in this case it is vital, is to de-energize the circuit. <u>Before you touch the meter, the meter leads, or any part of the circuit, be sure the circuit is deenergized</u>. Set the function switch to the proper position and set the range switch to a larger value than the circuit. If the voltage value to be measured is uncertain, start with the highest voltage range position and work down until an easily read meter deflection is accomplished. Ensure that the meter range setting is not reduced below the voltage in the circuit, or the meter may be damaged. Connect the meter in parallel across the potential difference to be measured.

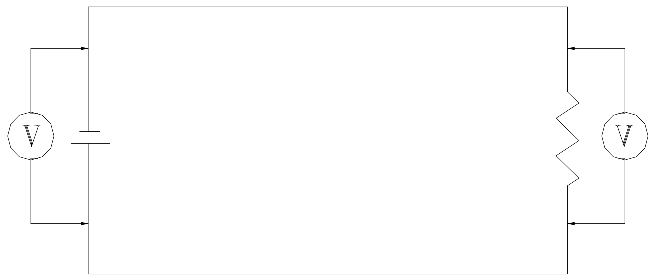


Figure: Voltmeter Connection

In measuring DC voltages, it is necessary to observe polarity. The negative side of the meter must be connected to the negative side of the source, and the positive side of the meter must be connected to the positive side of the source.

The range switch sets the meter for use as a voltmeter, an ammeter, or an ohmmeter and determines the scale on which the values are to be read. The three settings for measuring resistance are at the lower right. Each of these settings specifies the multiplier for the value read on the scale. Thus, when the range switch is in the (R X 10,000) position and the pointer indicates 15 on the scale, the resistance is 150,000, or 150 thousand ohms (150K ohms).

The zero ohms set knob is used for fine adjustment to compensate for aging or inaccuracy of the meter batteries. To ensure accurate readings the meter should be zeroed each time the range switch is moved.

I. DIRECT CURRENT (DC) REVIEW QUESTIONS/ANSWERS

Q. What is the smallest part that a substance can be divided into and retain its original characteristics?
A. Molecule

Q. What is a molecule of a pure element made of?
A. Atoms

Q. What are atoms made of?
A. Protons, neutrons, and electrons

Q. When is an atom electrically balanced or neutral?
A. When it contains an equal number of protons and electrons

Q. What are materials classified as that have totally bound electrons in their outer shells?
A. Insulators

Q. What are materials classified as that have loosely bound electrons in their outer shell?
A. Conductors

Q. What is an electric current?
A. The movement of electrons through a conductor

Q. What is voltage?
A. Electrical pressure, potential difference or electromotive force

Q. What is required to force 1 ampere of current through a resistance of 1 ohm?
A. One volt

Q. What is the electron theory of current flow?
A. Current flows from a negative potential to a positive potential

Q. What are five ways of producing electricity?
A. Heat, magnetism, chemical action, light or friction

Q. What is electrical resistance?
 A. Opposition to current flow

Q. What determines the amount of resistance of a given conductor?
 A. The conductor's material, length, cross sectional area, and temperature

Q. What is an insulator?
 A. A material that has a high resistance to current flow and has tightly bound electrons in the outer shell

Q. What materials are widely used as electrical conductors?
 A. Copper, aluminum and carbon

Q. What is the law of attraction and repulsion between magnets?
 A. Like poles repel each other and unlike poles attract each other

Q. What determines the strength of the magnetic field produced by an electromagnet?
 A. The amount of current flow through the coil, the number of turns in the coil, and the material of which the core is made

Q. What determines the magnetic poles of an electromagnet?
 A. The direction of current flow through the coil

Q. Explain the electromagnetic induction principle.
 A. A voltage is produced in a conductor when the conductor is moved through a magnetic field or a magnetic field cuts across a conductor

Q. What is direct current?
 A. A steady flow of electrons through a conductor in one direction only

Q. What is a generator?
 A. A rotating machine that converts mechanical energy to electrical energy

Q. What is the basic principle by which generators produce electricity?
 A. The electromagnetic induction principle; current is generated when conductors in the generator are rotated through a magnetic field

Q. How is the voltage output of a practical generator controlled?
A. By controlling the amount of current flow through the field coils

Q. What are the three main parts of a generator?
A. The stator, the rotor, and the end bells

Q. What determines the voltage of a battery cell?
A. They type of electrolyte and the electrode material

Q. What is the voltage output of three 1.5-volt dry cell batteries connected in series?
A. 4.5 volts

Q. How many cells does a 24-volt lead-acid storage battery contain?
A. 12 cells

Q. What is in the electrolyte of a lead acid storage battery?
A. Sulfuric acid and water

Q. What is the total amperage capacity of two 50-ampere hour batteries connected in parallel?
A. 100 amperes

Q. How does an increase in voltage affect the current flow through a circuit?
A. The current flow increases proportionately

Q. Which law is commonly used to compute voltage, current, and resistance in electric circuits?
A. Ohm's law

Q. State Ohm's law formula for each of the following: voltage, current, and resistance.
A. Voltage: $(E = I \times R)$ Current: $I = \frac{E}{R}$ Resistance: $R = \frac{E}{I}$

Q. Name the three basic types of circuits.
A. Series, parallel, and series/parallel

Q. What three items are required before you can have a simple operating circuit?

A. A unit of resistance (load), a source of power, and conductors to connect the load to the power source

Q. What describes a series circuit?

A. A circuit in which there is only one path for current flow

Q. What is the current flow through a 24-volt circuit that has two 6-ohm resistors in series?

A. 2 amperes

Q. What is the definition of total resistance in a series circuit?

A. The total resistance is the sum of the individual resistances

Q. Describe a parallel circuit.

A. A circuit in which there are two or more paths for the current to flow

Q. How does current in a parallel circuit divide?

A. Current flows according to the resistance of each path. Current flow is inversely proportional to the resistance in each parallel path.

Q. What is the total resistance of two 20-ohm resistors connected in parallel?

A. 10 Ω

Q. A parallel circuit with a total resistance of 10 ohms has a total current flow of 5 amperes. What is the applied voltage?

A. 50 volts

Q. When computing voltage, current, and resistance in a series- parallel circuit, which portion of the circuit must be computed first?

A. The parallel portion of the circuit

Q. Using Ohm's Law, compute the wattage for a DC circuit that has a total resistance of 20 ohms and a current flow of 6 amperes. What is the power consumed?

A. 720 watts

Q. What is the flow of electrons through a conductor?

A. Current

Q. What is opposition to the flow of current through a conductor?
A. Resistance (Ω)

Q. What is the total resistance of two 12-ohm resistors in series?
A. 24 Ω

Q. What is the current flow through a 4-ohm resistor, if 12 volts are applied across the resistor?
A. 3 amperes

Q. What is the first step to take when coming upon a person who is in contact with an electrical wire?
A. Immediately deenergize the power

Q. What are materials such as rubber, glass, and plastic good for?
A. Insulators

Q. What are materials such as copper, aluminum, and carbon good for?
A. Conductors

Q. What are resistors usually rated in?
A. Ohms (Ω) and watts

Q. An electrical light uses 240 watts of power when connected to a 120-volt source. How much current flows through the electrical light?
A. 2 amperes

Q. During the charging of a lead acid battery, what highly explosive gas is liberated from the battery?
A. Hydrogen

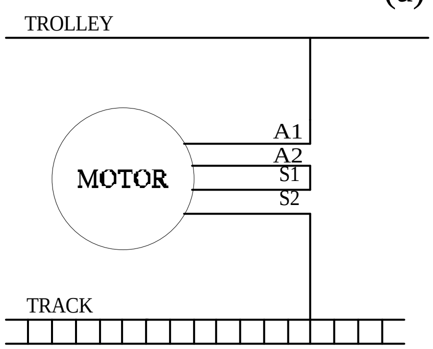
Q. Which type of DC motor has a series field and shunt field windings?
A. Compound motor

Q. What will happen if resistance is added in series with the armature of a running DC motor?
A. The speed of the motor will decrease

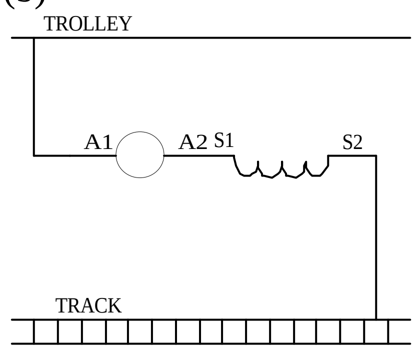
Q. How is a battery's ability to hold an electrical charge expressed?
   A. Ampere-hours

Q. In the following drawing, connect the motor as a series motor and label all leads.
   A. (a) (b)

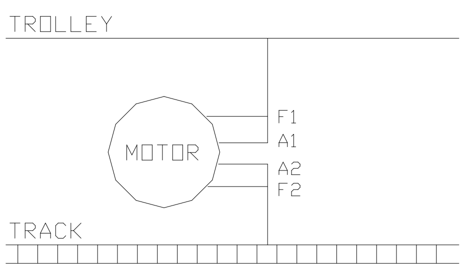
(a)

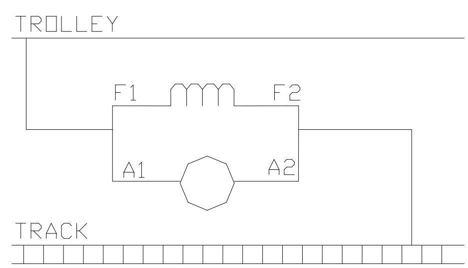


(b)



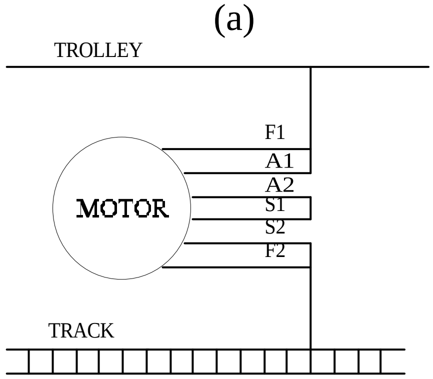
Q. In the following drawing, connect the motor as a shunt motor and label all leads.
   A.(a) (b)



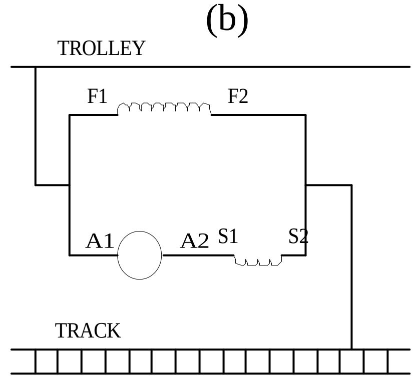


Q. In the following drawing, connect the motor as a compound motor and label all leads.
   A. (a) (b)

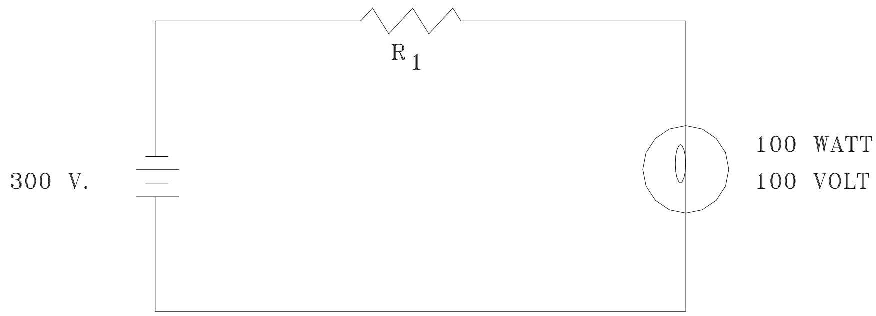
(a)



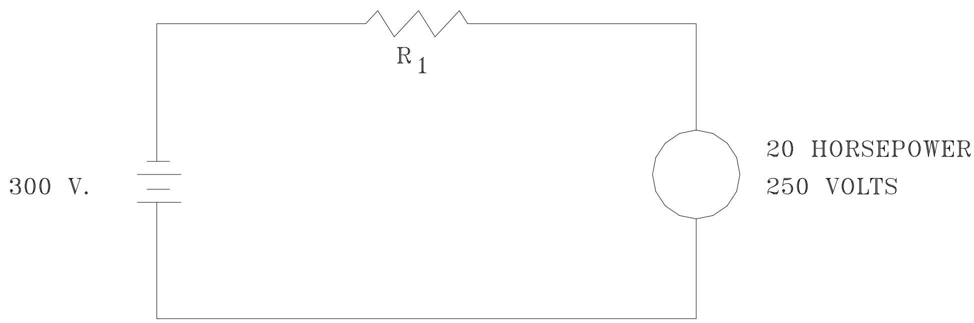
(b)



Q. What value of resistance (R_1) is required to apply proper voltage to the light?
A. 200 Ω



Q. What value of resistance (R_1) is required to apply proper voltage to the motor? (Assume 100 percent efficiency)
A. .838 Ω

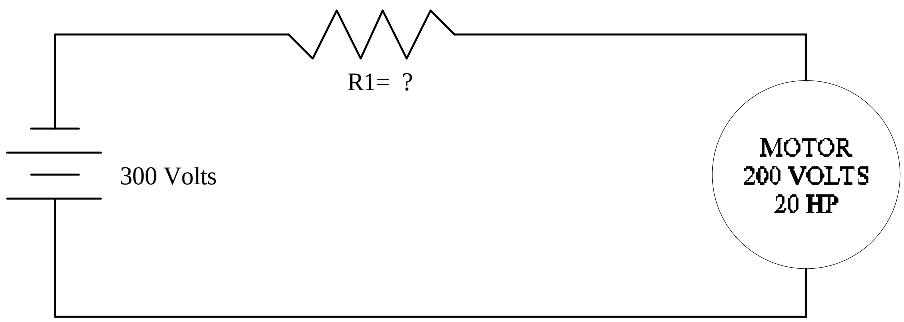


Q. What is the voltage drop at the resistor in the above circuit?
A. V_{R1} = 50 volts

Q. How many watts are equal to one horsepower?
A. 746 watts

Q. What is the resistance required to apply the proper (200 Volts) to the motor?

A. Watts = 20 horsepower X 746 = 14,920 Watts
I = Current = 14,920 Watts divided by 200 volts = 74.6 amps
Voltage at R_1 = Total Volts – Motor Voltage
Voltage at R_1 = 300 Volts – 200 Volts = 100 Volts
Resistance R_1 = 100 Volts divided 74.6 amps = 1.34 Ω



Q. What is the electron flow in an electrical circuit?

A. From negative to positive

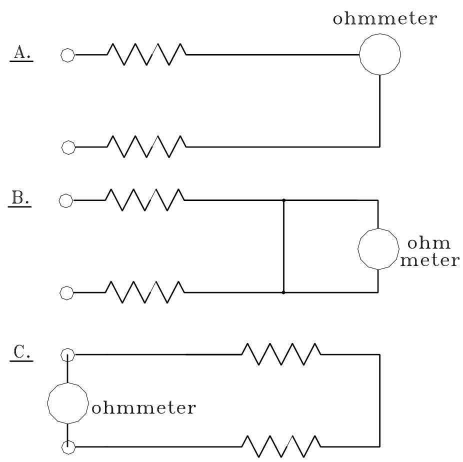
Q. An ohmmeter supplies current through a resistance by means of its own voltage source. Which circuits are correct for measuring resistance?

A.

_______a.

_______b.

__X____c.

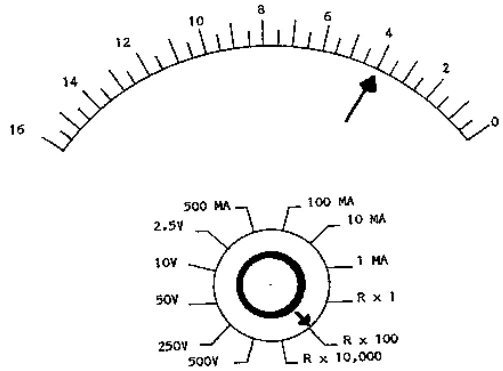


Q. What is the resistance value for the reading shown?
A.

______a. 400 Meg ohms

___X__b. 400 ohms

______c. 0.4 ohms

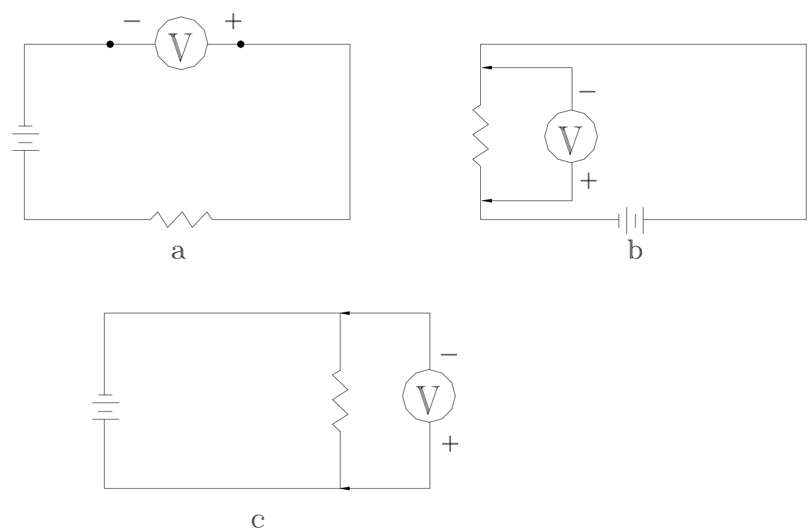


Q. In making AC voltage measurements, it is unnecessary to observe polarity. For DC voltages, polarity must be observed. Which schematic shows the multimeter correctly installed for DC voltage measurements?
A.

______a.

______b.

__X___c.



Q. Which meters are correctly connected for measuring voltage?
A.

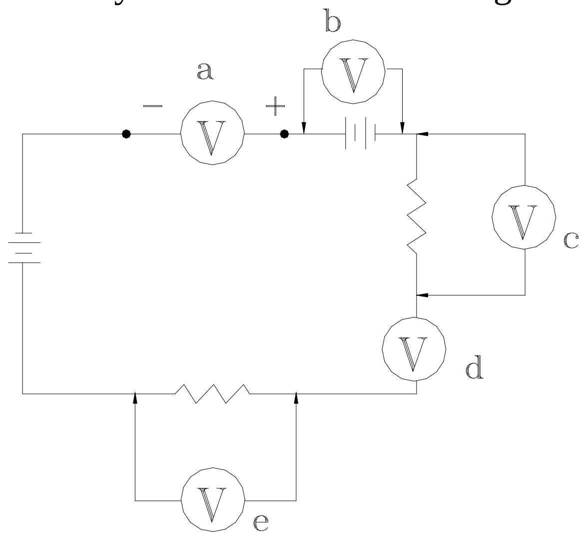
______a.

__X___b.

__X___c.

______d.

__X___e.



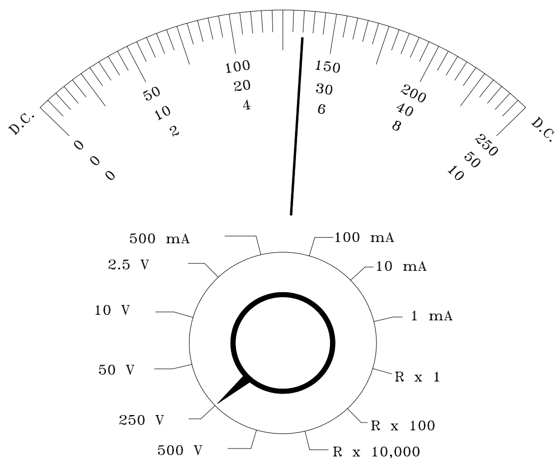
Q. What voltage reading is illustrated?
A. 135 Volts

__X___a. 135 V

______b. 5.4 V

______c. 270 V

______d. 54 V



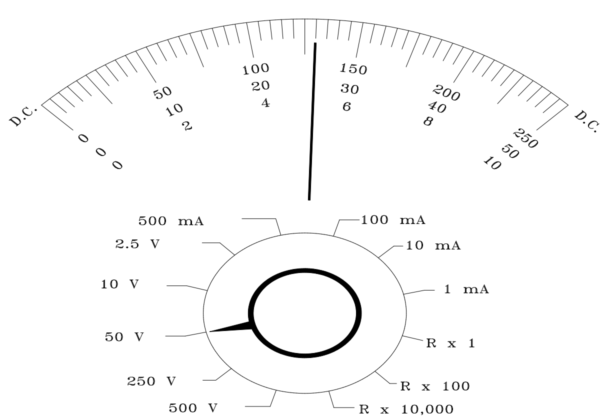
Q. What voltage reading is illustrated?
A. 26 volts

______a. 130 V

__X___b. 26 V

______c. 5.2 V

______d. 35 V



J. GLOSSARY OF TERMS

Arc - Intense light and heat created when an electric circuit is opened

Battery - Source of DC electricity created from a chemical reaction

Cable - Insulated copper or aluminum wires contained in an insulated outer jacket used to conduct power to electric equipment

Circuit Breaker - Device used to manually disconnect power from a circuit or automatically disconnect power under abnormal conditions

Combustible - Capable of burning, i.e., coal, methane, grease, wood, etc

Conductor - Copper or aluminum wires that carry electric current to electric equipment

Current - Movement of small particles (electrons) through electric conductors measured in amperes (I)

De-energize - To disconnect an electrical circuit from its source of power

Electrocution - Death from an electric current flowing through the body

Enclosure (Electrical) - A metallic box or frame that encloses electrical equipment or circuits

Energized - A circuit that has electric power connected to it

Ground Wire or Frame Ground Wire - A wire, connected to the metal frames of electric equipment on one end and the earth ground on the other. The ground wire is used to prevent electric shock

Insulation – Non conducting material such as rubber or plastic used to cover electric conductors

Megohmmeter – A high resistance measuring device used to measure insulation such as transformer insulation and insulation around cable conductors

Resistance - The opposition to electric current flow is resistance (R)

Shock (Electrical) - Sensation caused by an electric current flowing through the body

Splice - Mechanical joining of conductors that have been separated

Switch - Device that is used to disconnect power from an electric circuit

Sulfuric Acid - A solution that can severely burn human tissues and is used in batteries to create electric power

Trailing Cable - Cable used to conduct power to mobile mining machines

Trolley Wire - Bare copper conductor supported from the mine roof that supplies DC power to electric locomotives

Trolley Feeder Wire - Bare copper or aluminum conductor paralleling the trolley wires that supplies DC electric equipment

Ventricular Fibrillation - A condition in which the heart ceases its normal pumping action and instead, feebly quivers

Voltage - Electrical pressure that forces a current to flow measured in volts. (E = V)

Chapter 2
Alternating Current

CHAPTER 2

Alternating Current

A. Introduction to Alternating Current

A current, which flows in one direction and then reverses and flows in the opposite direction, is alternating current (AC). One direction is called positive (+) and the other direction is called negative (-).

Batteries provide DC current. Alternating current originates from a mechanical device called a generator, or alternator. Starting with zero voltage, the AC generator builds up a voltage in the positive direction. This positive voltage increases until a maximum is reached, after which it decreases again to zero value. The voltage then builds up to a maximum value in the negative (opposite) direction and finally decreases to zero. The period of time required to go from zero to positive, maximum, and back to zero, to negative, maximum and again to zero, is called a cycle. The number of cycles occurring per second is the frequency.

The next figure shows a graph (sine wave) of one cycle of 60 cycles AC voltage with a 120 volt maximum. In this graph, the voltage strength is measured on the vertical line, and the time during one cycle is measured on the horizontal line. Remember that alternating current is the result of an alternating voltage. As the voltage reverses its direction, the current also reverses its direction.

From the sine wave in the next figure, the value of the voltage can be determined at any instant. Point one is the beginning of the cycle zero voltage. From point one to point two, or during the first quarter of the cycle, the voltage increases from zero to 120 volts positive. Between points two and three, the voltage decreases to zero. From point three to point four, the voltage increases in the negative direction to the negative maximum (-120 volts).

One complete cycle takes 1/60 second when the frequency equals 60. A frequency of 60 is defined as 60 cycles per second. If the frequency were 20, then one cycle is completed in 1/20 second. With a frequency of 120, a cycle is completed in 1/120 second.

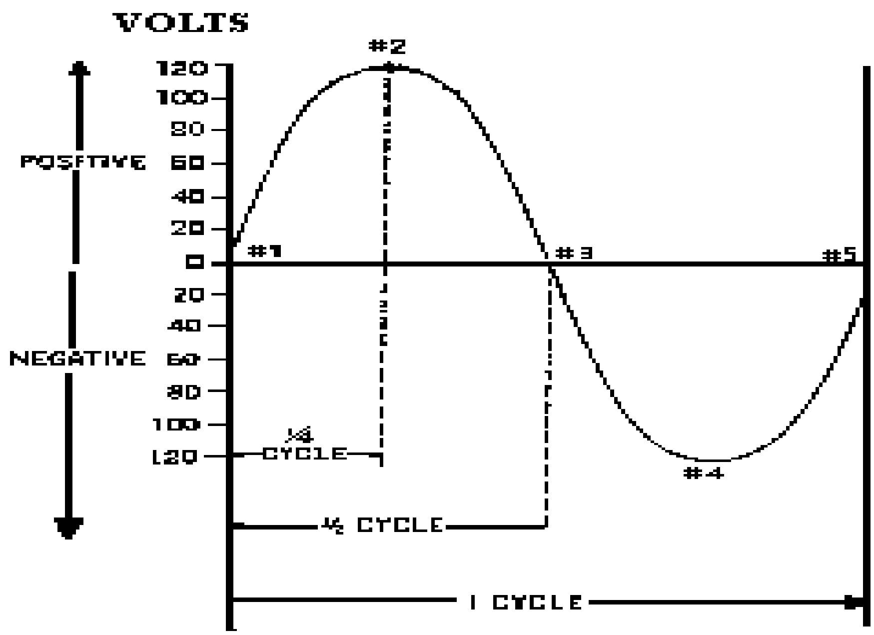


Figure: Alternating Current Sine Wave

AC and DC

Alternating current is current which constantly changes in amplitude, and which reverses direction at regular intervals. Direct current flows only in one direction and the number of electrons flowing past a point in a circuit in one second determines the amplitude of current. For example, a coulomb of electrons moves past a point in a wire in one second and all of the electrons are moving in the same direction. The amplitude of direct current in the wire is one ampere. Similarly, if half a coulomb of electrons moves in one direction past a point in the wire in half a second then reverses direction and moves past the same point in the opposite direction during the next half second, a total of one coulomb of electrons passes the point in one second. The amplitude of the alternating current is one ampere.

Disadvantages of DC Compared to AC

When commercial use of electricity became wide-spread in the United States, certain disadvantages in using direct current in the home became apparent. If a commercial direct current system is used, the voltage must be generated at the level (amplitude or value) required by the load. For example to properly light a 240-volt lamp, the DC generator must deliver 240 volts. If a 120 volt lamp is to be supplied power from the 240 volt generator, a resistor or another 120 volt lamp must be placed in series with the 120 volt lamp to drop the extra 120 volts. When the resistor is used to reduce the voltage, an amount of power equal to that consumed by the lamp is dissipated as heat and wasted.

Another disadvantage of the direct current system becomes evident when the direct current (I) from the generating station must be transmitted a long distance over wires to the consumer. When this happens, a large amount of power is lost due to the resistance (R) of the wire. The power loss is equal to $I^2 R$. However, this loss can be greatly reduced if the power is transmitted over the lines at a very high voltage level and a low current level. This is not a practical solution to the power loss in the DC system since the load would then have to be operated at a dangerously high voltage. Because of the disadvantages related to transmitting and using direct current, all modern commercial electric power companies generate and distribute alternating current (AC).

Unlike direct voltages, alternating voltages can be stepped up or down in amplitude by a device called a transformer. Use of the transformer permits efficient transmission of electrical power over long distance lines. At the electrical power station, the transformer output power is at high voltage and low current levels. At the consumers end of the transmission lines, a transformer steps down the voltage to the value required by the load. Due to its inherent advantages and versatility, alternating current has replaced direct current in commercial power distribution systems.

B. Electromagnetism

The sine wave is a plot of a current, which changes amplitude and direction. Although there are several ways of producing this current, the method based on the principles of electromagnetic induction is by far the easiest and most common method in use.

How magnetism can be used to produce electricity has been only briefly mentioned. This section provides a more in depth study of magnetism. The main points of this section are how magnetism is affected by an electric current and, conversely, how electricity is affected by magnetism. This general subject area is most often referred to as electromagnetism. To become proficient in the electrical field, you must become familiar with the relationships between magnetism and electricity. For example, you must know that:

- An electric current always produces some form of magnetism.

- Magnetism is the most common way for producing or using electricity.

- Magnetic influences cause odd behavior of electricity under certain conditions.

Magnetic Field around a Current Carrying Conductor

If a compass is placed near a current carrying conductor, the compass needle will align itself at right angles to the conductor, thus indicating the presence of a magnetic force.

The relation between the direction of the magnetic lines of force around a conductor and the direction of current in the conductor may be determined by means of the **left hand rule for a conductor**. If you grasp the conductor in your left hand with the thumb extended in the direction of the electron flow (current) (- to +), your fingers will point in the direction of the magnetic lines of force. Note that your fingers point in the direction that the north pole of the compass points when it is placed in the magnetic field surrounding the wire.

An arrow is generally used in electrical diagrams to denote the direction of current in a length of wire. Where a cross section of a wire is shown, an end view of the arrow is used. The direction of the current is indicated by a dot, representing the head of the arrow. Also illustrated is a conductor that is carrying current away from the observer. Note that the direction of current is indicated by a cross, representing the tail of the arrow. Also note that the magnetic field around a current carrying conductor is perpendicular to the conductor, and that the magnetic lines of force are equal along the length of the conductor.

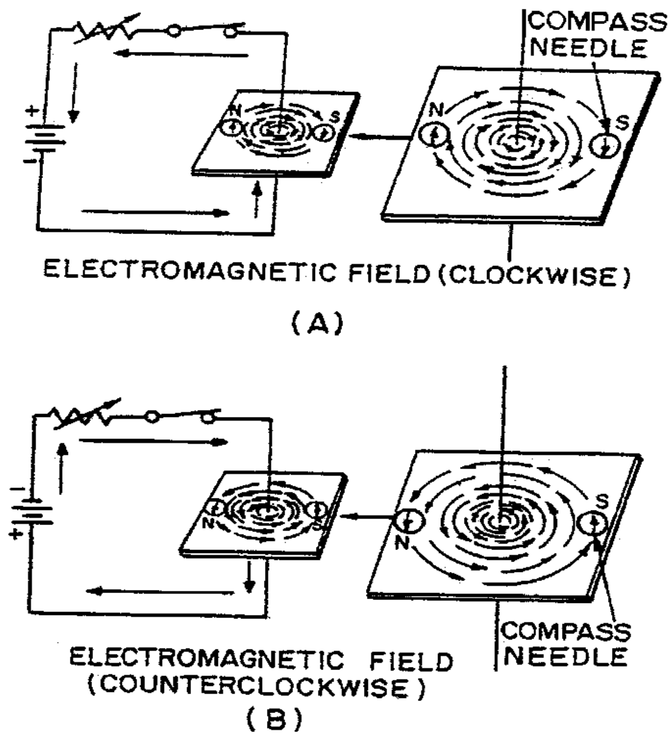


Figure 1: Magnetic field around current- carrying conductor , detailed view.

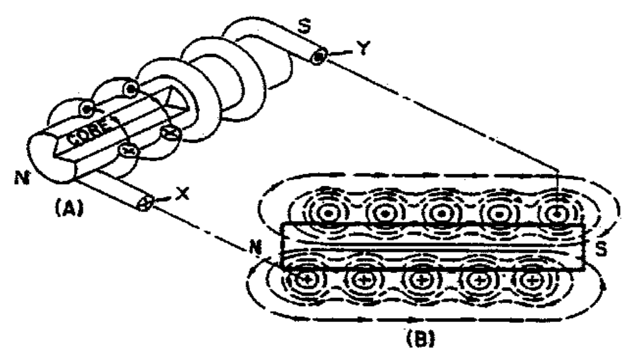


Figure 2: Magnetic Field around a Current Carrying Conductor

When two adjacent parallel conductors are carrying current in the same direction, the magnetic lines of force combine and increase the strength of the field around the conductors.

Polarity of an Electromagnetic Coil

The direction of the magnetic field around a straight wire depends on the direction of current in that wire. Thus, a reversal of current in a wire causes a reversal in the direction of the magnetic field that is produced. It follows that a reversal of the current in a coil also causes a reversal of the two pole magnetic field about the coil.

When the direction of the current in a coil is know, you can determine the magnetic polarity of the coil by using, the **left hand rule for coils**. This rule is stated as follows:

If you grasp the coil in your left hand, with your fingers "wrapped around" in the direction of the current. Your thumb will then point toward the north pole of the coil.

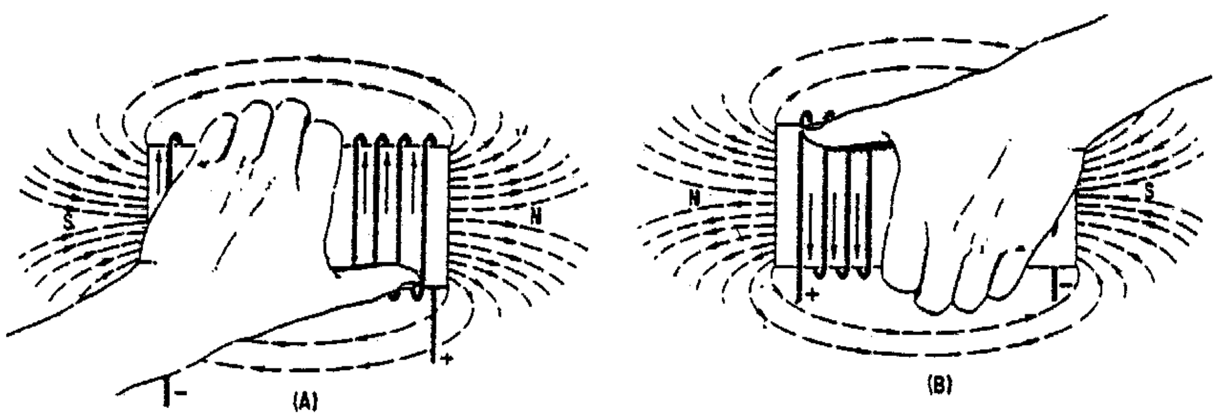


Figure: Left Hand Rule

Strength of an Electromagnetic Field

The strength or intensity of a coil's magnetic field depends on a number of factors. The main factors are listed below.

- Number of turns of wire in the coil
- Amount of current flowing in the coil
- Ratio of the coil length to the coil width
- Type of material in the core

C. Basic AC Generation

A current carrying conductor produces a magnetic field. If a conductor is moved through a magnetic field or the magnetic field is moved across the conductor, then a voltage/emf is induced in the conductor. This effect is called electromagnetic induction.

Cycle
If a loop of wire (conductor) is suspended and rotated in a clockwise direction through the magnetic field between the poles of a permanent magnet, half will move along (parallel to) the lines of force. Consequently, it is cutting zero lines of force. The same is true of the other half, which will move in the opposite direction. Since the conductors are cutting no lines of force, zero emf is induced. As the loop rotates toward the field (lines of force), it will cut more and more lines of force per second (inducing an ever increasing voltage/emf). If the conductor was shown completing one quarter of a complete revolution (or 90 degrees) of a complete circle, the conductor would be at maximum voltage, as it would be cutting directly across the field. If the induced voltages at various points during rotation were plotted on a graph (and the points connected), a curve would appear. If the loop would continue to rotate toward the direction of current, it cuts fewer and fewer lines of force. The induced voltage decreased from its peak value. Eventually, the loop is once again moving in a plane parallel to the magnetic field, and no emf is induced in the conductor.

When the same procedure is applied to the second half of rotation (180 degrees through 360 degrees), the difference is in the polarity of the induced voltage. Where previously the polarity was positive, it would now be negative.

The sine curve shows the induced voltage at each instant of time during rotation of the loop. This curve contains 360 degrees, or two alternations. Two Alternations represent ONE complete CYCLE of rotation.

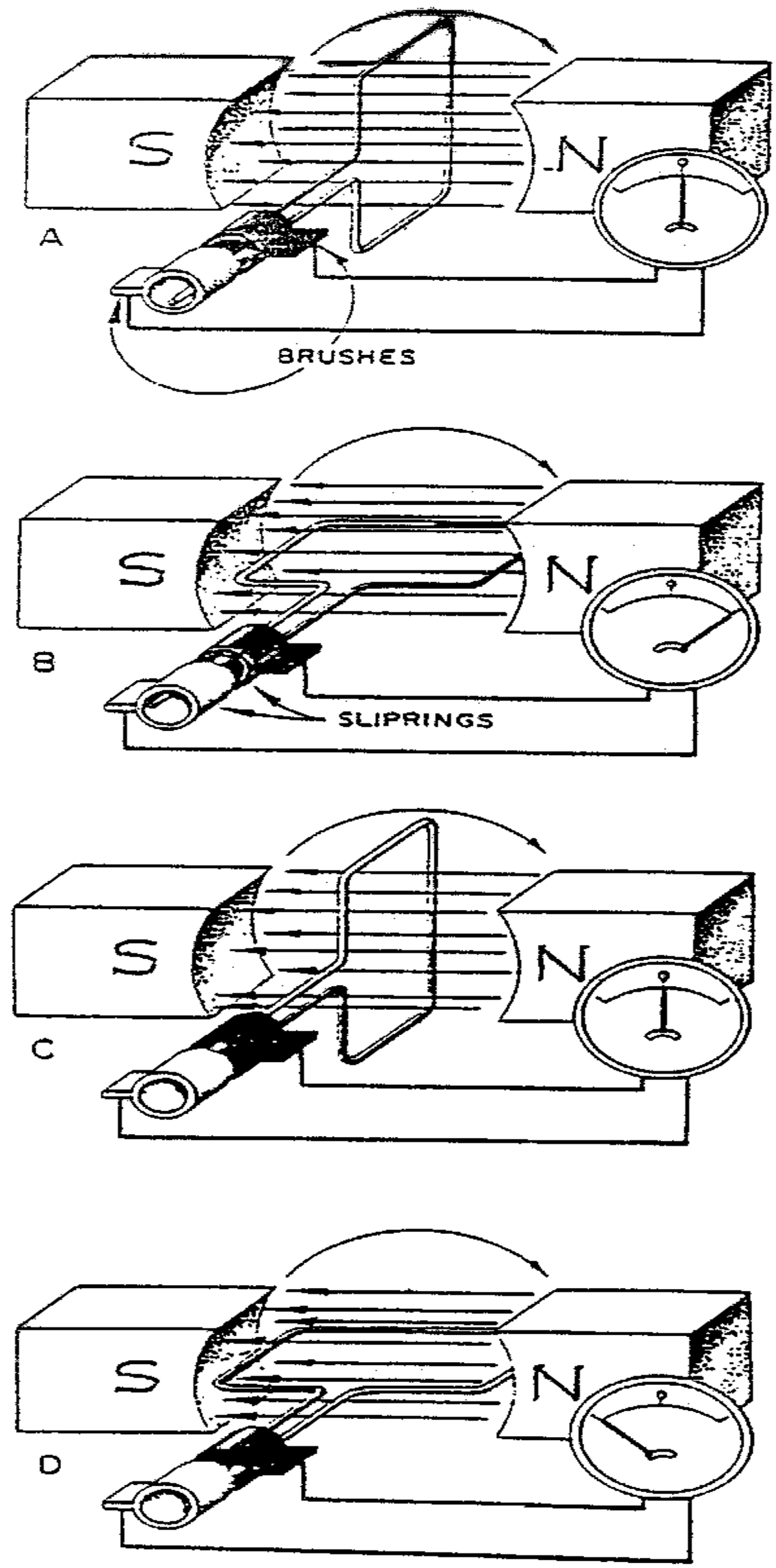


Figure: Simplified Diagram of an AC Generator

If the loop is rotated through 360 degrees at a steady rate, and if the strength of the magnetic field is uniform, the voltage produced is a sine wave of voltage. Continuous rotation of the loop will produce a series of sine wave voltage cycles or, in other words, an AC voltage.

As mentioned previously, the cycle consists of two complete alternations in a period. Hertz (Hz) indicates one cycle per second. If one cycle per second is one hertz, then 100 cycles per second are equal to 100 hertz, and so on. The term cycle is used when on specific time element is involved, and the term Hertz (Hz) is used when the time element is measured in seconds.

Frequency

If the loop makes one complete revolution each second, the generator produces one complete cycle of AC during each second (1 Hz). Increasing the number of revolutions to two per second will produce two complete cycles of AC per second (2 Hz). The number of complete cycles of alternating current or voltage completed each second is referred to as the Frequency. Frequency is always measured and expressed in Hertz (cycles/second).

The United States uses 60 cycles per second for electrical transmissions. Alternating current frequency is an important term to understand since most AC electrical equipment requires a specific frequency for proper operation.

Each cycle of the sine wave consists of two identically shaped variations in voltage. The variation, which occurs during the time the voltage is positive, is called the positive alternation. The variation, which occurs during the time the voltage is negative, is called the negative alternation. In a sine wave, these two alternations are identical in size and shape, but opposite in polarity.

The distance from zero to the maximum value of each alternation is called the amplitude. The amplitude of the positive alternation and the amplitude of the negative alternation are the same.

Wavelength

The time it takes for a sine wave to complete one cycle is defined as the period of the waveform. The distance traveled by the sine wave during this period is referred to as wavelength. The point on the waveform that measurement of wavelength begins is not important as long as the distance is measured to the same point on the next cycle.

D. Alternating Current Values

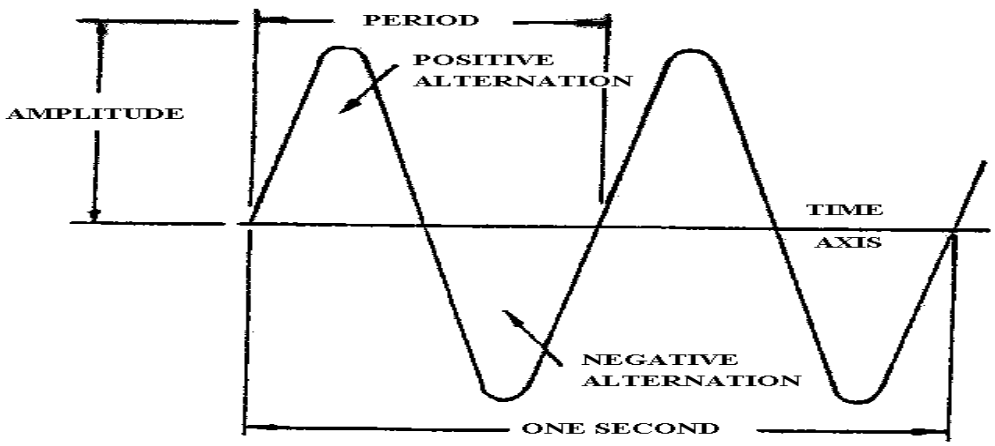
In discussing alternating current and voltage, you will often find it necessary to express the current and voltage in terms of MAXIMUM or PEAK values, PEAK to PEAK values, EFFECTIVE values, AVERAGE values, or INSTANTANEOUS values. Each of these values has a different meaning and is used to describe a different amount of current or voltage.

Peak and Peak To Peak Values
If you looked at a positive alternation of a sine wave (a half cycle of AC) and DC waveform that occurred simultaneously, you would note that the DC starts and stops at the same moment as does the positive alternation.
However, the DC values would be greater than the corresponding AC values at all points except the point at which the positive alternation passes through its maximum value. At this point, the DC and AC values are equal. This point on the sine wave is the maximum or peak value.

Magnetic Field of a Coil When a conductor is wound around a core, it forms a coil. When current flows through the coil of wire, the magnetic fields around the coils combine. The combined influence of all of the fields around the turns produce a two pole magnet similar to that of a simple bar magnet. When the direction of current in the coil is reversed, the polarity of the two pole field of the coil is reversed.

The number of cycles of AC per second is referred to as the FREQUENCY. AC frequency is measured in Hertz. Most AC equipment is rated by frequency as well as by voltage and current. A cycle is a complete set of positive and negative values of alternating current.

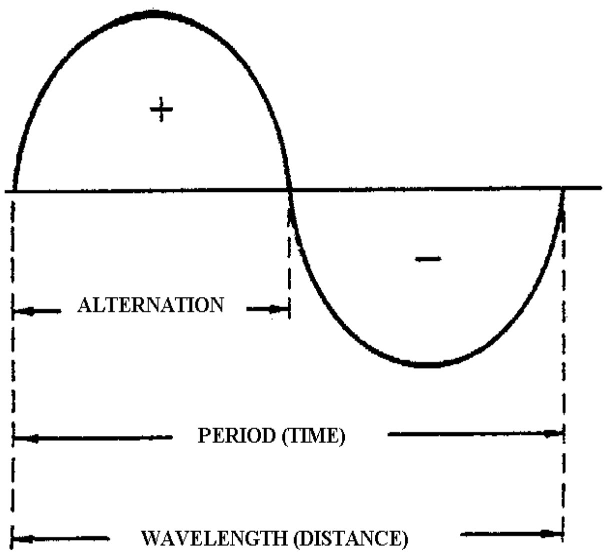
Each AC sine wave is composed of two alternations. The alternation, which occurs during the time the sine wave is positive, is called the positive alternation. The alternation, which occurs during the time the sine wave is negative, is called the negative alternation. In each cycle of sine wave, the two alternations are identical in size and shape, but opposite in polarity.

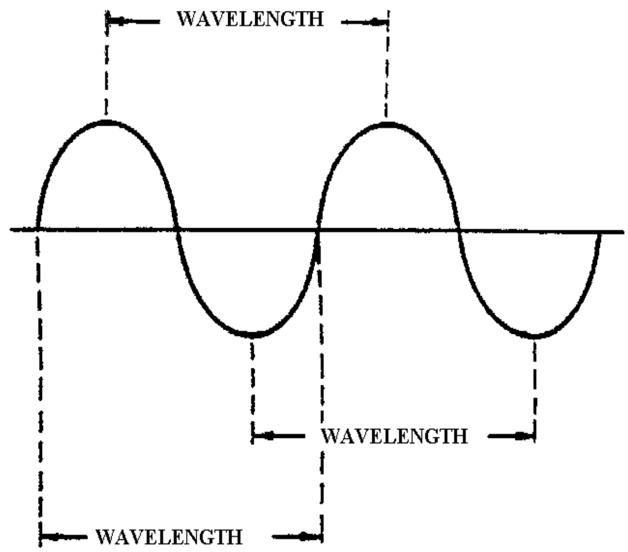


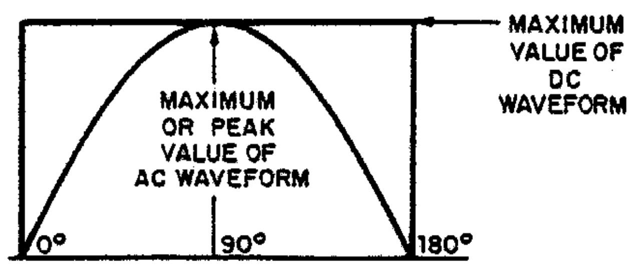
The period of a sine wave is inversely proportional to the frequency; e.g., the higher the frequency, the shorter the period. The mathematical relationships between time and frequency are:

$t = 1/f$ and $f = 1/t$

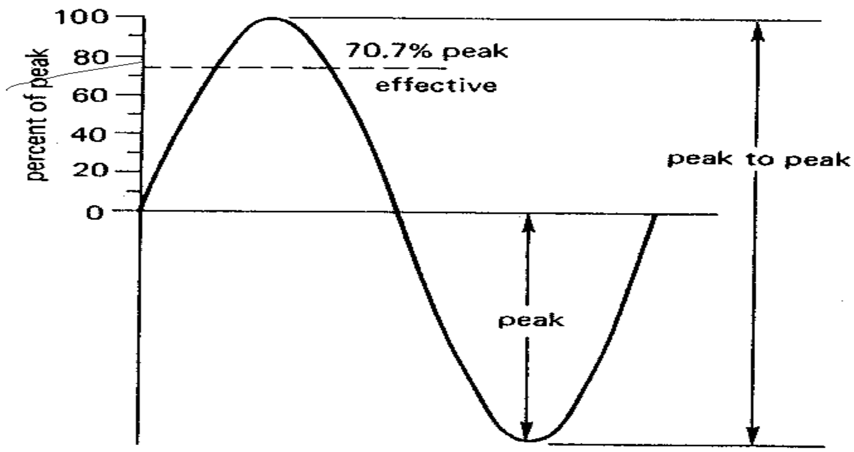
Wavelength-
The period of a sine wave is defined as the time it takes to complete one cycle. The distance the waveform covers during this period is referred to as the wavelength.







Peak and Peak-to-Peak Values: The maximum value reached during one alternation of a sine wave is the peak value. The maximum reached during the positive alternation to the maximum value reached during the negative alternation is the peak to peak value. The peak to peak value is twice the peak value.



The instantaneous value of a sine wave of alternating voltage or current is the value of voltage or current at one particular instant of time. There are infinite number of instantaneous values between zero and the peak value.
The average value of a sine wave of voltage or current is the average of all the instantaneous values during one alternation. The average value is equal to 0.636 of the peak value. The formulas for average voltage and average current are:

$E_{avg} = 0.636 (E_{max})$

$I_{avg} = 0.636 (I_{max})$

Remember: The average value (E_{avg} or I_{max}) is for one alternation only. The average value of a complete sine wave is zero.

The effective value of an alternating current or voltage is the value of alternating current or voltage that produces the same amount of heat in a resistive component that would be produced by the same component with a direct current or voltage of the same value. The effective value of a sine wave is equal to 0.707 times the peak value. The effective value is also called the root mean square (rms) value. An AC voltmeter reads the effective voltage of the circuit. Using the instantaneous value of voltage or current uses the term rms value to describe the process of determining the effective value of a sine wave. You can find the rms value of a current or voltage by taking equally spaced instantaneous values on the sine wave and extracting the square root of the average of the sum of the instantaneous values. This is where the term "Root Mean Square" (rms) value comes from.

The formula for effective and maximum (peak) values of voltage and current are:

$E_{eff} = (0.707)\ E_{max\ (peak)}$

$E_{max} = (1.414)\ E_{eff}$

E peak to peak $= (2)\ E_{max}$

$I_{eff} = (0.707)\ I_{max}$
$I_{max} = (1.414)\ I_{eff}$

When two sine waves are exactly in step with each other, they are said to be in phase. To be in phase, both sine waves must go through their minimum and maximum points at the same time and in the same direction.

When two sine waves go through their minimum and maximum points at different times, a phase difference exists between them. The two waves are said to be out of phase with each other. To describe this phase difference, the terms lead and lag are used. The wave that reaches its minimum (or maximum) value first is said to lead the other wave. The term lag is used to describe the wave that reaches its minimum (or maximum) value some time after the first wave does. When a sine wave is described as leading or lagging, the difference in degrees is usually stated. For example, wave E_1 leads wave E_2 by 90 degrees, or wave E_2 lags wave E_1 by 90 degrees. Two sine waves can differ by any number of degrees except zero degrees or by 360. Sine waves that differ by zero or 360 degrees are considered to be in phase. Two sine waves that are opposite in polarity and differ by 180 degrees are said to be out of phase, even though they go through their minimum and maximum points at the same time.

Ohm's Law in A. C. Circuit: All DC rules and laws apply to an AC circuit that contains <u>only resistance.</u> An important point to remember is: Do not <u>mix AC values.</u> Ohm's Law formulas for AC circuits are given below:

$I = E/R$; $I_{eff} = \frac{E^{eff}}{R}$; $I_{avg} = \frac{E^{avg}}{R}$; $I_{max} = \frac{E^{max}}{R}$; $I_{peak\ to\ peak} = \frac{E^{peak\ to\ peak}}{R}$

E. Inductive and Capacitive Reactance

Inductance and Alternating Current

When voltage or current are in step, going through a cycle together, falling together and rising together, they are in phase. When they are out of phase, the angle of lead or lag, the number of electrical degrees by which one of the values leads or lags the other is a measure of the amount they are out of step. The time it takes the current in an inductor to build up to maximum and to fall to zero is important for another reason. A very useful characteristic of an inductive circuit is the current through the inductor always lags the voltage across the inductor. Inductance is the property of a circuit, which opposes change in current flow.

A circuit having pure resistance (if such a thing were possible) would have the alternating current through it and the voltage across it rising and falling together. In the case of a circuit having inductance, the opposing force of the counter emf would be enough to keep the current from remaining in phase with the applied voltage.

With an AC voltage, in the first quarter-cycle (zero degrees to 90 degrees) the voltage is continually increasing. If there were no inductance in the circuit, the current would also increase during this first quarter-cycle. Since inductance opposes any change in current flow, no current flows during the first quarter-cycle. In the next quarter-cycle (90 degrees to 180 degrees) the voltage decreases back to zero; current begins to flow in the circuit and reaches a maximum value at the same instant the voltage reaches zero. The applied voltage now begins to build up to maximum in the other direction, to be followed by the resulting current. When the voltage again reaches its maximum at the end of the third quarter-cycle (270 degrees) all values are exactly opposite to what they were during the first half-cycle. The applied voltage leads the resulting current by one quarter-cycle or 90 degrees. To complete the full 360 degrees cycle of the voltage, the voltage again decreases to zero and the current builds to a maximum value.

These values do not stop at a particular instant. Until the applied voltage is removed, both current and voltage are always changing in amplitude and direction.

The sine wave can be compared to a circle. Just as you mark off a circle into 360 degrees, you can mark off the time of one cycle of a sine wave into 360 electrical degrees.

Inductive Reactance

When the current flowing through an inductor continuously reverses itself, as in the case of an AC source, the inertia effect of the counter EMF (CEMF) is greater than with DC. The greater the amount of inductance (L), the greater the opposition from this inertia effect. Also, the faster the reversal of current, the greater this inertial opposition. This opposing force, which an inductor presents to the FLOW of alternating current, cannot be called resistance, since it is not the result of friction within a conductor. The name given to it is INDUCTIVE REACTANCE because it is the "reaction" of the inductor to alternating current. Inductive reactance is measured in ohms and its symbol is X_L.

As you know, the induced voltage in a conductor is proportional to the rate at which magnetic lines of force cut the conductor. The greater the rate (the higher the frequency), the greater the CEMF. In addition, the induced voltage increases with an increase in inductance, the more ampere turns, and the greater the CEMF. Reactance, then, increases with an increase of frequency and with an increase of inductance. The formula for inductive reactance is as follows:

$X_L = (2)\,\pi\, f\, L$ Where: X_L is inductive reactance in ohms.

π is a constant in which the Greek letter, called "pi" represents 3.1416 and
$(2)\,\pi$ = approximately 6.28.

f = frequency of the alternating current measured in Hz.

L = inductance measured in henrys.

The following example problem illustrates the computation of X_L.

Given: f = 60 Hz L = 20 henries (H)

Solution: $X_L = (2)\,\pi\, f\, L$

$X_L = 6.28 \times 60\text{ Hz} \times 20\text{H} = 7{,}536\text{ ohms}$

Capacitance

The inductance is the property of a coil that causes energy to be stored in a magnetic field about the coil. The energy is stored in such a way as to <u>oppose any change in current.</u> CAPACITANCE is similar to inductance because it also causes storage of energy. <u>Therefore, extreme caution must be taken when working on circuits that contain capacitors.</u> Capacitors must be discharged before performing electrical repairs. A CAPACITOR is a device that stores energy in an electrostatic field. The energy is stored in such a way as to <u>oppose any change in voltage.</u> Capacitors are measured in farads (C).

Capacitive Reactance

The capacitor is a device, which passes AC, and in which the only opposition to the alternating current has been the normal circuit resistance present in any conductor. However, capacitors themselves offer a very real opposition to current flow. This opposition arises from the fact that, at a given voltage and frequency, the number of electrons, which go back and forth from plate to plate, is limited by the storage ability. This is the capacitance of the capacitor. As the capacitance is increased, a greater number of electrons change plates every cycle, and (since current is a measure of the number of electrons passing a given point in a given time) the current is increased.

Increasing the frequency will also decrease the opposition offered by a capacitor. This occurs because the number of electrons which the capacitor is capable of handling at a given time (greater current flow). The opposition, which a capacitor is capable of handling at a given voltage, will change plates more often. As a result, more electrons will pass a given point in a given time (greater current flow). The opposition, which a capacitor offers to AC, is therefore inversely proportional to frequency and to capacitance. This opposition is called CAPACITIVE REACTANCE. You may say that capacitive reactance decreases with increasing frequency or, for a given frequency, the capacitive reactance decreases with increasing capacitance. The symbol for capacitive reactance is X_C and varies inversely with the product of the frequency and capacitance. The formula is:

X_C = capacitive reactance in ohms $\quad X_C = \dfrac{1}{(2)\,\pi\, f\, C}$

f = frequency in hertz (Hz) = 60 cycles-per-second

L = 0.1 henries

Capacitor = 4000 microfarads (μF)
C = Capacitance in Farads = (4000 X .000001) = .004

(2) π = (2 x 3.1416) = 6.28

Total Reactance

Solution: (Inductive Reactance) $X_L = (2)\,\pi\, f\, L$

X_L = (6.28) (60 Hz) (0.1 H) = 37.68 (ohms)

(Capacitive Reactance)

$$X_C = \frac{1}{(2)\,\pi\, f\, C}$$

$$X_C = \frac{1}{(6.28)\,(60\ \text{Hz})\,(.004)}$$

$$X_C = \frac{1}{1.5072}$$

$$X_C = 0.6634\ \text{(ohms)}$$

(Total Reactance) $X = X_L - X_C$ (ohms)
X = 37.68 - 0.6634 (ohms) = 37.01 (ohms) (inductive)

Impedance = Total opposition to current flow in an alternating current circuit.

Impedance = $Z = \sqrt{R^2 + (X_L - X_C)^2}$ = ohms

Alternating Current Circuits

Voltage and current determine power in a DC circuit. The same factors determine power in an AC circuit but with this difference: current and voltage do not reach maximum at the same time and are out of phase with each other. In a DC circuit, voltage times current (E x I) gives "true Power." In an AC circuit voltage times current equals "apparent power." True power in an AC circuit is the apparent power multiplied by the power factor (pf). The power factor is determined by the phase difference between voltage and current and is given in a percentage. Since the loads in AC circuits are sometimes reactive, the power factor is less than 100 percent or less than one.

The formula for true power in an AC circuit is voltage times current times power factor and is written: True Power = (E) (I) (pf). What is the true power consumed by an induction motor rated for 220 volts, 4.3 amperes at 80 percent power factor?

True Power = (E) (I) (pf)

True Power = (220 volts) (4.3 amps) (.8) = 756.8 watts of apparent power

The power rating of a distribution transformer is sometimes given in kilowatts, but more usually, a distribution transformer is rated in kilovolt amperes (KVA). One kilovolt ampere is 1000 volt amperes. Voltage ratings are also given for both primary and secondary. Thus, it is possible to calculate the maximum secondary current that may be drawn. For example, a 10 KVA transformer with a 120-volt secondary would be able to deliver 83 amperes. The KVA is first converted to volt amperes. This is 10,000 divided by 120, which equals slightly more than 83 amps.

F. Transformers and Rectifiers

The power requirement is not the same for all electrical devices and equipment. Some equipment requires high voltage AC, while other equipment requires low voltage. On the other hand, some equipment requires DC for its operation. Transformers and rectifiers are both used as power supplies to furnish electrical energy for specific needs. Transformers are used to either step up or to step down AC voltage or current. Rectifiers are used to convert AC into DC.

Transformers. When an alternating current flows through a coil, an alternating magnetic field is produced around the coil. This alternating magnetic field expands outward from the center of the coil and collapses into the coil as the AC through the coil varies from zero to maximum and back to zero again.

If the alternating magnetic field generated by one coil cuts across or through a second coil, then a voltage is induced into the second coil. The voltage induced into the second coil is the result of mutual induction, commonly called transformer action. In mutual induction, electrical energy is transferred from one coil (primary) to another coil (secondary) by means of a varying magnetic field.

The basic transformer consists of two coils mounted close together, and electrically insulated from each other. The coil to which the AC source is applied is called the primary or line side. It produces the magnetic field, which, in turn, cuts across and induces a voltage in the secondary coil or load side. The primary terminals are normally marked with "H" and the secondary terminals are normally marked with "X".

The ratio between the numbers of turns in the primary to the number of turns in the secondary determines the voltage ratio of the transformer. The next figure shows a diagram, which illustrates the relation between the turns ratio and the voltage. If the left hand coil is connected to a 120 volt AC incoming power source, then it is the primary winding (11 turns). The turns ratio is stated as 1 to 2, the primary number (1) being given first. The secondary has twice as many turns (22) in the secondary winding as compared to the primary winding. The voltage induced in the secondary (240) is twice the voltage applied to the primary. A transformer with a greater secondary voltage is called a step up transformer.

If, in the next figure, we applied 240 volts to the 22-turn winding, the output of the secondary (11 turns) would be 120 volts. This would be called a step down transformer because the secondary voltage would be less than the primary. The ratio of the transformer when connected in this way is stated as 2 to 1.

The ratio between the number of turns in the primary to the number of turns in the secondary determines the current ratio. Step down transformers with a 2 to 1 ratio will step down 120 volts to 60 volts. If the primary current were two amps, then the secondary current would be four amps. As voltage is transformed down, current is transformed up.

A step up transformer with a one to four ratio will step up 120 volts to 480 volts. If the primary current were eight amps, then the secondary current would be two amps. As voltage is transformed up, the current is transformed down.

The KVA rating of each transformer is determined by multiplying the primary voltage rating by the primary current rating or by multiplying the secondary voltage rating by secondary current rating. For example, a transformer rated for 500 volts primary and four amps primary will have a KVA rating of 2 KVA.

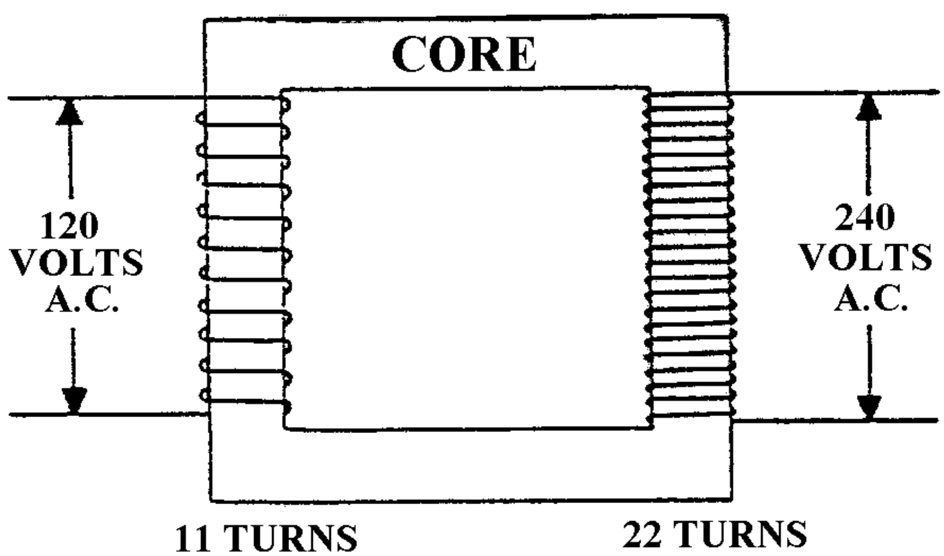


Figure: A Typical Transformer

Transformers

A. Mutual Induction - Mutual induction is the induction of an emf in one coil because of a current change in a neighboring coil or conductor.

B. Transformer - A transformer consists of two or more windings coupled, usually by an iron core, so that almost all flux lines interact with the windings.

C. Step up Transformer/Step down Transformer - the voltage ratio in a transformer is proportional to the turns ratio. When the number of secondary turns is greater than the number of primary turns, the transformer is a step up transformer. When the number of secondary turns is less than the number of primary turns, the transformer is a step down transformer.

D. Primary Power = Secondary Power - as the turns ratio of a transformer changes, the voltage and current change to keep the primary power equal to the secondary power.

E. Transformer Losses – Transformer losses, which are usually small, include copper loss, flux leakage loss, hysteresis loss, eddy current loss, and saturation loss.

F. Phase Relationship - In a resistivity loaded transformer, the primary voltage and current are essentially in phase, and the secondary voltage and current are in phase but opposite in polarity to the primary.

G. Adjustable Variable Transformers - Adjustment of the turns ratio allows voltage changes.

The following points help explain the theory of transformer operation:

A. A transformer is an AC device, which has a primary winding, a secondary winding, and an iron core.

B. The primary and secondary windings are insulated from each other but are linked together by the action of the magnetic field.

C. The number of turns in the windings determines the turns of the transformer and the ratio between the primary and the secondary voltages.

D. A step up transformer produces a secondary voltage, which is higher than the primary voltage. Secondary current is less than the primary current.

E. A step down transformer produces a secondary voltage lower than the primary. Here the secondary current is greater than the primary current.

F. The secondary winding may be tapped to produce more than one voltage.

G. Disregarding the core losses and charging current, the power in the primary winding is the same as the power in the secondary winding.

H. Transformers are rated in volt amps. Large transformers in the mining industry are rated in kilovolt amps (KVA). Transformers are rated as a unit. Therefore, the primary KVA is equal to the secondary KVA.

The mining industry commonly uses three phase transformer. Three phase transformers are constructed of three single-phase transformers. Single-phase transformers that are interconnected to form a three phase bank should have the same voltage, impedance and KVA rating. Three-phase transformers have three primary and three secondary windings, all of which are interconnected, independently. The primary and secondary windings can be delta or wye connected with complete electrical separation between the primary and secondary windings.

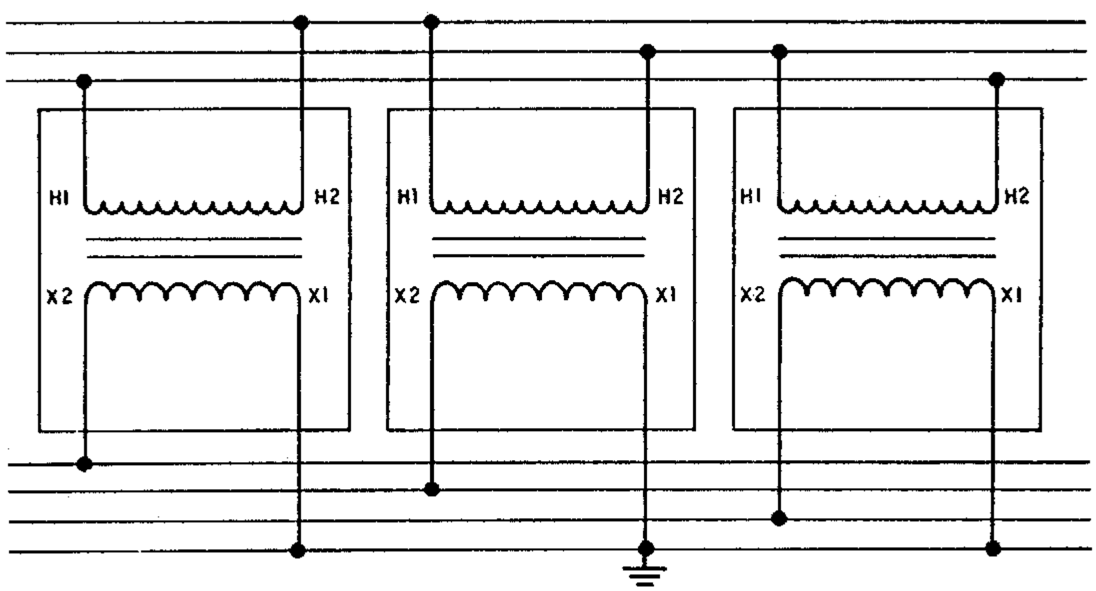


Diagram – Delta Primary and Wye Secondary Three Phase Transformers

The four connections of three phase transformers are wye-wye, delta-delta, wye-delta, and delta-wye. Delta-wye connections are most popular in the mining industry. The neutral of the wye-connected secondary provides a grounding point for the electrical system. With a delta-wye configuration, primary line to the line voltage becomes secondary line to neutral voltages and primary phase currents transform to secondary line currents.

G. Importance of Grounding

The purpose of the grounding resistor is to limit the ground fault current to a predetermined value during fault conditions. The current value is selected to limit the voltage that will appear on the frames of equipment during a phase-to-ground fault while providing sufficient ground fault current for reliable relaying. Grounding resistors used in mine, power systems usually have a current rating of 15, 25, or 50 amperes. The resistor is designed and rated for particular systems. The resistance (R) of a grounding resistor can be calculated from the phase-to-neutral voltage of the system (V) and the current rating of the resistor (I_R), using Ohm's Law.

Example: V = 2,400 volts I_R = 25 amperes

$$R = \frac{V}{I_R}$$

$$R = \frac{2400 \text{ volts}}{25 \text{ amperes}}$$

R = 96 ohms

This section limits the voltage drop in the high voltage grounding circuit external to the grounding resistor to not more than 100 volts because a person's body is essentially in parallel with the grounding circuit when he/she stands on the earth and touches the frame of a unit of equipment that is connected to the grounding circuit. During a phase-to-ground fault, most of the voltage drop appearing across the grounding circuit will also appear across the person's body. Consequently, if a 25-ampere-grounding resistor is used, the maximum impedance of the grounding circuit cannot exceed 4 ohms. See following figure:

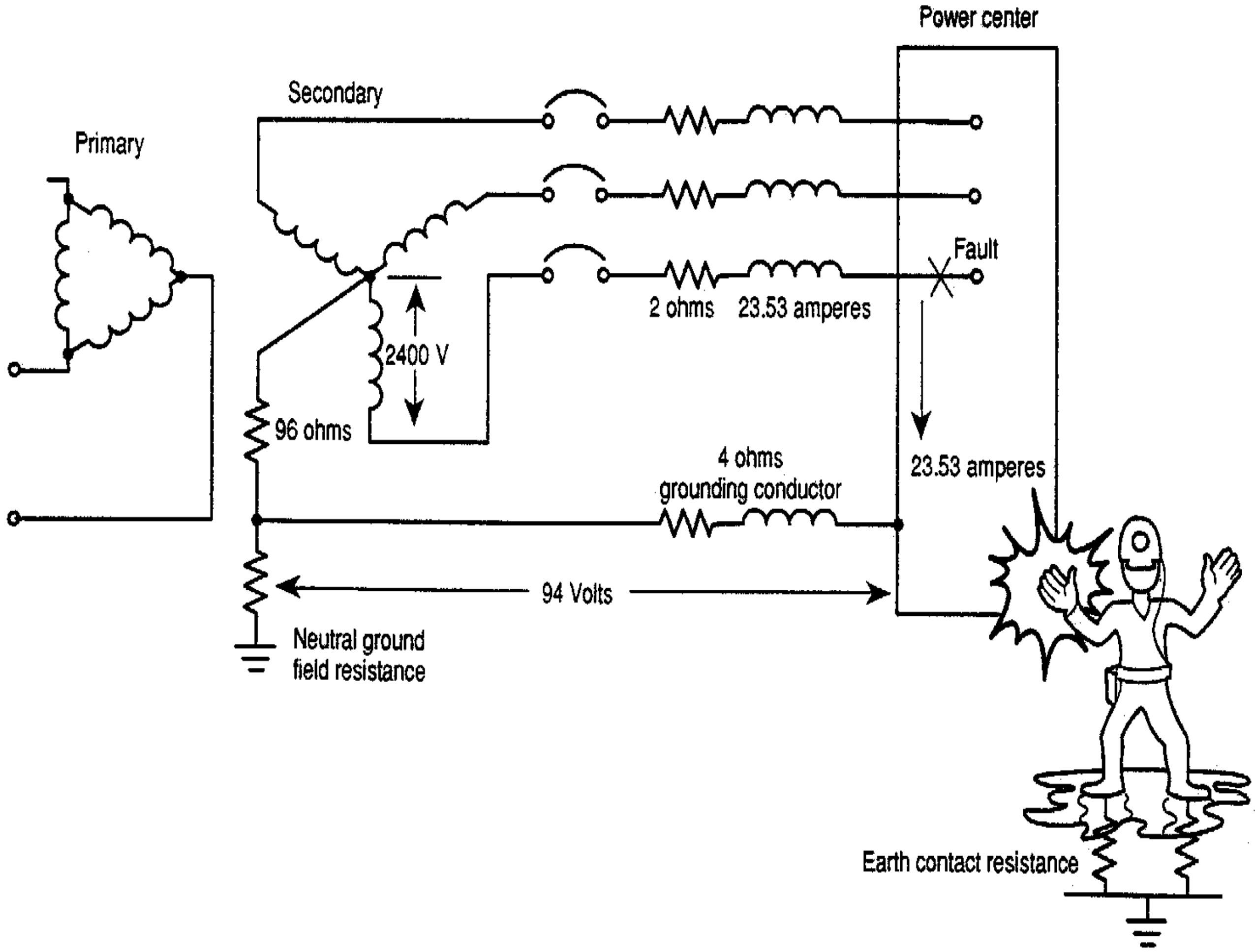


Figure: Touch Potential of Resistance Grounded System under Faulty Conditions

Resistance Grounded Circuits and Equipment

System neutrals are normally obtained by using source transformers or generators with wye-connected secondary windings. The neutral is then readily available for grounding purposes. For delta-connected, systems grounding transformers are used to derive a neutral that is then grounded through a suitable resistor.

The following show in simplified form the proper method of connecting resistance grounded circuits extending underground.

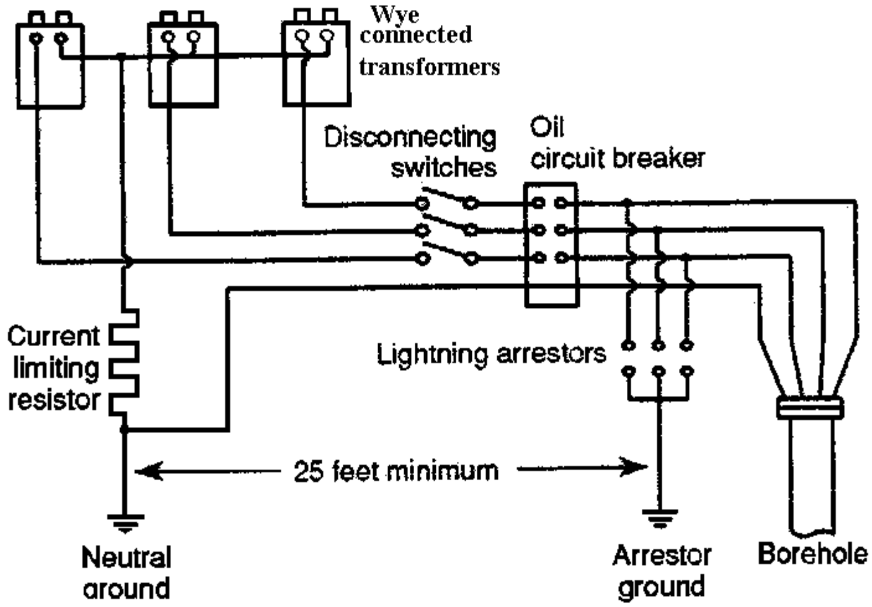


Figure: Wye-Connected Power System with Current-Limiting Resistor

A zigzag transformer is used in a delta-connected secondary to derive a neutral for grounding purposes. A zigzag transformer is a transformer with half the turns per winding going one direction and the other half of the turns going in the opposite direction. The effect of this type of winding is that due to the inductances created, the impedance is very high between any two of the coils. Under normal load conditions virtually no current flows through the zigzag. The impedance of the coils to ground is very low (less than 4 ohms) so that high ground currents may flow freely through the phase to neutral connection of the zigzag. The transformer divides the ground current into three equal components and allows them to flow through the windings of the transformer. Because of the opposite direction of the windings in the zigzag, any magnetic flux is cancelled (except for a small leakage).

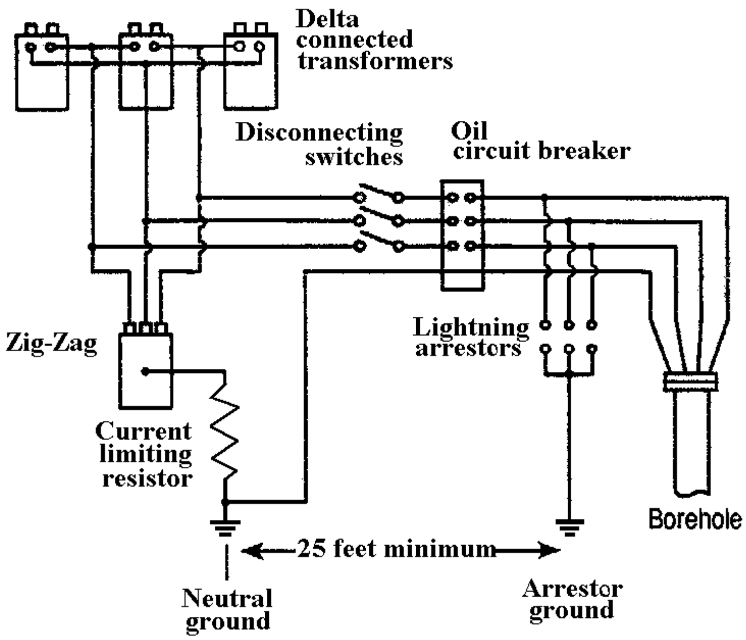


Figure: Delta Connected Power System with (Zigzag) Grounding Transformer and Current Limiting Resistor

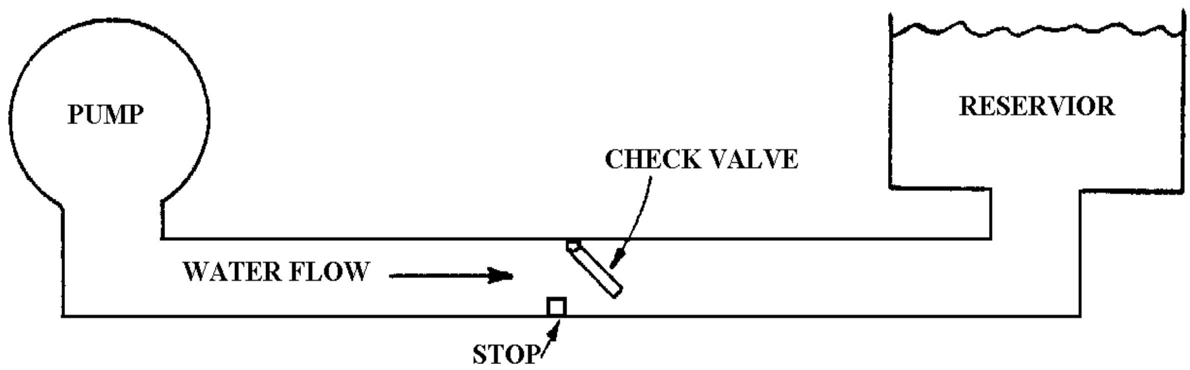
H. Diodes and Rectifiers

The basic component in a diode grounding system is the silicon diode. The diode is a semi-conductor, which permits current to flow easily in one direction but opposes current flow in the opposite direction.

The action of a diode is very similar to a check valve placed in a water pipe. As the pump moves the water toward the reservoir, the check valve will open and permit water to flow through the pipe. If the water reverses direction and starts to flow backward toward the pump, the check valve will rotate toward the stop and block the flow of water back toward the pump (See next drawing).

Diodes have minimum forward resistances that vary from zero to 10 ohms and resistances in the opposite direction in the hundreds of megohms range. Diode resistances are extremely sensitive to temperature. A diode must never be operated outside its temperature limits. Diodes are made of silicon or germanium. Silicon is preferred for high current applications because of its better temperature characteristics.

When the diode is forward biased, its resistance is very low, thus permitting current to flow. When the diode is reverse biased, its resistance is extremely high and it essentially blocks all current flow except for a minute amount called the leakage current.



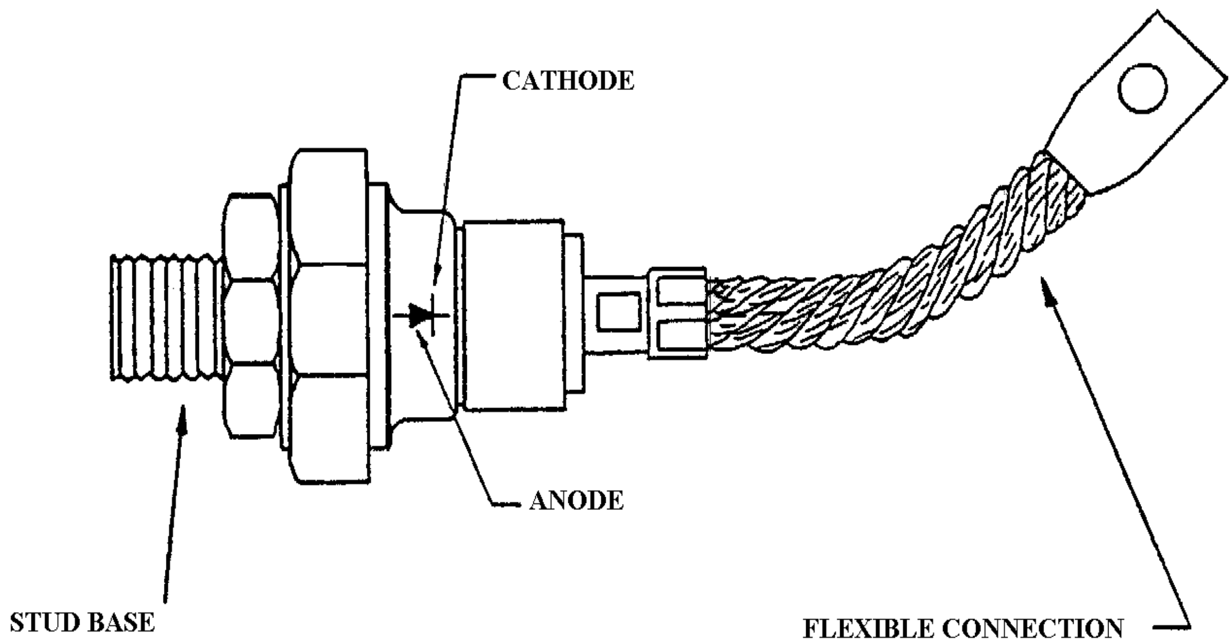


Figure: DIODE

The silicone diode used in mining machines is a heavily constructed component. One end of the diode has a stud base so it can mount to a metal plate. DIODES ARE RATED IN FORWARD CURRENT AND REVERSE VOLTAGE.

When a diode is conducting current, heat is removed from the diode by mounting the base of the diode to a heat sink, which consists of metal plate or fins. The other end of the diode has a flexible connection so it can be attached to a conductor or terminal.

Rectifiers

Rectifiers in the mining industry are rated in kilowatts (KW). A rectifier is a device using an AC input to give a DC output. It operates on the principle of offering high resistance to current in one direction. Rectifiers are used extensively in AC meters and voltage regulators. Meters for measuring alternating current may use a half wave or full wave rectifier. Battery chargers also may use either a half or full wave rectifier. Voltage regulators use full wave rectifiers to get smoother operation.

The operation of a half wave rectifier is illustrated in the next figure. The AC input follows a uniform sine wave. The high resistance of the diode acts like an open switch toward half of each cycle. The DC output curve shows that only a very small amount of current gets through on the lower half of each cycle. The main flow of the current occurs as a series of pulses 60 times a second. Diodes may be arranged in a stack connected in series to rectify high voltages. The number of diodes used determines the voltage rating of a rectifier.

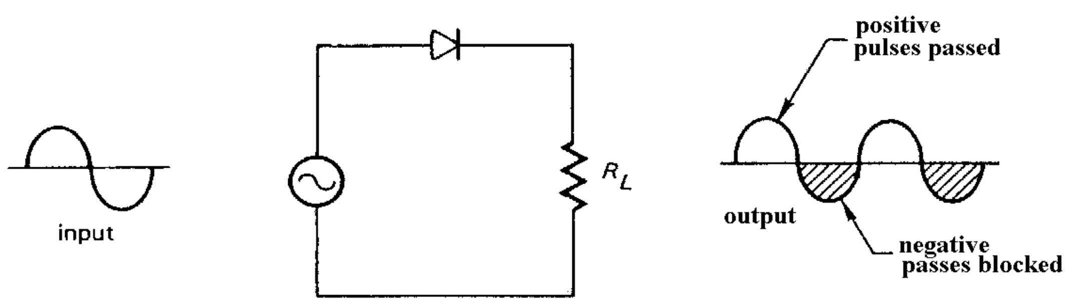


Figure: Half Wave Rectifier Circuit

In the connections of a full wave rectifier, there are four diodes, or stacks, which form a bridge circuit. The operation of a full wave rectifier is shown in the next figure. Thus, the DC output voltage is maintained in a uniform direction to give direct current through the load.

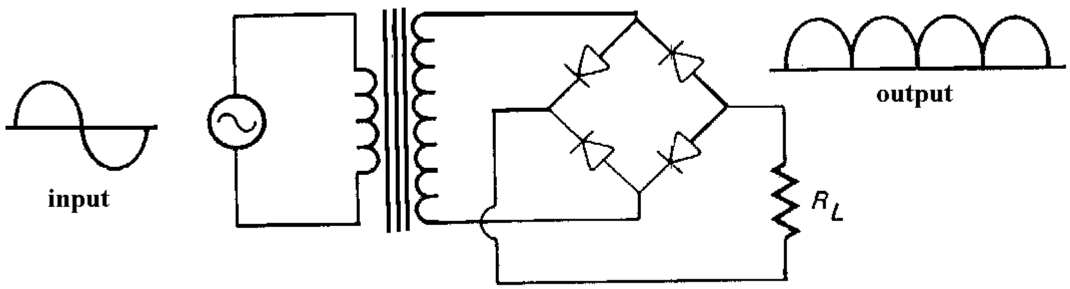


Figure: Full Wave Rectifier Circuit

A rectifier circuit of the type shown in the preceding figure may be used to supply a constant trickle charge to a battery. The battery is connected where the load is shown, with the polarity as indicated. Rectifier voltage output is slightly higher than that of the battery so that small current flows through the battery to keep it fully charged. An emergency battery for lights or alarm circuits uses this type of rectifier. When a rectifier is changed or replaced, the polarity markings must be maintained properly for the unit to work. Wrong connections cause damage to the rectifier or battery.

RECTIFIER FORMULAS:

HALF WAVE RECTIFIER

$E_{out} = .5\ E_{in}$

FULL WAVE RECTIFIER

$E_{out} = .9\ E_{in}$

THREE-PHASE RECTIFIER

$E_{out} = 1.35\ E_{in}$

I. Three Phase Motor Construction

While AC motors are manufactured in a wide range of sizes and capacities, their basic construction is essentially the same. The two major parts of a motor are the rotor and the stator. Remember the key elements of the 3-phase motor are:

- The part of a 3-phase motor that rotates is called the rotor.
- The part of a 3-phase motor that remains stationary is known as the stator.

The purpose of a motor is to convert electrical energy to mechanical energy. When and electrical force is applied to the stator, the rotor which is connected to the shaft rotates. The shaft is connected to a mechanical device. The conversion of electrical to mechanical energy can be made useful.

The rotor fits inside the stator, as shown in this illustration.

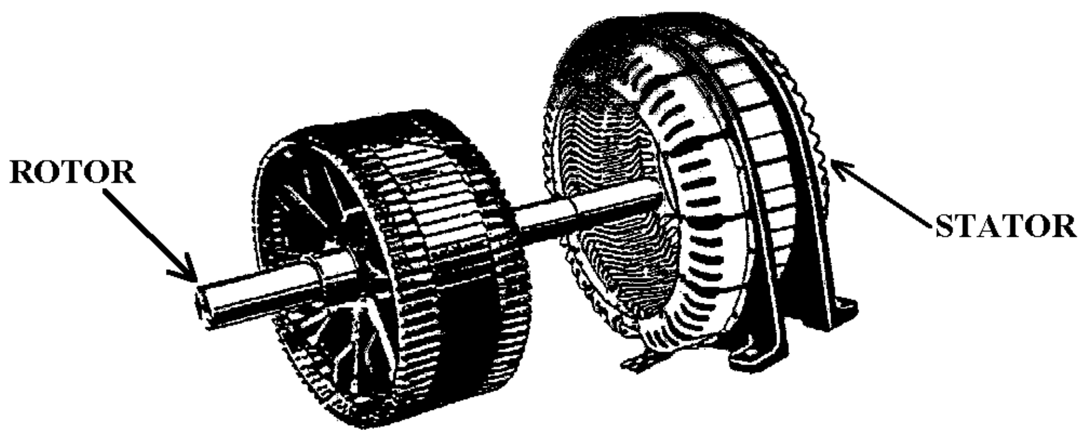


Figure: Rotor & Stator

Of course, the rotor and stator are not always clearly visible, since casings enclose most motors. However, keep these basic elements in mind:

- The stator remains stationary and receives electrical power to energize its primary windings from an external AC electrical source. In the 3-phase motor, a rotating magnetic field is established in the stator.
- The rotor tries to rotate with the rotating magnetic field of the stator. Therefore, the rotor rotates and provides output mechanical energy through its rotating shaft.

Interchanging any two, line leads to the three motor terminals may change the direction of the rotation of the magnetic revolving field. As shown here:

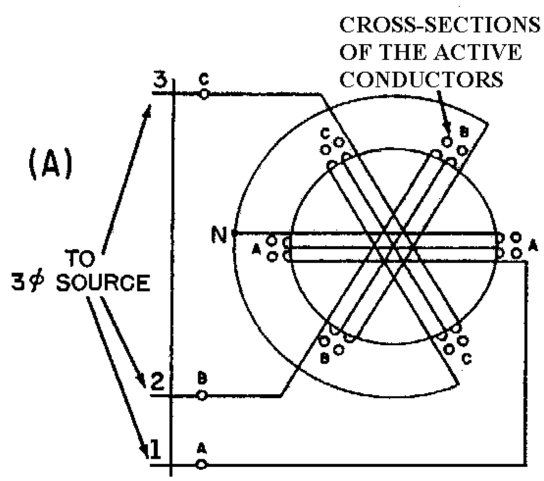


Figure: Rotating Magnetic Field

If Line 1 connected to Phase A, Line 2 to Phase B, and Line 3 to Phase C, the line currents reach their positive maximum values in the 1, 2, 3 sequence. The phase sequence is A, B, C, and the rotation is clockwise. However, if Lines 1 and 2 are interchanged, the phase sequence becomes B, A, and C. The revolving field would then turn counter clockwise.
Three phase squirrel cage induction motors used in mining today operate on three phase power sources and are the most popular type. When a 3-phase source of power is connected to a 3-phase motor, the combined effects of the out-of-phase currents and magnetic fields of each phase produce a rotating magnetic field.

Single-phase motors operate from a single-phase source, would only have one magnetic field that oscillates, or "flip-flops," back and forth. Therefore, a single-phase motor will not start by itself. To overcome this problem, an additional winding usually called the “starting winding" is placed on the stator. The starting winding is fed by the same source as the main, or "running", winding. However, the phase is shifted slightly, often by the use of a capacitor.

The stator windings of synchronous and induction motors are essentially the same. However, the rotor windings of synchronous motors are more like those of a salient pole AC generator.

The 3-phase squirrel cage induction motor consists of three poles spaced 120 degrees apart. As a load is applied to a three-phase motor, the current rises and results in a stronger motor torque. The voltage of a three phase motor is determined and rated as phase-to-phase voltage. Reversing any two incoming phases, reverse the rotation of 3-phase motors. One term that is commonly used in 3-phase systems is "single-phase". Single phase is defined as when one phase of a 3-phase system is interrupted or opened. Normally, a 3-phase motor will not start under a single-phase condition, but may continue to operate if the motor is running when the single-phase condition occurs.

Motors must have devices installed in the circuitry that protects them from excessive overload to prevent damage to motor components. Motor overloads are installed to provide motor protection against excessive voltages and currents that damage motor components.

Another type of 3-phase motor commonly used in the mining industry is the wound rotor motor. Wound rotor motors are suited to high torque loads such as crushers, belt drives, etc. The wound rotor motor has a series of fixed resistances that are bypassed on a predetermined schedule. The starting and run sequence creates a decrease in starting current and an increase in starting torque. Applications for wound- motor motors include constant torque, variable speed or high torque, slow start up.

When a motor is started, it functions much like a transformer with a shorted secondary. Starting current can easily be as much as four or five times normal full load current.

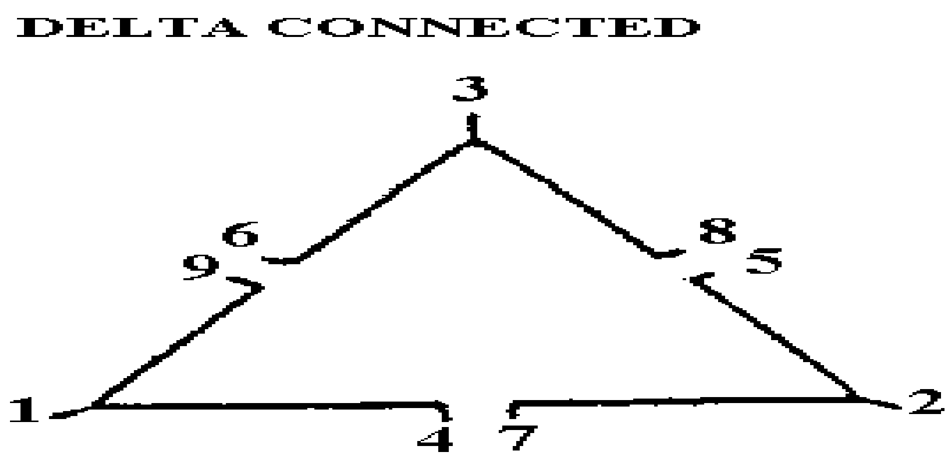
If a 3-phase, squirrel cage induction motor has two nonsalient field poles wound in each of the single-phase windings and this 3- phase winding is connected to a 3-phase, 60-cycle source, the synchronous speed of the revolving field is:

$$S = \frac{120\ F}{P} = \frac{120 \times 60}{2} = 3600 \text{ rpm}$$

The synchronous speeds of the 3-phase induction motors with different numbers of poles and operating at frequencies of 25 and 60 cycles are given in the next table.

Speed in RPM

Poles	25 cycles	60 cycles
2	1500	3600
4	750	1800
6	500	1200
8	375	900

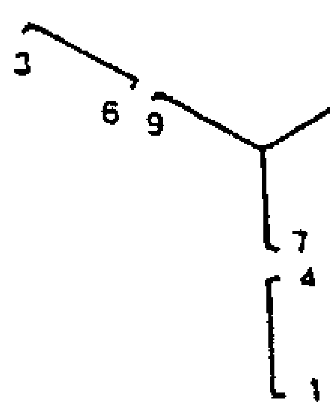


TERMINAL MARKINGS AND CONNECTIONS
CONNECTIONS FOR NINE-LEAD
THREE-PHASE MOTORS

Voltage	Line 1	Line 2	Line 3	Together
Low	1,6,7	2,4,8	3,5,9	None
High	1	2	3	(4,7) (5,8) (6,9)

TERMINAL MARKINGS & CONNECTIONS
CONNECTIONS FOR TWO-SPEED
THREE-PHASE MOTORS

STAR CONNECTED



Voltage	Line 1	Line 2	Line 3	Together
Low	1,7	2,8	3,9	4,5,6
High	1	2	3	(4,7) (5,8) (6,9)

J. Alternating Current Review (Questions/Answers)

Q. What is AC voltage?
A. Voltage, which varies in magnitude and polarity

Q. What is a cycle?
A. The period of time it takes an AC voltage to go from zero to maximum voltage, back to zero, to a maximum negative value, and back to zero. Cycle is also known as a complete set of positive and negative values.

Q. What is frequency?
A. The number of cycles per second

Q. What effect does inductance have on an AC electric circuit?
A. It opposes change in current

Q. What is the symbol for inductance?
A. L

Q. What is the formula for finding inductive reactance?
A. $X_L = 2 \pi f L$ = ohms

Q. Complete the parts for the formula $X_L = (2) \pi f L$.
A. X_L = Inductive Reactance in ohms
$2 \pi = 2 \times 3.14 = 6.28$
f = Frequency in Hertz
L = Inductance in henrys

Q. What effect does capacitance have on an AC electrical circuit?
A. Opposes any change in the voltage of a circuit

Q. Capacitors are measured in:
A. Farads (f) or microfarads (μf)

Q. What does one (1) microfarad (μf) equal?
A. One millionth of a farad = 1/1,000,000

Q. What formula is used to measure capacitance reactance?
A. $X_C = \frac{1}{2 \pi f C}$ = ohms

Q. Complete the parts for the formula $X_C = \frac{1}{2 \pi f C}$

A. X_C = Capacitive Reactance = ohms
2 π = 2 (3.14) = 6.28
f = Frequency in Hertz
C = Capacitance in farads

Q. Capacitors placed in parallel will:
A. Increase the plate area and increase the capacitance

Q. When capacitors are placed in parallel, what does the total capacitance equal?
A. The sum of all the capacitors

Q. What is the total capacitance of capacitors placed in series?
A. Smaller than any one capacitor; the plate area is decreased and the total capacitance is decreased.

Q. What is impedance?
A. Total opposition to current flow in an alternating current (AC) circuit

Q. What is the unit of measurement for impedance?
A. Ohms

Q. What is the mathematical symbol for impedance?
A.

Q. What is the formula for solving impedance?
A. $Z = \sqrt{R^2 + (X_L - X_C)^2}$ = ohms

Q. How is a transformer rated?
A. VA (volt amps) or KVA (thousand volt amps)

Q. What is a transformer used for?
A. Step up or step down AC voltage/current

Q. What is the line voltage in a 3-phase Delta connected system?
A. Line voltage = the coil voltage

Q. What is the line voltage in a Wye connected 3-phase transformer system?
A. Line voltage = 1.73 times the coil voltage

Q. What is the primary or line side of a transformer often called?
A. High side (Terminals usually indicated with H's)

Q. What is the secondary often called?
A. Load side (Terminals usually indicated with X's)

Q. The two basic hookups for secondary 3-phase transformers are Delta and Wye. Which type must utilize a zigzag transformer for grounding?
A. Delta connected secondary utilizes a zigzag transformer for grounding purposes.

Q. What is a zigzag transformer used for?
A. Derive a neutral for grounding purposes of a 3-phase Delta connected transformer

Q. What is the purpose of the grounding resistor?
A. Grounding resistor provides grounding protection to limit ground fault current

Q. What part of a Wye connected 3-phase transformer is used for grounding?
A. The grounding resistor is connected to the neutral point of the Wye connection

Q. What is the most widely used type of three phase motor?
A. Squirrel Cage Induction Motor (SCIM)

Q. How can the direction of rotation of a three phase motor be reversed?
A. Reversing any two incoming line leads

Q. What is the relationship between the starting current and the operating current of a three phase motor?
A. The starting current will always be higher.

Q. What is the purpose of a holding circuit?
A. To seal in the start switch

Q. How is an AC Single phase motor reversed?
A. Reversing the starting winding leads or the running winding leads

Q. What usually causes a motor to heat above normal temperature?
A. Overload, undervoltage, (improper ventilation)

Q. If a motor fails to start, what test should first be made?
A. Check fuse or circuit breaker

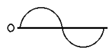
Q. What is a three phase AC motor required to have to operate properly?
A. Rotating magnetic field

Q. What will an alternating current circuit that has a varying magnetic field cause?
A. An induced voltage

Q. What are the three main types of three phase AC motors?
A. Squirrel cage, wound rotor and synchronous

Q. What voltage does an ordinary AC voltmeter read?
A. Effective voltage

K. Symbols:

 One cycle

L — Symbol for inductance: Henry is unit of measurement for inductance

X_L — Inductive reactance (ohms) ($X_L = 2 \pi f L$)

π — 3.14 (Symbol for “pi”)

C — Capacitance (farads) Unit of measurement for capacitance

μf — Microfarad

X_C — Capacitive reactance (ohms) ($X_C = \frac{1}{2 \pi f C}$)

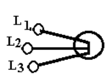
 Capacitor

Z — Impedance (ohms) ($Z = \sqrt{R^2 + (X_L - X_C)^2}$)

 Circuit breaker

 Inductor coil

 Overload

 Motor (three phase)

KVA — Ratings for transformers (kilovolt amps)

KW — Ratings for rectifiers (kilowatts)

Primary — Line side

Secondary: Load side

Δ — Delta

Y — Wye

$\Delta\ \Delta$ — Delta-Delta

Δ Y — Delta-Wye

Y Δ — Wye-Delta

Chapter 3
Electrical Circuits and Equipment

CHAPTER 3
Electrical Circuits and Equipment

A. Electrical Inspections

Electrical inspections should include at least the following elements:

1. Surface
   a. Map of the electrical system
   b. List of qualified certified electricians
   c. Records of monthly circuit breaker tests
   d. Records of monthly, examinations of surface electrical equipment

2. High-Voltage Installations Supplying Underground Circuits
   a. Transformers and connections
   b. Grounding resistors and connectors
   c. Ground fields
   d. Frame grounding of transformers, circuit breakers, etc.
   e. Lightning protection
   f. Visible disconnecting switches
   g. Circuit breakers
      1) Overcurrent relays
      2) Current transformer ratios
      3) Ground check circuits
      4) Ground fault relays
      5) Undervoltage relays

3. Low and Medium Voltage Installations Supplying Underground Circuits
   a. Direct and derived neutral
   b. Grounding resistors
   c. Circuit breakers and associated relaying
   d. Lightning protection
   e. Visible protection
   f. Ground check circuits

4. Underground High-Voltage Circuits
   a. Type and capacity of cables
   b. Splices, terminations, and couplers
   c. Visible disconnecting devices

   d. Circuit identification
   e. Mechanical protection for cables
   f. Power centers, transformers, and rectifiers

5. Trolley and Direct-Current Circuits
   a. Ampacity of conductors
   b. Splices and track bonding
   c. Cutout switches
   d. Short circuit and overload protection
   e. Guarding of trolley and trolley feeder wires
   f. Condition of track rails
   g. Insulation of conductors
   h. Record of 6-month calibration

6. Underground Low and Medium Voltage Circuits
   a. Ground circuits
   b. Ampacity of conductors
   c. Circuit breakers and associated relays
   d. Circuit identification
   e. Visible disconnecting devices

7. Stationary Electric Equipment
   a. Overload and short circuit protection
   b. Frame grounding
   c. Safe Operating controls
   d. Cables and wiring, fittings, insulators
   e. Fire protection
   f. Cleanness of equipment
   g. Permissibility of equipment in face areas and return airways

8. Mobile Equipment
   a. Overload and short circuit protection
   b. Frame grounding (off-track equipment)
   c. Safe operating controls
   d. Cables and wiring, entrance glands, mechanical protection
   e. Fire protection
   f. Cleanliness of equipment
   g. Sand rigging
   h. Brakes

   i. Lights
   j. Permissibility of equipment in face areas and return airways
   k. Record of weekly calibration of methane monitors

9. Trailing Cables
   a. Condition of outer jacket, conductor insulation; and splices
   b. Short circuit protection
   c. Size of dual element fuses
   d. Trip element and setting of circuit breakers
   e. Visible disconnecting devices
   f. Identification of cables
   g. Continuity of grounding conductors
   h. Mechanical protection

10. Illumination of Working Places
   a. Statement of test and evaluation
   b. Maintenance of illumination systems

11. Records of weekly examination of all underground electrical equipment

A qualified and Virginia certified electrical repairman shall examine electrical underground equipment weekly. A record shall be made of the examination.

Shock Hazards

Electricity is a pure form of energy. Most electrical energy produced in the United States is generated in power plants that burn coal as a source of fuel. The mining industry needs electricity to extract and process coal and other minerals. Mining equipment such as continuous miners, loaders, shuttle cars, draglines, shovels and drills need electricity. It is used for the transportation of material on conveyors, electric railroads and track haulage. It is used in preparation plants to power equipment that cleans the mined material. Large quantities of electricity are used in mining, but this is only a small percentage of the total electrical energy generated.

While electricity is necessary in mining, there are hazards associated with its use that must be understood and avoided. The primary hazards are those created by electrical arcs, electrically generated heat, electrocution and explosions.

The body is a conductor and like a conductor, has a resistance. Current will flow through a body when a voltage difference is present between two points on the body. (Example: hand on a power wire and standing on the ground). Ohm's Law (I = E/R) is used to calculate values of current across different parts of the body. Information on the next page illustrates values of resistance in ohms that were determined by actual tests. If a voltage existed between the hand and the foot, a resistor of 500 ohms (average) would be in the circuit. The 110 volts, divided by 500 ohms, would give a current value of .22 amps or 220 milliamps. A milliamp (MA), is 1/1000th of an amp or, explained another way, it takes 1000 ma to equal one amp. A standard household 100-watt bulb requires less than one amp to light.

As calculated, a person touching an energized wire or circuit with any part of the body and standing on the ground would be subject to unsafe values of current. The most damaging current path is across the chest area. This path will pass current through the heart muscles disrupting the rhythm or beat of the heart. Low values of current flowing across the chest area could be fatal.

Investigations have shown that electrocutions involving as little as 27 volts can be fatal. Use caution around ALL electrical circuits. Information on the next page gives values of current and effects on the body.

Effects of 60-Hz Current on an Average Human

CURRENT VALUES THROUGH BODY TRUNK EFFECT

SAFE CURRENT VALUES	1 Milliampere or less is at threshold of perception	CAUSES NO SENSATION NOT FELT
	1 to 8 Milliamperes	Sensation of shock; Not painful; Individual can let go at will, as muscular control is not lost; 5 MA is accepted as maximum harmless current intensity
UNSAFE CURRENT VALUES	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 is 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); Disrupts or changes rhythm of the heart
	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.)

B. Instruments and Meters

Ohmmeter

Multimeters are designed to allow the electrician to have two or more meters in one case. Many meters used in the mining industry contain volt, ohm and ammeters.

An ohmmeter is used to measure resistance. It is very important that power is de-energized from the circuit before an ohmmeter is used. An ohmmeter can measure individual resistance or total resistance of a circuit. Ohmmeters normally have many ranges that allow the electrician to measure low and high resistance.

The following ohmmeter has a reading of "8". The meter is on the "R X 10,000" scale. Therefore, the meter indicates that there is 8 X 10,000 ohms resistance or resistance would equal 80,000 (ohms).

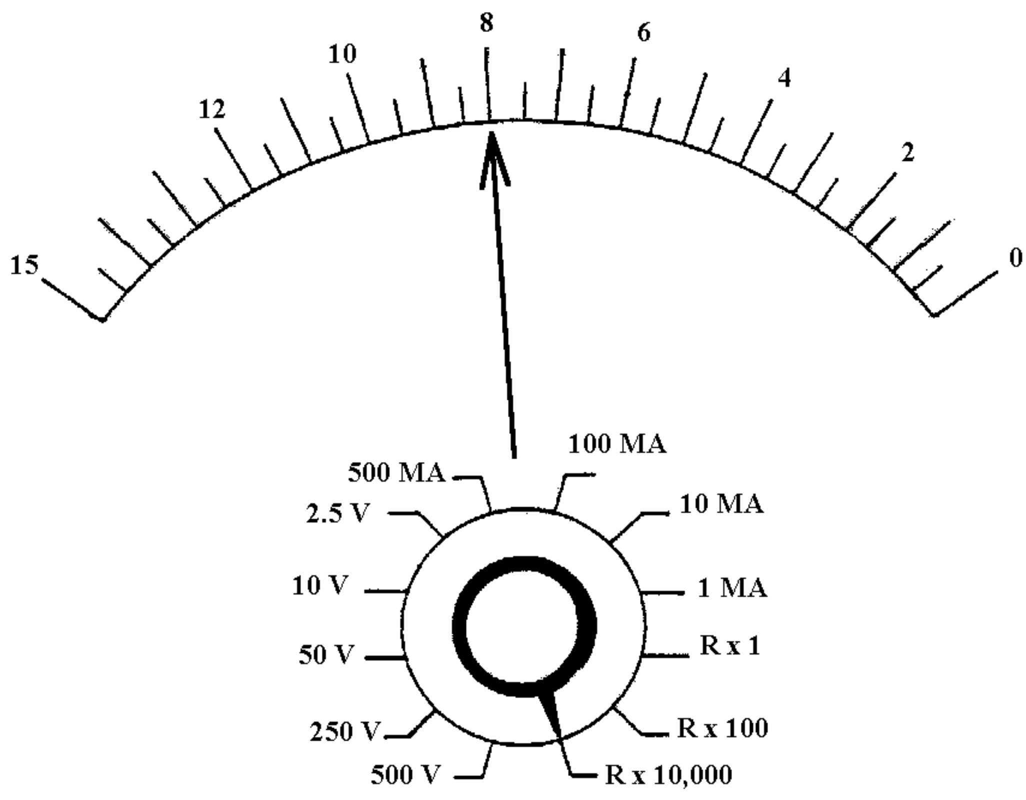


Figure: Ohmmeter

Voltmeter

A Voltmeter is used to measure voltage. It is very important that the voltmeter is designed to measure the voltage of the circuit (AC or DC). Only a certified and qualified electrician should measure voltage on energized circuits. Extreme caution should be used when testing and troubleshooting energized circuits.

The electrician should be familiar with and follow all recommendations of the manufacturer of the voltmeter and circuit being tested. The electrician should determine the circuit voltage and determine the appropriate voltmeter and range for the circuit.

A voltmeter can be used to measure voltage drop across components such as a resistor, magnetic coil, light bulbs, etc. A voltmeter can also be used to measure power supply outputs such as batteries, transformers and generators.

The following voltmeter is set on the 150-volt scale. The needle is deflected to 120 volts.

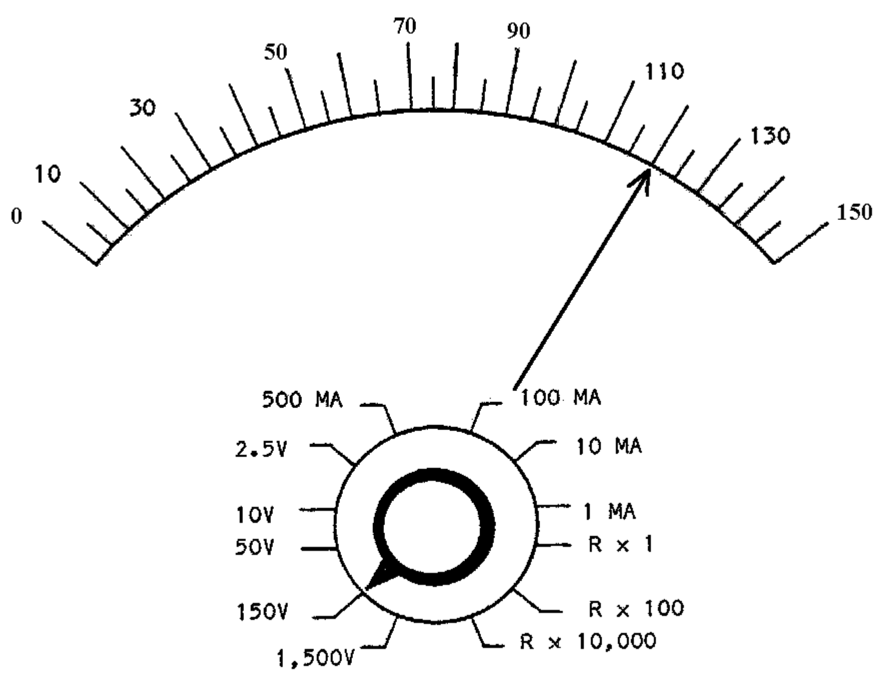


Figure: Voltmeter

Ammeters

An ammeter is needed to measure amps (current) within a circuit. An ammeter is connected in series within the circuit. Ammeters usually have many ranges that allow the electrician to measure milliamps or high amps. The electrician should be familiar with and follow all safety precautions and manufactures recommendations of the ammeter and circuit being tested.

The electrician may use an ammeter that clamps around a single electrical conductor. This type of meter is often called a TONG TESTER. In order to obtain an accurate reading, the meter must be placed around one conductor. If the meter is placed around two or more conductors, the meter will not provide an accurate reading.

The ammeter is an ampere meter. It tells us how many amperes of current (coulombs of electron charge per second) are moving through the circuit. A pointer in front of a calibrated dial face registers the amount of current flowing through the ammeter. The pointer moves in proportion to the rate of electron movement through the meter, so that it registers the amount of charge that goes by each second. Since the dial is calibrated, the current must pass through the ammeter in the direction of the calibrations from negative to positive. Thus, the ammeter has negative and positive terminals, like a battery.

Measurements of the same circuit taken by several different meters can vary slightly. This is because some of the circuit energy is used to operate the meter, and since no two meters are exactly alike, they do not all use exactly the same amount of energy. Normally a meter will be accurate within a ± 5 percent tolerance range. However, because of these slight variations, ammeter readings must be considered as approximate, not exact.

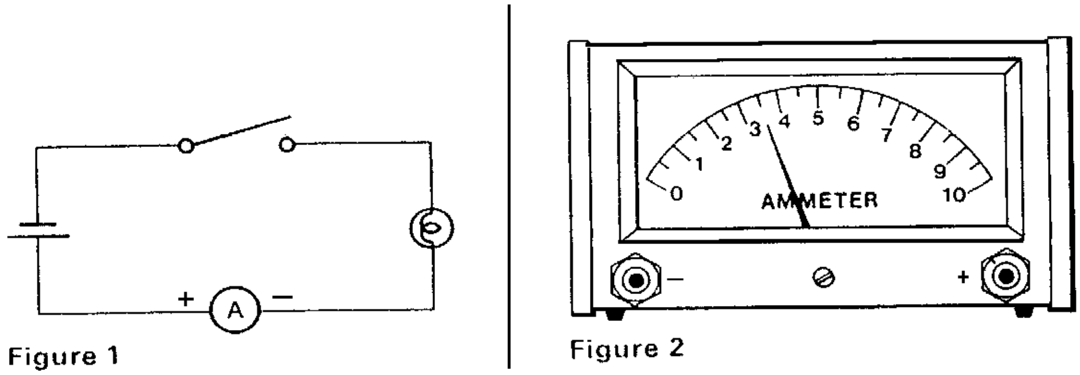


Figure: Ammeter

Megohmeter (Megger)

The megger is a device to used to measure high resistance for insulation break down. The megger is used to measure transformer, cable, and motor insulation.

C. BATTERIES

The most common storage battery is the lead-acid type. Each lead cell produces 2 volts. Automobile batteries rated at 12 volt contain six lead cells connected in series.

The Ampere-Hour Rating

Storage batteries are rated in volts and ampere-hours. An ampere-hour is the amount of charge delivered by one ampere in one hour. The ampere-hour rating of a battery is determined from its measured ability to produce current for 20 hours at 80 degrees F. Therefore, a battery that produces 6 amperes steadily for 20 hours at 80 degree F has a rating of 120 ampere-hours. If the discharge rate of the battery is 1 or 2 amperes instead of 6 amperes, a 120-ampere hour battery can produce more than 120 ampere-hours. The battery cannot produce 120 amperes for one hour; the actual value of ampere-hours produced depends on the current.

Battery Charging

A rectifier or DC generator is required to charge a battery. The battery is charged by forcing a direct current through it in a direction opposite to that of normal battery operation. In the lead cell, this reversal of current reverses the chemical changes that take place in the cell when it furnishes energy. (Recall that in primary cells, the chemical changes cannot be reversed).

The charging process in the lead cell is a series of chemical reactions. Recall that a current through a solution of sulfuric acid in water produces hydrogen at the negative plate and oxygen at the positive plate. If the plates are already covered with a thin layer of lead sulfate (from the discharging process), then the H^+ ions are forced toward the negative plate.

Battery Safety Precautions

1. <u>Explosions</u> can result from ignited gases produced by a battery:
   a) Do not smoke, use an open flame, or create arcs or sparks in the vicinity of a battery.
   b) Charge a battery only in a well-ventilated area with the tray cover removed.

c) Do not charge the battery at a current greater than 5 amps per 100-amp-hour capacity at the end of the charging process.

2. Severe burns can be caused by the sulfuric acid contained in the batteries covered by these instructions:
   a) Do not get acid in eyes, on skin or clothing. In case of contact, flush immediately and thoroughly with clean water. Obtain medical attention when eyes are affected.
   b) In handling sulfuric acid, wear a face shield, plastic or rubber apron, and gloves. Avoid spilling acid.
   c) Bicarbonate of soda solution (one pound to a gallon of water) will neutralize any acid accidentally spilled on clothing or material. Apply the solution until bubbling stops, and then rinse with clear water.
   d) When diluting concentrated acid, always add acid to water. Pour slowly and stir constantly, to avoid excessive heat or violent chemical reaction.

3. The battery is electrically live at all times:
   a) Keep the top of the battery clean and dry to prevent ground shorts and corrosion.
   b) Do not lay metallic objects on the battery, and insulate all tools used in working on the battery to prevent short circuits. Also, remove all jewelry before working on the battery.
   c) Ground the battery (in accordance with the most recent MSHA requirements) during charging.
   d) Be careful when working on battery plugs.

4. When lifting the battery, observe the following precautions:
   a) Wear safety shoes and a hard hat.
   b) Temporarily cover the top of the cells with an insulating material (sheet of plywood, thick rubber, etc.) to reduce the risk of a short circuit from the chain or the hooks.
   c) Use a lifting device whose two safety hooks are electrically insulated from each other to prevent short circuits.

5. Keep the vent plugs firmly in place at all times, except when adding water or taking hydrometer and temperature readings.

6. Only personnel who have been trained in battery installation, charging and maintenance should be allowed to work on the battery.

Inspecting Battery Shipment

1. Upon receipt, examine batteries for physical damage or loss of acid. Acid levels can settle during shipment. Add water, when necessary, to bring level 1/8-inch above splash cover.

2. Shipping damage should be reported to carrier.

Storage of Batteries

When your battery will be out of service for three or more months:

1. Give an equalizing charge.

2. Store in a cool and dry location.

3. Check specific gravity of several cells at regular intervals, and when it falls to 1.240 or below, give another equalizing charge.

Installation of Batteries

1. The battery compartment should be ventilated in a manner to keep out water, coal, dirt, and other foreign matter. Drainage holes or channels should be located in the floor of the battery compartment.

2. Each battery consists of two trays. Number each battery as a pair (example: tray number 1-A and 1-B for battery #1, etc.). Keep each pair together at all times, on charge, on tractor, or idle.

3. When lifting the battery, use an insulated device that exerts a vertical pull on the battery's lifting tabs.

4. Battery should be blocked, not wedged, to allow 1/8-inch clearance on all sides for easy removal from battery compartment.

D. FUSES

Fuses are calibrated conductors that are designed to open (blow) when a specific current flows through the fuse. Fuses are resistors using special metals with very low resistance values and a low melting point, which are designed to blow out and thus open the circuit when the current exceeds the fuse's rated value. When the power consumed by the fuse raises the temperature of the metal too high, the metal melts and the fuse blows. Blown fuses can usually be identified by a broken filament and darkened glass. If you are uncertain, you can remove the fuse and check it with an ohmmeter.

Excessive current may seriously damage electrical equipment, motors, test instruments, radio receivers, etc. Fuses are cheap, yet the other equipment is much more expensive. It is very important that the proper size fuses are used and fuses are <u>not</u> bypassed with jumper wires. If an oversized fuse is used to replace a blown fuse, then electrical equipment may be damaged or a fire may result.

There are two types of fuses in use today. Conventional fuses blow immediately when the circuit is overloaded. Slow-blowing fuses can accept momentary overloads without blowing, but if the overload continues, they will open the circuit. These slow-blow fuses are used in circuits that have a sudden rush of high current when turned on, such as motors or some appliances. If such circuits used a conventional fuse with a high enough value to handle the high starting currents, there would be little protection under normal running conditions. It is important that you replace fuses with the proper type, whether conventional or slow blowing.

Dual-Element Fuses

Unlike single-element fuses, the dual-element fuse can be applied in circuits subject to temporary motor overloads and surge currents to provide both high performances <u>short-circuit</u> and <u>overload protection</u>. Over sizing in order to prevent nuisance openings is not necessary. The dual-element fuse contains two distinctly separate types of elements. Electrically, the two elements are series connected. The fuse links similar to those used in the single-element fuse perform the short- circuit protection function; the overload element provides protection against low-level over currents or overloads and will hold an overload which is five times greater than the ampere rating of the fuse for a minimum time of 10 seconds.

The overload section consists of a copper heat absorber and a spring operated trigger assembly. The heat absorber strip is permanently connected to the short-circuit link and to the short-circuit link on the opposite end of the fuse by the "S shaped" connector of the trigger assembly. The connector electrically joins the one short-circuit link to the heat absorber in the overload section of the fuse. These elements are joined by a "calibrated" fusing alloy. An overload current causes heating of the short-circuit link connected to the trigger assembly. Transfer of heat from the short-circuit link to the heat absorbing strip in the mid-section of the fuse begins to raise the temperature of the heat absorber. If the overload is sustained, the temperature of the heat absorber eventually reaches a level which permits the trigger spring to "fracture" the calibrated fusing alloy and pull the connector free of the short-circuit link and the heat absorber. As a result, the short-circuit link is electrically disconnected from the heat absorber, the conducting path through the fuse is opened, and overload current is interrupted. A critical aspect of the fusing alloy is that it retains its original characteristic after repeated temporary overloads without degradation.

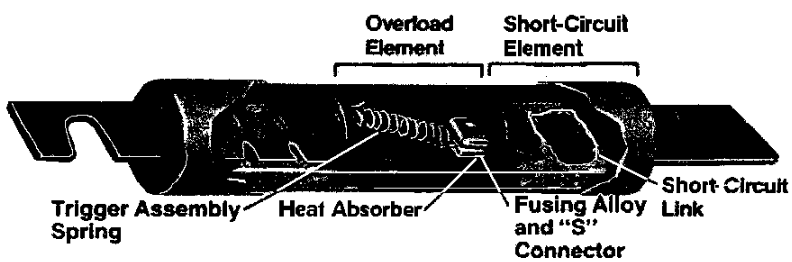


Figure: Dual Element Fuse

E. OHMS LAW/POWER

Resistors in Series. Resistors in a D. C. circuit limit current flow. Current can be determined by dividing the total voltage by the total resistance. In any complete circuit, the total current leaving a power supply is equal to the current returning to the power supply. Total resistance in a series circuit can be determined by adding all the resistors in the series circuit.

To determine the total resistance (R_T) in the following series circuit, we add all resistors. Total current (I_T), can be determined by dividing the total resistance (R_T) into the total voltage (E).

$$R_T = R_1 + R_2 + R_3 + R_4 = \text{ohms}$$

$$R_T = 25 + 125 + 225 + 25$$

$$R_T = 400 \text{ ohms}$$

$$I_T = \frac{E}{R} = \frac{120 \text{ volt}}{400 \text{ ohms}}$$

$$I_T = .3 \text{ amps}$$

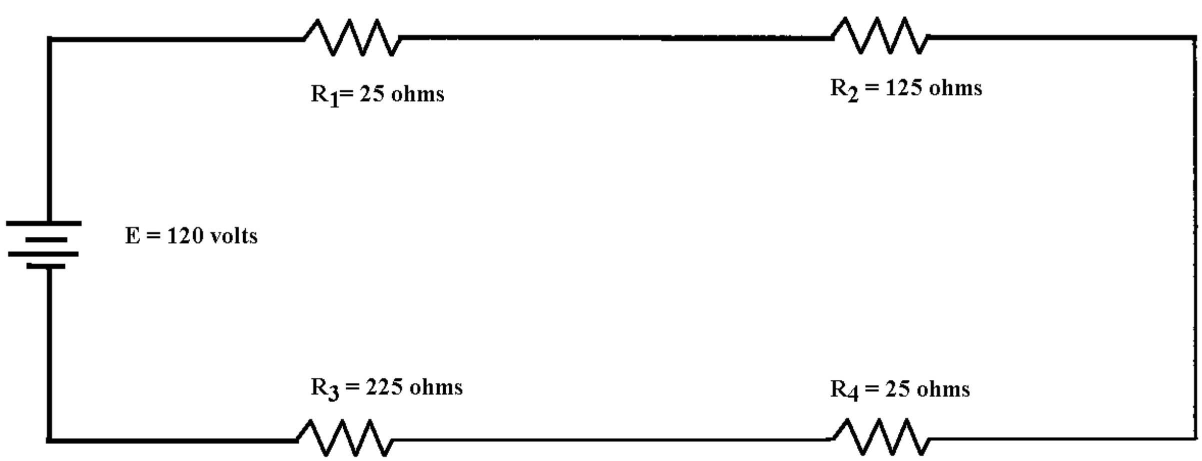


Figure: Resistors in Series

Resistors in Parallel

Parallel circuit exists when there are two or more paths for the current to follow. A parallel circuit is one in which the total current is the sum of the current in the branches. The total resistance in the circuit is less than any individual resistance.

$$R_E = R_{12} = \frac{R_1 \times R_2}{R_1 + R_2}$$

$$R_E = \frac{2 \times 4}{2 + 4} = \frac{8}{6} = 1.33 \text{ ohms}$$

$$R_T = \frac{R_E \times R_3}{R_E + R_3}$$

$$R_T = \frac{1.33 \times 2}{1.33 + 2} = \frac{2.66}{3.33} = .79 \text{ ohms}$$

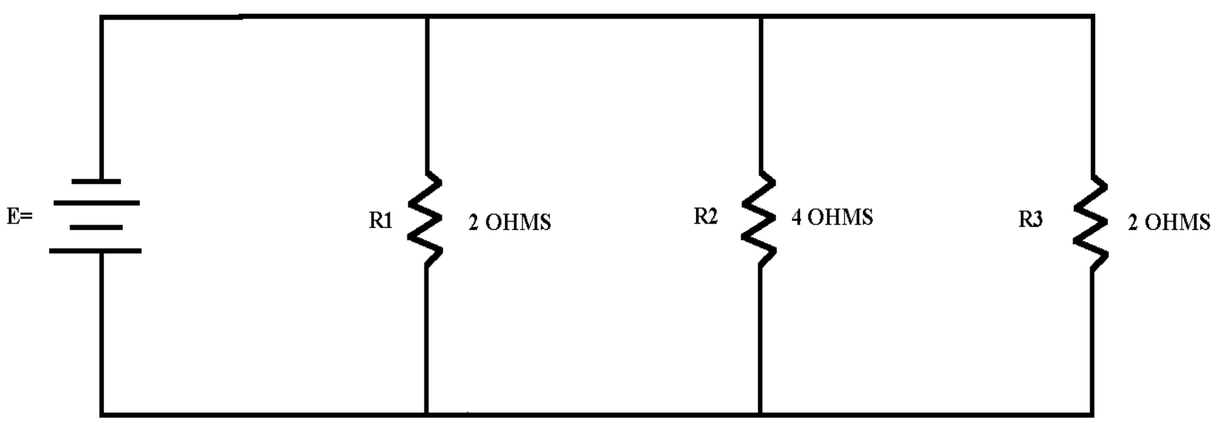


Figure: Resistors in Parallel

Voltage Series

Voltage is electromotive force (EMF) or electrical pressure. Voltage in a series circuit is equal to the sum of all voltage drops.

$$E_T = E_1 + E_2 + E_3 + E_4$$

In the following circuit, four 120-volt batteries are connected in series. The total output voltage of this circuit would be the sum of all batteries connected in series. E_T = 120 volts + 120 volts + 120 volts + 120 volts
E_T = 480 volts

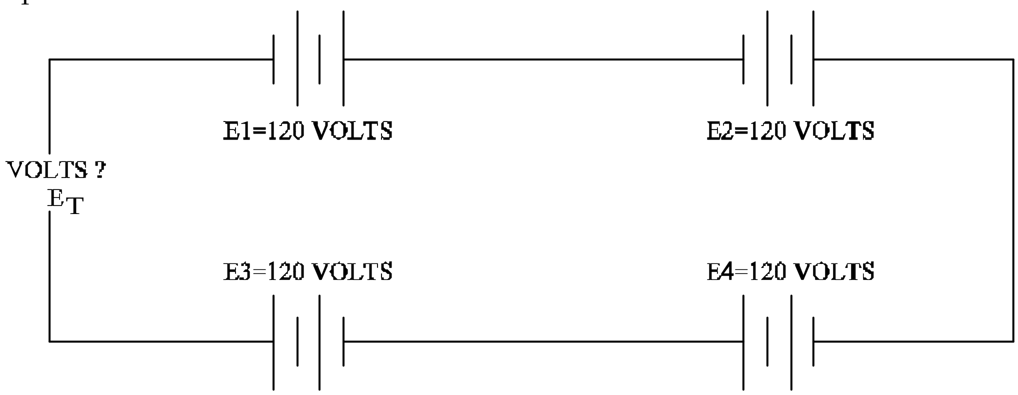


Figure: Voltage in Series

In the following circuit, the sum of the total voltage (E_T) is equal to the sum of the voltage drops in series.

$E_T = E_1 + E_2 + E_3 + E_4$

$E_T = 50 + 25 + 10 + 15$

E_T = 100 volts

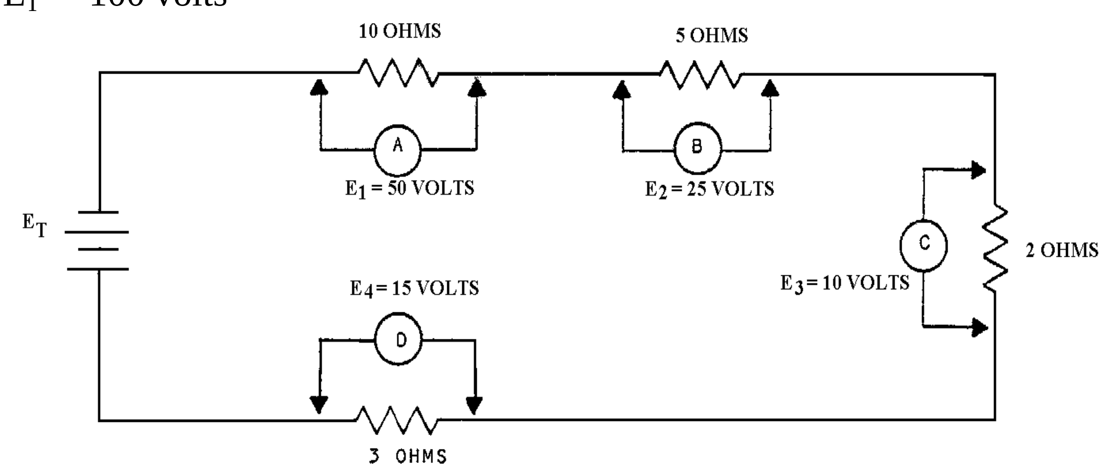


Figure: Series Total Voltage

Voltage in Parallel

Voltage in a parallel circuit is equal in all branch circuits:
$E_T = E_1 = E_2 = E_3 = E_4$

In the following circuit, four 120-volt batteries are connected in parallel. The total output voltage of this circuit would be equal to each branch circuit.

E_T = 120 volts = 120 volts = 120 volts = 120 volts
E_T = 120 volts

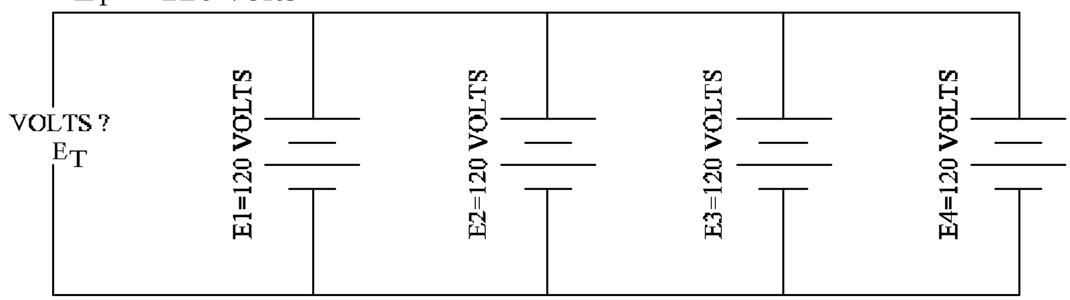


Figure: Voltage in Parallel

In the following parallel circuit, the voltage output (E_T) is equal to each branch circuit voltage.

$E_T = E_1 = E_2 = E_3 = E_4$
E_T = 10 volts

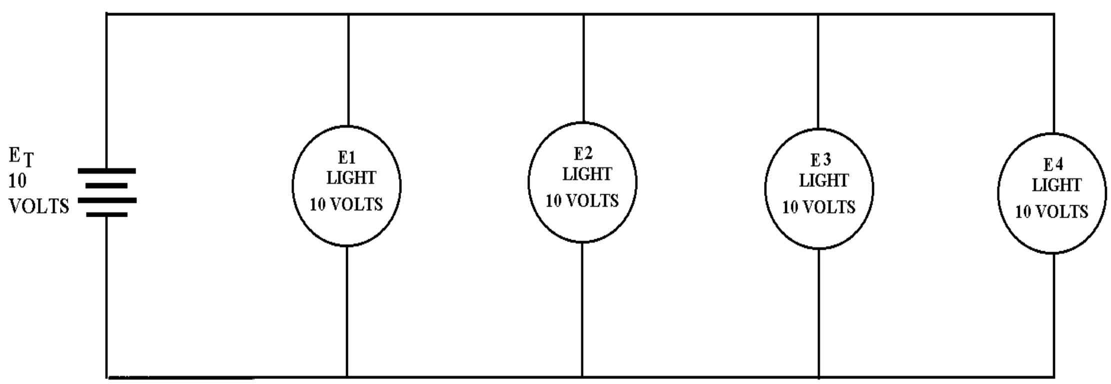


Figure: Parallel Voltage Output

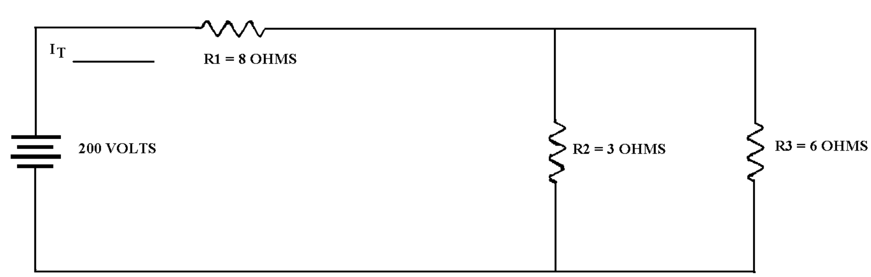


Figure: Series/Parallel

What is total resistance in the previous figure (series/parallel)?

$$R_{2\&3} = \frac{R_2 \times R_3}{R_2 + R_3} = \frac{3 \times 6}{3 + 6} = \frac{18}{9} = 2 \text{ ohms}$$

$$R_T = R_1 + R_{2\&3} = 8 + 2 = 10 \text{ ohms}$$

What is the total current?

$$I_T = \frac{E_T}{R_T} = \frac{200}{10} = 20 \text{ amps}$$

How many amps flow through R_1

$I_T = I_1 = 20$ amps

How many volts are dropped across R_1 ?

$E_1 = I_1 \times R_1 = 20$ amps x 8 ohms = 160 volts

How many volts would be dropped across R_2 and R_3 parallel circuit
$E_{23} = E_T - E_1 = 200 - 160 = 40$ volts

How many amps would flow through R_2 ?

$$I_2 = \frac{E_2}{R_2} = \frac{40 \text{ volts}}{3 \text{ ohms}} = 13.33 \text{ amps}$$

How many amps would flow through R_3 ?

$$I_3 = \frac{E_3}{R_3} = \frac{40 \text{ volts}}{6 \text{ ohms}} = 6.67$$

Power

Electrical power in a circuit is measured in watts. In an electrical circuit, power is often dissipated in heat through resistance. Electrical power is also consumed by an electric motor. Even though motors are rated in horsepower (HP), this can be converted to watts by using the standard factor of 1 HP is equal to 746 watts. Power can be determined in an electrical circuit by the following formula:

Watts = volts x amps

Watts = I^2 x R

Watts = $\frac{E^2}{R}$

746 watts = 1 horsepower

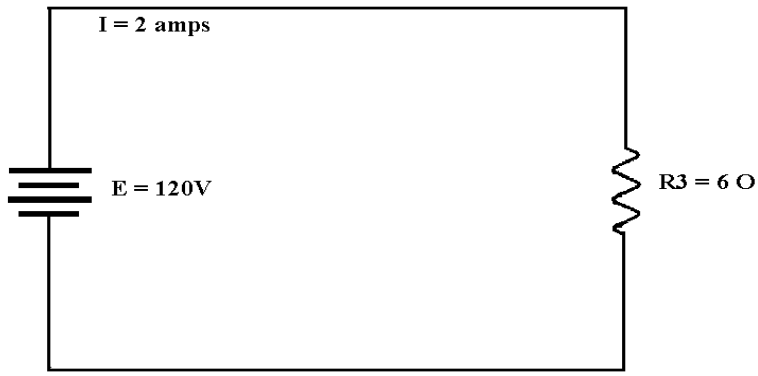


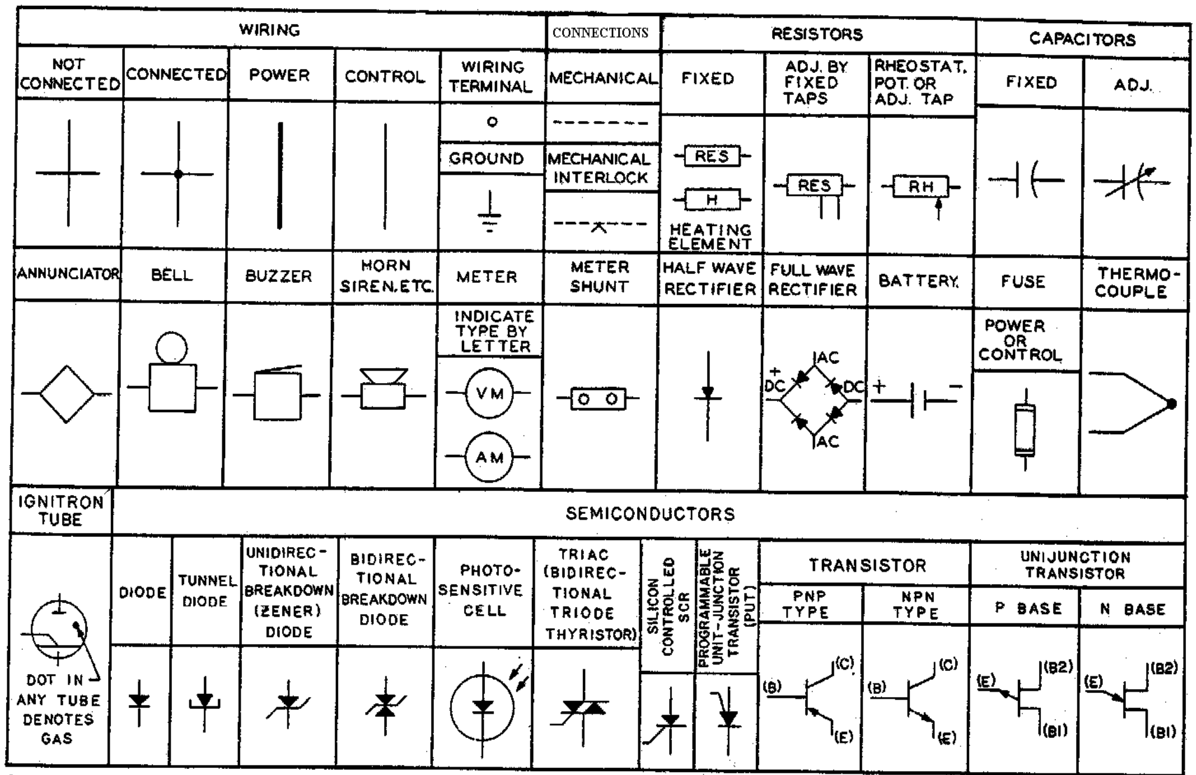
Figure: Power

For example, if a circuit has an applied voltage of 120 volts and a current flow of 2 amps, the power is 240 watts. This is found by the formula.

P = I x E = volts x amps = 120 volts x 2 amps = 240 watts

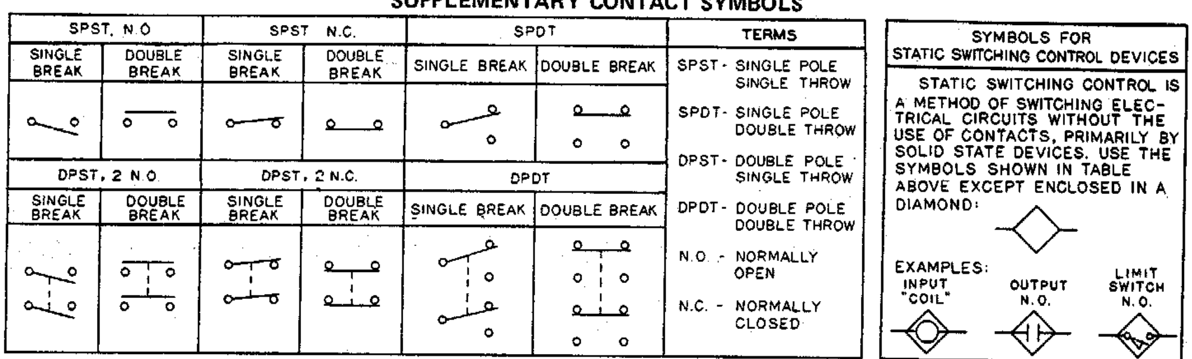
Kilowatts (kw) = $\frac{\text{watts}}{1000} = \frac{240}{1000}$ = .240 KW

F. CIRCUIT CONTROLS



2

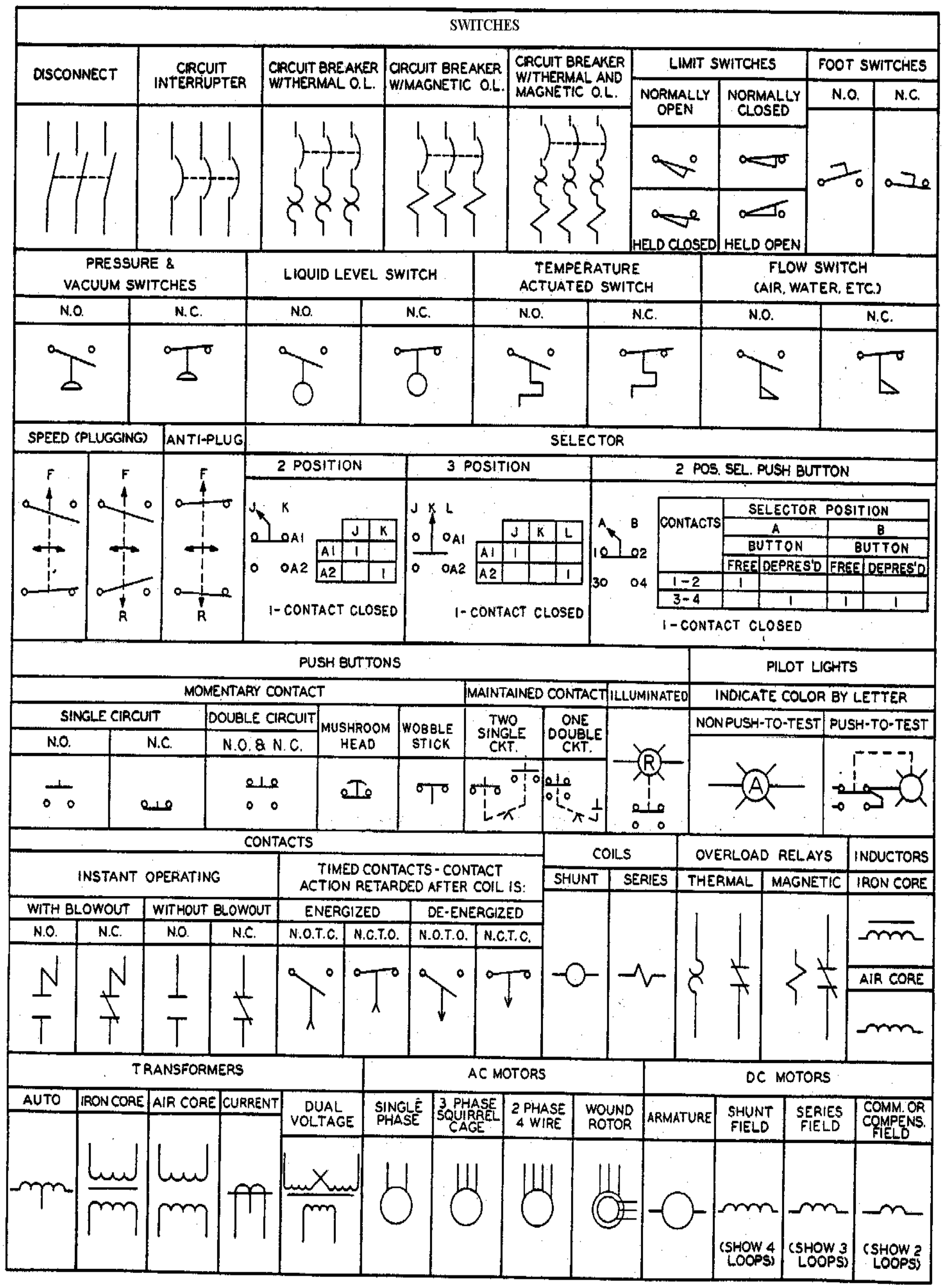
SUPPLEMENTARY CONTACT SYMBOLS



CONTROL AND POWER CONNECTIONS - 600 VOLTS OR LESS - ACROSS-THE-LINE STARTERS
(From NEMA Standard ICS 2-321A.60)

		1 PHASE	2 PHASE 4 WIRE	3 PHASE
LINE MARKINGS		L1, L2	L1,L3-PHASE 1 L2,L4-PHASE 2	L1, L2, L3
GROUND WHEN USED		L1 IS ALWAYS UNGROUNDED	—	L2
MOTOR RUNNING OVERCURRENT UNITS IN	1 ELEMENT 2 ELEMENT 3 ELEMENT	L1 — —	— L1, L4 —	— — L1, L2, L3
CONTROL CIRCUIT CONNECTED TO		L1, L2	L1, L3	L1, L2
FOR REVERSING INTERCHANGE LINES		—	L1, L3	L1, L3

G. STANDARD ELEMENTARY DIAGRAM SYMBOLS



Wiring Diagram

A Wiring Diagram shows, as clearly as possible, the actual location of all of the component parts of the device. The open terminals (marked by an open circle) and arrows represent connections made by the user.

Since wiring connections and terminal markings are shown, this type of diagram is helpful when wiring the device, or tracing wires when troubleshooting. Note that bold lines denote the power circuit, and thin lines are used to show the control circuit. Conventionally, in AC magnetic equipment, black wires are used in power circuits and red wiring is used for control circuits.

A wiring diagram, however, is limited in its ability to convey a clear picture of the sequence of operation of a controller. Where an illustration of the circuit in its simplest form is desired, the elementary diagram is used.

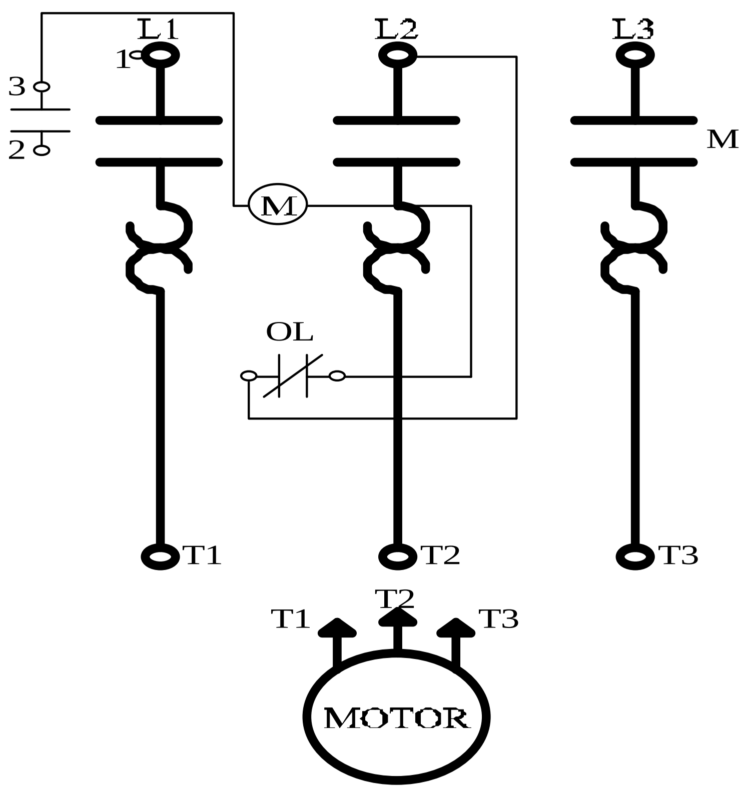


Figure: 3-Phase Wiring Diagram

Elementary Schematic Diagram

The elementary diagram gives a quick easily understood picture of the circuit. The devices and components are not shown in their actual positions. All the control circuit components are shown as directly as possible, between a pair of vertical lines, representing the control power supply. The arrangement of the components is designed to show the sequence of operation of the devices, and helps in understanding how the circuit operates. The effect of operating various interlocks, control devices, etc. can be readily seen, this aids in understanding how the circuit operates and in trouble shooting, particularly with the more complex controllers. This form of electrical diagram is sometimes referred to as a "schematic" or "line" diagram.

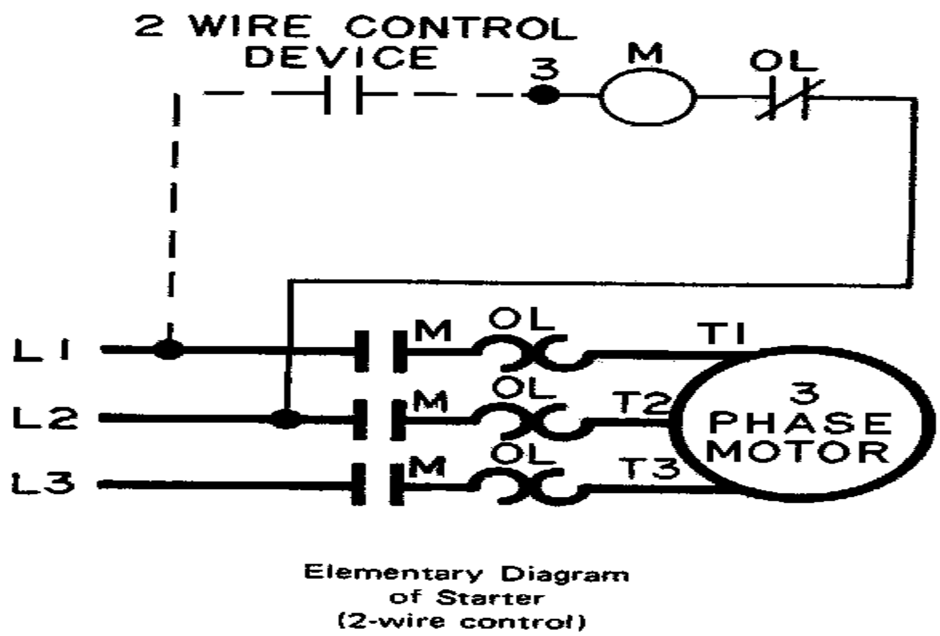


Figure: Schematic Diagram

Basic Alternating Control (AC) Control Circuit

A step down transformer can be used to provide a control circuit voltage lower than line voltage for safety reasons. This scheme shows one of the ways overcurrent protection can be provided for control circuits.

Primary voltage is transformed to the secondary control voltage. The fuse provides overcurrent protection for the control circuit. The start switch is depressed allowing current to flow through the "M" electromagnetic coil. The "M" auxiliary contact is closed by the electromagnetism from "M" coil. The start switch can be released and the "M" auxiliary contact circuit will provide the current path to keep "M" coil energized until the stop switch is depressed. Other contacts of the "M" coil may be used to energize motors, etc.

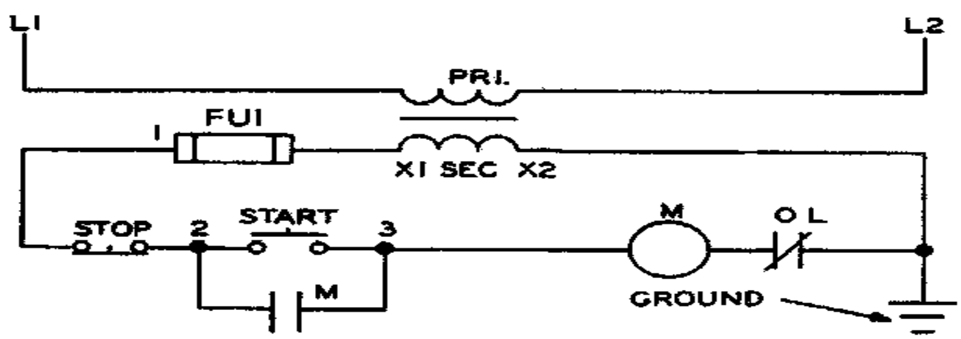


Figure: Three-Wire Control with Fused Control Circuit Transformer

Start-Stop Stations

In the following figure, pressing the "Start" button energizes the control relay that in turn energizes the "M" coil. The normally open "M" interlock and control relay contact then form a holding circuit around the "Start" button. Pressing the "Jog" button energizes the "M" coil independent of the relay and no holding circuit forms, thus jogging can be obtained.

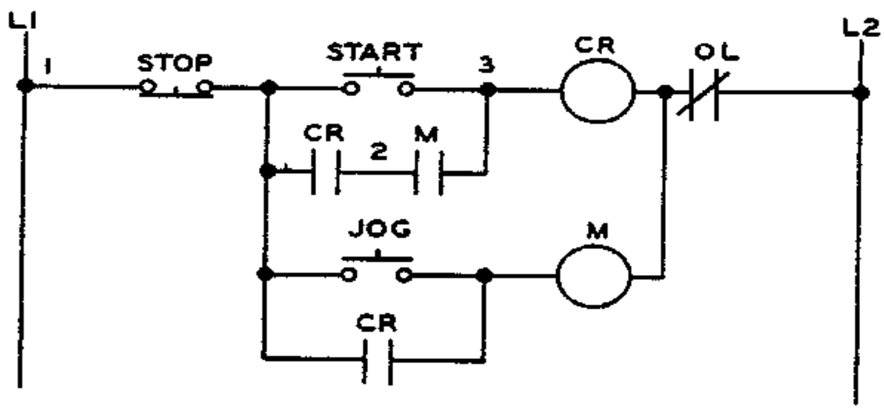


Figure: Jogging Using a Control Relay

DC Motor Starter

The following figure illustrates a starter for a DC compound motor. The bold lines indicate the power circuit and the control circuit operates as follows:

"Start switch is depressed"
"M" Electromagnetic coil is energized
"M" main contact is closed supplying power to the power circuit (resistor, armature, series and shunt field). The motor turns slowly.
"M" auxiliary contactor also closes supplying power to "IAR" solid-state timer.
After a preset time (1-2 seconds), the "IA" coil is energized. "IA" power contactor is closed, which shorts out part of the starting resistor and speeds up the motor.
"IA" auxiliary contact closes, which supplies power to solid state timer

"2AR". After a preset time (1-2 seconds), "2A" coil is energized. "2A" power contact is closed, which shorts out the entire starting resistor. The motor runs at full speed.

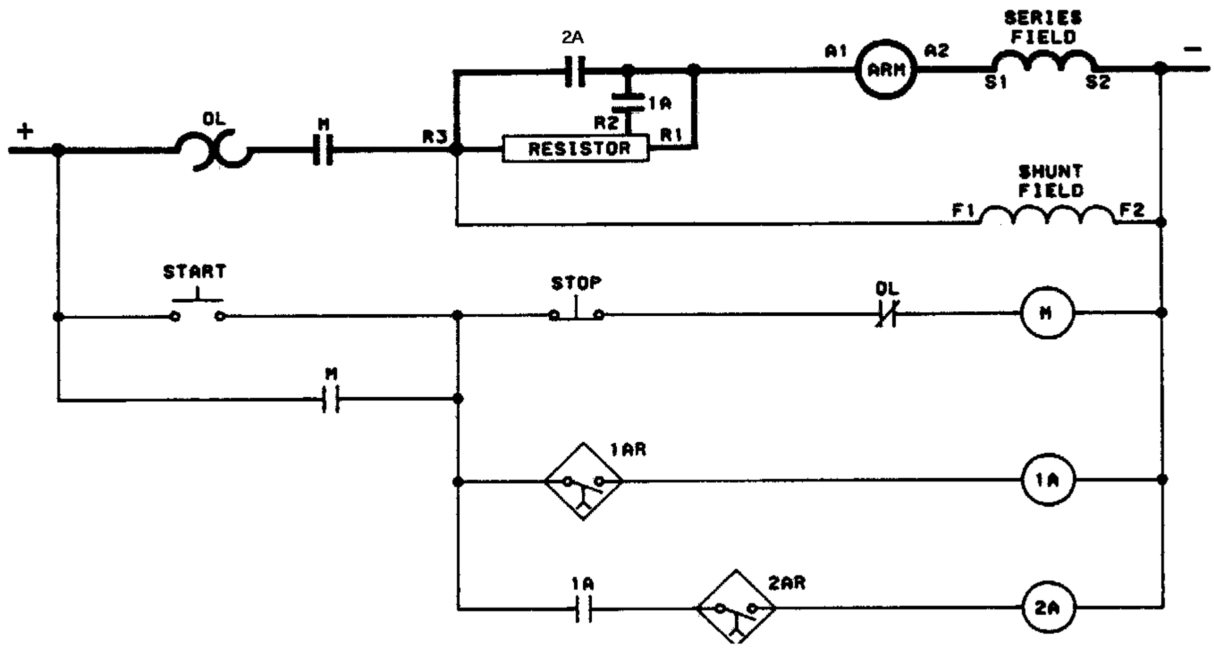


Figure: DC Compound Motor Starter

H. PROTECTIVE DEVICES

Slippage and sequence switches are controls used for protection of belt conveyors.

§ 45.1-161.135.G. Clearances on Haulage Roads

Belt conveyors shall be equipped with control switches to automatically stop the driving motor in the event the belt is stopped by slipping on the driving pulley, by breakage or other accident.

75.1102 Underground belt conveyors shall be equipped with slippage and sequence switches.

Circuit Breakers and Enclosures

Manufacturers produce many different types of circuit breakers. Circuit breakers are comprised of five main components: molded case (frame), operating mechanism, arc extinguishers, contacts, trip elements and terminal connectors. Circuit breakers provide different types of protection such as short circuit, overload, ground fault, and undervoltage. Some circuit breakers are equipped with shunt trip coils, which are used as a circuit breaker tripping device.

Short Circuit Protection

Short circuit protection is required for underground trailing cables. Circuit breakers are designed with adjustable short circuit protection. Current transformers, solid-state trips or electromagnetism can provide instantaneous trip or short circuit protection.

The electrical repairman should be familiar with circuit breaker settings and state and federal requirements. The short circuit protection provides protection when one phase lead comes into contact with another phase lead. As a result, high current will flow. Therefore, protection is provided instantaneously.

The following figure indicates the adjustable instantaneous trip:

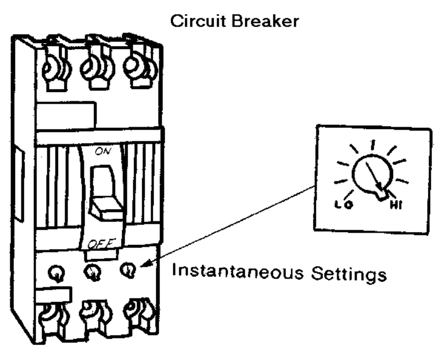


Figure: Adjustable Instantaneous Trip

The following figure indicates the short circuit adjustments for a three-phase circuit breaker. The circuit breaker is designed to protect a number 4 AWG trailing cable. The maximum allowable instantaneous setting is 500 amps. If the adjustable instantaneous trip range is 300-700 amps, the repairman can figure the position of the maximum setting by dividing the difference of the range by 8 (settings). All three phases should be set below 500 amps and as low as possible without creating nuisance tripping.

For example: The instantaneous trip range = 700 - 300 = 400 amps

There are eight settings on the instantaneous trip unit

Each mark or setting = $\frac{400}{8}$ = 50 amps

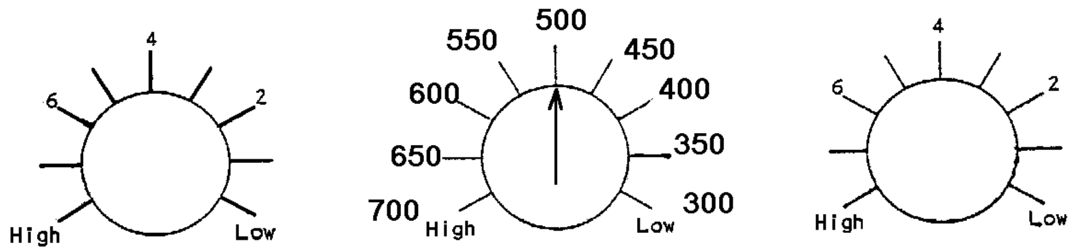


Figure: Adjustable Three-Phase Instantaneous Trip

ENCLOSURE SELECTION GUIDE: INSTANTANEOUS TRIP SELECTION

The electrical repairman should be familiar with the following charts:

Maximum instantaneous-trip settings

Conductor size	Maximum allowable instantaneous setting, A	Conductor size	Maximum allowable instantaneous setting, A
AWG:		AWG:	
14	50	1	1,000
12	75	1/0	1,250
10	150	2/0	1,500
8	200	3/0	2,000
6	300	4/0	2,500
4	500	MCM:	
3	600	250 to 500	2,500
2	800		

Commonly available magnetic-trip ranges for mining-service molded-case breakers

Frame size, A	Magnetic-trip range, A	Range of allowable conductor sizes
100	50– 180	14–10 AWG
	150– 500	10–4 AWG
225	300– 700	6–3 AWG
	500–1,000	4–1 AWG
	300–1,000	6–1 AWG
400	500–1,000	4–1 AWG
	800–1,600	2–2/0 AWG
	500–1,500	4–2/0 AWG
600	900–3,000	1 AWG – 500 MCM
800	750–1,500	2–2/0 AWG
	1,000–2,000	1–3/0 AWG
	1,500–3,000	2/0 AWG – 500 MCM
	2,000–4,000	3/0 AWG – 500 MCM
1,200	1,500–3,000	2/0 AWG – 500 MCM
	2,000–4,000	3/0 AWG – 500 MCM
	2,500–5,000	4/0 AWG – 500 MCM

MAGNETIC TRIP RANGE
(Trailing Cable Short Circuit Protection)

(Trip Ranges)	Lo	1	2	3	4	5	6	7	Hi
150 - 480 Amps	150	191	232	274	315	356	397	439	480
300 - 700 Amps	300	350	400	450	500	550	600	650	700
500 - 1000 Amps	500	562	625	687	750	812	875	937	1000
750 - 1500 Amps	750	844	938	1031	1125	1219	1313	1407	1500
800 - 1600 Amps	800	900	1000	1100	1200	1300	1400	1500	1600
1500 - 3000 Amps	1500	1688	1875	2063	2250	2436	2625	2813	3000
2000 - 4000 Amps	2000	2250	2500	2750	3000	3250	3500	3750	4000
2500 - 5000 Amps	2500	2812	3125	3437	3750	4062	4375	4687	5000

	Lo	1	2	3	4	5	6	7	8	9	10	11	12
50 - 150 Amps	50	58	65	73	80	88	95	103	111	118	126	134	142
66 - 190 Amps	66	75	85	94	104	113	123	132	142	151	161	170	180
150 - 480 Amps	150	175	200	225	250	275	300	325	350	375	400	425	450

Thermal (Overload Protection)

The thermal trip unit/overload device protects electrical circuits from excessive overcurrent. Thermal trip action is achieved using a bimetal strip that is heated by the overload current. On a sustained overload, the bimetal strip will deflect, causing the tripping mechanism to operate. The thermal overload must cool before the circuit can be reenergized.

A bimetal consists of two strips of metal bonded together. Each strip has a different thermal rate of heat expansion. Heat due to excessive current will cause the bimetal to bend or deflect. The metal having the greater rate of expansion will be on the outside (longer boundary) of the bend curve. To trip the breaker the bimetal must deflect far enough to physically push the tripping mechanism and unlatch the contacts.

Deflection is predictable as a function of current and time. This means that a typical 100-amp circuit breaker might trip in 1800 seconds at 135% of rating. Consequently, bimetals provide a long time delay on light overloads; yet have a fast response on heavier overloads.

Thermal elements are calibrated at the factory and are not field adjustable. A specific thermal element must be supplied for each current rating. Circuit breakers are available with various interchangeable thermal overload elements.

Circuit breakers that protect underground trailing cables require four protections:

(1) Overload (2) Under voltage (3) Short circuit (4) Grounded phase

Fixed or Interchangeable Trip Unit

Conventional breakers are available with either a fixed or interchangeable electro-mechanical trip unit, depending upon the type and frame size. On a fixed trip breaker, the entire breaker must be replaced if a new trip unit is needed. On an interchangeable trip breaker, only the trip unit has to be changed up to the maximum rating of the frame. The trip unit can be changed with the breaker already installed and with no modification necessary.

Interchangeable trip breakers have adjustable magnetic elements. The thermal setting is fixed.

Solid State Circuit Breakers

Molded case breakers historically have utilized bimetals and electromagnets to provide overload and short circuit protection. Now, there are molded case breakers on the market that utilize current transformers and solid-state trip units that are reliable, accurate and repeatedly function properly. Once the tripping point is established, it remains constant. The circuit breaker will trip at precisely the established tripping point, time after time. This kind of accuracy and repeatability gives the designer of today's complex electrical systems the most reliable circuit protection.

Terminal Connectors

The function of a terminal connector is to connect a circuit breaker to a desired power source and load. There are various methods of connecting the line and load side of circuit breakers: bus bars, panel board straps, rear connected studs, plug-in adapters, etc. Whenever conductors (cables) are used on the line/load side, terminals are used to connect the conductor to the circuit breaker. There are many different types and sizes available to accommodate single or multiple conductors. The connectors are usually made of copper (for use with copper conductors) or aluminum (for use with copper or aluminum conductors). Whenever aluminum conductors are used, joint compound is recommended to break down oxidation in order to get a better metal-to-metal connection and prevent over heating.

Undervoltage Protection

A potential transformer, and an inverse time undervoltage relay may provide this protection. The relay can either be induction or attraction type. This relay shall trip the circuit breaker when line voltage <u>decreases</u> to 40 percent. Three phase circuit breakers providing protection for equipment shall be equipped with under voltage protection. Before the circuit breaker can be closed, the undervoltage relay must be energized.

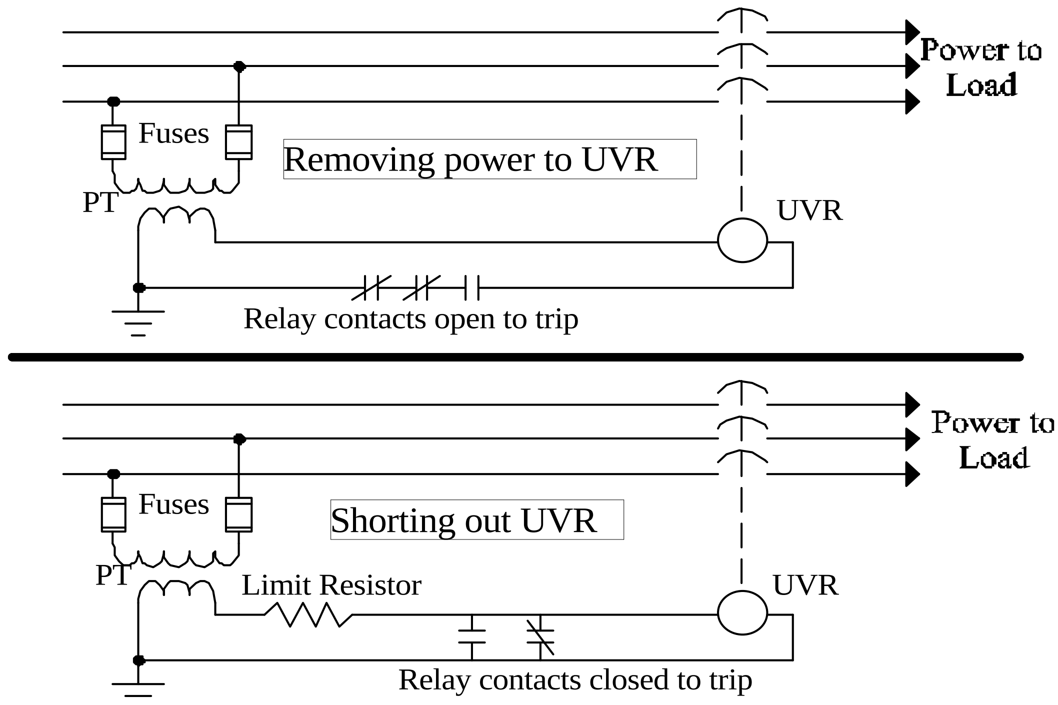


Figure: Typical Control Wiring for UVR

Grounded Phase Protection/Ground Fault Protection

Ground fault protection is essential for the personal protection of coal miners, when a phase to ground fault occurs. For example, if a motor brush lead would loosen and come into contact with the motor frame, then ground fault protection would deenergize the circuit breaker.

Ground fault protection can be accomplished by using four common methods:

1. <u>Direct Relaying</u>
   Measuring ground fault current directly with a current transformer in the grounded neutral line.

2. <u>Balanced Flux Relaying</u>
   Ground fault current can be determined by the unbalance in a three-phase circuit. Ground fault protection is accomplished by using a thru-type (doughnut) current transformer. The three-phase leads are inserted through the center of the current transformer. The ground wire will be kept external to the transformer.

EXAMPLE: Current transformer ratio 50/5 or 10/1
50 N relay pickup = .5 amperes
Ground trip settings = .5 amps x 10 = 5 amperes

3. Potential Relaying
   The voltage drop across the grounding resistor under fault conditions energize a potential transformer and cause a voltage relay in the transformer secondary to operate.

4. Residual Trip Relaying
   Detect the ground fault current as the unbalance in the line current transformers. The ground current would be reflected in the secondary of the current transformers.

Ground-Fault Protection

Ground-fault relays should pick up at no more than 30% of the maximum current limit of the grounding system to provide an ample margin of safety in high-resistance grounded systems. For a 25-amp current limit, this represents a line-conductor unbalance producing a zero- sequence current of about 8 amps. However, such a demand is lower than present protective-circuitry detection capabilities when electromechanical relays are used. For instance, the optimum arrangement with induction-disk relays is zero-sequence circuitry with a 25:5 ampere-turns current transformer in which the most reliable pickup limit is connected to the fact that the window-type current transformer needs a large opening in order to pass the three line conductors through. Here, zero-sequence currents less than 12- amps do not generate enough capacity from the current transformer to drive the relay immediately.

Shunt Trip Protection

The importance of the shunt trip and undervoltage relay is far ranging, as they allow the protection capabilities of circuit breakers to be extended. The molded-case breaker alone can provide overload and short-circuit protection in an outgoing circuit. The UVR adds undervoltage protection; in fact, undervoltage protection is normally required at most underground circuit breaker locations. Note that undervoltage protection is required for all equipment, but it is not required on all circuit breakers as long as all equipment downstream from the breaker has undervoltage protection. The undervoltage protection provided by UVR is actually "loss-of-voltage" protection, since the dropout level is well outside the recommended operating range of most motors. Through a specific combination of relays and sensing devices, additional types of protection can be applied through shunt or UVR tripping. With a shunt trip, the relay completes the circuit between the control circuit power source and the shunt trip solenoid coil. When a UVR is used, the relay removes the control voltage across the solenoid coil. The shunt trip relay differs from the UVR relay in that the shunt trip coil becomes energized and trips the circuit breaker. The UVR trips the circuit breaker when the UVR is de- energized.

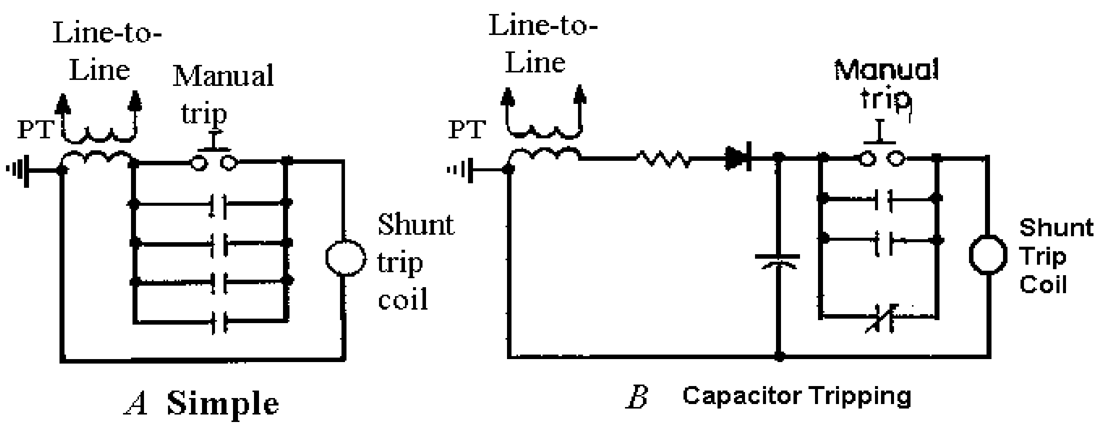
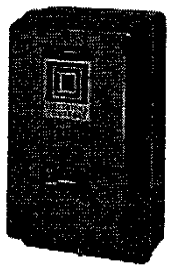
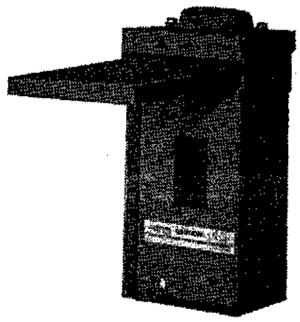
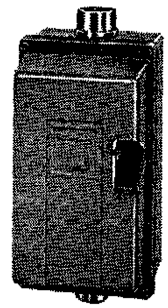


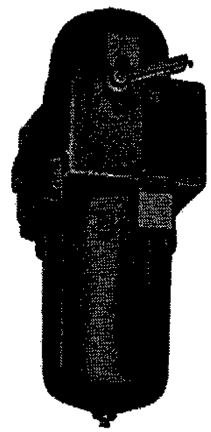
Figure: Typical Control Wiring for Shunt-Tripping Element

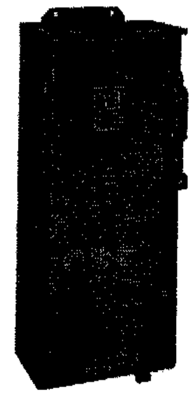
ENCLOSURE SELECTION GUIDE


NEMA Type 1

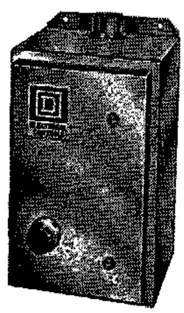

NEMA Type 3R

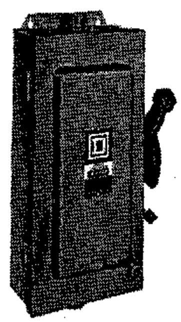

NEMA Type 4X


NEMA Type 7 & 9 SPIN TOP

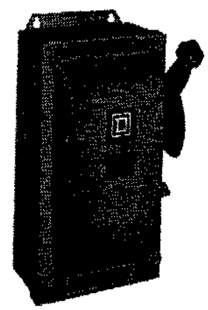

NEMA Type 12


NEMA Type 3


NEMA Type 4


NEMA Type 4 & 5


NEMA Type 9


NEMA Type 12K with Knockouts


NEMA Type 13

ENCLOSURES FOR NON-HAZARDOUS LOCATIONS

Provides Protection Against	Type of Enclosure								
	NEMA Type 1	NEMA Type 3◐	NEMA Type 3R◐	NEMA Type 4▲	NEMA Type 4X▲	Type 5	NEMA Type 12†	Type 12K	NEMA Type 13
Accidental contact with enclosed equipment	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Falling dirt	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Falling liquids and light splashing	...	Yes	Yes	Yes	Yes	...	Yes	Yes	Yes
Dust, lint, fibers and flyings	...	...	...	Yes	Yes	Yes	Yes	Yes	Yes
Hosedown and splashing water	...	...	...	Yes	Yes	...	...	...	...
Oil and coolant seepage	...	...	...	...	...	...	Yes	Yes	Yes
Oil and coolant spraying and splashing	...	...	...	...	...	...	...	...	Yes
Corrosive agents	...	...	...	...	Yes	...	...	...	...
Rain, snow and sleet‡	...	Yes	Yes	△	Yes	...	...	...	...
Windblown dust	...	Yes	...	△	Yes	Yes	...	...	...

ENCLOSURES FOR HAZARDOUS LOCATIONS

Provides Protection Against	Class*	Group*	Type of Enclosure					
			NEMA Type 7			NEMA Type 9		
			7B	7C	7D	9E	9F	9G
Hydrogen, manufactured gas	I	B	Yes	...	...	...	...	...
Ethyl ether, ethylene, cyclopropane	I	C	Yes	Yes	...	...	...	...
Gasoline, hexane, naphtha, benzine, butane, propane, alcohol, acetone, benzol, natural gas, lacquer solvent	I	D	Yes	Yes	Yes	...	...	...
Metal dust	II	E	...	...	...	Yes	...	...
Carbon black, coal dust, coke dust	II	F	...	...	...	Yes	Yes	...
Flour, starch, grain dust	II	G	...	...	...	Yes	Yes	Yes

I. GROUNDING

Mining machines are grounded to avoid unnecessary and dangerous differences of potential between the mining machine and other machines to earth. Most underground mining equipment uses trailing cables to furnish electrical power to its electrical motors. Trailing cables are difficult to maintain in adverse conditions of coal mining. Motors and frames of electrical equipment shall be maintained at ground potential of zero volts at all times.

"Knowledge of grounding is important because electrical grounding is a means of protection for personnel and equipment. Loss of life, personal injury and extensive damage to equipment can result because of improper grounding of electrical equipment". The two types of electrical grounding used to achieve this purpose are:

(1) Equipment grounding (2) System grounding

Equipment Grounding

An equipment ground is a connection to ground of one or more of the non-current-carrying metal parts of the wiring system or equipment connected to the system. Equipment includes conduit, motor frames, switch boxes, outlet boxes, transformer cases, switchgear enclosures, substation fences, and any other metal enclosing or encasing electrical circuits.

The main objectives of an equipment ground are to:

1. Limit the voltage between the metal frames of equipment.

2. Limit the voltage between the metal frames of equipment and the earth to a safe value under all conditions of system operation.

Proper equipment grounding can be achieved by:

1. Connecting together all frames of electrical equipment throughout the grounding system to the source/service ground.

2. Equipment grounding conductors providing a low-resistance return path for ground-fault current to travel to enable the ground fault current protective devices in the circuit to operate.

Four basic components of an equipment grounding system are defined as follows:

1. Ground Electrode: a conductor embedded into the earth for maintaining a ground potential on conductors connected to it.

2. Ground Field: a system of grounding electrodes and interconnected bare conductors buried in the earth to provide a common ground for electrical circuits and equipment.

3. Ground Electrode Conductor: a conductor used to connect the grounding electrode to the equipment-grounding conductor at the source of a mine power system.

4. Equipment Grounding Conductor: a conductor used to connect the non-current carrying metal parts of equipment, raceways, and other enclosures to the grounding electrode conductor at the service equipment or at the source of a separately derived system.

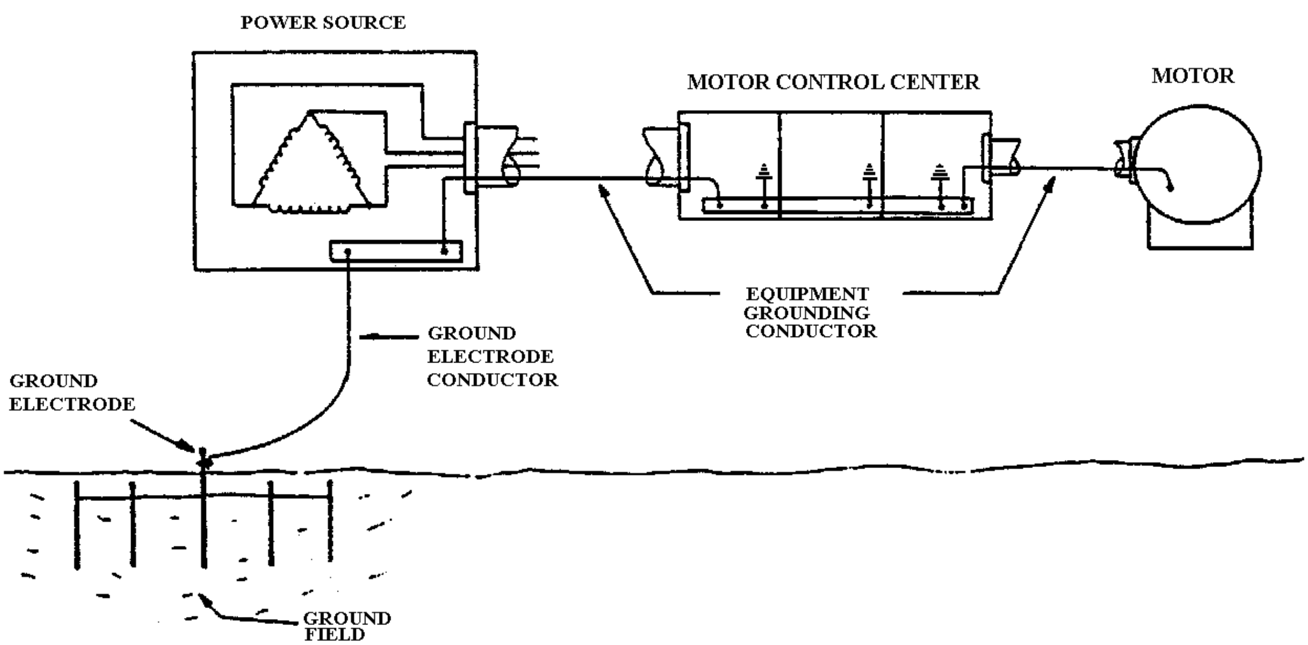


Figure: Basic Grounding

A ground electrode is a conductor of rod, pipe, metal plate, or conductive material used to connect a ground electrode conductor to earth (See previous figure). Sometimes a dependable ground can be obtained by driving a ground rod or pipe into the ground. In some instances, mines have drilled deep boreholes and put copper cable/wire into the borehole to obtain a good ground. The cable/wire serves as a ground electrode.

Neutral Ground

A neutral ground is a connection between the earth and the neutral point of a wye-connected transformer or to the neutral point of a grounding transformer such as a zigzag transformer.

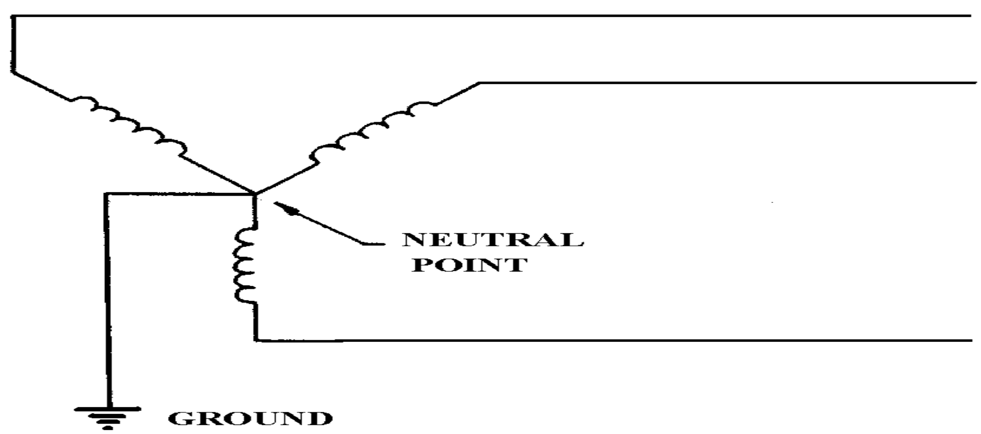


Figure: Neutral Ground

Neutral Ground 75.802 (a)

High-voltage circuits extending underground and supplying portable, mobile, or stationary high-voltage equipment shall contain either a direct or derived neutral which shall be grounded through a suitable resistor at the source transformers, and a grounding circuit, originating at the grounding side of the grounding resistor, shall extend along with the power conductor and serve as a grounding conductor for the frames of all high-voltage equipment supplied power from the circuit.

Single-Phase, 110-220-Volt Circuits

When electrical equipment is powered by a single-phase, 110-220 volt circuit, the one approved method of grounding the metallic frame, casing or other metal enclosure of that equipment and that method is a separate grounding conductor which establishes a continuous connection to a grounded center tap of the transformer feeding that circuit.

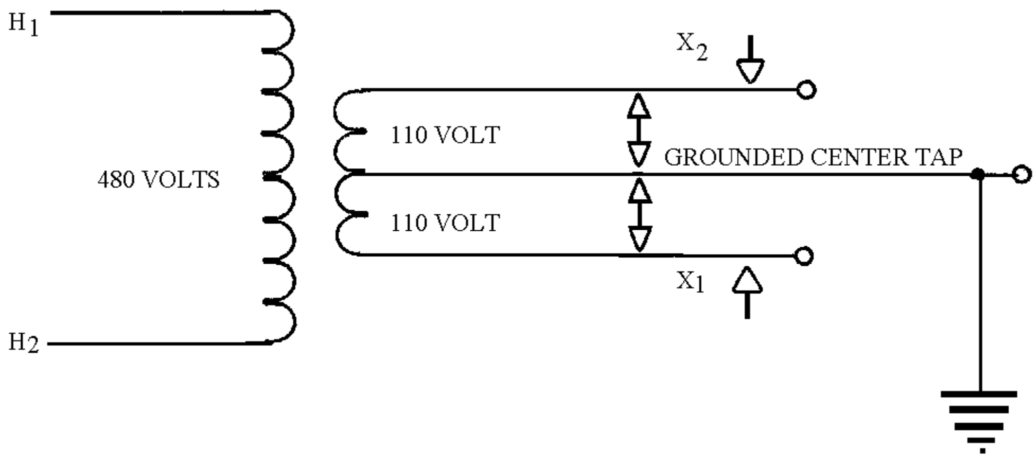


Figure: 110/220 Volt Grounding

The circuit in the following figure illustrates a three-phase wye connection for a mining machine. The voltage system between any phase and ground is 277 volts and a 100-ampere circuit breaker serves the machine through an underground circuit.

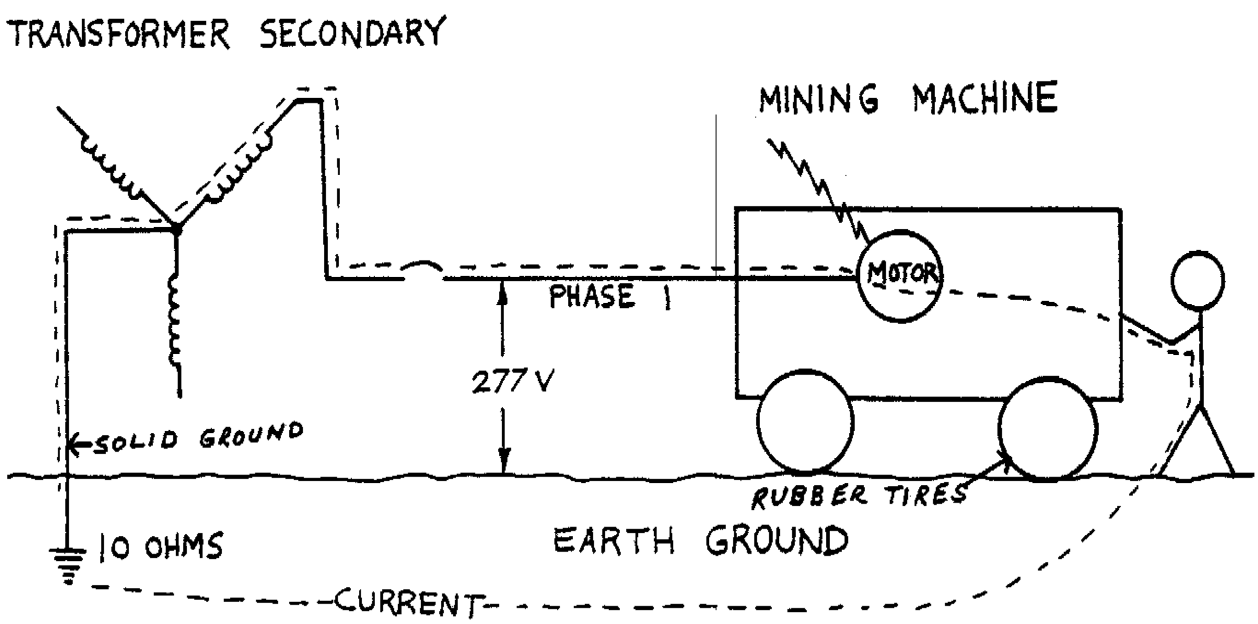


Figure: Mining Machine without Ground Conductor

Assume that Phase 1 becomes grounded to the motor frame inside the mining machine, thereby energizing the mining machine. The machine is now at the same potential as Phase 1 (277 volts to ground).

Without a frame, ground conductor on the machine there would be no fault current, and the machine frame would remain at 277 volts to ground indefinitely. When a person standing on the earth touches the frame of the machine, the current passes through their body, through the earth, back to the source through the ground electrode conductor, and back through the circuit again.

The current will continue flowing indefinitely because there is not enough fault current to cause the circuit breaker to interrupt. The individual exposed to this machine would experience an electrical shock--perhaps fatal.

The following figure shows a circuit grounded at the neutral of the transformer and the mining machine with a frame ground.

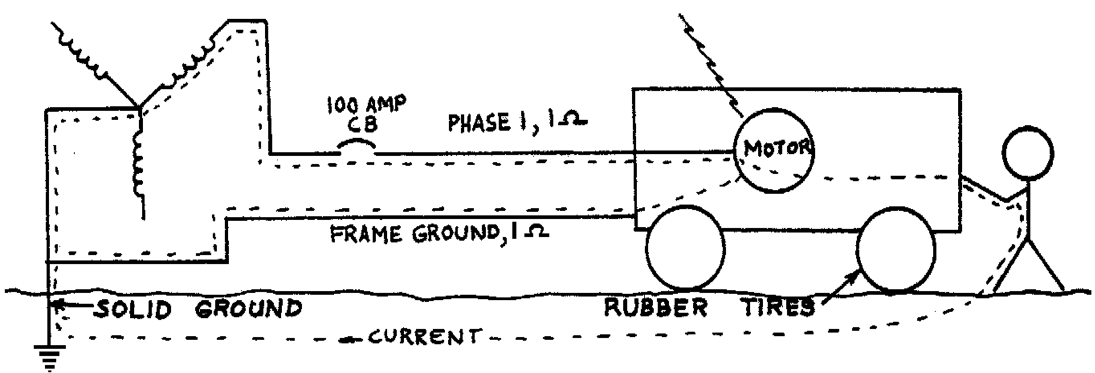


Figure: Mining Machine without a Neutral Ground Resistor

What happens to the circuit when a frame ground conductor is added to the circuit? Whenever a fault develops between phase 1 and the motor frame, there is a fault circuit through the frame ground conductor and back to the source. A voltage of 277 volts begins to force current through the phase wire and back through the frame ground wire. The resistance of the phase conductor is 1 ohm and the resistance of the frame ground wire is 1 ohm. The total resistance if this circuit is 2 ohms. The current that flows is:

$$I = \frac{E}{R} = \frac{277}{2} = 138.5 \text{ amperes}$$

The current, 138.5 amperes is enough to trip the circuit breaker, if set properly.

What would happen if the circuit breaker was not operating properly or bridged out? The fault current would not trip the circuit breaker. The voltage across the frame ground conductor is:

E = I x R
E = 138.5 amperes x 1 ohm
E = 138.5 volts

This is an unsafe voltage. Anyone touching the machine frame can be electrocuted.

The following figure represents the following three conditions:

1. Circuit grounded at machine
2. Mining machine with frame ground
3. Neutral grounding resistor

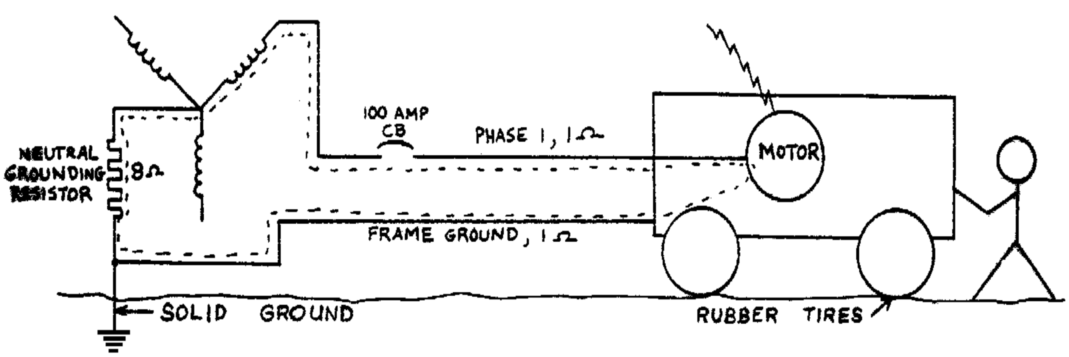


Figure: Mining Machine with Phase to Frame Fault
and Neutral Resistor in Circuit

The circuit above has an 8-ohm neutral ground resistor added to the circuit. When an electrical fault occurs at the motor, the fault current travels through phase 1 conductor, machine frame, frame ground conductor, neutral grounding resistor, transformer winding and back through the circuit again. The fault current is:

$$I = \frac{E}{R} = \frac{277}{10} = 27.7 \text{ amperes}$$

The addition of an 8-ohm neutral ground resistor changes the value of the voltage that can exist on the machine frame. The voltage on the frame of the machine is:

E = I x R
E = (27.7 amperes) x (1 ohm)
E = 27.7 volts

This voltage meets requirements.

Most of the supply voltage is dropped across the 8-ohm neutral grounding resistor. The voltage dropped across the resistor is:

E = I x R
E = (27.7 amperes) (8 ohms)
E = 221.6 volts

The neutral grounding resistor is located inside a power center. The grounding resistor, the ground wire, and the circuit breaker help protect mining personnel from shock or burn hazards.

J. GROUND MONITORING CIRCUITS

Occasionally, phase to ground faults occur on underground electrical equipment. Protection of persons exposed to this equipment depends on a continuous ground wire from the power source to the equipment frame. If the ground wire were broken when a ground fault occurs, a person would be exposed to line-to-neutral voltage. For this reason, the condition of the ground wire is monitored continuously.

To monitor the ground wire, an insulated wire in the cable is used with the ground wire to form a circuit as shown in the figure below.

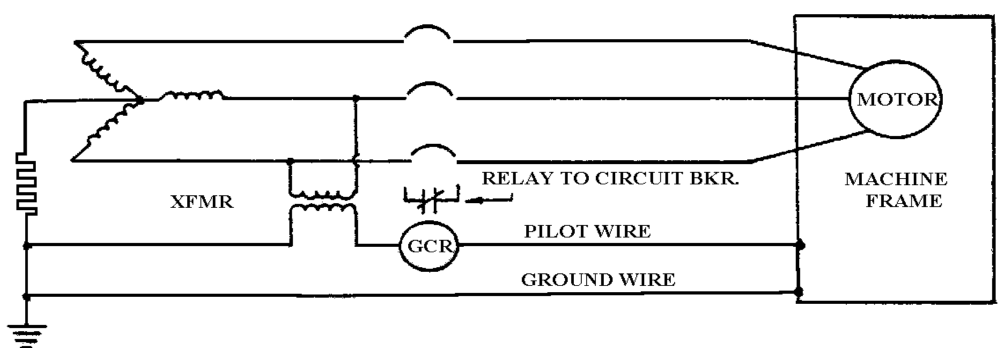


Figure: Pilot (Ground Monitor)

The monitor circuit consists of:

1. Ground wire
2. Pilot wire
A. 3. Ground check relay coil
4. Transformer (supplies power to monitor circuit)

The voltage generated by the transformer causes current to flow through the ground wire, pilot wire, and the ground monitor relay coil. During normal operation, the relay coil keeps the relay contacts closed. The relay contacts are connected to an undervoltage release, which is located inside the main circuit breaker.

What happens when the ground wire or pilot wire is broken? If either of these wires is broken, the ground check relay will be deenergized. The deenergized relay contacts open, thus causing the undervoltage release to trip the main circuit breaker. The main circuit breaker deenergizes the voltage to the machine and removes the shock hazard.

Another method to monitor the ground wire is illustrated below.

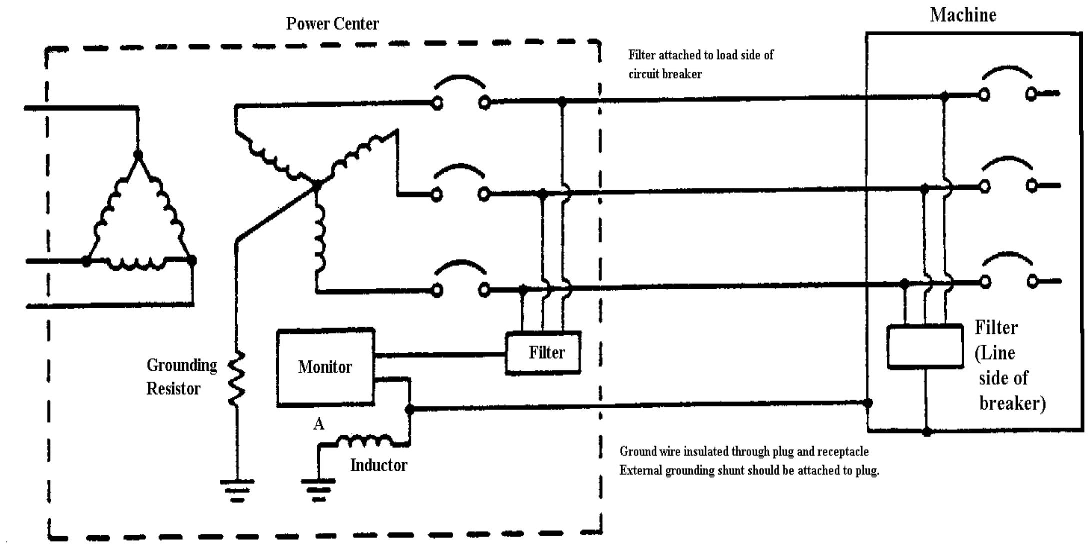


Figure: Continuity-Type Monitor with Inductor-Type Suppressor

The monitor circuit consists of:

1. Ground wire
2. Monitor
3. Filters
4. Parallel path suppression device

A signal generated by the monitor is passed through a filter that is connected to each phase on the load side of the circuit breaker. The signal is transmitted on the phase conductors to the machine where it passes through another filter and returns to the monitor on the ground wire. If the signal path is interrupted (open ground wire) relay contacts in the monitor, which are connected to the circuit breaker undervoltage relay trip unit, causes the circuit to be deenergized.

Due to the possibility of the signal returning to the monitor through the earth or other means than the ground wire, a parallel path suppression device is often installed in the power center.

Fail Safe Ground Check Circuits on High-Voltage Resistance Grounded Systems

Several ground monitoring circuit schemes are acceptable provided they meet the following criteria:

(a) Fail safe design that will deenergize the circuit breaker if ground continuity is broken.
(b) Monitor continuously
(c) Monitor all ground conductors of the system
(d) Use a monitor conductor No. 8 or larger
(e) Voltage source not in excess of 96 volts

The following circuit schemes meet the above specifications:

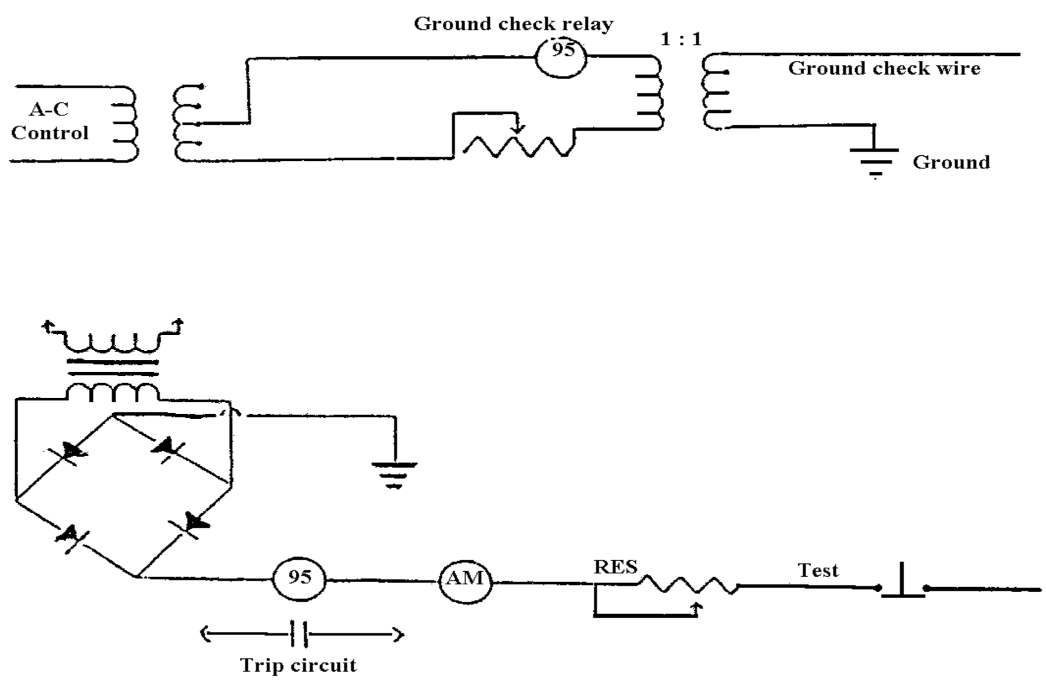


Figure: Ground Monitor

K. RECTIFIERS

Commercial power lines normally provide us with alternating current. However, a great variety of DC motors, welders, electro-chemical processes, and electronic devices need a steady supply of direct current for their operations. In general, a rectifier is a device for converting alternating current to direct current (AC to DC). Diodes are also used to provide frame grounding for direct current equipment.

Three-phase rectifiers are used in the mining industry for battery charging and trolley wires. The three-phase rectifier will have an output DC voltage that is 1.35 times the input voltage.

$E_{(DC\ OUTPUT)} = 1.35 \times E_{LL}$

$E_{(DC\ OUTPUT)} = 1.35 \times 480 = 638$ volts (DC)

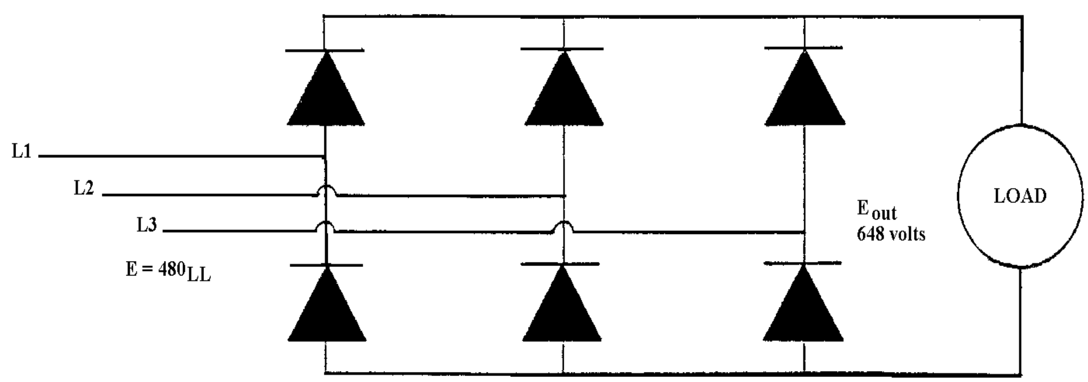


Figure: Three-Phase Rectifier

L. TRANSFORMERS

A transformer is an electrical device consisting of a primary and a secondary winding linked by a mutual magnetic field. The voltage across the primary coil (winding) is supplied by an external source. The voltage appearing across the secondary coil is induced by the magnetic flux of the primary coil. Transformers come in many sizes, ranging from about the size of a peanut to very large ones that are used by the utility companies and the mining industry. A transformer is a device that transfers electrical energy from one circuit to another by means of electromagnetic mutual induction. The energy is always transferred without a change in frequency, but changes in voltage and current are usually involved. A transformer will step up or down AC voltage.

It should be noted that a transformer is strictly an AC device. If the primary of a transformer was connected to a DC source, once the current reached the maximum steady value described by Ohm’s law, there would be no change in current, the frequency would be zero, and there would be inductive reactance. The coil would act like a straight piece of wire, and because of its low resistance, the current would become too great and burn out the transformer.

Turns Ratio

The total voltage induced into the secondary winding of a transformer is determined by the ratio of primary turns to secondary turns and the amount of voltage applied to the primary. A transformer in which the primary consists of ten turns of wire and the secondary consisting of one turn, the ratio will be 10:1. Therefore, for every ten volts measured across the primary, one volt will be measured across the secondary. The same principal can be used in the appropriate way to calculate turns ratio for a step up transformer.

The total current induced into the secondary winding of a transformer is determined by the ratio of primary turns to secondary turns and the amount of current applied to the primary. A transformer in which the primary consists of ten turns of wire and the secondary consisting of one turn, the ratio will be 10:1. Therefore, for every amp across the primary, 10 amps will be measured across the secondary. The current ratio is opposite of the voltage ratio for transformers.

Three-Phase Transformers

Three phase transformers are three identical single phase transformers connected (wired) together to take advantage of different characteristics. For example, a wye-connected secondary has a neutral point that may be used for a grounding point.

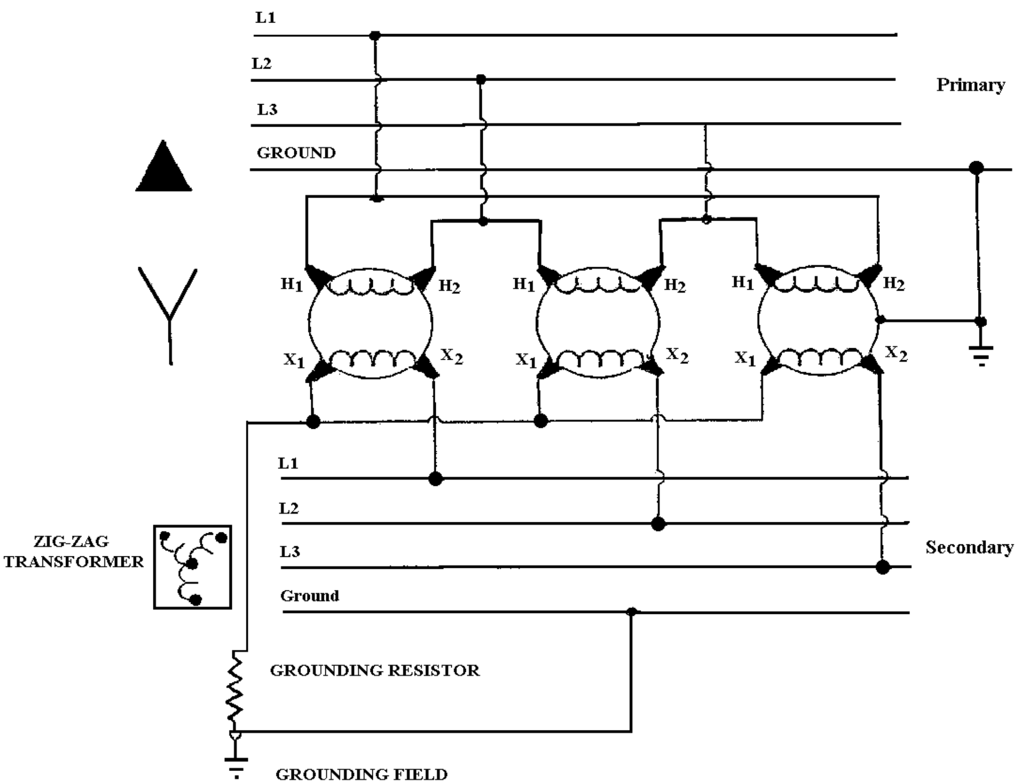


Figure: Delta/Wye-Connected Power System with Grounding Resistor

There are four possible ways a three-phase transformer can be connected: delta-wye, wye-delta, delta-delta, and wye-wye.

The use of the wye-delta provides for a natural step-up or step-down. The wye-delta connection does not provide for a neutral point for grounding on the secondary. Therefore, a grounding transformer "zigzag" is used to establish a neutral for grounding purposes.

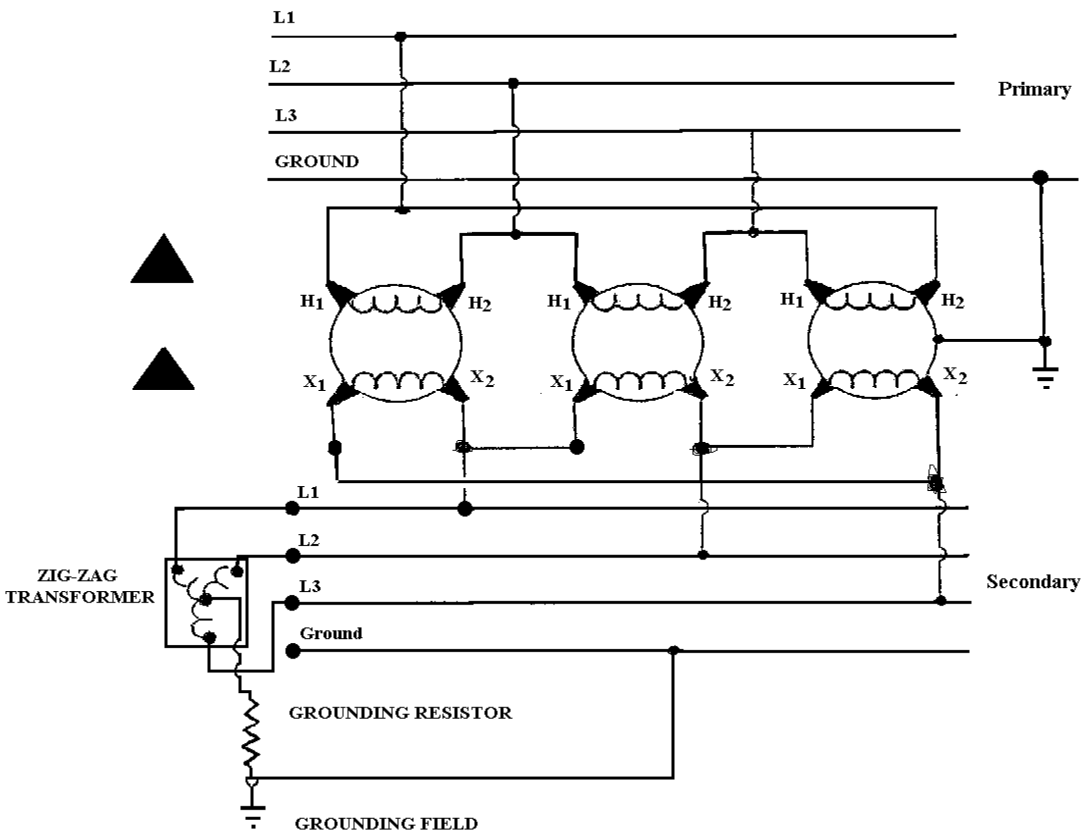


Figure: Delta/Delta with Grounding Transformer

The delta connection has no neutral. This can be an advantage as well as a disadvantage. In order for a delta connected system to be used as a power supply to a coal mine using mobile electrical equipment, it is required that the delta system be effectively grounded by a zigzag transformer or other suitable means.

A zigzag transformer is a transformer with half the turns per winding going one direction and the other half of the turns going in the opposite direction. The effect of this type of winding is due to the inductances created. The impedance is very high between any two of the coils. Under normal load conditions virtually no current flows through the zigzag. The impedance of the coils to ground is very low (less than 4 ohms) so that high ground currents may flow freely through the phase to neutral connection of the zigzag. The transformer divides the ground current into three equal components and allows them to flow through the windings of the transformer. Because of the opposite direction of the windings in the zigzag, any magnetic flux is cancelled (except for a small leakage).

M. METHANE MONITORS

Methane monitors are devices used to detect the presence of methane (CH4). Methane monitors shall be installed and maintained in accordance with manufacturer recommendations. It is very important for the certified electrical repairman to understand the operation and maintenance of the methane monitor. If there is any doubt, the repairman should contact the manufacturer of the methane monitor for specific instructions.

§ 45.1-161.195 Inspection of electric equipment and wiring; checking and testing methane monitors.

A. Electric equipment and wiring shall be inspected by a certified person at least weekly if located underground, and at least monthly if located on the surface, and more often if necessary to assure safe operating conditions, and any hazardous condition found shall be promptly corrected or the equipment or wiring shall be removed from service. Records of such examination shall be maintained at the mine for a period of one year.

B. A functional check of methane monitors on electrical face equipment shall be conducted to determine that such monitors are de-energizing the electrical face equipment properly. Such check shall be made on each production shift and shall be conducted by the equipment operator in the presence of a mine foreman, and shall be recorded in the on-shift report of the mine foreman.

C. Weekly calibration tests on methane monitors on electrical face equipment to determine the accuracy and operation of such monitors shall be conducted with a known mixture of methane at the flow rate recommended by the methane monitor and manufacturer. A record of the results shall be maintained.

D. Required methane monitors shall be maintained in permissible and proper operating condition.

§ 45.1-161.215 Notice of monitor tampering prohibition

Notice of monitor tampering prohibition.
The operator or agent, shall display, in bold-faced type, on a sign placed at the mine office, at the bath house, and on a bulletin board at the mine site,

the following notice:
NOTICE: IT IS UNLAWFUL TO DISTURB, DISCONNECT, BYPASS, IMPAIR, OR OTHERWISE TAMPER WITH METHANE MONITORS OR OTHER DEVICES CAPABLE OF DETECTING THE PRESENCE OF EXPLOSIVE GASES IN AN UNDERGROUND COAL MINE. A VIOLATION IS PUNISHABLE AS A CLASS 6 FELONY.

§ 45.1-161.232 Tampering with methane monitoring devices prohibited; penalty

A. No person shall intentionally disturb, disconnect, bypass, impair, or otherwise tamper with methane monitors or other devices capable of detecting the presence of explosive gases used in an underground coal mine. If the methane monitor is installed on a face cutting machine, continuous miner, longwall face equipment, loading machine, or other mechanized equipment used to extract or load coal as required pursuant to 30 CFR Part 75.342, and the monitor or the equipment malfunctions, the monitor may be disconnected or bypassed for the purposes of removing the monitor or the equipment in order to make necessary repairs to the monitor or the equipment. Any other methane monitor may be disconnected, bypassed or removed.

B. Any person convicted of a violation of this section shall be guilty of a Class 6 felony.

Cross References. --As to punishment for Class 6 felonies see § 18.2-10.

§ 45.1-161.233. Allowing persons to work in mine where methane-monitoring equipment disconnected; penalty.
An operator, agent, or mine foreman shall not knowingly permit any miner to work in any area of the underground coal mine where such operator, agent, or mine foreman has knowledge that a methane monitor or other device capable of detecting the presence of explosive gases has been impaired, disturbed, disconnected, or bypassed in violation of § 45.1-161.232. Any person convicted of a violation of this

N. Surface Electrical and the National Electric Code

The Mine Safety Laws of Virginia section 45.1-161.246 requires that Article 9 of Surface Coal Mines also apply to the surface areas of underground mines.

Article 9, section 45.1-161.228 requires:

- Automatic circuit breaking devices or fuses of the correct type and capacity shall be installed so as to protect all electric equipment and power circuits against excessive overload. Wires or other conducting materials shall not be used as a substitute for properly designed fuses, and circuit breaking devices shall be maintained in safe operating condition.
- Operating controls, such as switches, starters, and switch buttons, shall be so installed that they are readily accessible and can be operated without danger of contact with moving or live parts.
- Electric equipment and circuits shall be provided with switches or other controls of safe design, construction and installation.
- Insulating mats or other electrically nonconductive material shall be kept in place at each power-control switch and at stationary machinery where shock hazards exist.
- Suitable danger signs shall be posted conspicuously at all high-voltage installations.
- All power wires and cables shall have adequate current-carrying capacity, shall be guarded from mechanical injury and installed in a permanent manner.
- Power circuits shall be labeled to indicate the unit or circuit they control.
- Persons shall stay clear of an electrically powered shovel or other similar heavy equipment during an electrical storm.
- All devices installed on or after July 1, 2005, which provide either short circuit protection or protection against overload, shall conform to the minimum requirements for protection of electric circuits and equipment of the **National Electric Code** in effect at the time of their installation.
- All electric conductors installed on or after July 1, 2005, shall be sufficient in size to meet the minimum current-carrying capacity

provided for in the **National Electric Code** in effect at the time of their installation.

- All trailing cables purchased on or after July 1, 2005, shall meet the minimum requirements for ampacity provided in the standards of the Insulated Power Cable Engineers Association - National Electric Manufacturers Association in effect at the time such cables are purchased.

The purpose of the **National Electric Code** (NEC) is the practical safe guarding of persons and of buildings and their contents from hazards arising from the use of electricity for light, heat, power, radio, signaling and for other purposes. The NEC contains basic minimum provisions considered necessary for safety. Compliance therewith and proper maintenance will result in an installation essentially free from hazard, but not necessarily efficient, convenient, or adequate for good service or future expansion of electrical use.

Hazards often occur because of overloading of wiring systems by methods or usage not in conformity with the NEC. This occurs because initial wiring did not provide for increases in use of electricity. For this reason it is recommended that the initial installation be adequate and that reasonable provisions for system changes be made as may be required for future increase in the use of electricity.

The NEC is not intended as a design specification nor an instruction manual for untrained persons. The NEC covers the electric conductors and equipment installed within or on public and private buildings and other premises, including yards, carnival and parking lots, and industrial substations; also the conductors that connect the installations to a supply of electricity, ant other outside conductors adjacent to the premises; also mobile homes and travel trailers.

The NEC does not cover installations underground in mines unless other wise required by the Code of Federal Regulations or Virginia Mine Safety Laws.

National Electric Code Questions and Answers

Q. All surface wiring and electrical equipment must meet the requirements of the ______________________.
A. National Electric Code that is in effect at the time of installation

Q. The National Electric Code is a _____________________________.
A. Recognized guideline for electrical installations

Q. What does continuous load mean?
A. A load where the maximum current is expected to continue for three hours or more

Q. What does enclosed mean?
A. Surrounded by a case, which will prevent a person from accidentally contacting live parts

Q. What is the purpose of a thermal strip in an AC line starter?
A. To provide overcurrent protection

Q. The part of the wiring system extending beyond the last overcurrent protective devices is called the ______________.
A. Branch circuit

Q. The minimum wire size for a 15-amp branch circuit is ____________.
A. No. 14 AWG

Q. By using the NEC, an electrician that knows a conductor's "AWG" can determine the ______________.
A. Allowable current carrying capacity of the conductor.

Q. "THW" marked on a conductor refers to that conductor's _________.
A. Application and insulation rating.

Q. When reference is made to conductors in the National Electric Code (NEC), what type of material is assumed?
A. Copper

Q. Grounded conductors (not the frame ground) will be identified by their color, which is _____________.
A. White or natural gray

Q. What color insulation is associated with the frame-grounding conductor?
A. Green

Q. What minimum length of free conductor should be left at each outlet and switch point for making up joints, or connecting fixtures or devices?
A. 6 inches

Q. The secondary winding of a single-phase transformer has a full load current of 30 amperes. The power leads are single conductor, type TW rated at 60 centigrade. What would be the minimum size conductor used on the secondary?
A. No. 10 AWG

Q. In most cases, the minimum sized (solid or stranded) conductor allowed when wiring a control panel is _______________.
A. No. 14 AWG

Q. The cable or wire insulation is rated for _______________.
A. Voltage, moisture resistance, and heat resistance

Q. Within one minute after a 550-volt capacitor is disconnected, its residual voltage must be reduced to _________________.
A. 50 volts or less

Q. If a branch circuit were protected by a 20-amp fuse, what would be the allowable continuous load of the circuit?
A. 16 amps

Q. The circuit breaker setting is the value of the _________________.
A. Current at which the circuit breaker is set to trip.

Q. The continuous load supplied by a branch circuit should not exceed a rating of ________________.
A. 80 percent

Q. Branch circuit conductors supplying a single motor should have an ampacity or not less that ___________of the motor full load rating.
A. 125 percent

Q. Thermal overload relays are designed to provide what type of protection?
A. Overload and single phase

Q. Cartridge fuses are rated for ___________.
A. Ampere rating, the name or trade mark of the manufacturer, and the voltage rating

Q. Grounding rods or pipes should be driven to a depth of at least:
A. 8 feet

Q. Appropriate materials for grounding electrode conductors are:
A. Copper, aluminum, or copper clad aluminum

Q. When used as a ground, the resistance of made electrodes should be:
A. 25 ohms or less to ground

Q. Single throw knife switches are mounted hinge end down so that:
A. Gravity will not tend to close the knife switches.

Q. The NEC requires that live parts of electrical equipment operating at _________ or more shall be guarded against accidental contact.
A. 50 volts

Q. An enclosure constructed, protected, or treated to prevent rain from interfering with successful operation of the apparatus is termed:
A. Rainproof

Q. An electrical apparatus enclosed in a case that is capable of withstanding an explosion from a specified gas or vapor is termed:
A. Explosion proof

Q. According to the NEC “dustproof” means so constructed or protected that:
A. Dust will not interfere with successful operation.

Q. According to the NEC "dust tight" means _____________.
A. Dust will not enter the enclosure case.

Q. According to the NEC "water tight" means _____________.
A. So constructed that moisture will not enter the enclosure case

Q. Locations that are hazardous due to the presence of combustible dust are classified by the NEC as _____________.
A. Class II

Q. Electrical equipment used in atmospheres containing hazardous concentrations of gases and vapors are classified as _____________.
A. Class I

Q. De-rating of conductors begins when the number of current carrying conductors pulled into a conduit exceeds ____________.
A. Three

Q. What is required when the conductor bushing at the entrance of a cabinet, junction box, or pull box is made entirely of insulating materials?
A. A locknut must be installed on the conduit both inside and outside the enclosure to which the conduit is attached.

Q. Conduit must be firmly fastened within how many feet of each outlet box, junction box, cabinet, or fitting?
A. 3-feet

Q. Flexible metal conduit must be secured within ___________ of each outlet box or fitting.
A. 12 inches

Q. Rigid metal conduit up to ¾ inch in size must be firmly fastened within 3 feet of each outlet box or fitting and be supported at what minimum interval?
A. Every 10 feet

Q. What is the maximum number of bends allowed in one run of conduit, between outlet and outlet, fitting and fitting, or fitting and outlet?
A. 4 quarter bends (360 degrees)

Q. Which device protects the wire from abrasion where conduit enters a disconnect switch box?
A. Bushings

Q. Conduit must be clearly and durably identified every ______________.
A. 10 feet

Q. What is the minimum sized metallic tubing that may be used?
A. ½ inch

Q. What is the minimum sized diameter allowed for rigid metal conduit?
A. ½ inch

O. ELECTRIC CIRCUITS AND EQUIPMENT REVIEW

Q. What is the resistance when a resistor is connected across a 250- volt source and dissipates 500-watts?

A. Current will equal the wattage divided by the voltage. The resistance will equal the voltage divided by the amperage. (125-ohms)

Q. What will happen if two terminal leads that feed a three-phase motor are reversed?

A. The motor's rotation will reverse.

Q. A megger (megohmeter) is used to check the resistance of _______.

A. Winding insulation to ground (Transformers, cables, motors)

Q. How are ground resistors rated?

A. Continuous duty and phase-to-phase voltage

Q. If 550 volts are measured from phase-to-phase on the secondary of a Wye-connected transformer, what is the phase-to-ground voltage?

A. 318 volts $E_{PG} = \frac{E_{PP}}{1.73}$

Q. The phase voltage to ground is equal to what times phase-to-phase voltage in a 3-phase Wye-connected motor?

A. .58 $E_{PG} = E_{PP} \times .58$

Q. Of the four possible combinations of three phase transformer connections, which will give the greatest current-handling capacity?

A. Delta to Delta

Q. What two protections will dual element fuses provide?

A. Short circuit and overload

Q. If two resistors of equal value were connected in parallel, what would be the total value?

A. The total resistance would be smaller and since the resistors are equal, the total resistance would be ½ the value of one of the resistors.

Q. If two capacitors were connected in series, what would be the total capacity?

A. The total capacitance would be smaller. Capacitors in series mathematically calculate like resistors in parallel.

Q. Will the capacity increase for capacitors connected in parallel?

A. Yes, capacitors in parallel calculate like resistors in series.

Q. What A.C. Motor requires the larger-cable wiring?

A. Motors with less voltage and higher horsepower require larger wiring in order to handle the higher current required to deliver the horsepower.

Q. If 13,200 volts are measured from phase-to-phase across a wye connected secondary, what is the phase-to-ground voltage?

A. 7,630 volts $E_{PG} = \frac{E_{PP}}{1.73}$

Q. A single-phase transformer has a primary voltage of 2,400 volts and a secondary reading of 120 volts. If there are 1,500 turns on the primary, how many turns are on the secondary?

A. 75 turns

Q. What is the smallest size trailing cable that can be used for underground AC powered mobile haulage equipment?

A. #6 AWG

Q. A transformer has 2,000 turns in the primary and 500 turns in the secondary. The primary voltage is 3,200 volts. What is the secondary voltage?

A. 800 volts

Q. What are AC transformers used for?

A. Step up or down AC voltage and AC current

Q. What kind of transformer usually has a 1 to 1 ratio?

A. Equalizing transformer or isolating transformer

Q. What does the primary of a step-down transformer have different from the secondary?
A. Higher voltage and lower current

Q. What distance should separate the neutral ground field of an underground mine from the lightning arrester grounds?
A. 25 feet

Q. For what duty should ground resistors be rated?
A. Continuous

Q. What is the total capacitance, when capacitors are connected in parallel?
A. The sum of the two capacitors

Q. Why is high voltage used to transmit power over long distances?
A. Because less current flowing at high voltage causes less line loss per kilowatt. With less current then the conductors can be smaller.

Q. What is the wire size in the secondary of a 10:1 step-down transformer?
A. Larger than that found in the primary winding

Q. If the conductors of a balanced, three-phase circuit pass through a current transformer, how many amps will flow in the transformer?
A. Zero amps

Q. What is the purpose of a zigzag transformer?
A. Derive a neutral for ground purposes

Q. How many feet from the neutral ground bed should lightning arrestor grounds be, at the surface of an underground mine?
A. 25 feet

Q. What is an acceptable method for the installation of surface transformers?
A. Surface transformers shall be surrounded by a locked 6 feet high fence or elevated by at least 8 feet.

Q. What kind of transmission is provided by AC power?
A. It provides excellent transmission with less voltage loss

Q. Where should ground resistors be located?
A. At the source transformer

Q. What is the minimum allowable size for trailing cables for mobile haulage equipment powered by direct current?
A. #4 AWG

Q. Should a ground fault occur, what device can be installed to limit the current in the neutral of a three-phase AC system?
A. Neutral grounding resistor

Q. What is the combined capacitance of two capacitors in series?
A. $$C_T = \frac{C_1 \times C_2}{C_1 + C_2}$$

Q. How many volts shall the grounding resistor limit the voltage drop in the grounding circuit external to the resistor?
A. 100 volts is the maximum voltage drop external to the grounding resistor (30 CFR 77.801)

Q. In a 4:1 step-down transformer, what will the primary current be?
A. The primary current is four times less than that of the secondary

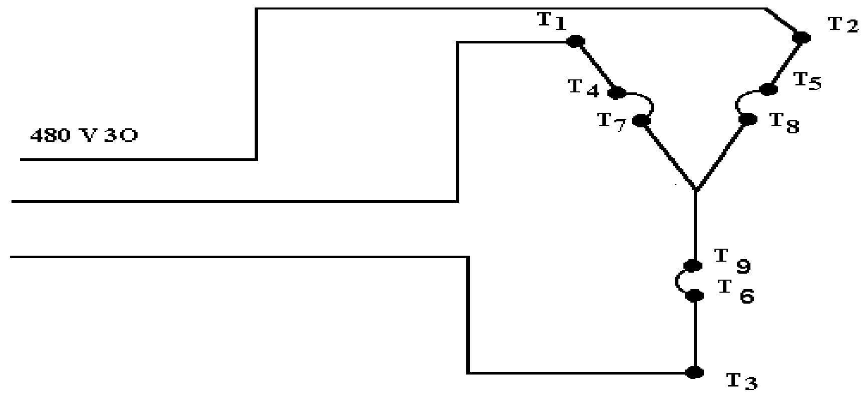
Q. What is the best device to limit the current in the neutral of a three-phase AC system, if a ground fault occurs?
A. Grounding resistor

Q. What should be the duty rating of a grounding resistor?
A. Continuous

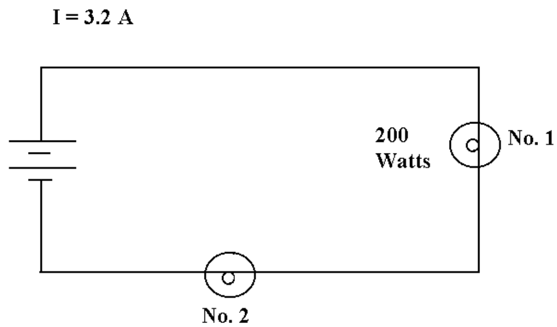
Q. What happens when two conductors of different potential come in contact with one another?
A. A short circuit occurs and high current flows

Q. Hook up the motor to run on high voltage and connect to the power source.

A.



Q. Determine the voltage across bulb number 1.

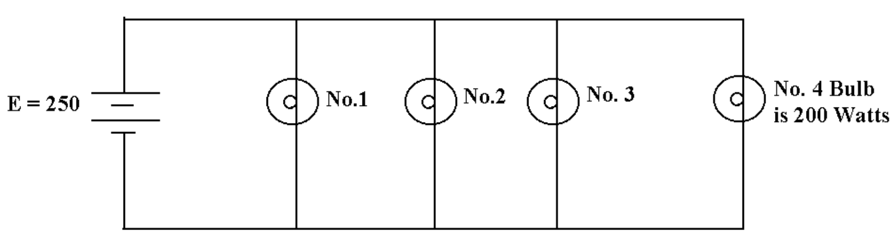


$$E = \frac{P}{I}$$

$$E = \frac{200}{3.2}$$

E = 62.5 volts

Q. Determine the voltage across bulb number 4 and the current through bulb number 4.

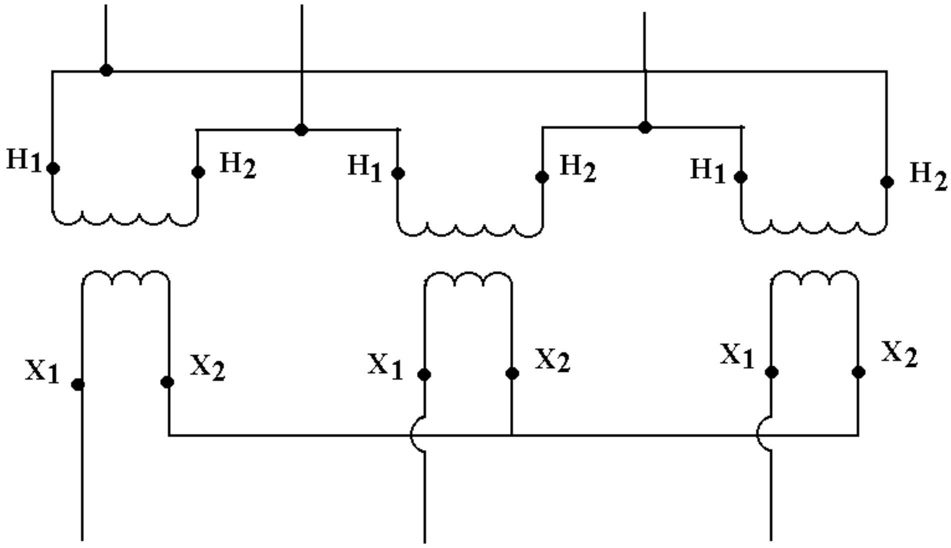


Voltage = 250 volts (source voltage) across bulb #4

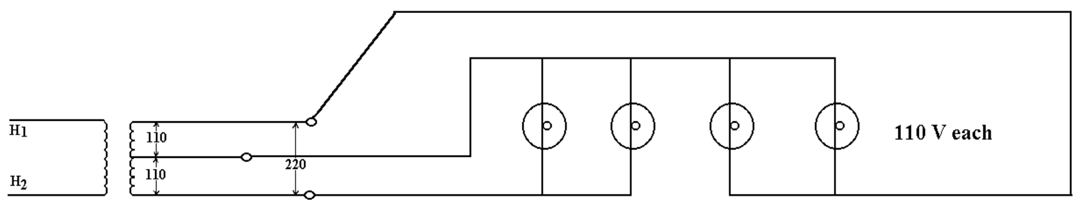
Current = through bulb #4

$$I = \frac{P}{E} \quad \text{or} \quad I = \frac{200}{250} \quad \text{or} \quad I = .8 \text{ amps}$$

Q. Label Delta-Wye (star) and connect the following transformer.



Q. Connect the four 110-volt lamps to provide a balanced load.
(Transformer winding produces 220 volts.)
A.



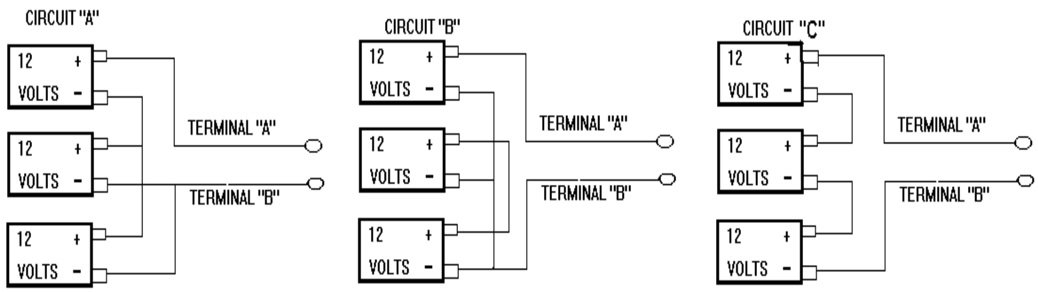
Q. Is it true, when a reverse low voltage is applied to a diode, a few microamperes will flow?
A. Yes, leakage current will flow

Q. What are the ratings, which are given for diodes by the manufacturers?
A. Forward current and reverse voltage

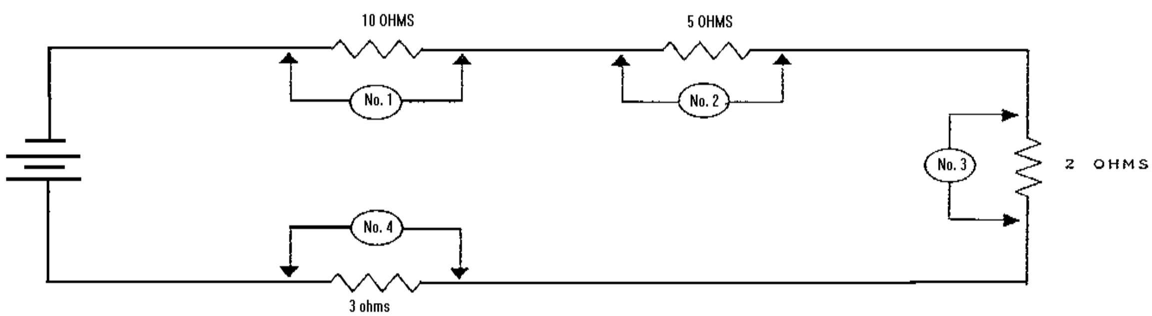
Q. What type of A C motor is most commonly found in a coal mine?
A. Squirrel cage induction motor (SCIM).

Q. What is the characteristic of a diode?
A. Current to flow in one direction only

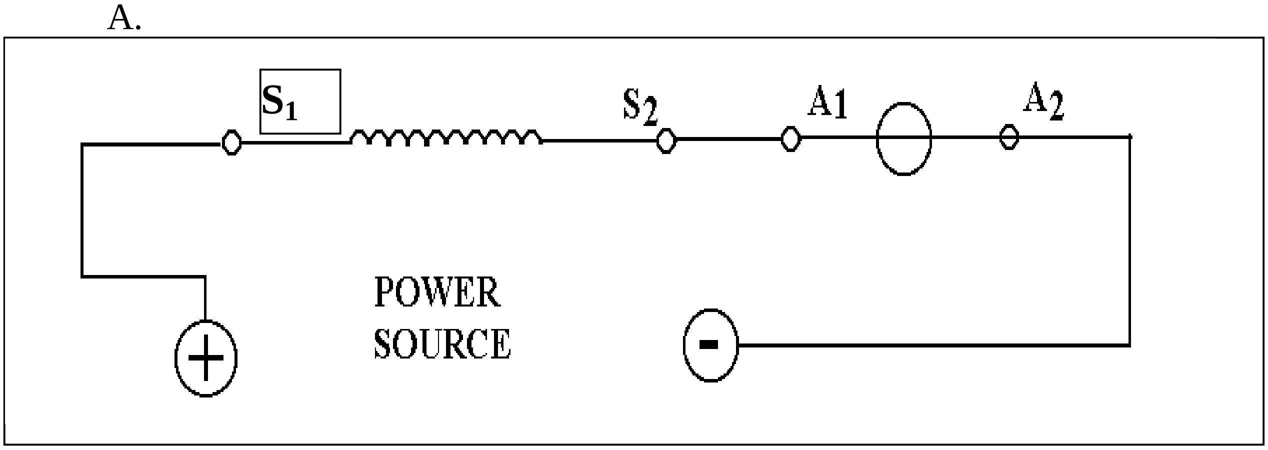
Q. Which of the following 12-volt battery hookups will produce 36 volts between terminals?
A. Circuit C



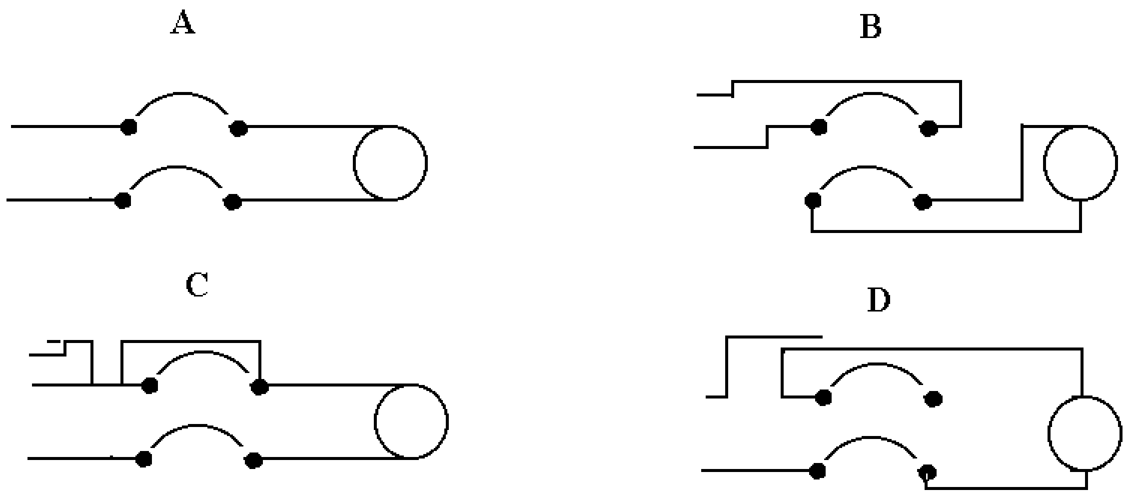
Q. Which voltmeter will read the highest voltage?
A. Voltmeter No.1



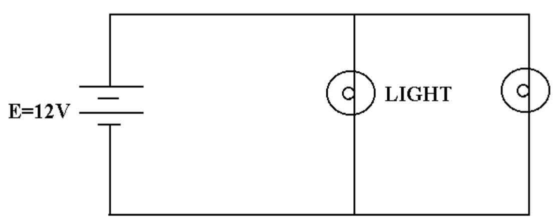
Q. Connect a D C series motor?
A.



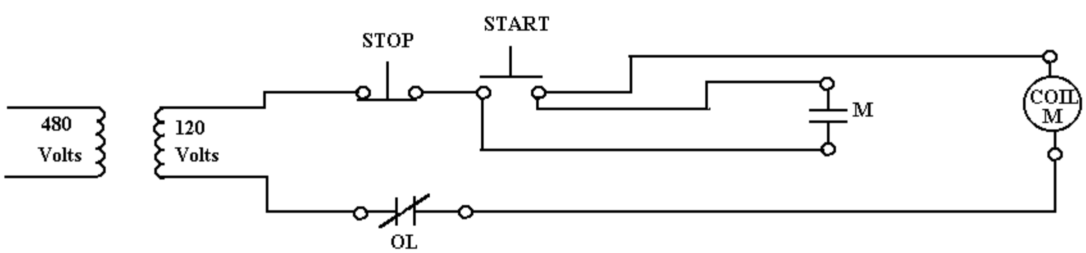
Q. Which diagram shows the correct way to connect a circuit breaker?
   A. Diagram A



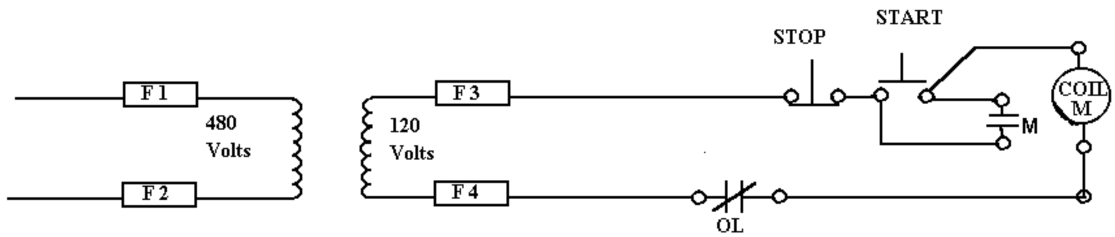
Q. Connect two headlights in parallel?
   A.



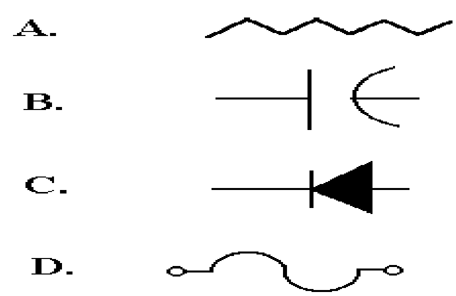
Q. Hook up a start-stop switch in a line starter coil circuit.
   A.



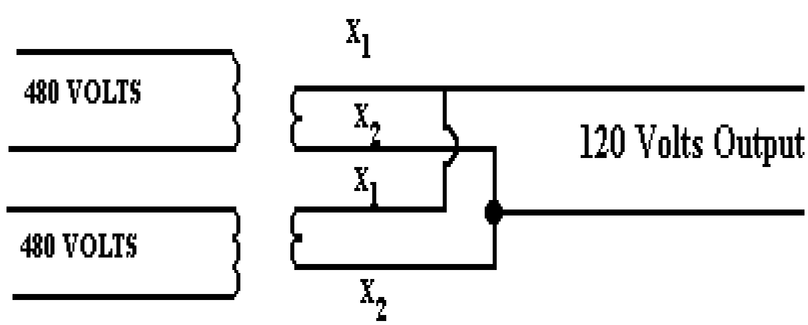
Q. Connect fuses in a control circuit.
A.



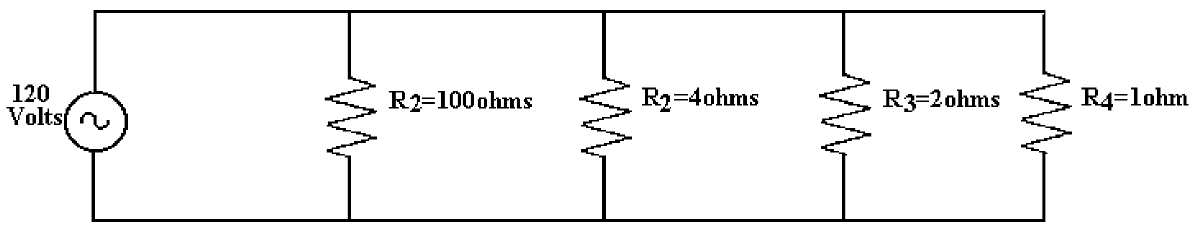
Q. Which symbol represents a diode in an electrical diagram?
A. C



Q. What is the correct way to parallel the low voltage output of two 480/120-volt transformers?
A.



Q. Which resistor will have the highest current through it?
A. R_4, the one-ohm resistor



Q. What is the purpose of the ground monitoring (ground check) circuit in a mine power system?
A. To ensure that the ground wire is continuous and properly connected

Q. What is the purpose of the overload relay coils and overload contacts in an A C motor circuit?
A. To keep the motor from overheating

Q. What device provides short circuit protection for a trailing cable?
A. Circuit breaker (instantaneous trip)

Q. What is the first step to take when starting to work on a piece of D C track equipment?
A. Disconnect the trolley pole from the trolley wire

Q. What will happen if the load on an AC motor is big enough to cause the motor to stall?
A. The current to the motor will increase rapidly

Q. What is the main purpose of the starting resistors for a DC motor?
A. To limit the motor current during starting

Q. What will an ohmmeter show, if it is connected across a 100-amp fuse and the fuse is good?
A. Low resistance reading (near zero)

Q. In a wye (star) transformer secondary connection, what is the line to neutral voltage?
A. Less than the line-to-line voltage by 58 percent

Q. What happens if five light bulbs are wired in series and one of the bulbs burns out?
A. The other bulbs will not burn.

Chapter 4
Cable Splicing

CHAPTER 4

CABLE SPLICING

A. Virginia Mine Safety Act

§ 45.1-161.188 Grounding

A. All metallic sheaths, armors, and conduits enclosing power conductors shall be electrically continuous throughout and shall be grounded effectively.

B. Metallic frames, casing, and other enclosures of stationary electric equipment that can become "alive" through failure of insulation or by contact with energized parts shall be grounded effectively, or equivalent protection shall be provided.

C. Three-phase alternating current circuits used underground shall contain either a direct or derived neutral which shall be grounded through a suitable resistor at the power center, and a grounding circuit, originating at the grounded side of the grounding resistor, shall extend with the power conductors and serve as the grounding conductor for the frames of all the electrical equipment supplied power from that circuit. High-voltage circuits extending underground shall be supplied with a grounding resistor of a proper ohmic value located on the surface to limit the voltage drop in the grounding circuit external to the resistor to not more than 100 volts under fault conditions. The grounding resistor shall be rated for maximum fault current continuously and insulated from ground for a voltage equal to the phase-to-phase voltage of the system. All resistance-grounded alternating circuits used underground shall include a fail-safe ground check circuit to monitor continuously the grounding circuit to assure the continuity of the ground conductor.

§ 45.1-161.189 Circuit Breakers and Switches

A. Automatic circuit breaking devices or fuses of the correct type and capacity shall be installed so as to protect all electric equipment and power circuits against excessive overload; however, this shall not apply to locomotives operated regularly on grades exceeding five percent. Wires or other conducting materials shall not be used as a substitute for properly designed fuses, and circuit breaking devices shall be maintained in safe operating condition.

B. An automatic circuit breaker of correct type and capacity shall be installed on each resistance grounded circuit used underground. Such circuit breaker shall be located at the power source and equipped with devices to provide protection against under-voltage, grounded phase, short circuit and overcurrent.

F. Insulating mats or other electrically nonconductive material shall be kept in place at each power-control switch and at stationary machinery where shock hazards exist.

G. Circuit breakers, disconnecting devices and switches shall be marked for identification.

§ 45.161.194 Trailing Cables

A. Trailing cables used underground shall be flame-resistant cables.

B. Trailing cables shall be provided with suitable short-circuit protection and means of disconnecting power from the cable. Power connections made in other than intake air shall be by means of permissible connectors.

C. Temporary splices in trailing cables shall be made in a workmanlike manner, mechanically strong, and well insulated.

D. No more than one temporary, unvulcanized splice shall be allowed in a trailing cable.

E. Permanent splices in trailing cables shall be made as follows:

(1) They shall be mechanically strong with adequate electrical conductivity and flexibility;
(2) They shall be effectively insulated and sealed so as to exclude moisture; and,
(3) The finished splice shall be vulcanized or otherwise treated with suitable materials to provide flame-resistant properties and good bonding to the outer jacket.
(4) If the cable has metallic shielding around each conductor, then the new shielding shall be equivalent to that of the original shielding.

F. Trailing cables shall be protected against mechanical damage. Trailing cables damaged in a manner that exposes the insulated inner power conductors shall be repaired promptly or removed from service.

§ 45.1-161.195 Inspection of electric equipment and wiring; checking and testing methane monitors

A. Electric equipment and wiring shall be inspected by a certified person at least weekly if located underground, and at least monthly if located on the surface, and more often if necessary to assure safe operating conditions, and any hazardous condition found shall be promptly corrected or the equipment or wiring shall be removed from service. Records of such examination shall be maintained at the mine for a period of one year.

B. A functional check of methane monitors on electrical face equipment shall be conducted to determine that such monitors are de-energizing the electrical face equipment properly. Such check shall be made on each production shift and shall be conducted by the equipment operator in the presence of a mine foreman, and shall be recorded in the on-shift report of the mine foreman.

A. Weekly calibration tests on methane monitors on electrical face equipment to determine the accuracy and operation of such monitors shall be conducted with a known mixture of methane at the flow rate recommended by the methane monitor and manufacturer. A record of the results shall be maintained.

B. Required methane monitors shall be maintained in permissible and proper operating condition.

§ 45.1-161.196 - Repairs to Circuits and Electric Equipment

No electrical work shall be performed on low-voltage, medium-voltage, or high-voltage distribution circuits or equipment, except by a certified person or by a person trained to perform electrical work and to maintain electrical equipment under the direct supervision of a certified person. All high-voltage circuits shall be grounded before repair work is performed. Disconnecting devices shall be locked out and suitably tagged by the persons who perform electrical or mechanical work on such circuits or equipment connected to the circuits, except that in cases where locking out is not possible, such devices shall be opened and suitably tagged by such persons. Locks and tags shall be removed only by the persons who installed them or, if such persons are unavailable, by certified persons authorized by the operator or his agent. However, miners may, where necessary, repair energized trolley wires if they wear insulated shoes and lineman's gloves. This section does not prohibit certified electrical repairmen from making checks on or troubleshooting energized circuits or the performance of repairs or maintenance on equipment by authorized persons once the power is off and the equipment is blocked against motion, except where motion is necessary to make adjustments.

B. 30 CFR REQUIREMENTS

18.45 Cable Reels

(a) A self-propelled machine, that receives electrical energy through a portable cable and is designed to travel at speeds exceeding 2.5 miles per hour, shall have a mechanically, hydraulically, or electrically driven reel upon which to wind the portable cable.

(b) The enclosure for moving contacts of slip rings of a cable reel shall be explosion-proof.

(c) Cable-reel bearings shall not constitute an integral part of a circuit for transmitting electrical energy.

(d) Cable reels for shuttle cars and locomotives shall maintain positive tension on the portable cable during reeling and unreeling. Such tension shall only be high enough to prevent a machine from running over its own cable(s).

(e) Cable reels and spooling devices shall be insulated with flame-resistant material.

(f) The maximum speed of travel of a machine when receiving power through a portable (trailing) cable shall not exceed 6 miles per hour.

(g) Diameters of cable reel drums and sheaves should be large enough to prevent undue bending strain on cables.

75.412-1 Qualified Person

To be a qualified person within the meaning of 75.512, an individual must meet the requirements of 75.153.

75.509 Electric Power Circuit and Electric Equipment; De-energization

All power circuits and electric equipment shall be deenergized before work is done on such circuits and equipment, except when necessary for trouble shooting or testing.

Electric Power Circuits and Electric Equipment: De-energization. If electrical or mechanical work is to be performed on a machine, both the machine and trailing cable are to be de-energized.

"Trouble-shooting or testing" for the purpose of this section would include the work of locating an electrical problem in the electrical circuits on an energized machine, but would never include the repair of same with the machine energized. (See 75.1725 for further application).

75.511 Low, Medium, or High-Voltage Distribution Circuits and Equipment Repair

No electrical work shall be performed on low, medium, or high-voltage distribution circuits or equipment, except by a qualified person or by a person trained to perform electrical work and to maintain electrical equipment under the direct supervision of a qualified person. Disconnecting devices shall be locked out and suitably tagged by the persons who perform such work, except that in cases where locking out is not possible, such devices shall be opened and suitably tagged by such persons. Locks or tags shall be removed only by the persons who installed them or, if such persons are unavailable, by persons authorized by the operator or his agent.

Section 75.511 refers to circuit breakers, capacitors, switchgear, cables, and other electrical equipment associated with a power distribution system. This section does not refer to trailing cables supplying power to mobile equipment since such cables could not be considered as distribution circuits.

"Suitably tagged" means that a sign with wording such as "Danger- Hands Off-Do Not Close-Men Working On Line" shall be attached to the locked switches. The signs or tags should bear the name of the workman who installed the tag and is working on the line.

Keys to locks used to lock out switches shall be kept on the person of the workman working on the line.

The wording "direct supervision" shall be interpreted to mean the following:

(1) The qualified person shall examine and/or test an electric circuit or machine and determine the need for repair or maintenance.

(2) The qualified person assigns a person trained to perform electrical work and to maintain electrical equipment under the direct supervision of a qualified person to perform the work necessary to ensure proper operation and maintenance of such circuit or equipment.

(3) The qualified person must give specific instructions to the employee assigned to perform this work with respect to the nature and extent of the repairs to be performed and where necessary, prescribes the manner in which the work is to be performed.

(4) The qualified person is at all times under continuing duty to instruct, advise, or consult with the employee, in the event the work which he has assigned cannot be performed by the employee in the manner prescribed.

(5) The qualified person must examine and test the completed work before the circuit is energized or the machine is returned to service.

75.512 Electric Equipment; Examination, Testing and Maintenance

All electric equipment shall be frequently examined, tested, and properly maintained by a qualified person to assure safe operating conditions. When a potentially dangerous condition is found on electric equipment, such equipment shall be removed from service until such condition is corrected. A record of such examinations shall be kept and made available to an authorized representative of the Secretary and to the miners in such mine.

This section requires that all electrical equipment including all locomotives, personnel carriers, electric track switches and derails, compressors, car hauls, crushers, conveyor units, pumps, rock-dusting machines, battery-powered equipment, starters, etc., as well as section equipment, including permissible equipment, must be examined and tested.

The record of examinations of electrical equipment required by this section shall list all major electrical equipment in the mine. All equipment on one section may be listed collectively. All drainage pumps in a mine may be listed collectively. All equipment in any one category may be listed collectively, provided the same qualified person inspects all equipment in the same category.

If the qualified person making the required examination and tests finds any potentially dangerous condition, such as missing inspection covers, improper overload protection, inoperative brakes, improper frame-grounding, exposed wiring, poorly-made splices in conductors, permissibility deficiencies, accumulations of lubricant and coal dust on electrical equipment, missing guards, defective steering or other controls, or motors or speed reducers heating abnormally, he shall immediately cause the defective equipment to be removed from service until such condition is corrected.

75.513 Electric Conductor; Capacity and Insulation

All electric conductors shall be sufficient in size, have adequate current carrying capacity, and be of such construction that a rise in temperature resulting from normal operation will not damage the insulating materials.

When power cables are manufactured in accordance with the Insulated Power Cable Engineers Association (IPCEA) standards, the ampacities published by the IPCEA shall be used for determining compliance with this section. IPCEA power cable ampacity tables for copper conductors with 75 degree C insulation and 90 degree C insulation are included in this manual. It should be noted that these ampacity tables have been calculated for a 40 degree C ambient temperature. The correction factors listed with each table should be used to correct the figures found in these tables to the prevailing mine ambient temperature.

75.514 Electrical Connections or Splices; Suitability

All electrical connections or splices in conductors shall be mechanically and electrically efficient and <u>suitable connectors</u> shall be used. All electrical connections or splices shall be reinsulated <u>at least to the same degree of protection as the remainder of the wire</u>.

75.516-1 Installed Insulators

Well-insulated insulators is interpreted to mean well-installed insulators. Insulated J-hooks may be used to suspend insulated power cables for temporary installation not exceeding 6 months and for permanent installation of control, cables such as may be used along belt conveyors.

75.516-2 Communication Wires and Cables; Installation; Insulation; Support

(a) All communication wires shall be supported on insulated hangers or insulated J-hooks.

(b) All communication cables shall be insulated as required by 75.517-1 and shall either be supported on insulated or annulated hangers or J-hooks, or securely attached to messenger wires, or buried, or otherwise protected against mechanical damage in a manner approved by the Secretary or his authorized representative.

(c) All communication wires and cables installed in track entries shall, except when a communication cable is buried in accordance with paragraph (b) of this section, be installed on the side of the entry opposite to trolley wires and trolley feeder wires. Additional insulation shall be provided for communication circuits at points where they pass over or under any power conductor.

(d) For purposes of this section, communication cable means two or more insulated conductors covered by an additional abrasion-resistant covering.

75.600 Trailing Cables; Flame Resistance

Trailing cables used in coal mines shall meet the requirements established by the Secretary for flame-resistant cables.

75.600-1 Approved Cables; Flame Resistance

The requirements for flame resistant cables are set forth in 18.64 of this chapter (Bureau of Mines Schedule 2G).

75.601 Short-Circuit Protection of Trailing Cables

Short circuit protection for trailing cables shall be provided by an automatic circuit breaker or other no less effective device approved by the Secretary of adequate current-interrupting capacity in each ungrounded conductor. Disconnecting devices used to disconnect power from trailing cables shall be plainly marked and identified and such devices shall be

equipped or designed in such a manner that it can be determined by visual observation that the power is disconnected.

75.601 Short Circuit Protection of Trailing Cables

Single-element trolley fuses are not acceptable for trailing cable short-circuit protection unless specifically listed in the Federal Register as being approved by the Secretary. Dual-element fuses with adequate interrupting capacity may be used when applied in accordance with the Tables in 75.601-3.

Adequate current interrupting capacity means that the fuse or circuit breaker is capable of interrupting the maximum short- circuit current the circuit may conduct without destruction to the device.

In systems where small rectifiers such as those used to supply direct current to shuttle cars that have both positive and negative lines ungrounded, short-circuit protection is necessary for both conductors of the trailing cable. A properly adjusted two-pole circuit breaker or approved fuses would be acceptable for this purpose.

Some visual means of disconnecting power from trailing cables shall be provided so that a workman can readily determine whether the cable is deenergized. Enclosed circuit breakers are not acceptable as visible evidence that power is disconnected. Plugs and receptacles located at the circuit breaker are acceptable as a visible means of disconnecting the power. These devices shall be plainly marked to lessen the chance of energizing a cable while repairs are being made to the cable. The loading machine cable-disconnecting device shall be plainly marked (LOADER), the shuttle car cable-disconnecting device shall be plainly marked (S.C. No. 1) or (S.C. No. 2) or the disconnecting device shall be readily identifiable by other equally effective means.

75.601-1 Short Circuit Protection; Ratings and Setting of Circuit Breakers

Circuit breakers providing short circuit protection for trailing cables shall be set so as not to exceed the maximum allowable instantaneous settings specified in this section; however, higher settings may be permitted by an authorized representative of the Secretary when he has determined that special applications are justified:

75.601-1 Short Circuit Protection; Ratings and Settings of Circuit Breakers (Cont'd) Conductor Circuit Breaker size instantaneous AWG or setting (amperes) MCM

14...50
12...75
10...150
8..200
6..300
4..500
3..600
2..800
1..1,000
1/0..1,250
2/0..1,500
3/0..2,000
4/0..2,500
250..2,500
300..2,500
350..2,500
400..2,500
450..2,500
500.... 2,500

75.601-2 Short Circuit Protection; Use of Fuses; Approval by the Secretary

Fuses shall not be employed to provide short circuit protection for trailing cables unless specifically approved by the Secretary.

75.601-3 Short Circuit Protection: Dual Element Fuses

Dual element fuses having adequate current-interrupting capacity shall meet the requirements for short circuit protection of trailing cables as provided in 75.601, however, the current ratings of such devices shall not exceed the maximum values specified in this section. The two common relays used are the Westinghouse CO relay and the General Electric 1AC relay. To determine the overcurrent setting on a breaker, the following information is required:

1. The current transformer ratio
2. The pickup current of the overcurrent relay
3. The ampacity of the high-voltage cable

The current transformer ratio is normally found on the current transformer nameplate or terminal block.

The pickup of the relay is determined by the tap setting and the pickup is changed by moving the tap screw to the desired tap block current setting on the CO or AC relays.

The ampacity of the cable is determined by use of the ampacity chart. When using any ampacity chart, the ambient temperature of the area the wire or cable is to be used in, must be considered.

Example: Cable size 2/0 - 75 degree C insulation
Voltage of system - 5 KV
Ambient temperature - 20 degree C
Current capacity from chart = 191 amperes
Current capacity at 20 degree C = 191 x 1.25 = 238.75 amperes

To determine maximum allowable relay setting for this cable, the 1968 National Electrical Code, Section 240-5, Exception No. 2, states that adjustable-trip circuit breakers of the thermal trip, magnetic time-delay trip or instantaneous-trip types shall be set to operate at not more than 125 percent of the allowable ampacity of the conductors.

Maximum allowable relay setting = 238.75 x 125% = 298.44 amperes
Current transformer ratio = 300/5 or 60/1
Tap screw setting = 5 amperes
Overcurrent relay setting = 5 x 60 = 300 amperes

It can be readily seen that if the relay tap screw was set at 7, the breaker would trip at 420 amperes, which would exceed the maximum applicable setting.

Other means of providing overcurrent protection could be the use of a series trip circuit breaker equipped with dashpot or bellows, or circuit breakers equipped with solid state circuitry.

Circuit Breakers - Tripping Circuits

The circuit breaker shall be provided with a fail-safe circuit to be used in the event of a control circuit power failure. Three common types of energy sources are: mechanical spring, battery or capacitor.

75.602 Trailing Cable Junctions

When two or more trailing cables junction to the same distribution center, means shall be provided to assure against connecting a trailing cable to the wrong size circuit breaker.

When two or more circuit breakers of different ratings are installed in the same power center and provide short circuit protection for cables of different sizes, some means shall be provided to prevent connecting the smaller cables to the large circuit breakers.

Compliance requires that plugs of different types or sizes connected to different size breakers be used for different size cables, unless the larger circuit breaker is adjusted low enough to protect the smaller cable in accordance with the table in 75.601-1. Plugs of the same size could be used for different size cables if dowel pins or other devices are provided to assure that each cable shall be connected to a circuit breaker of the proper size or by connecting the plugs and receptacles together with a short length of chain only long enough to permit the plug to be inserted into and withdrawn from the proper receptacle.

Cable Splicing

75.603 Temporary Splice of Trailing Cable

One temporary splice may be made in any trailing cable. Such trailing cable may only be used for the next 24-hour period. No temporary splice shall be made in a trailing cable within 25 feet of the machine, except cable reel equipment. Temporary splices in trailing cables shall be made in a workmanlike manner and shall be mechanically strong and well insulated. Trailing cables or hand cables which have exposed wires or which have splices that heat or spark under load shall not be used. As used in this section, the term "splice" means the mechanical joining of one or more conductors that have been severed.

The term "splice" means the mechanical joining of one or more conductors that have been severed in a trailing cable. The grounding conductor in a trailing cable when severed and mechanically joined will constitute a splice and shall satisfy the requirements of 75.603. Both power conductors and grounding conductors in all splices shall be joined together with a mechanical connector.

A trailing cable that supplies power to any piece of electric equipment may be used for twenty-four production-shift hours after the temporary splice is made. The production-shift hours shall be counted whether the cable is used or not, in determining the "next 24 hour period."

The connection of the trailing cable made inby the strain clamp on cable reel equipment that does not have provisions for the trailing cable to enter the collector ring compartment shall be considered a temporary splice. The method of cable attachment accepted in the approval of permissible equipment will comply with this provision.

When a single conductor trailing cable is used, one temporary splice shall be allowed in the cable for a period not exceeding twenty-four production hours.

The conductors of a temporary splice shall be joined together so that the passage of current will not create excessive heat at the connection. All power conductors, ground conductors, and ground check conductors shall be properly spliced utilizing a proper splicing sleeve, ring, or clamp and each power conductor and ground conductors.

75.604 Permanent Splicing of Trailing Cables

Materials listed as flame-resistant for use in making permanent splices in trailing cables shall be used in complete accordance with manufacturer's instructions. Splice insulating kits shall be applied without any substitution or alternations of parts in order to duplicate the conditions under which the materials were tested and accepted. Any deviation would require additional evaluation or testing and if used without such evaluation shall constitute noncompliance with this provision.

An acceptance number will generally be provided in the outer sleeving or jacket of permanent, splices.

"When permanent splices in trailing cables are made, they shall be:

(1) Mechanically strong with adequate electrical conductivity and flexibility;
(2) Effectively insulated and sealed so as to exclude moisture; and
(3) Vulcanized or otherwise treated with suitable materials to provide flame-resistant qualities and good bonding to the outer jacket."

All splices shall be inspected to ascertain whether they are effectively insulated and sealed to exclude moisture. Particular attention should be paid to splices, which are made with lapped tape to assure compliance with the above-mentioned sections.

The splices, regardless of who the manufacturer may be, or what has been printed in the industry literature, must conform to the requirements of Section 75.604 and 77.602.

Particular attention shall be given to the manner in which permanent splices are made in trailing cables. Manufacturer’s specifications on all portable splice kits emphasize the importance of proper cable preparation and primarily that of cleaning the cable to assure that the splice sleeves bond to the conductor and cable jackets. Inspection personnel shall take advantage of every opportunity to observe cable splicing underground and shall discuss the importance of proper cable preparation with mine personnel. If cables are not well cleaned, the slice outer jacket will have a tendency to slip on the cable and fray at the ends. These frayed ends will hang on protruding objects such as ribs, chunks of coal, and cable reel guides, and cause further damage to the cable.

75.605 Clamping of Trailing Cables to Equipment

<u>Trailing cables shall be clamped to machines in a manner to protect the cables from damage and to prevent strain on the electrical connections</u>.

If a strain clamp is used, it shall be insulated to keep the sharp edges of the clamp from puncturing the insulation and becoming grounded to the machine frame. A piece of fire-resistant conduit hose will be accepted as insulating material between a metal clamp and the cable. Cable grips, such as Kellems grips, anchored to the cable may be used in lieu of insulated strain clamps.

75.606 Protection of Trailing Cables

Trailing cables shall be adequately protected to prevent damage by mobile equipment. Trailing cables shall be placed away from roadways and haulage ways where they will not be run over or damaged by mobile equipment.

75.607 Breaking Trailing Cable and Power Cable Connections

Trailing cable and power cable connections to junction boxes shall not be made or broken under load.

75.700 Grounding Metallic Sheaths, Armors, and Conduits Enclosing Power Conductors

All metallic sheaths, armors, and conduits enclosing power conductors shall be electrically continuous throughout and shall be grounded by methods approved by an authorized representative of the Secretary.

Grounded Phase Protection

1. Residual Trip Relaying:
   Detect the ground fault current as the unbalance in the line current transformers. The ground current would be reflected in the secondaries of the current would be reflected in the secondaries of the current transformers.

Example: Current transformer ratio 50/5 or 10/1
Ground trip relay pickup = 0/5 amperes
Ground fault trip setting - C. T. ratio x pickup current
Ground fault trip setting = 10 x 0/5 - 5 amperes

2. Direct Relaying:
   Measuring ground current directly with a current transformer in the grounded neutral line.

Example: Current transformer ratio 25/5 or 5/1
Ground trip relay pickup = 1
Ground trip setting = 5 x 1 = 5 amperes

Short Circuit Protection

Short circuit protection can be provided by utilizing an instantaneous unit of an overcurrent relay or by the inverse overcurrent relay with a minimum time setting.

The instantaneous unit pickup is determined by the position of the screw on the top of the unit. The top of the screw is adjacent to the pickup setting. The pickup for this unit is independent of the pickup on the time inverse unit.

Example: Current transformer ratio 100/5 or 20/1
Instantaneous Unit Setting = 20 amperes
Instantaneous setting for breaker = 20 x 20 = 400 amperes

Overcurrent Protection

The reason for overcurrent protection for wire is to protect the wire or insulation from damage due to excessive temperatures. The temperature of the conductor is a factor of the current squared times the resistance of the conductor times the amount of time the current is present. The higher the current the faster the temperature rise of the conductor.

75.701-5 Use of Grounding Connectors

The attachment of grounding wires to a mine track or other grounded power conductor will be approved if <u>separate clamps</u>, suitable for such purpose, are used and installed <u>to provide a solid connection</u>.

75.703-3 Approved Methods of Grounding off-Track Mobile, Portable and Stationary Direct Current Machines

Diode grounding of equipment is not acceptable on direct-current systems, which have both the positive and negative polarities, ungrounded.

Two suggested methods of testing silicon diode ground circuits are required weekly by 75.512 may be conducted as follows:

Running Test (Suitable precaution should be exercised during this test to avoid the danger of electrical shock).

1. Start the pump motor on the machine being tested. Using a resistance such as a resistance-type welder set to a low amperage, pass current from the trolley wire to the frame of the machine. Assuming the current flow is higher than the trip setting of the ground trip relay,

   the pump motor will stop running, thus proving that the ground trip relay is operating, as it should.

2. Reverse the trailing cable connections (positive to track-negative to trolley, or (vise versa). Extreme caution should be used during this electrical equipment in the mine. All equipment on one section may be listed collectively. All drainage pumps in a mine may be listed collectively. All equipment in any one category may be listed collectively, provided the same qualified person inspects all equipment in the same category. Records of the required examinations shall be kept on file for a period of not less than six months.

If the qualified person making the required examination and tests finds any potentially dangerous condition, such as missing inspection covers, improper overload protection, inoperative brakes, improper frame-grounding, exposed wiring, poorly-made splices in the conductors, permissibility deficiencies, accumulations of lubricant and coal dust on electrical equipment, missing guards, defective steering or other controls, or motors or speed reducers heating abnormally, he shall immediately cause the defective equipment to be removed from service until such condition is corrected.

75.706 Deenergized Underground Power Circuits; Idle Days - Idle Shifts

When not in use, power circuits underground shall be deenergized on idle days and idle shifts, except that rectifiers and transformers may remain energized.
Circuit Breakers

Undervoltage Protection:
A potential transformer, and an inverse time undervoltage relay could provide this protection. The relay can either be induction or attraction type. This relay must trip the circuit breaker when line voltage decreases to 40 percent. (Three common relays, which are used to provide this protection, are General Electric type 1AV 51 series and Westinghouse types CV and SV series.)

Short Circuit Protection
Short circuit protection can be provided by utilizing an instantaneous unit of overcurrent relay or by the inverse overcurrent relay with a minimum time setting.

The instantaneous unit pickup is determined by the position of the screw on the top of the unit. The top of the screw is adjacent to the pickup setting. The pickup for this unit is independent of the pickup on the time inverse unit.

Overcurrent Protection
The reason for overcurrent protection for wire is to protect the wire or insulation from damage due to excessive temperatures. The temperature of the conductor is a factor of the current squared times the resistance of the conductor times the amount of time the current is present. The higher the current the faster the temperature rise of the conductor. Since the temperature rise is a factor of time and current.

75.800-3 Testing, Examination And Maintenance of Circuit Breakers; Procedures

(a) Circuit breakers and their auxiliary devices protecting underground high-voltage circuits shall be tested and examined at least once each month by a person qualified as provided in 75.1.53;
(b) Test shall include:
  (1) Breaking continuity of the ground check conductor, where ground check monitoring is used; and
  (2) Actuating at least two (2) of the auxiliary protective relays.
(c) Examination shall include visual observation of all components of the circuit breaker and its auxiliary devices, and such repairs or adjustments as are indicated by such tests and maintained as prescribed by the Secretary. Such breakers shall be equipped with devices to provide protection against under-voltage, grounded phase, short circuit, and overcurrent.

75.803 Fail Safe Ground Check Circuits on High-Voltage Resistance Grounded Systems

On and after September 30, 1970, high-voltage, resistance grounded systems shall include a fail safe ground check circuit to monitor continuously the grounding circuit to assure continuity and the fail safe ground check circuit shall cause the circuit breaker to open when either the ground or pilot check wire is broken, or other no less effective device approved by the Secretary or his authorized representative to assure such continuity, except that an extension of time, not in excess of 12 months, may be permitted by the Secretary on a mine-by-mine basis if he determines that such equipment is not available.

75.805 Couplers

Couplers that are used with medium voltage or high-voltage power circuits shall be of three-phase type with a full metallic shell, except that the Secretary may permit, under such guidelines as he may prescribe, no less effective couplers constructed of materials other than metal. Couplers shall be adequate for the voltage and current expected. All exposed metal to the metallic couplers shall be grounded to the ground conductor in the cable. The coupler shall be constructed so that the ground check conductor shall be broken first and the ground conductors shall be broken last when the coupler is being uncoupled.

75.810 High Voltage Cable Splices

In general, the following procedure shall be followed in the making of splices in high-voltage cables:

(1) The conductor shall be joined together by soldering or mechanical connectors.
(2) Each individual conductor shall be insulated with high- voltage insulating tape to the same degree of insulation as the original cable.
(3) The semi-conducting tape shall be replaced over the insulator.
(4) The metallic shielding shall be replaced around each individual conductor and be continuous across the splice.
(5) All grounding conductors shall be individually spliced.
(6) The ground check conductor shall be reinsulated at least to the same degree as the original.
(7) An outer jacket comparable to the original shall be placed over the completed splice.

75.810 High-Voltage Cable Splices (Cont'd)

Section 75.810 requires that splices and terminations in high voltage cables be made according to manufacturer's specifications, but does not state whether the "manufacturer" refers to the manufacturer of the cable or manufacturer of the splice and termination material; therefore, please be guided by the following: High-voltage tapes and other insulating materials shall be acceptable for insulation of high-voltage conductors and for the formation of terminations and outer jackets for single and multiple conductor cables provided the manufacturer of the insulating materials certifies that the electrical and mechanical strength of the material when properly applied is equal to or greater than that of the original cable. Furthermore, the insulating material shall be applied in accordance with specifications of the manufacturer of the insulating material.

In all high-voltage splices, the semi-conducting tape, individual ground conductors and shielding shall be continuous.

Frames, supporting structures and enclosures of stationary, portable, or mobile underground high-voltage equipment and all high-voltage equipment supplying power to such equipment receiving power from resistance grounded systems shall be effectively grounded to the high-voltage ground.

75.900 Low and Medium Voltage Circuits Serving Three-Phase Alternating Current Equipment; Circuit Breakers

Low and medium voltage power circuits serving three-phase alternating current equipment shall be protected by suitable circuit breakers of adequate interrupting capacity, which are properly tested and maintained as prescribed by the Secretary. Such breakers shall be equipped with devices to provide protection against undervoltage, grounded phase, short circuit, and overcurrent.

75.901 Protection of Low and Medium Voltage Three-Phase Circuits Used Underground

Low and medium voltage three-phase alternating-current circuits used underground shall contain either a direct or derived neutral which shall be grounded through a suitable resistor at the power center, and a grounding circuit, originating at the grounded side of the grounding resistor, shall extend along with the power conductors and serve as a grounding conductor for the frames of all the electrical equipment supplied power from that circuit, except that the Secretary or his authorized representative may permit ungrounded low and medium voltage circuits are either steel armored or installed in grounded rigid steel conduit throughout their entire length. The grounding resistor, where required, shall be of the proper ohmic value to limit the ground fault current to 25 amperes. The grounding resistor shall be rated for maximum fault current continuously and insulated from ground for a voltage equal to the phase-to-phase voltage of the system.

75.903 Disconnecting Devices

Disconnecting devices shall be installed in conjunction with the circuit breaker to provide visual evidence that the power is disconnected

75.904 Circuit Breakers shall be Marked for Identification

77.600 Surface Trailing Cables; Short-circuit Protection; Disconnecting Devices

Short-circuit protection for trailing cables shall be provided by an automatic circuit breaker or other no less effective device, approved by the Secretary, of adequate current-interrupting capacity in each underground conductor. Disconnecting devices used to disconnect power from trailing cables shall be plainly marked and identified and such devices shall be equipped or designed in such a manner that it can be determined by visual observation that the power is disconnected.

77.601 Trailing Cables or Portable Cables; Temporary Splices

Temporary splices in trailing cables or portable cables shall be made in a workmanlike manner and shall be mechanically strong and well insulated. Trailing cables or portable cables with exposed wires or splices that heating spark under load shall not be used.

77.602 Permanent Splicing of Trailing Cables

When permanent splices in trailing cables are made, they shall be:
(a) Mechanically strong with adequate electrical conductivity;
(b) Effectively insulated and sealed so as to exclude moisture; and,
(c) Vulcanized or otherwise made with suitable materials to provide good bonding to the outer jacket.
(d) High Voltage (HV) gloves for HG trailing cables.

77.603 Clamping of Trailing Cables to Equipment

Trailing cables shall be clamped to machines in a manner to protect the cables from damage and to prevent strain on the electrical connections.

77.604 Protection of Trailing Cables

Trailing cables shall be adequately protected to prevent damage by mobile equipment.

77.605 Breaking Trailing Cable and Power Cable Connections

Trailing cable and power cable connections between cables and to power sources shall not be made or broken under load.

C. CABLE REQUIREMENT REVIEW

Q. What is the minimum allowable size for trailing cable on direct current powered shuttle cars?
A. No. 4 AWG for DC (No. 6 AWG for AC)

Q. What is the minimum allowable size conductor (including ground check conductor) to be used as a trailing cable?
A. 10 AWG

Q. What is the period of time that J-Hooks may be used for insulated power cable installations?
A. 6 months

Q. How many temporary splices are allowed in a trailing cable?
A. One

Q. What is the ordinary length of a portable trailing cable?
A. 500 feet

Q. The outer cover on a trailing cable shall be _________.
A. Flame resistant

Q. What is the maximum speed of a machine equipped with a cable reel, when receiving power through a portable trailing cable?
A. 6 miles per hour (2.5 mph without a cable reel)

Q. What is the first thing that must be done before working on a power cable?
A. The power shall be disconnected locked out and tagged

Q. Circuit breakers and disconnecting switches underground shall be marked for:
A. Identification

Q. When permanent splices are made in trailing cables, they shall be mechanically strong, flexible, effectively insulated and sealed to exclude moisture and vulcanized or otherwise treated with suitable materials to provide flame resistant qualities and good bonding to the outer jacket:
A. True

Q. When a cable has been disconnected and tagged, who shall remove the tag and reconnect the cable?
A. Locks and tags shall be removed only by the persons who installed them.

Q. Temporary splice can be made in a trailing cable within 25 feet of the machine except cable reel equipment.
A. False

Q. When a temporary splice is made in a trailing cable, how long can it remain before removing it and making a permanent splice?
A. 24 hours

Q. Trailing cables shall be clamped to machines in a matter to protect the cables from damage and to prevent strain on the electrical connections.
A. True

Q. How often should the ground continuity be checked in a trailing cable?
A. Weekly or more often if necessary

Q. Splices shall be made in a workmanlike manner to insure good electrical conductivity, insulation and mechanical strength.
A. True

Q. Who must approve short circuit protection for trailing cable provided by an automatic circuit breaker or other effective device?
A. The Secretary (MSHA)

Q. What is the minimum experienced required for a person to become a qualified person to do electrical work?
A. Twelve months

Q. When are splices made with permanent splice kits not acceptable?
A. When improperly made

Q. How often should cables on face equipment be examined?
A. The start of each shift

Q. What is a splice?
A. Rejoining, re-insulating of one or more conductors that have been severed

Q. Distribution center cables shall be marked or identified.
A. True

Q. When looking for a defect in a cable, what precautions should be taken?
A. Make sure proper cable is de-energized, locked out and tagged

Q. Who should disconnect the cable from the power center?
A. The certified and qualified person who will repair the cable

Q. What is the most common cause of mine fires?
A. Defective splices in trailing cables

Q. What is the purpose for allowing the ground wire to be longer than the power conductors?
A. To eliminate the possibility of the ground wire being pulled apart first

Q. Why is it important to be certain the proper power cable is de-energized, locked out and tagged?
A. To guard against electrical shock, injury or possible fatality

Q. Why is it important to be certain the proper cable is de- energized, locked out and tagged?
A. To prevent electrical accidents to yourself and your fellow workman by cutting into the energized cable

Q. What are some precautions necessary when cutting with a knife?
A. Direct your cutting motion away from you to prevent cutting yourself

Q. Why is it important to stagger the individual conductor connections when making a cable splice?
A. To take advantage of as much original insulation as possible

Q. Why is the amount of pressure that is applied to tighten a connector important?
A. Connectors that are applied too loosely will easily come apart.

Q. Why is it important to select the proper size connector in splicing a conductor?
A. The specified correct size connection is essential to restore the original electrical conductivity.

Q. Why should the power conductors be connected with equal tension?
A. If all of the tension is placed on one conductor, the splice will fail prematurely.

Q. Should all of the conductors in the cable be connected?
A. Yes. Do not leave any conductors un-spliced. This can be very dangerous, causing possible electric shock or electrocution to yourself or other workmen.

Q. How should trailing cables be protected?
A. By properly fused trolley taps or automatic circuit breaking devices

Q. If you saw the following markings, P-102 BM on a trailing cable, what would this indicate to you?
A. That the cable is flame resistant

Q. What precaution should be taken when trailing cables are not in use?
A. Power disconnected

Q. In a splice, the ground wire is always shorter than the power conductor?
A. False

Q. What must be done before beginning a cable splice?
A. The person at risk to shock, the certified/qualified electrician, must de-energize lockout and tag the circuit.

Q. What does a splice that is wet and smoking indicate?
A. That the splice is not properly insulated

Q. What would be the most effective way to join a severed cable?
A. To use proper connectors

Q. What is the best way to cut a cable so you will have square ends?
A. Use the proper cable cutter

Q. Cables that are on self propelled cable reel machines do not have to be spliced with a permanent type splice since they are laying on the ground all of the time.
A. False

Q. When using a pilot check wire ground monitoring system, how many pilot check conductors are used?
A. <u>One insulated</u> pilot check conductor

Chapter 5
High Voltage

CHAPTER 5

HIGH VOLTAGE

A. Virginia Mine Safety Act

§ 45.1-161.181 Surface Electrical Installations

A. Overhead high-potential power lines shall be placed at least fifteen feet above the ground and twenty feet above driveways shall be installed on insulators, and shall be supported and guarded to prevent contact with other circuits.

B. Surface transmission lines including trolley circuits shall be protected against short circuits and lightning. Each power circuit that leads underground shall be equipped with lightning arrestors within 100 feet of where the circuit enters the mine.

C. Electric wiring in surface buildings shall be installed to prevent fire and contact hazards.

§ 45.1-161.182 Surface Transformers

A. Surface transformers, which are not isolated by elevation of eight feet or more above the ground, shall be enclosed in a transformer house or surrounded by a suitable fence at least six feet high. If the enclosure or fence is of metal, it shall be grounded effectively. The door to the enclosure or the gate to the fence shall be kept locked at all times unless persons authorized to enter the gate or the enclosure is present.

B. Surface transformers containing flammable oil and installed near mine openings, in or near combustible buildings, or at other places where they present a fire hazard shall be provided with means to drain or to confine the oil in the event of rupture of the transformer casing.

§ 45.1-161.183 Underground Transformers

All transformers used underground shall be air-cooled or filled with nonflammable liquid or inert gas.

§ 45.1-161.184 Stations and Substations

A. Suitable danger signs shall be posted conspicuously at all transformer stations.

B. All transformer stations, substations, battery-charging stations, pump stations, and compressor stations shall be kept free of nonessential combustible materials and refuse.

C. Reverse-current protection shall be provided at storage-battery-charging stations to prevent the storage batteries from energizing the power circuits in the event of power failure.

§ 45.161.186 Power Circuits

A. All underground power wires and cables shall have adequate current-carrying capacity, shall be guarded from mechanical injury, and shall be installed in a permanent manner.

B. Wires and cables not encased in armor shall be supported by well-installed insulators and shall not touch combustible materials, roof, or ribs; however, this shall not apply to ground wires, grounded power conductors, and trailing cables.

C. Power wires and cables installed in belt-haulage slopes shall be insulated adequately and buried in a trench not less than 12 inches below combustible material, unless encased in armor or otherwise fully protected against mechanical injury.

D. Splices in power cables shall be made in accordance with the following:

(1) Mechanically strong with adequate electrical conductivity;
(2) Effectively insulated and sealed so as to exclude moisture; and
(3) If the cable has metallic armor, mechanical protection and electrical conductivity equivalent to that of the original armor.
(4) If the cable has metallic shielding around each conductor, then the new shielding shall be equivalent to that of the original shielding.

E. All underground high-voltage transmission cables shall be:

(1) Installed only in regularly inspected airways;

(2) Covered, buried, or placed on insulators to afford protection against damage by derailed equipment if installed along the haulage road;
(3) Guarded where miners regularly work or pass under them unless they are 6 1/2 feet or more above the floor or rail,
(4) Securely anchored, properly insulated, and guarded at ends; and
(5) Covered, insulated or placed to prevent contact with trolley circuits and other low-voltage circuits.

F. New high-voltage disconnects installed on or after January 1, 2007, on all underground electrical installations shall automatically ground all three power leads when in the open position.

G. All power wires and cables shall be insulated adequately where they pass into or out of electrical compartments, where they pass through doors and stoppings, and where they cross-bare power wires.

§ 45.1-161.189 Circuit Breakers and Switches

A. Automatic circuit breaking devices or fuses of the correct type and capacity shall be installed so as to protect all electric equipment and power circuits against excessive overload; however, this shall not apply to locomotives operated regularly on grades exceeding five percent. Wires or other conducting materials shall not be used as a substitute for properly designed fuses, and circuit-breaking devices shall be maintained in good operating condition.

B. An automatic circuit breaker of correct type and capacity shall be installed on each resistance grounded circuit used underground. Such circuit breaker shall be located at the power source and equipped with devices to provide protection against under-voltage, grounded phase, short circuit and overcurrent.

C. Operating controls, such as switches, starters, and switch buttons shall be so installed that they are readily accessible and can be operated without danger of contact with moving or live parts.

D. Disconnecting switches shall be installed underground in all main power circuits within approximately 500 feet of the bottoms of shafts and boreholes, and at other places where main power circuits enter the mine.

E. Electric equipment and circuits shall be provided with switches or other controls of safe design, construction and installation.

F. Insulating mats or other electrically nonconductive material shall be kept in place at each power-control switch and at stationary machinery where shock hazards exist.

G. Circuit breakers, disconnecting devices and switches shall be marked for identification.

Important Reminders!

Be sure you understand the circuits!

Take your time do not rush!

Use your head!

Take a second look!

Watch out for your coworker!

Always de-energize, lockout, ground, and tag!

If it is not grounded, it is not dead!

B. 30 CFR REQUIREMENTS

75.2 Definitions

30 CFR CH. 1 (7-1-91 Edition) Statutory Provisions

For the purpose of this Part 75, the term --

(a) "Certified" or "registered" as applied to any person means a person certified or registered by the State in which the coal mine is located to perform duties prescribed by this Part 75, except that in a State where no program of certification or registration is provided or where the program does not meet at least minimum Federal standards established by the Secretary, such certification or registration shall be by the Secretary;
(b) "Qualified person," means, as the context requires,
(1) An individual deemed qualified by the Secretary and designated by the operator to make tests and examinations required by this Part 75; and
(2) An individual deemed, in accordance with minimum requirements to be established by the Secretary, qualified by training, education, and experience, to perform electrical work, to maintain electrical equipment, and to conduct examinations and tests of all electrical equipment;
(c) "Permissible" as applied to --
(1) Equipment used in the operation of a coal mine, means equipment, other than permissible electric face equipment, to which an approval plate, label, or other device is attached as authorized by the Secretary and which meets specifications which are prescribed by the Secretary for the construction and maintenance of such equipment and are designed to assure that such equipment will not cause a mine explosion or a mine fire.
(2) The manner of use of equipment means the manner of use prescribed by the Secretary;
(d) "Low voltage" means up to and including 660 volts; "medium voltage" means voltages from 661 to 1,000 volts; and "higher voltage" means more than 1,000 volts;

75.511 Low, Medium, or High-Voltage Distribution Circuits and Equipment Repair

No electrical work shall be performed on low, medium, or high- voltage distribution circuits or equipment except by a qualified person or by a person trained to perform electrical work and to maintain electrical equipment under the direct supervision of a qualified person. Disconnecting devices shall be locked out and suitably tagged by the persons who perform such work, except that in cases where locking out is not possible, such devices shall be opened and suitably tagged by such persons. Locks or tags shall be removed only by the persons who installed them or, if such persons are unavailable, by persons authorized by the operator or his agent.

75.519 Main Power Circuits; Disconnecting Switches

In all main power circuits, disconnecting switches shall be installed underground within 500 feet of the bottoms of shafts and boreholes through which main power circuits enter the underground area of the mine and within 500 feet of all other places where main power circuits enter the underground area of the mine.

§ 75.705-1 Work on High-Voltage Lines

(a) Section 75.705 specifically prohibits work on energized high-voltage lines underground;
(b) No high-voltage line, either on the surface or underground, shall be regarded as deenergized for the purpose of performing work on it, until it has been determined by a qualified person (as provided in § 75.153) that such high-voltage line has been deenergized and grounded. Such qualified person shall be visual observation:

(1) Determine that the disconnecting devices on the high-voltage circuit are in open position and;

(2) Ensure that each ungrounded conductor of the high-voltage circuit upon which work is to be done is properly connected to the system-grounding medium. In the case of resistance grounded or solid wye-connected systems, the neutral wire is the system-grounding medium. In the case of an ungrounded power system, either the steel armor or conduit enclosing the system or a surface-grounding field is a system-grounding medium;

(c) No work shall be performed on any high-voltage line on the surface, which is supported, by any pole or structure, which also supports other high-voltage lines until:

(1) All lines supported on the pole or structure are deenergized and grounded in accordance with all of the provisions of this section which apply to the repair of energized surface high-voltage lines; or

(2) The provisions of § 75.7O5-2 through §75.705-10 have been compiled with, with respect to lines, which are supported on the pole or structure.

(d) Work may be performed on energized surface high-voltage lines only in accordance with the provisions of § 75.705.2 through §75.705-10, inclusive.

75.705-9 Operating Disconnecting or Cutout Switches

Disconnecting or cutout switches or energized high-voltage lines shall be operated only with insulated sticks, fuse tongs, or pullers, which are adequately insulated and maintained to protect the operator from the voltage to which he is exposed. When such switches are operated from the ground, the person operating such devices shall wear protective rubber gloves, except where such switches are bonded to a metal mat as provided in § 77.513.

75.706 Deenergized Underground Power Circuits: Idle Days-Idle Shifts

When not in use, power circuits underground shall be deenergized on idle days and idle shifts, except that rectifiers and transformers may remain energized.

75.800 High-Voltage Circuits; Circuits Breakers

High voltage circuits entering the underground area of any coal mine shall be protected by suitable circuit breakers of adequate interrupting capacity, which are properly tested and maintained as prescribed by the Secretary. Such breakers shall be equipped with devices to provide protection against under-voltage, grounded phase, short circuit, and overcurrent.

75.800-1 Circuit Breakers; Location

Circuit breakers protecting high-voltage circuits entering an underground area of any coal mine shall be located on the surface and in no case installed either underground or within a drift.

75.800-2 Approved Circuit Schemes

The following circuit schemes will be regarded as providing the necessary protection to the circuits required by 75.800:

A. Ground check relays may be used for undervoltage protection if the relay coils are designed to trip the circuit breaker when line voltage decreases to 40 percent to 60 percent of the nominal line voltage;

B. Ground trip relays on resistance grounded systems will be acceptable as grounded phase protection;

C. One circuit breaker may be used to protect two or more branch circuits, if the circuit breaker is adjusted to afford overcurrent protection for the smallest conductor.

75.800-3 Testing, Examination and Maintenance of Circuit Breakers; Procedures

A. Circuit breakers and their auxiliary devices protecting underground high-voltage circuits shall be tested and examined at least once each month by a person qualified as provided in 75.153;

B. Tests shall include:

(1) Breaking continuity of the ground check conductor, where ground check monitoring is used; and

(2) Actuating at least two of the auxiliary protective relays.

C. Examination shall include visual observation of all components of the circuit breaker and its auxiliary devices, and such repairs or adjustments as are indicated by such tests and examinations shall be carried out immediately.

75.801 Grounding Resistors

The grounding resistor, where required, shall be of the proper ohmic value to limit the voltage drop in the grounding circuit external to the resistor to not more than 100 volts under fault conditions. The grounding resistor shall be rated for maximum fault current continuously and insulated from the ground for a voltage equal to the phase-to-phase voltage of the system.

75.802 Protection of High-Voltage Circuits Extending Underground

A. Except as provided in paragraph (b) of this section, high-voltage circuits extending underground and supplying portable, mobile, or, stationary high-voltage equipment shall contain either <u>a direct or derived neutral which shall be grounded through a suitable resistor</u> at the source transformers, and a grounding circuit, originating at the grounded side of the grounding resistor, shall extend along with the power conductors and serve as a grounding conductor for the frames of all high-voltage equipment supplied power from the circuit.

B. Notwithstanding the requirements of paragraph (a) of this section, the Secretary or his authorized representative may permit ungrounded high-voltage circuits to be extended underground to feed stationary electric equipment if:

(1) Such circuits are either steel armored or installed in grounded, rigid steel conduit throughout their entire length; or,

(2) The voltage of such circuits is nominally 2,400 volts or less phase-to-phase and the cables used in such circuits are equipped with metallic shields around each power conductor, and contain one or more ground conductors having a total cross sectional area of not less than one-half the power conductor; and

(3) Upon a finding by the Secretary or his authorized representative that the use of the circuits described in paragraphs (b) (1) and (2) of this section does not pose a hazard to the miners.

C. Within 100 feet of the point on the surface where high-voltage circuits enter the underground portion of the mine, disconnecting devices shall be installed and so equipped or designed in such a manner that it can be determined by visual observation that the power is disconnected, except that the Secretary or his authorized representative may permit such devices to be installed at a greater distance from such area of the mine if he determines, based on existing physical conditions, that such installation will be more accessible at a greater distance and will not pose any hazard to the miners.

Grounding

75.803 Fail Safe Ground Check Circuits on High-Voltage Resistance Grounded Systems

On and after September 30, 1970, high-voltage, resistance grounded systems shall include a fail safe ground check circuit to monitor continuously the grounding circuit to assure continuity and the fail safe ground check circuit shall cause the circuit breaker to open when either the ground or pilot check wire is broken, or other no less effective device approved by the Secretary or his authorized representative to assure such continuity, except that an extension of time, not in excess of 12 months, may be permitted by the Secretary on a mine-by-mine basis if he determines that such equipment is not available.

75.803-1 Maximum Voltage Ground Check Circuits.

The maximum voltage used for ground check circuits under 75.803 shall not exceed 96 volts.

75.803-2 Ground Check Systems Not Employing Pilot Check Wires; Approval by the Secretary

Ground check systems not employing pilot check wires will be approved only if it is determined that the system includes a fail safe design causing the circuit breaker to open when ground continuity is broken.

75.804 Underground High-Voltage Cables

A. Underground high-voltage cables used in resistance grounded systems shall be equipped with metallic shields around each power conductor with one or more ground conductors having a total cross sectional area of not less than one-half the power conductor, and with an insulated external conductor not smaller than No. 8 (AWG) or an insulated internal ground check conductor not smaller than No. 10 (AWG) for the ground continuity check circuit.

B. All such cables shall be adequate for the intended current and voltage. Splices made in such cables shall provide continuity of all components.

75.805 Couplers

Couplers that are used with medium voltage or high-voltage power circuits shall be of the three-phase type with a full metallic shell, except that the Secretary may permit, under such guidelines as he may prescribe, no less effective couplers constructed of materials other than metal. Couplers shall be adequate for the voltage and current expected. All exposed metal on the metallic couplers shall be grounded to the ground conductor in the cable. The coupler shall be constructed so that the ground check continuity conductor shall be broken first and the ground conductors shall be broken last when the coupler is being uncoupled.

75.806 Connection of Single-Phase Loads

Single-phase loads, such as transformer primaries, shall be connected phase-to-phase.

Installation of High Voltage

75.807 Installation of High-Voltage Transmission Cables

All underground high-voltage transmission cables shall be installed only in regularly inspected air courses and haulage ways, and shall be covered, buried, or placed so as to afford protection again damage, guarded where men regularly work or pass under them unless there are 6 1/2 feet or more above the floor or rail, securely anchored, properly insulated, and guarded at ends, and covered, insulated, or placed to prevent contact with trolley wires and other low voltage circuits.

75.808 Disconnecting Devices

Disconnecting devices shall be installed at the beginning of branch lines in high-voltage circuits and equipped or designed in such a manner that it can be determined by visual observation that the circuit is deenergized when the switches are open.

75.809 Identification of Circuit Breakers and Disconnecting Switches

Circuit breakers and disconnecting switches underground shall be marked for identification.

75.810 High-Voltage Trailing Cables; Splices

In the case of high-voltage cables used as trailing cables, temporary splices shall not be used and all permanent splices shall be made in accordance with 75.604. Terminations and splices in all other high-voltage cables shall be made in accordance with the manufacturer's specifications.

Electrical Equipment

75.811 High Voltage Underground Equipment; Grounding

Frames, supporting structures and enclosures of stationary, portable, or mobile underground high-voltage equipment and all high-voltage equipment supplying power to such equipment receiving power from resistance grounded systems shall be effectively grounded to the high-voltage ground.

75.812 Movement of High-Voltage Power Centers and Portable Transformers; Permit

Power centers and portable transformers shall be deenergized before they are moved from one location to another, except that, when equipment powered by sources other than such centers or transformers is not available, the Secretary may permit such centers and transformers to be moved while energized, if he determines that another equivalent or greater hazard may otherwise be created, and if they are moved under the supervision of a qualified person, and if such centers provide protection against undervoltage, grounded phase, short circuit, and overcurrent.

Testing and Equipment

75.812-1 Qualified Person

A person who meets the requirements of 75.153 is a qualified person within the meaning of 75.812.

75.812-2 High-Voltage Power Centers and Transformers; Record of Examination

The operator shall maintain a record of all examinations conducted in accordance with 75.812. Such record shall be kept in a book approved by the Secretary.

75.900-4 Testing, Examination, and Maintenance of Circuit Breakers; Record

The operator of any coal mine shall maintain a written record of each test, examination, repair, or adjustment of all circuit breakers protecting low and medium voltage circuits serving three phase alternating current equipment used in the mine. Such record shall be kept in a book approved by the Secretary.

Breaking Continuity Ground Check

75.902-1 Maximum Voltage Ground Check Circuits

The maximum voltage used for such ground check circuits shall not exceed 40 volts.

75.902-2 Approved Ground Check Systems Not Employing Pilot Check Wires

Ground check systems not employing pilot check wires will be approved only if it is determined that the system includes a fail safe design causing the circuit breaker to open when ground continuity is broken.

75.902-4 Attachments of Ground Conductors and Ground Check Wires to Equipment Frames; Use of Separate Connections

In grounding equipment frames of all stationary, portable or mobile equipment receiving power from resistance grounded systems separate connections shall be used when practicable.

Surface Laws

77.606 Energized Trailing Cables; Handling

Energized medium and high-voltage trailing cables shall be handled only by persons wearing protective rubber gloves (See Section 77.606.1) and, with such other protective devices as may be necessary and appropriate under the circumstances.

77.606-1 Rubber Gloves; Minimum Requirements

A. Rubber gloves (Lineman's gloves) worn while handling high-voltage trailing cables shall be rated at least 20,000 volts and shall be used and tested in accordance with the provisions of Sections 77.704-6 through 77.704-8.

B. Rubber gloves (wireman's gloves) worn while handling trailing cables energized by 660 to 1,000 volts shall be rated at least 1,000 volts and shall not be worn inside our or without protective leather gloves.

C. Rubber gloves shall be inspected for defects before use on each shift and at lest once thereafter during the shift when such rubber gloves are used for extended periods. All protective rubber gloves, which contain defects, shall be discarded and replaced prior to handling energized cables.

77.701-3 Grounding Wires; Capacity

Where grounding wires are used to ground metallic sheaths, armors, conduits, frames, casings, and other metallic enclosures, such grounding wires will be approved if:

A. Where the power conductor used is No. 6 AWG, or larger, the cross-sectional area of the grounding wire is at least one-half the cross-sectional area of the power conductor.

B. Where the power conductor used is less than No. 6 AWG, the cross-sectional area of the grounding wire is equal to the cross- sectional area of the power conductor.

77.701-4 Use of Grounding Connectors

If ground wires are attached to grounded power conductors, separate clamps, suitable for such purpose, shall be used and installed to provide a solid connection.

77.702 Protection other than Grounding

Methods other than grounding, which provide no less effective protection, may be permitted by the Secretary or his authorized representative. Such methods may not be used unless so approved.

77.703 Grounding Frames of Stationary High-Voltage Equipment Receiving Power from Ungrounded Delta Systems

The frames of all stationary high-voltage equipment receiving power from ungrounded delta systems shall be grounded by methods approved by an authorized representative of the Secretary.

77.703-1 Approved Methods of Grounding

The methods of grounding stated in 77.701-1 will be approved with respect to the grounding of frames of high-voltage equipment referred to in 77.703.

77.704 Work on High-Voltage Lines; De-energizing and Grounding

High-voltage lines shall be deenergized and grounded before work is performed on them, except that repairs may be permitted on energized high-voltage lines if (a) such repairs are made by a qualified person in accordance with procedures and safeguards set forth in Section 77.704 through 77.704-11 of the Subpart H as applicable, and (b) the operator has tested and properly maintained the protective devices necessary in making such repairs.

77.704-1 Work on High-Voltage Lines

A. No high-voltage line shall be regarded as deenergized for performing work on it, until it has been determined by a qualified person (as provided in Section 77.103) that such high-voltage line has been deenergized and grounded. Such qualified person shall by visual observation

(1) determine that the disconnecting devices on the high-voltage circuit are in open position, and

(2) insure that each ungrounded conductor of the high-voltage circuit upon which work is to be done is properly connected to the system grounding medium. In the case of resistance grounded or solid wye-connected systems, the neutral wire is the system grounding medium. In the case of an ungrounded power system, either the steel armor or conduit enclosing the system or a surface grounding field is a system grounding medium;

B. No work shall be performed on any high-voltage line, which is supported, by any pole or structure, which also supports other high-voltage lines until:

C. (1) All lines supported on the pole or structure are deenergized and grounded in accordance with all of the provisions of the Section 77.704-1 which apply to the repair of deenergized surface high-voltage lines; or

(2) the provisions of Sections 77.704-2 through 77.704-10 have been complied with, respect to all energized lines, which are supported on the pole or structure.

C. Work may be performed on energized surface high-voltage lines only in accordance with the provisions of Sections 77.704-2 through 77.704-10, inclusive.

77.704-3 Work on Energized High-Voltage Surface Lines; Reporting

Any operator designating and assigning qualified persons to perform repairs on energized high-voltage surface lines under the provisions of 77.704-2 shall maintain a record of such repairs. Such record shall contain a notation of the time, date, location, and general nature of the repairs made together with a copy of the information filed with the operator by the qualified person designated as responsible for performing such repairs.

77.704-4 Simultaneous Repairs

When two or more persons are working on an energized high-voltage surface line simultaneously and any one of them is within reach of another, such persons shall not be allowed to work on different phases or on equipment with different potentials.

77.704-5 Installation of Protective Equipment

Before repair work on energized high-voltage surface lines is begun, protective equipment shall be used to cover all bare conductors, ground wires, guys, telephone lines, and other attachments in proximity to the area of planned repairs. Such protective equipment shall be installed from a safe position below the conductors or other apparatus being covered. Each rubber protective device employed in the making of repairs shall have a dielectric strength of 20,000 volts, or more.

77.704-9 Operating Disconnecting or Cutout Switches

Disconnecting or cutout switches on energized high-voltage switches on energized high-voltage surface lines shall be operated only with insulated sticks, fuse tongs, or pullers which are adequately insulated and maintained to protect the operator from the voltage to which he is exposed. When such switches are operated from the ground, the person using such devices shall wear protective rubber lineman's gloves, except where such switches are bonded to a metal mat as provided in § 77.513.

C. High Voltage Review

Q. What precautions must be taken when two or more persons are working within reach of each other on energized high-voltage lines?
A. They must not work on equipment with different potentials.

Q. What is an air switch?
A. A visible disconnect

Q. Shall a record be kept of repair work done on energized high-voltage surface lines?
A. Yes

Q. Where must high-voltage disconnect devices be installed?
A. At the beginning of all branch lines

Q. When are temporary splices in high-voltage cables allowed?
A. Not permitted under any circumstances

Q. The beginning of each high-voltage branch circuit must be equipped with:
A. A disconnecting device

Q. Where in a mine should the high-voltage cable be placed?
A. Regularly inspected air courses

Q. What must be done to identify circuit breakers and disconnecting devices underground?
A. Marked for identification

Q. Why is a donut CT also called a "flux" CT?
A. It detects an imbalance in the phases

Q. What will happen if the donut CT detects an unbalanced condition?
A. It will cause an automatically operating switch to open the circuit.

Q. What must circuit breakers protecting high-voltage lines entering an underground area of any coal mine provide?
A. Short-circuit, overcurrent, undervoltage and grounded-phase protection

Q. By what means is alternating current changed to direct current?
A. Rectifier

Q. What is the maximum voltage that can be used for high-voltage ground check circuits?
A. 96 volts

Q. What should be used to operate disconnecting or cutout switches on energized high-voltage surface lines?
A. Insulated sticks or fuse tongs

Q. What should be done with high-voltage cable with any metal exposed?
A. Grounded to the earth through a grounding resistor

Q. What is necessary when splices are made in high-voltage cables?
A. They must be made in accordance with the manufacturer's specifications

Q. What is the acceptable method of splicing a copper wire to an aluminum wire?
A. By soldering with a fusible metal or alloy or by using a special connector which prevents contact of dissimilar conductors

Q. Where should the grounding circuit of a high-voltage circuit originate when the circuit extends underground?
A. It should originate at the grounded side of the grounding resistor.

Q. What is the most common hookup of transformers in mining situations?
A. Delta-wye

Q. What is the insulation value when the neutral grounding resistor in a high-voltage circuit must be insulated from ground?
A. The phase-to-phase voltage of the system

Q. What is the minimum clearance for high-voltage power lines, which are located above driveways?
A. Minimum clearance of 20 feet

Q. Who is the person responsible for the special report concerning the repair of high-voltage line?
A. Mine operator

Q. What should you do to portable substations and transformers before they are moved from one location to another?
A. Deenergized

Q. What is the minimum size of an insulated internal ground check conductor that may be used for the ground continuity check circuit?
A. #10 AWG

Q. What is the limit of the voltage drop in the grounding circuit external to the resistor, if a high-voltage circuit includes a grounding resistor?
A. 100 volts

Q. How often must circuit breakers be tested and examined?
A. Once a month

Q. When cable couplers are constructed, what conductor should "break" first when the coupler is being uncoupled?
A. The ground check conductor

Q. When cable couplers are constructed, what conductor should "break" last when the coupler is being uncoupled?
A. Ground conductor

Q. What can be used to obtain a "derived neutral" on a transformer with a delta-connected secondary?
A. A zig-zag transformer

Q. What must be worn when handling high-voltage trailing cables?
A. Rubber or lineman's gloves (rated to at least 20,000 volts)

Q. How often should rubber gloves used to work on energized high-voltage lines be visually inspected for defects by the person using them?
A. Prior to use and at least once each day

Q. What does a high-voltage, ground-monitoring system do?
A. Opens the breaker whenever either the ground or pilot check wire is broken

Q. Where may high-voltage cables be installed underground?
A. Only in regularly inspected air courses

Q. What must all branch lines in underground high-voltage circuits have?
A. Disconnecting devices designed so that you can tell by visual observation that a line is de-energized

Q. How should single-phase loads be connected on a resistance-grounded power system?
A. Phase-to-phase

Q. What must surround each power conductor of high-voltage trailing cables?
A. A metallic shield

Q. What is the maximum feet from where high voltage cable enters the underground portion of the mine must surface disconnecting switches be installed?
A. 100 feet

Q. What shall be installed on all high voltage circuits leading underground?
A. Lighting arrestors

Q. Transformers on the surface shall be enclosed by suitable fence, unless elevated ___________ feet above the ground?
A. 8 feet

Q. How high shall the fence around surface transformers be?
A. 6 feet

Q. What must be done to the metallic shield around high voltage conductors?
A. They must be grounded.

Q. How can three-phase Delta connected transformers be grounded?
A. Derived neutral by mean of a zig-zag grounding transformer

Q. Why is high voltage used to transmit electrical energy for long distances?
A. Less line loss and smaller conductors

Q. How are high voltage transformers rated?
A. Kilo-volt-amps (KVA) which is found by multiplying primary current by primary voltage or by multiplying secondary current by secondary voltage

Q. What instrument is used to check high voltage cable insulation?
A. Megger

Q. On a high voltage step down transformer, which winding will have the smaller current carrying capacity?
A. Primary

Chapter 6
Legal Requirements

A. Virginia Mine Safety Act

§ 45.1-161.124. Shop and other equipment.

A. The following items of shop and other equipment shall be guarded and maintained adequately:

1. Gears, sprockets, pulleys, fan blades or propellers, friction devices and couplings with protruding bolts or nuts;
2. Shafting and projecting shaft ends that are within seven feet of floor or platform level;
3. Belt, chain or rope drives that are within seven feet of the floor or platform;
4. Fly wheels, provided that fly wheels extending more than seven feet above the floor shall be guarded to a height of at least seven feet;
5. Circular and band saws and planers;
6. Repair pits, provided that guards shall be kept in place when the pits are not in use;
7. Counterweights; and
8. The approach to mine fans shall be guarded.

B. Machinery shall not be repaired or serviced while the machinery is in motion; however, this shall not apply where safe remote devices are used.

C. A guard or safety device removed from any machine shall be replaced before the machine is put in operation.

D. Mechanically operated grinding wheels shall be equipped with (i) safety washers and tool rests; (ii) substantial retaining hoods, the hood opening of which shall not expose more than a 90 degree sector of the wheel; and (iii) eye shields, unless goggles are worn by the miners. Retaining hoods shall include either a device to control and collect excess rock, metal or dust particles, or a device providing equivalent protection to the miners operating such machinery.

E. The operator or his agent shall develop procedures for examining for potential hazards, completing proper maintenance, and properly operating each type of centrifugal pump. The procedures shall, at a minimum, address the manufacturer's recommendations for start-up and shutdown of the pumps, proper actions to be taken when a pump is suspected of overheating, safe location of start and stop switches, and actions to be taken when signs of structural metal fatigue such as cracks in the frame, damaged cover mounting brackets, or missing bolts or other components are detected. All miners who repair, maintain, or operate such pumps shall be trained in these procedures.

§ 45.1-161.140 Maintenance of equipment.

Locomotives, mine cars, shuttle cars, supply cars, conveyors, self-propelled mobile equipment, and all other equipment shall be maintained in a safe operating condition.

§ 45.1-161.175 Protective Clothing

B. Every person entering an underground mine must wear reflective materials adequate to be visible from all sides. The reflective material shall be placed on hard hats and at least one other item such as belts, suspenders, jackets, coats, coveralls, shirts, pants, vests, or other item of outer clothing.
E. Welders and helpers shall use proper shields or goggles to protect their eyes.
G. Gloves shall be worn when material, which may injure the hands, is handled. Gloves with gauntlet cuffs shall not be worn around moving equipment. Gloves shall be worn when handling energized cables.

§45.1-161.181. Grounding.

A. Overhead high-potential power lines shall be placed at least fifteen feet above the ground and twenty feet above driveways, shall be installed on insulators, and shall be supported and guarded to prevent contact with other circuits.
B. Surface transmission lines including trolley circuits shall be protected against short circuits and lightning. Each power circuit that leads underground shall be equipped with lightning arrestors within 100 feet of where the circuit enters the mine.

§ 45.1-161.182. Surface transformers.

A. Surface transformers which are not isolated by elevation of eight feet or more above the ground shall be enclosed in a transformer house or surrounded by a suitable fence at least six feet high. If the enclosure or fence is of metal, it shall be grounded effectively. The door to the enclosure or the gate to the fence shall be kept locked at all times unless persons authorized to enter the gate or enclosure are present.

§ 45.1-161.184. Stations and substations.

A. Suitable danger signs shall be posted conspicuously at all transformer stations.
C. Reverse-current protection shall be provided at storage-battery-charging stations to prevent the storage batteries from energizing the power circuits in the event of power failure.

§ 45.1-161.186. Power Circuits

A. All underground power wires and cables shall have adequate current-carrying capacity, shall be guarded from mechanical injury, and shall be installed in a permanent manner.
B. Wires and cables not encased in armor shall be supported by well installed insulators and shall not touch combustible materials, roof, or ribs; however, this shall not apply to ground wires, grounded power conductors, and trailing cables.
C. Power wires and cables installed in belt-haulage slopes shall be insulated adequately and buried in a trench not less than 12 inches below combustible material, unless encased in armor or otherwise fully protected against mechanical injury.
F. New high-voltage disconnects installed on or after January 1, 2007, on all underground electrical installations shall automatically ground all three power leads when in the open position.
G. All power wires and cables shall be insulated adequately where they pass into or out of electrical compartments, where they pass through doors and stoppings, and where they cross bare power wires.

§ 45.1-161.195. Inspection of Electric Equipment and Wiring; Checking and Testing Methane Monitors

A. Electric equipment and wiring shall be inspected by a certified person at least weekly if located underground, and at least monthly if located on the surface, and more often if necessary to assure safe operating conditions, and any hazardous condition found shall be promptly corrected or the equipment or wiring shall be removed from service. Records of such examination shall be maintained at the mine for a period of one year.
B. A functional check of methane monitors on electrical face equipment shall be conducted to determine that such monitors are de-energizing the electrical face equipment properly. Such check shall be made on each production shift and shall be conducted by the equipment operator in the

presence of a mine foreman, and shall be recorded in the on-shift report of the mine foreman.

C. Weekly calibration tests on methane monitors on electrical face equipment to determine the accuracy and operation of such monitors shall be conducted with a known mixture of methane at the flow rate recommended by the methane monitor and manufacturer. A record of the results shall be maintained.

D. Required methane monitors shall be maintained in permissible and proper operating condition.

§ 45.1-161.196. Repairs to circuits and electric equipment.

No electrical work shall be performed on low-voltage, medium-voltage, or high-voltage distribution circuits or equipment, except by a certified person or by a person trained to perform electrical work and to maintain electrical equipment under the direct supervision of a certified person. All high-voltage circuits shall be grounded before repair work is performed. Disconnecting devices shall be locked out and suitably tagged by the persons who perform electrical or mechanical work on such circuits or equipment connected to the circuits, except that in cases where locking out is not possible, such devices shall be opened and suitably tagged by such persons. Locks and tags shall be removed only by the persons who installed them or, if such persons are unavailable, by certified persons authorized by the operator or his agent. However, miners may, where necessary, repair energized trolley wires if they wear insulated shoes and lineman's gloves. This section does not prohibit certified electrical repairmen from making checks on or troubleshooting energized circuits or the performance of repairs or maintenance on equipment by authorized persons once the power is off and the equipment is blocked against motion, except where motion is necessary to make adjustments.

§ 45.1-161.207. Arcs, sparks and flames.

A. The intentional creation of any open arc, open spark or open flame, except as provided in subsection B, shall be prohibited.

B. Welding and cutting with arc or flame or soldering underground in other than a fireproof enclosure ventilated with intake air shall be done by or under the direct instruction of a certified foreman or repairman. A person certified in gas detection shall test for methane before and during such operations in underground mines and shall make a diligent search for fire after such operation in all mines. Rock dust or suitable fire extinguishers shall be immediately available during such welding or cutting. Welding operations shall be performed only in well ventilated areas.

§ 45.1-161.232. Tampering with methane monitoring devices prohibited; penalty.

A. No person shall intentionally disturb, disconnect, bypass, impair, or otherwise tamper with methane monitors or other devices capable of detecting the presence of explosive gases used in an underground coal mine. If the methane monitor is installed on a face cutting machine, continuous miner, longwall face equipment, loading machine, or other mechanized equipment used to extract or load coal as required pursuant to 30 CFR Part 75.342, and the monitor or the equipment malfunctions, the monitor may be disconnected or bypassed for the purposes of removing the monitor or the equipment in order to make necessary repairs to the monitor or the equipment. Any other methane monitor may be disconnected, bypassed or removed.
B. Any person convicted of a violation of this section shall be guilty of a Class 6 felony.

§ 45.1-161.233. Allowing persons to work in mine where methane monitoring equipment disconnected; penalty.

An operator, agent, or mine foreman shall not knowingly permit any miner to work in any area of the underground coal mine where such operator, agent, or mine foreman has knowledge that a methane monitor or other device capable of detecting the presence of explosive gases has been impaired, disturbed, disconnected, or bypassed in violation of § 45.1-161.232. Any person convicted of a violation of this section shall be guilty of a Class 6 felony.

§ 45.1-161.233:1 Intentionally bypassing safety devices; prohibition.

No person shall intentionally bypass, bridge, or otherwise impair an electrical or hydraulic circuit that affects the safe operation of electrical or mechanical equipment. This shall not prohibit No person shall intentionally bypass, bridge, or otherwise impair an electrical or hydraulic circuit that affects the safe operation of electrical or mechanical equipment. This shall not prohibit (i) a certified electrical repairman from by-passing energized circuits for troubleshooting; (ii) an authorized person from performing repairs or maintenance on equipment once the power is off and the equipment is blocked against motion except where motion is necessary to make adjustments or to move the equipment to a safe location; (iii) an authorized person from bypassing a hydraulic circuit for the purpose of troubleshooting or moving equipment to a safe location in order to make necessary repairs or be taken out of service; or (iv) an authorized person from activating an override feature that is designed by the machine manufacturer to allow the machine to be moved to a safe location in order to make necessary repairs or to be take out of service.

§ 45.1-161.267 Fire Precautions

B. No person shall smoke or use an open flame within twenty-five feet of locations used to handle or store flammable or combustible liquids or where an arc or flame may cause a fire or explosion.
C. Areas surrounding flammable liquid storage tanks, electrical substations and transformers shall be kept free of combustible material for at least twenty-five feet in all directions. Such storage tanks, substations and transformers shall be posted with readily visible fire hazard warning signs.
D. Structures or areas used for storage of flammable materials shall be constructed of fire resistant material, well ventilated, kept clean and orderly and posted with readily visible fire hazard warning signs.
E. Fuel lines shall be equipped with shut-off values at the sources. Such values shall be readily accessible and maintained in good operating condition.
F. Battery charging areas shall be well ventilated and posted with warning signs prohibiting smoking or open flames within twenty- five feet.
G. Oil, grease, other flammable hydraulic fluid, and other flammable material shall be kept in closed metal containers and separated from other materials to not create a fire hazard.
H. Combustible materials, grease, lubricants, paints and other flammable materials shall not be allowed to accumulate where they could create a fire hazard. Provisions shall be made to prevent the accumulation of such material on any equipment, at storage areas and any location where the material is used.
I. Electric motors, switches, lighting fixtures, and controls shall be protected by dust-tight construction.
J. Precautions shall be taken to ensure that sparks or other hot materials do not result in a fire when welding or cutting. Welding or cutting with arc or flame shall not be done in excessively dusty atmospheres or locations.

Fire-fighting apparatus shall be readily available when welding or cutting is performed.

K. Precautions shall be taken before applying heat, cutting or welding on any pipe or container that has contained a flammable or combustible material.

L. Oxygen and acetylene bottles shall be stored in racks designated and constructed for the storage of such bottles with caps in place and secured when not in use. Such bottles shall not be stored near oil, grease, and other flammable material.

M. Oxygen and acetylene gauges and regulators shall be kept clean and free of oil, grease, and other combustible materials.

N. Belt conveyors shall be equipped with control switches to automatically stop the driving motor of the conveyor in the event slipping on the driving pulley, by breakage or other accident stops the belt.

O. Areas surrounding main fan installations and other mine openings shall be kept free from grass, weeds, underbrush and other combustible materials for twenty-five feet in all directions.

P. Internal combustion engines, except diesel engines, shall be shut off prior to fueling.

§ 45.1-161.280. Transformers.

C. Suitable danger signs shall be posted conspicuously at all transformer stations on the surface.

D. All transformer stations on the surface shall be kept free of nonessential combustible materials and refuse.

E. No electrical work shall be performed on low-voltage, medium-voltage, or high-voltage distribution circuits or equipment, except by a certified person or by a person trained to perform electrical work and to maintain electrical equipment under the direct supervision of a certified person. All high-voltage circuits shall be grounded before repair work is performed. Disconnecting devices shall be locked out and suitably tagged by the persons who perform electrical or mechanical work on such circuits or equipment connected to the circuits, except that in cases where locking out is not possible, such devices shall be opened and suitably tagged by such persons. Locks and tags shall be removed only by the persons who installed them or, if such persons are unavailable, by certified persons authorized by the operator or his agent. However, employees may, where necessary, repair energized trolley wires if they wear insulated shoes and lineman's gloves. This section does not prohibit certified electrical repairmen from making checks on or troubleshooting energized circuits or the performance of repairs or maintenance on equipment by authorized persons once the power is off and the equipment is blocked against motion, except where motion is necessary to make adjustments.

§ 45.1-161.288. Inspection of electric equipment and wiring; checking and testing methane monitors.

A. Electric equipment and wiring that extend to underground areas shall be inspected by a certified person at least once a week and more often if necessary to assure safe operating conditions, and any hazardous condition found shall be corrected or the equipment or wiring shall be removed from service. This surface inspection is required for trailing cables and circuit breakers used in conjunction with such equipment and wiring.
B. The Chief may require the operator of a mine to functionally check on a daily basis methane monitors on electrical face equipment to determine that such monitors are de-energizing the electrical face equipment properly. Such check shall be made on each production shift and shall be conducted by the equipment operator in the presence of a foreman, and shall be recorded in the on-shift report of the surface foreman.
C. The Chief may require the operator of a mine to perform weekly calibration tests on methane monitors on electrical face equipment to determine the accuracy and operation of such monitors.

B. 30 CFR Requirements

Electrical Equipment

75.150 Tests for Methane and for Oxygen Deficiency; Qualified Person

A. The provisions of Subpart D-Ventilation of this part and 75.1106 require that tests for methane and for oxygen deficiency by made by a qualified person. A person is a qualified person for this purpose if he is a certified person under 75.100.

B. Pending issuance of Federal standards, a person will be considered a qualified person for testing for methane and for oxygen deficiency;
(1) If he has been qualified for this purpose by the State in which the coal mine is located; or
(2) The Secretary may qualify persons for this purpose in a coal mine in which persons are not qualified for this purpose by the State upon an application and a satisfactory showing by the operator of the coal

mine that each such person has been trained and designated by the operator to test for methane and oxygen deficiency and has made such tests for a period of 6 months immediately preceding the application. Applications for Secretarial qualification should be submitted to the Health and Safety Activity, Mine Safety and Health Administration, Certification and Qualification Center, P. O. Box 25367, Denver Federal Center, Denver, Colorado 80225.

(3) He has at least 1 year of experience, prior to the date of the application required by paragraph (c) of this section, in performing electrical work underground in a coal mine, in the surface work areas of an underground coal mine, in a surface coal mine, in a non-coal mine, in the mine equipment manufacturing similar equipment, and he attains a satisfactory grade on each of the series of five written tests approved by the Secretary and prescribed in paragraph (b) of this section.

C. An individual qualified in accordance with this section shall, in order to retain qualification, certify annually to the District Manager, that he has satisfactorily completed a coal mine electrical retraining program approved by the Secretary.

75.154 Repair of Energized Surface High Voltage Lines; Qualified Person

An individual is a qualified person within the meaning of 75.705 for the purpose of repairing energized surface high voltage lines only if he has had at least 2 years experience in electrical maintenance, and at least 2 years experience in the repair of energized high voltage surface lines located on poles or structures.

75.503 Permissible Electric Face Equipment; Maintenance

The operator of each coal mine shall maintain in permissible condition all electric face equipment required by 75.500, 75.501, 75.504 to be permissible which is taken into or used inby the last open crosscut of any such mine.

75.503-1 Statement Listing All Electric Face Equipment

Each operator of a coal mine shall complete and file Mine Safety and Health Administration Form No. 6-1496 entitled "Coal Operator's

Electrical Survey" and Form 6-1496 Supplemental entitled "Operator's Survey of Electrical Face Equipment". Forms may be obtained from any Coal Mine Safety District Office or Sub-district Office of the Mine Safety and Health Administration. Separate forms shall be filed for each mine. Copies one and two of the completed form shall be filed with the Coal Mine District or Sub-district Manager for the district in which each mine is located on or before May 30, 1970 An operator must list all electric face equipment being used at each mine as of the time of filing, all such equipment being repaired, and all standby electric equipment stored at or in the mine which the operator intends to use as face equipment.

75.504 Permissibility of New, Replacement, Used, Reconditioned, Additional, and Rebuilt Electric Face Equipment

On and after March 30, 1971, all new, replacement, used, reconditioned, and additional electric face equipment used in any mine referred to in 75.500, 75.501 and 75.503 shall be permissible and shall be maintained in a permissible condition, and in the event of any major overhaul of any item of electric face equipment in use on or after March 30, 1971, such equipment shall be put in, and thereafter maintained in, a permissible condition, unless in the opinion of the Secretary, such equipment or necessary replacement parts are not available.

75.505 Mines Classed Gassy; Use and Maintenance of Permissible Electric Face Equipment

Any coal mine, which, prior to March 30, 1970, was classed gassy under any provision of law and was required to use permissible electric face equipment and to maintain such equipment in a permissible condition shall continue to use such equipment and to maintain such equipment in such condition.

75.506 Electric Face Equipment; Requirements for Permissibility

A. Electric-driven mine equipment and accessories manufactured on or after March 30, 1973, will be permissible electric face equipment only (1) if they are fabricated, assembled, or built under an approval, or any extension thereof, issued by the Bureau of Mines or the Mine Safety and Health Administration in accordance with schedule 2G, or any subsequent Bureau of Mines schedule promulgated by the Secretary after March 30, 1970, which amends, modifies, or supercedes the permissibility requirements of schedule 2G, and (2) if they are maintained in a permissible condition.

C. Except as provided in paragraph (c) of this 75.506 electric-driven mine equipment and accessories manufactured prior to March 30, 1973, will be permissible electric face equipment
(1) If they were fabricated, assembled, or built under an approval, or any extension thereof, issued by the Bureau of Mines in accordance with the schedules set forth below, and
(2) if they are maintained in a permissible condition.

75.507 Power Connection Points

Except where permissible power connection units are used, all power-connection points outby the last open crosscut shall be in intake air.

75.507-1 Electric Equipment Other Than Power-Connection Points; Outby the Last Open Crosscut; Return Air; Permissibility Requirements

A. All electric equipment, other than power-connection points, used in return air outby the last open crosscut in any coal mine shall be permissible except as provided in paragraphs (b) and (c) of this section.

B. Notwithstanding the provisions of paragraph (a) of this section, in any coal mine where non-permissible electric face equipment may be taken into or used inby the last open crosscut until March 30, 1974, such non-permissible electric face equipment may be used in return air outby the last open crosscut.

C. Notwithstanding the provisions of paragraph (a) of this section, in any coal mine where a permit for noncompliance is in effect, non-permissible electric face equipment specified in such permit for noncompliance may be used in return air outby the last open crosscut for the duration of such permit.

75.508 Map of Electrical System

The location and the electrical rating of all stationary electric apparatus in connection with the mine electric system, including permanent cables, switchgear, rectifying substations, transformers, permanent pumps, and trolley wires and trolley feeder wires, and settings of all direct-current circuit breakers protecting underground trolley circuits, shall be shown on a mine map. Any changes made in a location, electric rating, or setting shall be promptly shown on the map when the change is made. Such map shall be available to an authorized representative of the Secretary and to the miners in such mine.

75.508-1 Mine Tracks

When mine track is used as a conductor of a trolley system, the location of such track shall be shown on the map required by section 75.508, with a notation of the number of rails and the size of such track expressed in pounds per yard.

75.509 Electric Power Circuit and Electric Equipment; Deenergization

All power circuits and electric equipment shall be deenergized before work is done on such circuits and equipment, except when necessary for trouble shooting or testing.

75.510 Energized Trolley Wires; Repair

Energized trolley wires may be repaired only by a person trained to perform electrical work and to maintain electrical equipment and the operator of a mine shall require that such person wear approved and tested insulated shoes and wireman's gloves.

75.510-1 Repair of Energized Trolley Wires; Training

The training referred to in 75.510 must include training in the repair and maintenance of live trolley wires, and in the hazards involved in making such repairs, and in the limitations of protective clothing used to protect against such hazards.

75.511 Low, Medium, or High Voltage Distribution Circuits and Equipment; Repair

No electrical work shall be performed on low, medium, or high- voltage distribution circuits or equipment, except by a qualified person or by a person trained to perform electrical work and to maintain electrical equipment under the direct supervision of a qualified person. Disconnecting devices shall be locked out and suitably tagged by the persons who perform such work, except that in cases where locking out is not possible, such devices shall be opened and suitably tagged by such persons. Locks or tags shall be removed only by the persons who installed them or, if such persons are unavailable, by the persons authorized by the operator or his agent.

75.512 Electric Equipment; Examination, Testing and Maintenance

All electric equipment shall be frequently examined, tested, and properly maintained by a qualified person to assure safe operating conditions. When a potentially dangerous condition is found on electric equipment, such equipment shall be removed from service until such condition is corrected. A record of such examinations shall be kept and made available to an authorized representative of the Secretary and to the miners in such mine.

75.512-1 Qualified Person

To be a qualified person within the meaning of 75.512, an individual must meet the requirements of 75.153.

75.512-2 Frequency of Examinations

The examinations and tests required by 75.512 shall be made at least weekly. Permissible equipment shall be examined to see that it is in permissible condition.

75.513 Electric Conductor; Capacity and Insulation

All electric conductors shall be sufficient in size, have adequate current carrying capacity, and be of such construction that a rise in temperature resulting from normal operation will not damage the insulating materials.

75.513-1 Electric Conductor; Size

An electric conductor is not of sufficient size to have adequate carrying capacity if it is smaller than is provided for in the **National Electric Code, 1968.** In addition, equipment and trailing cables that are required to be permissible must meet the requirements of the appropriate schedules of the Bureau of Mines.

75.516 Power Wires; Support

All power wires (except trailing cables on mobile equipment, specially designed cables conducting high-voltage power to underground rectifying equipment or transformers, or bare or insulated ground and return wires) shall be supported on well--insulated insulators and shall not contact combustible material, roof, or ribs.

75.516-1 Installed Insulators

Well-insulated insulators is interpreted to mean well-installed insulators. Insulated J-hooks may be used to suspend insulated power cables for temporary installation not exceeding 6 months and for permanent installation of control, cables such as may be used along belt conveyors.

75.516-2 Communication Wires and Cables; Installation; Insulation; Support

A. All communication wires shall be supported on insulated hangers or insulated J-hooks.

B. All communication cables shall be insulated as required by 75.517-1 and shall either be supported on insulated or uninsulated hangers or J-hooks, or securely attached to messenger wires, or buried, or otherwise protected against mechanical damage in a manner approved by the Secretary or his authorized representative.

C. All communication wires and cables installed in track entries shall, except when a communication cable is buried in accordance with paragraph (b) of this section, be installed on the side of the entry opposite to trolley wires and trolley feeder wires, additional insulation shall be provided for communication circuits at points where they pass over or under any power conductor.

D. For purposes of this section, communication cable means two or more insulated conductors covered by an additional abrasion- resistant covering.

75.518-1 Electric Equipment and Circuits; Overload and Short Circuit Protection; Minimum Requirements

A device to provide either short circuit protection or protection against overload which does not conform to the provision of the National Electric Code, 1968, does not meet the requirement of Section 75.518. In addition, such devices on electric face equipment and trailing cables that are required to be permissible must meet the requirements of the applicable schedules of the Bureau of Mines.

75.519 Main Power Circuits; Disconnecting Switches

In all main power circuits, disconnecting switches shall be installed underground within 500 feet of the bottoms of shafts and boreholes through which main power circuits enter the underground area of the mine and within 500 feet of all other places where main power circuits enter the underground area of the mine.

75.519-1 Main Power Circuits; Disconnecting Switches; Locations

Section 75.519 requires (a) that a disconnecting switch be installed on the surface at a point within 500 feet of the place where the main power circuit enters the underground area of a mine, and (b) that, in an instance on which a main power circuit enters the underground area through a shaft or borehole, a disconnecting switch be installed underground within 500 feet of the bottom of the shaft or borehole.

75.520 Electric Equipment; Switches

All electric equipment shall be provided with switches or other controls that are safely designed, constructed and installed.

75.521 Lightning Arresters; Ungrounded and Exposed Power Conductors and Telephone Wire

Each ungrounded, exposed power conductor and each ungrounded, exposed telephone wire that leads underground shall be equipped with suitable lightning arresters of approved type within 100 feet of the point where the circuit enters the mine. Lightning arresters shall be connected to a low resistance-grounding medium on the surface, which shall be separated from neutral grounds by a distance of not less than 25 feet.

75.522 Lightning Devices

No device for lighting any coal mine, which has not been approved, by the Secretary or his authorized representative shall be permitted in such mine.

75.601-3 Short Circuit Protection; Dual Element Fuses; Current Ratings; Maximum Values

Dual element fuses having adequate current-interrupting capacity shall meet the requirements for short circuit protection of trailing cables as provided in 75.601, however, the current ratings of such devices shall not exceed the maximum values specified in this section.

75.700 Grounding Metallic Sheaths, Armors, and Conduits Enclosing Power Conductors

All metallic sheaths, armors and conduits enclosing power conductors shall be electrically continuous throughout and shall be grounded by methods approved by an authorized representative of the Secretary.

75.701 Grounding Metallic Frames, Casings and Other Enclosures of Electric Equipment

Metallic frames, casings and other enclosures of electric equipment that can become "alive" through failure of insulation or by contact with energized parts shall be grounded by methods approved by an authorized representative of the Secretary.

75.701-3 Approved Methods of Grounding Metallic Frames, Casings and Other Enclosures of Electric Equipment Receiving Power from Direct Current Power Systems with One Polarity Grounded

For the purpose of grounding metallic frames, casings and enclosures of any electric equipment or device-receiving power from a direct-current power system with one polarity grounded, the following methods of grounding will be approved:

A. A solid connection to the mine track;

B. A solid connection to the grounded power conductor of the system;

C. Silicon diode grounding; however, this method shall be employed only when such devices are installed in accordance with the requirements set forth in paragraph (d) of 75.703-3; and

D. Any other method, approved by an authorized representative of the Secretary, which insures that there is no difference in potential between such metal enclosures and the earth.

75.701-4 Grounding Wires; Capacity of Wires

Where grounding wires are used to ground metallic sheaths, armors, conduits, frames, casings, and other metallic enclosures, such grounding wires will be approved if:

A. The cross-sectional area (size) of the grounding wire is at least one-half the cross-sectional area (size) of the power conductor where the power conductor used is No. 6 AWG, or larger.

B. Where the power conductor used is less than No. 6 AWG, the cross-sectional area (size) of the grounding wire is equal to the cross-sectional area (size) of the power conductor.

75.701-5 Use of Grounding Connectors

The attachment of grounding wires to a mine track or other grounded power conductor will be approved if separate clamps, suitable for such purpose, are used and installed to provide a solid connection.

75.702 Protection Other Than Grounding

Methods other than grounding, which provide no less effective protection, may be permitted by the Secretary or his authorized representative.

75.702-1 Protection Other Than Grounding; Approved by an Authorized Representative of the Secretary

Methods other than grounding, which provide no less effective protection, may be permitted by the Secretary or his authorized representative.

75.702-1 Protection Other Than Grounding; Approved by an Authorized Representative of the Secretary

Under this subpart, no method other than grounding may be used to ensure against a difference in potential between metallic sheaths, armors and conduits, enclosing power conductors and frames, casings and metal enclosure of electric equipment, and the earth, unless approved by an authorized representative of the Secretary.

75.703 Grounding off-Track Direct-Current Machines and the Enclosures of Related Detached Components

The frames of all off-track direct-current machines and the enclosures of related detached components shall be effectively grounded, or otherwise maintained at no less safe voltages, by methods approved by an authorized representative of the Secretary.

75.703-1 Approved Method of Grounding

In instances where the metal frames both of an off-track direct- current machine and of the metal frames of its component parts are grounded to the same grounding medium the requirements of 75.703 will be met.

75.703-2 Approved Grounding Mediums

For purposes of grounding off-track direct-current machines, the following grounding mediums are approved:

A. The grounded polarity of the direct-current power system feeding such machines; or,

B. The alternating current grounding medium where such machines are fed by an ungrounded direct-current power system originating in a portable rectifier receiving its power from a section power center. However, when such a medium is used, a separate grounding conductor must be employed.

75.703-3 Approved Methods of Grounding off-Track Mobile, Portable and Stationary Direct-Current Machines

In grounding off-track direct-current machines and the enclosures of their component parts, the following methods of grounding will meet the requirements of 75.703:

A. The use of a separate grounding conductor located within the trailing cable of mobile and portable equipment and connected between such equipment the direct-current grounding medium;

B. The use of a separate ground conductor located within the direct-current power cable feeding stationary equipment and connected between such stationary equipment and the direct-current grounding medium;

C. The use of a separate external ground conductor connected between stationary equipment and the direct-current grounding medium; or

D. The use of silicon diodes; however, the installation of such devices shall meet the following minimum requirements:

(1) Installation of silicon diodes shall be restricted to electric equipment receiving power from a direct-current system with one polarity grounded;

(2) Where such diodes are used on circuits having a nominal voltage rating of 250, they must have a forward current rating of 400 amperes or more, and have a peak inverse voltage rating of 400 or more;

(3) Where such diodes are used on circuits having a nominal voltage rating of 550, they must have a forward current rating of 250 amperes or more, and have a peak inverse voltage of 800 or more;

(4) Where fuses approved by the Secretary are used at the outby end of a trailing cable connected to electrical equipment employing silicon diodes the rating of such fuses must not exceed 150 percent of the nominal current rating of the grounding diodes;

(5) Where circuit breakers are used at the outby end of a trailing cable connected to electrical equipment employing silicon diodes, the instantaneous trip setting shall not exceed 300 percent of the nominal current rating of the grounding diode;

(6) Overcurrent devices must be used and installed in such a manner that the operating coil circuit of the main contractor will open when a fault current with a value of 25 percent or less of the diode rating flows through the diode;

(7) The silicon diode installed must be suitable to the grounded polarity of the power system in which it is used and its threaded base must be solidly connected to the machine frame on which it is installed;

(8) In addition to the grounding diode, a polarizing diode must be

installed in the machine control circuit to prevent operation of the machine when the polarity of a trailing cable is reversed;

(9) When installed on permissible equipment, all grounding diodes, overcurrent devices, and polarizing diodes must be placed in explosion proof compartments;

(10) When grounding diodes are installed on a continuous miner, their nominal diode current rating must be at least 750 amperes or more; and;

(11) All grounding diodes shall be tested, examined and maintained as electrical equipment in accordance with the provisions of 75.512.

75.800-3 Testing, Examination and Maintenance of Circuit Breakers; Procedures

A. Circuit breakers and their auxiliary devices protecting underground high-voltage circuits shall be tested and examined at least once each month by a person qualified as provided in 75.153;

B. Tests shall include: (1) Breaking continuity of the ground check conductor, where ground check monitoring is used; and (2) Actuating at least two (2) of the auxiliary protective relays.

C. Examination shall include visual observation of all components of the circuit breaker and its auxiliary devices, and such repairs of adjustments as are indicated by such tests and examinations shall be carried out immediately.

75.800-4 Testing, Examination and Maintenance of Circuit Breakers; Record

The operator of any coal mine shall maintain a written record of each test, examination, repair, or adjustment of all circuit breakers protecting high voltage circuits, which enter any underground area of the coal mine. Such record shall be kept in a book approved by the Secretary.

75.801 Grounding Resistors

The grounding resistor, where required, shall be of the proper ohmic value to limit the voltage drop in the grounding circuit external to the resistor to not more than 100 volts under fault conditions. The grounding resistor shall be rated for maximum fault conditions. The grounding resistor shall be rated for maximum fault current continuously and insulated from ground for a voltage equal to the phase-to-phase voltage of the system.

75.808 Disconnecting Devices

Disconnecting devices shall be installed at the beginning of branch lines in high-voltage circuits and equipped or designed in such a manner that it can be determined by visual observation that the circuit is deenergized when the switches are open.

75.809 Identification of Circuit Breakers and Disconnecting Switches

Circuit breakers and disconnecting switches underground shall be marked for identification.

75.812-1 Qualified Person

A person who meets the requirements of 75.153 is a qualified person within the meaning of 75.812.

75.812-2 High-Voltage Power Centers and Transformers; Record of Examination

The operator shall maintain a record of all examinations conducted in accordance with 75.812. Such record shall be kept in a book approved by the Secretary.

75.900 Low and Medium Voltage Circuits Servicing Three-phase Alternating Current Equipment; Circuit Breakers

Low and medium voltage power circuits serving three-phase alternating current equipment shall be protected by suitable circuit breakers of adequate interrupting capacity, which are properly tested and maintained as prescribed by the Secretary. Such breakers shall be equipped with devices to provide protection against undervoltage, grounded phase, short circuit, and overcurrent.

75.900-3 Testing, Examination, and Maintenance of Circuit Breakers; Procedures

Circuit breakers protecting low and medium voltage alternating current circuits serving three-phase alternating current equipment and their auxiliary devices shall be tested and examined at least once each month by a person qualified as provided in 75.153. In performing such tests, actuating any of the circuit breaker auxiliaries or control circuits in any manner, which causes the circuit breaker to open, shall be considered a proper test. All components of the circuit breaker and its auxiliary devices shall be visually examined and such repairs or adjustments as are indicated by such tests and examinations shall be carried out immediately.

75.900-4 Testing Examination, and Maintenance of Circuit Breakers; Record

The operator of any coal mine shall maintain a written record of each test, examination, repair, or adjustment of all circuit breakers protecting low and medium voltage circuits serving three-phase alternating current equipment used in the mine. Such record shall be kept in a book approved by the Secretary.

75.901 Protection of Low and Medium Voltage Three-phase Circuits Used Underground

A. Low and medium voltage three-phase alternating-current circuits used underground shall contain either a direct or derived neutral which shall be grounded through a suitable resistor at the power center, and a grounding circuit, originating at the grounded side of the grounding resistor, shall extend along with the power conductors and serve as a grounding conductor for the frames of all the electrical equipment supplied power from that circuit, except that the Secretary or his authorized representative may permit underground low and medium voltage circuits to be used underground to feed such stationary electrical equipment if such circuits are either steel armored or installed in grounded rigid steel conduit throughout their entire length. The grounding resistor, where required, shall be of the proper ohmic value to limit the ground fault current to 25 amperes. The grounding resistor shall be rated for maximum fault current continuously and insulated from ground for a voltage equal to the phase-to-phase voltage of the system.

75.902 Low and Medium Voltage Ground Check Monitor Circuits

On or before September 30, 1970, low and medium voltage resistance grounded systems shall include a fail-safe ground check circuit to monitor continuously the grounding circuit to assure continuity which ground check circuit shall cause the circuit breaker to open when either the ground or pilot check wire is broken, or other not less effective device approved by the Secretary or his authorized representative to assure such continuity, except that an extension of time, not in excess of 12 months, may be permitted by the Secretary on a mine-by-mine basis if he determines that such equipment is not available. Cable couplers shall be constructed so that the ground check continuity conductor shall be broken first and the ground conductors shall be broken last when the coupler is being uncoupled.

75.902-1 Maximum Voltage Ground Check Circuits for Low and Medium Voltage

The maximum voltage used for such ground check circuits shall not exceed 40 volts.

75.902-2 Approved Ground Check Systems not Employing Pilot Check Wires

Ground check systems not employing pilot check wires will be approved only if it is determined that the system includes a fail safe design causing the circuit breaker to open when ground continuity is broken.

75.902-4 Attachment of Ground Conductors and Ground Check Wires to Equipment Frames; Use of Separate Connections

In grounding equipment frames of all stationary, portable or mobile equipment receiving power from resistance grounded systems separate connections shall be used when practicable.

75.903 Disconnecting Devices

Disconnecting devices shall be installed in conjunction with the circuit breaker to provide visual evidence that the power is disconnected.

75.904 Identification of Circuit Breakers

Circuit breakers shall be marked for identification.

75.905 Connection of Single-phase Loads

Single-phase loads shall be connected phase-to-phase.

75.907 Design of Trailing Cables for Medium Voltage Circuits

Trailing cables for medium-voltage circuits shall include grounding conductors, a ground check conductor, and grounded metallic shields around each power conductor or a ground metallic shield over the assembly, except that on equipment employing cable reels, cables without shields may be used if the insulation is rated 2,000 volts or more.

Fire Protection

75.1100-1 Type and Quality of Firefighting Equipment

A. Portable fire extinguisher: A portable fire extinguisher shall be either (1) a multipurpose dry chemical type containing a nominal weight of 5 pounds of dry powder and enough expellant to apply the powder or (2) a foam-producing type containing at least 2 1/2 gallons of foam-producing liquids and enough expellant to supply the foam. Only fire extinguishers approved by the Underwriters Laboratories, Inc., or Factory Mutual Research Corporation, carrying appropriate labels as to type and purpose, shall be used. After March 30, 1971, all new portable fire extinguishers acquired for use in a coal mine shall have a 2A 10 BC or higher rating.

75.1100-2 Quantity and Location of Fire-fighting Equipment

A. Transportation

Each track or off-track locomotive, self-propelled man-trip car, or personnel carrier shall be equipped with one portable fire extinguisher.

B. Electrical Installations

(1) Two portable fire extinguishers or one extinguisher having at least twice the minimum capacity specified for a portable fire extinguisher in 75.1100-1(e) shall be provided at each permanent electrical installation.
(2) One portable fire extinguisher and 240 pound of rock dust shall be provided at each temporary electrical installation.

C. Oil Storage Stations

Two portable fire extinguishers and 240 pounds of rock dust shall be provided at each permanent underground oil storage station. One portable fire extinguisher shall be provided at each working section, where 25 gallon or more of oil are stored in addition to extinguishers required under paragraph (a) of this section.

75.1100.3 Condition and Examination of Firefighting Equipment

All firefighting equipment shall be maintained in a usable and operative condition. Chemical extinguishers shall be examined every 6 months and the date of the examination shall be written on a permanent tag attached to the extinguisher.

75.1503-5 Criteria-Belt Conveyors

A. Positive-active stop controls should be installed along all belt conveyors used to transport men and such controls should be readily accessible and maintained so that the belt can be stopped or started at any location.

B. Belt conveyors used for regularly scheduled mantrips should be stopped while men are loading or unloading.

C. All belt conveyors used for transportation of persons should have minimum vertical clearance where men board or leave such belt conveyors.

D. When men are being transported on regularly scheduled mantrips on belt conveyors the belt speed should not exceed 300 feet per minute when the vertical clearance is less than 24 inches and should not exceed 350 feet per minute when the vertical clearance is 24 inches or more.

E. Adequate illumination including colored lights or reflective signs should be installed at all loading and unloading stations. Such colored lights and reflective signs should be so located as to be observable to all persons riding the belt conveyor.

F. After supplies have been transported on belt conveyors, such belts should be examined for unsafe conditions before the transportation of men on regularly scheduled mantrips, and belt conveyors should be clear before men are transported.

G. A clear travel way at least 24 inches wide should be provided on both sides of all belt conveyors installed after March 30, 1970. Where roof supports are installed within 24-inches of belt conveyor, a clear travel way at least 24 inches wide should be provided on the side of such support farthest from the conveyor.

H. On belt conveyors that do not transport men, stop and start controls should be installed at intervals not to exceed 1,000 feet. Such controls should be properly installed and positioned so as to be readily accessible.

I. Telephone or other suitable communications should be provided at points where men or supplies are regularly loaded on or unloaded from the belt conveyors.

J. Persons should not cross moving belt conveyors, except where suitable crossing facilities are provided.

Surface Law

75.1722 Mechanical Equipment Guards

A. Gears; sprockets; chains; drive, head, tail, and take-up pulleys; flywheels; couplings, shafts, saw blades; fan inlets; and similar exposed moving machine parts which may be contacted by persons shall be guarded.

B. Guards at conveyor-drive, conveyor-head, and conveyor-tall pulleys shall extend a distance sufficient to prevent a person from reaching behind the guard and becoming caught between the belt and the pulley.

C. Except when testing the machinery, guards shall be securely in place while machinery is being operated.

75.1723 Stationary Grinding Machines; Protective Devices

A. Stationary grinding machines other than special bit grinders shall be equipped with:

(1) Peripheral hoods (less than 90 degrees throat openings) capable of withstanding the force of a bursting wheel.

(2) Adjustable tool rests set as close as practical to the wheel.

(3) Safety washers.

B. Grinding wheels shall be operated within the specifications of the manufacturer of the wheel.

C. Face shields or goggles, in good condition, shall be worn when operating a grinding wheel.

75.1724 Hand-held Power Tools; Safety Devices

Hand-held power tools shall be equipped with controls requiring constant hand or finger pressure to operate the tools or shall be equipped with friction or other equivalent safety devices.

75.1725 Machinery and Equipment; Operation and Maintenance

A. Mobile and stationary machinery and equipment shall be maintained in safe operating condition and machinery or equipment in unsafe condition shall be removed from service immediately.

B. Machinery and equipment shall be operated only by persons authorized to operate such machinery or equipment.

C. Repairs or maintenance shall not be performed on machinery until the power is off and the machinery is blocked against motion, except where machinery motion is necessary to make adjustments.

D. Machinery shall not be lubricated manually while in motion, unless equipped with extended fittings or cups.

76.1001 Overcurrent Protection

Trolley wires and trolley feeder wires shall be provided with overcurrent protection.

(a) Electric wiring in surface buildings shall be installed to prevent fire and contact hazards.

C. Legal Requirements Review

Q. How shall centrifugal pumps be examined, operated and maintained?
A. The mine operator shall develop procedures for examining, operating and maintaining each type of centrifugal pump.

Q. When can an electrical or hydraulic circuit that affects the safe operation be bypassed, birdged or otherwise impaired?
A. A certified electrical repairman can bypass for troubleshooting. An authorized person may perform repairs or maintenance once the power is off and the equipment is blocked against motion except where motion is necessary to make adjustments or move to a safe location.

Q. If surface transformers are isolated by elevation, they shall be at least how many feet above the ground?
A. Eight feet or more

Q. What must be posted conspicuously at all transformer stations on the surface and underground?
A. Suitable danger signs

Q. When both rails or main line track is welded or bonded at every joint, how close must cross bonds be installed?
A. At least every two hundred feet

Q. Trolley wires shall be aligned properly and installed on insulators at least how many inches outside the rail?
A. Six inches

Q. How many temporary splices are allowed in a trailing cable?
A. One

Q. While electric equipment is operating in the face region, test for methane shall be made at least every?
A. Twenty minutes

Q. What must be done with energized parts that come in contact with metallic frames, casings and other enclosures of stationary electric equipment that become alive through failure of insulation or by contact?
A. Grounded

Q. What electric equipment can remain energized on idle days or idle shifts although it is not in use?
A. Transformers and rectifiers

Q. What must be installed on all telephone lines at the point they enter the mine?
A. Lightning arresters

Q. Should telephone lines other than cables be installed on the same side as trolley wire?
A. No

Q. How often is the ground continuity to be checked in trailing cables?
A. Weekly

Q. Neutral grounding resistors, where required, are required to be located at __________.
A. The source transformer

Q. All power circuits and electric equipment shall be deenergized before work is performed on them except when____________.
A. Necessary for trouble shooting or testing

Q. What must be worn when repairing an energized trolley wire?
A. Insulated shoes and wireman's gloves

Q. Before work is performed on electric equipment or circuits, who must tag the disconnecting devices after they are locked out?
A. The person who is to perform the work

Q. What four protections are required on low and medium circuit breakers?
A. Short circuit, overcurrent, undervoltage and grounded phase

Q. What must be used to make splices in conductors?
A. Suitable connectors

Q. How often shall all low and medium voltage circuit breakers be examined?
A. Monthly

Q. What shall all low and medium voltage circuit breakers be marked for?
A. Identification

Q. Insulated J-hooks may be used to suspend insulated power conductors for temporary installation for a period of not more than?
A. Six months

Q. How often shall all chemical fire extinguishers be examined?
A. Every six months

Q. The grounding resistor, where required, shall be of the proper OHMIC value to limit the ground fault current to__________.
A. Twenty-five amps

Q. What is the purpose of disconnecting devices in conjunction with circuit breakers?
A. Provide visual evidence that power is removed

Q. How shall 110-220 volt circuits receiving power from single phase be grounded?
A. Grounded center tap of the transformer

Q. What are the methods of grounding off-track D.C. equipment?
A. Grounding conductor and diodes

Q. What type diodes are used in a D. C. system with one polarity grounded?
A. Silicon Diodes

Q. What must be done before work is performed on high-voltage circuits?
A. De-energized, locked out and tagged

Q. On a machine using diode grounding, what must be installed in the machine's control circuit to keep the machine from operating when the polarity of the cable is reversed?
A. A polarizing diode

Q. Where shall circuit breakers protecting high-voltage circuits in underground area of any coal mine be located?
A. On the surface

Q. What is the maximum voltage allowed for ground check voltage in high-voltage circuits?
A. Ninety-six volts for high voltage and 40 volts for low and medium voltage

Q. A disconnecting device must be designed or equipped so that it can be determined that the device is open by what type inspection?
A. Visual

Q. What type of explosive gas is omitted at a battery-charging station when batteries are being charged?
A. Hydrogen

Q. Where shall trolley wire cut out switches be installed?
A. Every fifteen hundred feet and beginning of all branch lines

Q. Where shall beltline control switches be installed?
A. At least every one thousand feet

Q. What is required to be shown on the mine electrical map?
A. Location and rating of all stationary electrical equipment

Chapter 7
Permissibility

A. Virginia Mine Safety Act

Modern underground coal mining requires extensive use of electrically powered equipment. Use of open type electrical equipment, in the past, frequently created ignitions/explosions, which resulted in many injuries and fatalities. As injuries and deaths from ignitions/explosions increased it became evident that electrical components causing arcs and sparks must be installed in enclosures classified as explosion proof. As of September 1971 all equipment used in other than intake air and used in and inby the last open cross cut was required to be approved as permissible and be maintained as permissible.

Schedule 2G of the Code of Federal Regulations established permissibility standards for manufacturers of electrically powered face equipment. Electrical Repairman should be acquainted with the requirements of Schedule 2G in order to inspect and maintain permissible equipment.

The Virginia Mine Safety Act requires that **electric and diesel** equipment taken into or used inby the last open crosscut or in other than intake air shall be permissible equipment and be maintained permissible.

§ 45.1-161.193

A. Electric equipment taken into or used inby the last open crosscut or in other than intake air shall be permissible equipment.

B. Permissible equipment used in areas specified in subsection A shall be maintained in permissible condition.

C. Electric equipment shall not be taken into or operated in any place where a methane level of one percent or more is detected.

D. Underground installations of electric face equipment shall not exceed 300 volts direct current. Alternating current circuit installations of a nominal voltage exceeding 1000 volts providing power to equipment at the working face shall be provided with necessary safety devices and components.

B. 30 Code of Federal Regulations Requirements

SUBPART A - GENERAL PROVISIONS

1. Electrical Equipment

18.1 Purpose

The regulations in this part set forth the requirements to obtain MSHA; (a) Approval of electrically operated machines and accessories intended for use in gassy mines or tunnels, (b) certification of components intended for use on or with approved machines, (c) permission to modify the design of an approved machine or certified component, (d) acceptance of flame-resistant cables, hoses, and conveyor belts, (e) accessories in gassy mines or tunnels; also, procedures for applying for such approval, certification, acceptance for listing; and fees.

18.2 Definitions

As used in this part:
"Acceptance" means written notification by MSHA that a cable, hose, or conveyor belt has met the applicable requirements of this part and will be tested by MSHA as acceptable flame resistant auxiliary equipment.

"Acceptance marking" means an identifying marking indicating that the cable, hose, or conveyor belt has been accepted by MSHA for listing as flame resistant.

"Accessory" means associated electrical equipment, such as a distributed or splice box that is not an integral part of an approved (permissible) machine.

"Administrator" means the Administrator, Mining Enforcement and Safety Administration.

"Afterburning" means the combustion of a flammable mixture that is drawn into a machine compartment after an internal explosion in the compartment.

"Applicant" means an individual, partnership, company, corporation, organization, or association that designs, manufactures, assembles, or controls the assembly of an electrical machine or accessory and seeks approval, certification, or permit, or MSHA acceptance for listing of flame resistant cable, hose, or conveyor belt.

"Approval" means a formal document issued by MSHA, which states that, a completely assembled electrical machine or accessory has met the applicable requirements of this part and which authorizes the attachment of an approval plate so indicating.

"Approval plate" means a metal plate, the design of which meets MSHA requirements, for attachment to an approved machine or accessory, identifying it as permissible for use in gassy mines or tunnels.

"Branch circuit" means an electrical circuit connected to the main circuit, the conductors of which are of smaller size than the main circuit.

"Bureau" means the U. S. Bureau of Mines.

"Certification" means a formal written notification, issued by MSHA, which states that an electrical component complies with the applicable requirements of this part and, therefore, is suitable for incorporation in approved (permissible) equipment.

"Certification label" means a plate, label, or marking, the design of which meets MSHA requirements, for attachment to a certified component identifying the component as having met the MSHA requirements for incorporation in a machine to be submitted for approval.

"Component" means an integral part of an electrical machine or accessory that is essential to the functioning of the machine or accessory.

"Connection box" (also known as conduit or terminal box" means an enclosure mounted on an electrical machine or accessory to facilitate wiring, without the use of external splices (Such boxes may have a joint common with an explosion-proof enclosure provided the adjoining surfaces conform to the requirements of Sub-part B of this part).

"Cylindrical joint" means a joint comprised of two contiguous, concentric, cylindrical surfaces.

"Distribution box" means an enclosure through which one or more portable cables may be connected to a source of electrical energy, and which contains a short-circuit protective device for each outgoing cable.

"Experimental equipment" means any electrical machine or accessory that an applicant or MSHA may desire to operate experimentally for a limited time in a gassy mine or tunnel (For example, this might include a machine constructed at a mine, an imported machine, or a machine or device designed and developed by MSHA).

"Explosion-proof enclosure" means an enclosure that complies with the applicable design requirements in Subpart B of this part and is so constructed that it will withstand internal explosions of methane-air mixtures: (1) Without damage to or excessive distortion of its walls or cover(s), and (2) without ignition of surrounding methane-air mixtures or discharge of flame from inside to outside the enclosure.

"Fire-resistant" as applied to conveyor belts means belting that will pass the flame tests hereafter specified.

"Flame-arresting path" means two or more adjoining or adjacent surfaces between which the escape of flame is prevented.

"Flame resistant" as applied to cable, hose, and insulating materials means material that will burn when held in a flame but will cease burning when the flame is removed.

"Flammable mixture" means a mixture of methane or natural gas and air that when ignited will propagate flame. Natural gas containing a high percentage of methane is a satisfactory substitute for pure methane in most tests.

"Incendiary arc or spark" means an arc or spark releasing enough electrical or thermal energy to ignite a flammable mixture of the most easily ignitable composition.

"Intrinsically safe" means incapable or releasing enough electrical or thermal energy under normal or abnormal conditions to cause ignition of a flammable mixture of methane or natural gas and air of the most easily ignitable composition.

"MSHA" means the United States Department of Labor, Mine Safety and Health Administration.

"Mobile equipment" means equipment that is self-propelled.

"Normal operation" means the regular performance of those functions for which a machine or accessory was designed.

"Permissible equipment" means a completely assembled electrical machine or accessory for which a formal approval has been issued, as authorized by the Administrator, Mining Enforcement and Safety Administration under the Federal Coal Mine Health and Safety Act of 1969. This definition has been superseded by the definition I part 75.2(i).

"Permit" means a formal document signed by the Administrator, authorizing the operation of specific experimental equipment in a gassy mine or tunnel under prescribed conditions.

"Plane joint" means two adjoining surfaces in parallel planes.

"Portable cable," or "trailing cable," means a flame-resistant, flexible cable or cord through which electrical energy is transmitted to a permissible machine or accessory (A portable cable is that portion of the power supply system between the last short circuit protective device, acceptable to MSHA, in the system and the machine or accessory to which it transmits electrical energy).

"Portable equipment" means equipment that may be moved frequently and is constructed or mounted to facilitate such movement.

"Potted component" means a component that is entirely embedded in a solidified insulating material within an enclosure.

"Pressure piling" means the development of abnormal pressure because of accelerated rate of burning of a gas-air mixture (Frequently caused by restricted configurations within enclosures).

"Qualified representative" means a person authorized by MSHA to determine whether the applicable requirements of this part have been complied with in the original manufacture, rebuilding, or repairing of equipment for which approval, certification, or a permit is sought.

"Splice box" means a portable enclosure in which electrical conductors may be joined.

"Step (rabbet) joint" means a joint comprised of two adjoining surfaces with a change(s) in direction between its inner and outer edges (A step joint may be composed of a cylindrical portion and a plane portion or of two or more plane portions).

"Threaded joint," means a joint consisting of a male and a female threaded member, both of which are of the same type and gage.

18.3 Consultation

By appointment, applicants or their representatives may visit Approval and Testing, Pittsburgh Technical Support Center, 4800 Forbes Avenue, Pittsburgh, PA. 15213, to discuss a proposed design to be submitted for approval, certification, or acceptance for listing. No charge is made for such consultation and no written report thereof will be made to the applicant.

18.4 Equipment for which approval will be issued

An approval will be issued only for a complete electrical machine or accessory. Assemblies that include one or more non-explosion- proof components will not be considered for approval unless such component(s) contains intrinsically safe circuits or is constructed in accordance with paragraph (b), Section 18.31.

18.5 Equipment for which certification will be issued

Certification will be issued for a component or subassembly suitable to incorporate in an approved machine. Certification may be issued for such components as explosion-proof enclosures, battery trays, and connectors.

18.8 Date for conducting investigation and tests

The date of receipt of an application will determine the order of precedence for investigation and testing. If an electrical machine component or accessory fails to meet any of the requirements, it shall lose its order of precedence. If an application is submitted to resume investigation and testing after correction of the cause of failure, it will be treated as a new application and the order of precedence for investigation and testing will be so determined.

18.10 Notice of approval or disapproval

(a) Upon completing investigation of a complete assembly of an electrical machine or accessory, MSHA will issue to the applicant either a written notice of approval or a written notice of disapproval, as the case may require. No informal notification of approval will be issued. If a notice of disapproval is issued, it will be accompanied by details of the defects, with recommendations for possible correction. MSHA will not disclose, except to the applicant, any information upon which a notice of disapproval has been issued.

(b) A formal notice of approval will be accompanied by a list of drawings, specifications, and related material, covering the details of a design and construction of the equipment upon which the approval is based. Applicants shall keep exact duplicates of the drawings, specifications, and descriptions that relate to equipment for which an approval has been issued, and the drawings and specifications shall be adhered to exactly in production of the approved equipment.

(c) An applicant shall not advertise or otherwise represent his equipment as approved (permissible) until he has received MSHA formal notice of approval.

18.11 Approval plate

(a) (1) The notice of approval will be accompanied by a photograph of an approval plate, bearing the emblem of Mining Enforcement and Safety Administration, the name of the complete assembly, the name of the applicant, and spaces for the approval number, serial number, and the type or model of machine.

(2) An extension of approval will not affect the original approval number except that the extension number shall be added to the original approval number on the approval plate (Example: Original approval No. 2G-3000; seventh extension No. 2G-3000-7).

(b) The applicant shall reproduce the design on a separate plate, which shall be attached in a suitable place, on each complete assembly to which it relates. The size, type, location, and method of attaching an approval plate is subject to MSHA concurrence. The method for affixing the approval plate shall not impair any explosion-proof feature of the equipment.

(c) The approval plate identifies as permissible the machine or accessory to which it is attached, and use of the approval plate obligates the applicant to whom the approval was issued to maintain in his plant the quality of each complete assembly and guarantees that the equipment is manufactured and assembled according to the drawings, specifications, and descriptions upon which the approval and subsequent extension(s) of approval were based.

(d) A completely assembled approved machine with an integral dust collector shall bear an approval plate indicating that the requirements of Part 33 of this chapter (Bureau of Mines Schedule 25B), have been complied with. Approval numbers will be assigned under each part of such joint approvals.

18.12 Letter of certification

(a) A letter of certification may be issued by MSHA for a component intended for incorporation in a complete machine or accessory for which an approval may be subsequently issued. A letter of certification will be issued to an applicant when a component has met all the applicable requirements of this part included in the letter of certification will be an assigned MSHA certification number that will identify the certified component.

(b) A letter of certification will be accompanied by a list of drawings, specifications, and related material covering the details of design and construction of a component upon which the letter of certification is based. Applicants shall keep exact duplicates of the drawings, specifications, and descriptions that relate to the component for which a letter of certification has been issued; and the drawings and specifications shall be adhered to exactly in production of the certified component.

(c) A component shall not be represented as certified until the applicant has received MSHA letter of certification for the component. Certified components are not to be represented as "approved" or "permissible" because such terms apply only to completely assembled machines or accessories.

18.13 Certification plate

Each certified component shall be identified by a certification plate attached to the component in a manner acceptable to MSHA. The method of attachment shall not impair any explosion-proof characteristics of the component. The plate shall be of serviceable material, acceptable, to MSHA, and shall contain the following:

Certified as complying with the applicable requirements of 30 CFR Part, Certification No.

The blank spaces shall be filled with appropriate designations. Inclusion of the information on a company nameplate will be permitted provided the plate is made of material acceptable to MSHA.

18.14 Identification of tested non-certified-explosion-proof enclosures

An enclosure that meets all applicable requirements of this part, but has not been certified by MSHA, shall be identified by a permanent marking on it in a conspicuous location. The design of such marking shall consist of capital letters USMSHA not less than 1/4 inch in height, enclosed in a circle not less than 1 inch in diameter.

18.15 Changes after approval or certification

If an applicant desires to change any feature of approved equipment or a certified component, he shall first obtain MSHA concurrence pursuant to the following procedure:

(a) Application shall be made as for an original approval or letter of certification requesting that the existing approval or certification be extended to cover the proposed changes(s) and shall be accompanied by drawings, specifications, and related information, showing the change(s) in detail.

(b) The application will be examined by MSHA to determine whether inspection or testing will be required. Testing will be required if there is a possibility that the change(s) may adversely affect safety.

(c) If the change(s) meets the requirements of this part, a formal extension of approval or certification will be issued, accompanied by a list of new or revised drawings, specifications, and related information to be added to those already on file for the original approval or certification.

(d) Revisions in drawings or specifications that do not involve actual change in the explosion proof features of equipment may be handled informally, without fee.

18.16 Withdrawal of approval, certification, or acceptance.

MSHA reserves the right to rescind, for cause, any approval, certification, acceptance, or extension thereof, issued under this part.

Subpart B-Construction and Design Requirements

18.20 Quality of material, workmanship, and design

(a) Electrically operated equipment intended for use in coal mines shall be rugged in construction and shall be designed to facilitate inspection and maintenance.

(b) MSHA will test only electrical equipment that in the opinion of its qualified representatives is constructed of suitable materials, is of good quality workmanship, based on sound engineering principles, and is safe for its intended use. Since all possible designs, circuits, arrangements, or combinations of components and materials cannot be foreseen, MSHA reserves the right to modify design, construction, and test requirements to obtain the same degree of protection as provided by the tests described in Subpart C of this part.

(c) Moving parts, such as rotating saws, gears, and chain drives, shall be guarded to prevent personal injury.

(d) Flange joints and lead entrances shall be accessible for field inspection, where practicable.

(e) An audible warning device shall be provided on each mobile machine that travels at a speed greater than 2.5 miles per hour.

(f) Brakes shall be provided for each wheel mounted machine, unless design of the driving mechanism will preclude accidental movement of the machine when parked.

(g) A headlight and red light-reflecting material shall be provided on both front and rear of each mobile transportation unit that travels at a speed greater than 2.5 miles per hour. Red light-reflecting material should be provided on each end of other mobile machines.

18.21 Machines equipped with powered dust collectors

Powered dust collectors on machines submitted for approval shall meet the applicable requirements of Part 33 of this chapter (Bureau of Mines Schedule 25B), and shall bear the approval number assigned by MSHA.

18.22 Boring-type machines equipped for auxiliary face ventilation

Each boring-type continuous mining machine that is submitted for approval shall be constructed with an unobstructed continuous space(s) of not less than 200 square inches total cross-sectional area on or within the machine to which flexible tubing may be attached to facilitate auxiliary face ventilation.

18.23 Limitation of external surface temperatures

The temperature of the external surfaces of mechanical or electrical components shall not exceed 150 degrees C. (302 degrees F.) under normal operating conditions.

18.24 Electrical clearances

The clearance between live parts and casings shall be sufficient to minimize the possibility of areas striking the casings. Where space is limited, the casing shall be lined with adequate insulation.

18.25 Combustible gases from insulating material

(a) Insulating materials that give off flammable or explosive gases when decomposed electrically shall not be used within enclosures where the materials are subjected to destructive electrical action.

(b) Parts coated or impregnated with insulating materials shall be heat-treated to remove any combustible solvent(s) before assembly in an explosion-proof enclosure. Air-drying insulating materials are accepted.

18.26 Static electricity

Nonmetallic rotating parts, such as belts and fans, shall be provided with a means to prevent an accumulation of static electricity.

18.27 Gaskets

A gasket(s) shall not be used between any two surfaces forming a flame-arresting path except as follows:

(a) A gasket of lead, elastomer, or equivalent will be acceptable provided the gasket does not interfere with an acceptable metal-to-metal joint.

(b) A lead gasket(s) or equivalent will be acceptable between glass and a hard metal to form all or a part of a flame--arresting path.

2. Protective Devices

18.28 Devices for pressure relief, ventilation, or drainage

(a) Devices for installation on explosion-proof enclosures to relieve pressure, ventilate or drain will be acceptable provided the length of the flame-arresting path and the clearances or size of holes in perforated metal will prevent discharge of flame in explosion tests.

(b) Devices for pressure relief, ventilation, or drainage shall be constructed of materials that resist corrosion and distortion, and be so designed that they can be cleaned readily. Provision shall be made for secure attachment of such devices.

(c) Devices for pressure relief, ventilation, or drainage will be acceptable for application only on enclosures with which they are explosion tested.

18.29 Access openings and covers, including unused lead- entrance holes

(a) Access openings in explosion-proof enclosures will be permitted only where necessary for maintenance of internal parts such as motor brushes and fuses.

(b) Covers for access openings shall meet the same requirements as any other part of an enclosure except that threaded covers shall be secured against loosening, preferably with screws having heads requiring a special tool.

(c) Holes in enclosures that are provided for lead entrances but which are not in use shall be closed with metal plugs secured by spot welding, brazing, or equivalent.

18.30 Windows and lenses

(a) MSHA may waive testing of materials for windows or lenses except headlight lenses. When tested, material for windows or lenses shall meet the test requirements prescribed in Section 18.66 and shall be sealed in place or provided with flange joints in accordance with Section 18.31.

(b) Windows or lenses shall be protected from mechanical damage by structural design, location, or guarding. Windows or lenses, other than headlight lenses, having an exposed area greater than 8 square inches, shall be provided with guarding or equivalent.

18.31 Enclosures-joints and fastenings

(a) Explosion-proof enclosures:

(1) Cast or welded enclosures shall be designed to withstand a minimum internal pressure of 150 pounds per square inch (gage). Castings shall be free from blowholes.

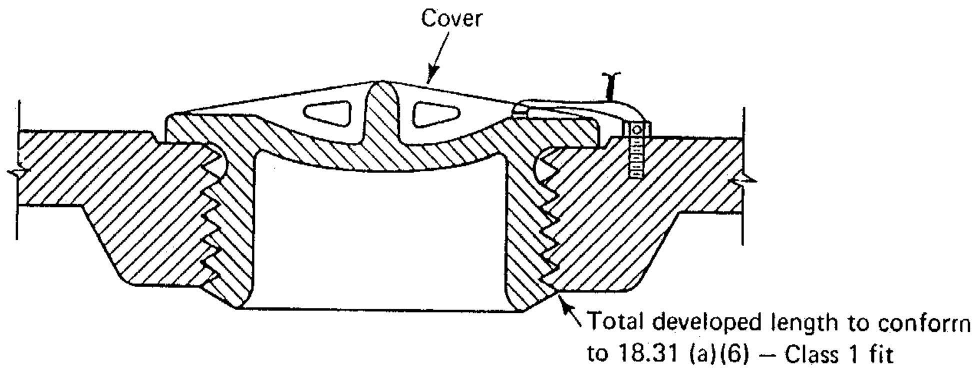
(2) Welded joints forming an enclosure shall have continuous gas-tight welds. All welds shall be made in accordance with American Welding Society standards.

(3) External rotating parts shall not be constructed of aluminum alloys containing more than 0.6 percent magnesium.

(4) MSHA reserves the right to require the applicant to conduct static-pressure tests on each enclosure when MSHA determines that the

particular design will not permit complete visual inspection or when the joint(s) forming an enclosure is welded on one side only (see Section 18.67).

(5) Threaded covers shall be designed with Class 1 (coarse, loose fitting) threads. The flame-arresting path of threaded joints shall conform to the requirements of subparagraph (6) of this paragraph.



(6) Enclosures shall meet the following requirements based on the internal volumes of the employ enclosure.

(b) Enclosures for potted components: Enclosures shall be rugged and constructed with materials having 75 percent, or greater, of the thickness and flange width specified in paragraph (a) of this section. These enclosures shall be provided with means for attaching hose conduit, unless energy carried by the cable is intrinsically safe.

Plugs shall be secured by spot welding or brazing. Weld may be on plug, clamp, or fastening bolt.

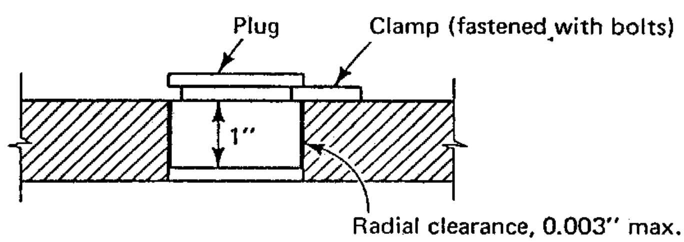


Figure: Typical slip-fit angle-type stuffing box and packing gland lead entrance and typical plug for spare lead entrance hole.

18.32 Fastening additional requirements

(a) Bolts, screws, or studs shall be used for fastening adjoining parts to prevent the escape of flame from an enclosure. Hinge pins or clamps will be acceptable for this purpose provided MSHA determines them to be equally effective.
(b) Lock washers shall be provided for all bolts, screws, and studs that secure parts of explosion-proof enclosures. Special fastenings designed to prevent loosening will be acceptable in lieu of lock washers, provided MSHA determines them to be equally effective.
(c) Fastenings shall be as uniform in size as practicable to preclude improper assembly.
(d) Holes for fastenings shall not penetrate to the interior of an explosion-proof enclosure, except as provided in paragraph (a) (9) of Section 18.34 and shall be threaded to insure that a specified bolt or screw will not bottom even if its lock washer is omitted.
(e) A minimum of 1/8 inch of stock shall be left at the center of the bottom of each hole drilled for fastenings.
(f) Fastenings used for joints on explosion-proof enclosures shall not be used for attaching nonessential parts or for making electrical connections.
(g) The acceptable sizes for and spacing of fastenings shall be determined by the size of the enclosure, as indicated in Section 18.31.
(h) MSHA reserves the right to conduct explosion tests with standard bolts, nuts, cap screws, or studs substituted for any special high-tensile strength fastening(s) specified by the applicant.

18.33 Finish of surface joints

Flat surfaces between bolt holes that form any part of a flame-arresting path shall be plane to within a maximum deviation of one-half the maximum clearance specified in Section 18.31(a)(b). All metal surfaces shall be finished in manufacture to not more than 250 micro inches. A thin film of non-hardening preparation to inhibit rusting may be applied to finished steel surfaces.

18.34 Explosion proof motor

(a) General
  (1) Motors shall have explosion-proof enclosures.
  (2) Motors submitted to MSHA for test shall be equipped with unshielded bearings regardless of whether that type of bearing is specified.

(3) MSHA reserves the right to test motors with the maximum clearance specified between the shaft and the mating part which rms the required flame-arresting path. Also reserved is the right to re-machine these parts, at the applicant's expense, to specified dimensions to provide the maximum clearance.

NOTE: For example, a shaft with a diameter greater than 2 inches at the flame-arresting portion might require such machining.

(4) Ball and roller bearings and oil seals will not be acceptable as flame-arresting paths; therefore, a separate path shall be provided between the shaft and another part, preferably inby the bearing. The length and clearances of such flame-arresting path shall conform to the requirements of Section 18.31.

(5) Labyrinths or other arrangements that provide change(s) in direction of escaping gases will be acceptable but the use of small detachable pieces shall not be permitted unless structurally unavoidable. The lengths of flame-arresting path(s) and clearance(s) shall conform to the requirements of Section 18.31.

(6) The widths of oil grooves and grooves for holding oil seals will be deducted in measuring the widths of flame-arresting paths.

NOTE: Oil seals will be removed from motors before explosion tests and therefore may be omitted from motors submitted for investigation.

(7) Openings for filling and draining bearing lubricants shall be so located as to prevent escape of flame through them.

(8) An outer bearing cap will not be considered as forming any part of a flame-arresting path unless the cap is used as a bearing cartridge.

NOTE: The outer bearing cap will be omitted during explosion tests unless it houses the bearing.

(a) If unavoidable, holes may be made through motor casings for bolts, studs, or screws to hold essential parts such as pole pieces, brush riggings, and bearing cartridges. Such parts shall be attached to the casing by at least two fastenings. The threaded holes in these parts shall be blind, unless the fastenings are inserted from the inside, in which case the fastenings shall not be accessible with the armature of the motor in place.

(b) Direct-current motors. For direct-current motors with narrow interpoles, the distance from the edge of the pole piece to any bolt hole in the frame shall be not less than 1/8 inch. If the distance is 1/8 to 1/4 inch, the diametrical clearance for the pole bolt shall not exceed 1/64 inch for not less than 1/2 inch through the frame. Furthermore, the pole piece shall have the same radius as the inner surface of the frame. Pole pieces may be shimmed as necessary.

(c) Alternating-current motors. Stator laminations that form a part of an explosion-proof enclosure will be acceptable provided:

(1) The laminations and their end rings are fastened together under pressure:

(2) the joint between the end rings and the laminations is not less than 1/4 inch, but preferably as close to 1 inch as possible; and

(3) it shall be impossible to insert a 0.0015-inch thickness gage to a depth exceeding 1/8 inch between adjacent laminations or between end rings and laminations.

(d) Small motors (alternating- and direct-current). Motors having internal free volume not exceeding 250 cubic inches and joints not exceeding 32 inches in outer circumference will be acceptable for investigation if provided with rabbet joints between the stator frame and the end bracket having the following dimensions:

DIMENSIONS OF RABBET JOINTS - INCHES

Minimum total width	Minimum width of clamped radial portion	Maximum clearance of radial portion	Maximum diametrical clearance at axial portion
3/8	3/64	0.0015	0.003
1/2	3/64	0.002	0.003
1/2	3/32	0.002	0.004

18.35 Portable (trailing) cables and cords

(a) Portable cables and cords used to conduct electrical energy to face equipment shall conform to the following:

(1) Have each conductor of a current-carrying capacity consistent with the Insulated Power Cable Engineers Association (IPCEA) standards.

(2) Have current-carrying conductors not smaller than No. 14 (AWG.) Cords with sizes 14 to 10 (AWG) conductors shall be constructed with heavy jackets.

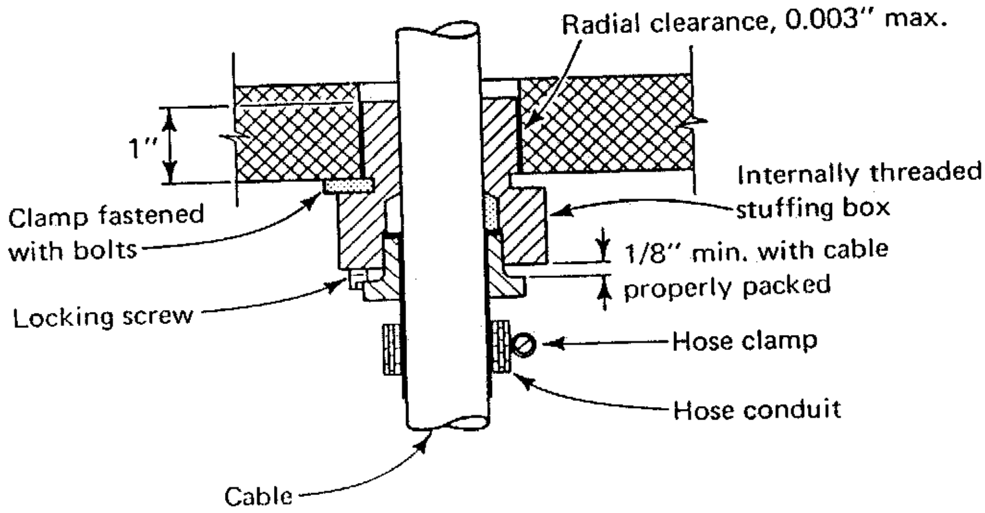
(3) Have flame-resistant properties.

(4) Have short-circuit protection at the outby.

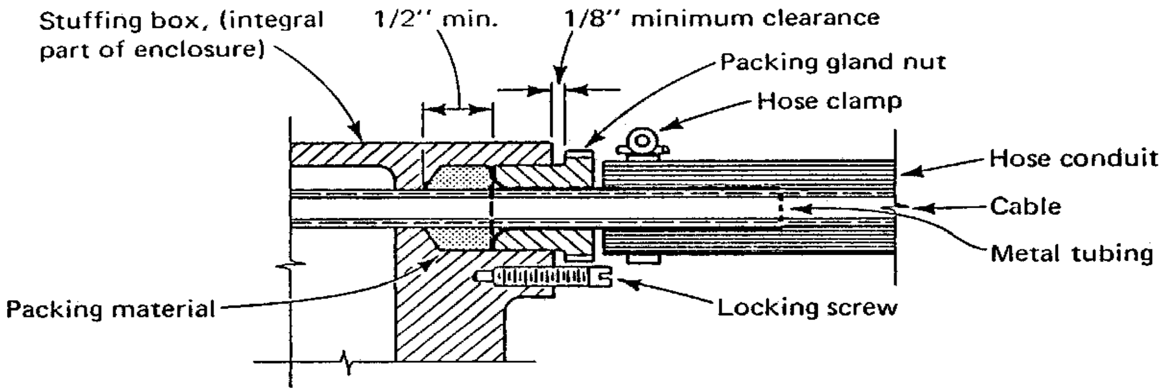
MAXIMUM LENGTH OF TRAILING CABLES

Cable Size	Length
6	550
4	600
3	650
2	700
1	750
1/0	800
2/0	850
3/0	900
4/0	1,000

4. Lead Entrance

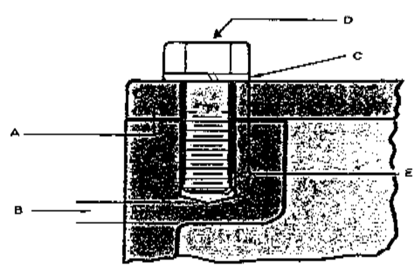


Typical slip fit straight type and angle type stuffing box and packing gland lead entrance



Typical threaded straight stuffing box and packing lead entrance
with provisions for hose conduit

PLANE FLANGE JOINT



(Volume of empty enclosure - more than 124 cubic inches)

REQUIREMENTS

A. Maximum clearance of plane flange joint is 0.004 inch (30 CFR 18.31).

B. A minimum of 1/8 inch of stock must be left at the center of the bottom of each hole drilled for fastenings (30 CFR 18.32).

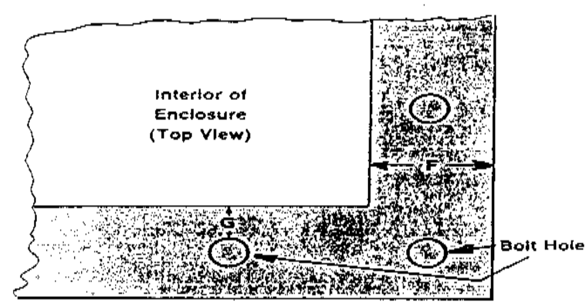
C. Lockwashers shall be provided for all bolts, screws and studs that secure parts of explosion-proof enclosures (30 CFR 18.32).

D. Minimum diameter of bolt for fastening 124 cu. in. enclosure (without regard to type of joint) is 3/8 inch (30 CFR 18.31).

E. Minimum thread engagement of bolt for 124 cu. in. enclosure is 3/8 inch (30 CFR 18.31).

NOTE: In general, minimum thread engagement shall be equal to or greater than the diameter of bolt specified. EXAMPLE: If a 3/4 inch diameter bolt is used to fasten a cover to the enclosure, then thread engagement should be 3/4 inch into the enclosure.

PLANE FLANGE JOINT



(Volume of empty enclosure - more than 124 cubic inches)

F. Minimum width of plane flange joint is 1 inch (30 CFR 18.31).

G. Minimum distance from interior of enclosure to the edge of a bolt hole is 7/16 inch (30 CFR 18.31).

NOTE: Sometimes a bolt hole is stripped out. If so, there are three common methods for repairing the hole:

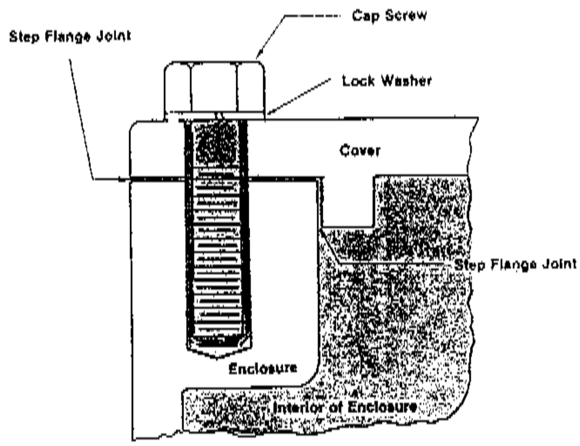
1. *Weld the hole and retap.*
2. *Retap to the next larger size hole.*
3. *Use a helicoil.*

All three methods are acceptable provided the minimum distance from the interior of the enclosure to the edge of the bolt hole is 7/16 inch.

Typical Plane Joint

All dimensions apply to enclosures larger than 124 cubic inches in volume (when empty). For smaller enclosures, refer to 18.31(a) (6).

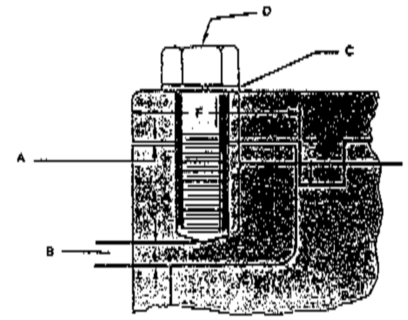
STEP FLANGE JOINT



DEFINITION

A step flange joint is formed when two surfaces, such as a cover and enclosure, meet at right angles or form a step with each other. End bells on motors and reset switches are typical examples of components which have step flange joints.

STEP FLANGE JOINT



(Volume of empty enclosure - more than 124 cubic inches)

REQUIREMENTS

A. Maximum clearance of step flange joint is 0.006 inch (30 CFR 18.31).

B. Minimum of 1/8 inch of stock must be left at the center of the bottom of each hole drilled for fastenings (30 CFR 18.31).

C. Lockwashers or equivalent shall be provided for all bolts, screws and studs that secure parts of explosion-proof enclosures (30 CFR 18.32).

D. Minimum diameter of bolt for fastening (without regard to type joint) is 3/8 inch (30 CFR 18.31).

E. Minimum thread engagement of bolt is 3/8 inch (30 CFR 18.31).

NOTE: In general, minimum thread engagement shall be equal to or greater than the diameter of the bolt specified.

EXAMPLE: If a 3/4 inch diameter bolt is used to fasten a cover to the enclosure, then thread engagement should be 3/4 inch into the enclosure.

F. Minimum width of joint (F & G), portions of which are in different planes, is 3/4 inch with no single portion less than 1/8 inch.

Typical Step Flange Joint

All dimensions apply to enclosures larger than 124 cubic inches in volume when empty. For smaller enclosures, refer to 18.31(a) (b).

Volume of Empty Enclosure	**Less than 45 cu. in.**	**45 to 124 cu. in. inclusive**	**More than 124 cu. in.**
Minimum thickness of material for walls	1/8"	3/16"	¼"
Minimum thickness of material for flanges and covers	¼"	3/8"	½"
Minimum width of joint-all in one plane	½"	¾"	1"
Minimum clearance-joint all in one plane	.002"	.003"	.004"
Minimum width of joint-portions of which are all in different planes-cylinders or equivalent	3/8"	5/8"	¾"
Maximum clearances-join in two or more planes-cylinders or equivalent (a) Portion perpendicular to plane (b) Plane portion	 .008" .006"	 .008" .006"	 .008" .006"
Maximum bolt spacing-joints all in one plane (with minimum 4 bolts)	6"	6"	6"
Maximum bolt spacing-joints, portions of which are in different planes	(9)	(9)	(9)
Minimum diameter of bolt (without regard to type of joint)	¼"	¼"	3/8"
Minimum tread engagement	1/4:"	¼"	3/8"
Maximum diametrical clearance between bolt body and unthreaded holes through which it passes	1/64"	1/32"	1/16"
Minimum distance from interior of enclosure to the edge of a bolt hole Joint-minimum width 1" Joint-less than 1" wide		 1/8"	 7/16" 3/16"
Cylindrical Joints			
Shafts centered by ball or roller bearings Minimum length of flame arresting path Maximum radial clearance	 ½" .020"	 ¾" .025"	 1" .010"
Other Cylindrical Joints Minimum length of flame arresting path Maximum radial clearance	 ½" .006"	 ¾" .008"	 1" .010"

7. Cable Between Machine Components

18.36 Cables between machine components

(a) Cables between machine components shall have:
(1) Adequate current carrying capacity for the loads involved,
(2) short-circuit protection,
(3) insulation compatible with the impressed voltage, and
(4) flame resistant properties unless totally enclosed within a flame resistant hose conduit or other flame resistant material.
(b) Cables between machine components shall be:
(1) Clamped in place to prevent undue movement,
(2) protected from mechanical damage by position, flame-resistant hose conduit, metal tubing, or troughs (flexible or threaded rigid metal conduit will not be acceptable),
(3) isolated from hydraulic lines, and
(4) Protected from abrasion by removing all sharp edges, which they might contact.
(c) Cables (cords) for remote-control circuits extending from permissible equipment will be exempted from the requirements of conduit enclosure provided the total electrical energy carried is intrinsically safe or that the cables are constructed with heavy jackets. Cables (cords) provided with hose-conduit protection shall have a tensile strength not less than No. 16 (AWG) three-conductor, type SO cord. (Reference: 7.7.7 IPCEA Pub. No. S-19-81, Fourth Edition.) Cables (cords) constructed with heavy jackets shall consist of conductors not smaller than No. 14 (AWG) regardless of the number of conductors.

18.37 Lead entrances

(a) Insulated cable(s), which must extend through an outside wall of an explosion-proof enclosure, shall pass through a stuffing-box lead entrance. All sharp edges that might damage insulation shall be removed from stuffing boxes and packing nuts.
(b) Stuffing boxes shall be so designed, and the amount of packing used shall be such, that with the packing properly compressed, the gland nut still has a clearance distance of 1/8 inch or more to travel without meeting interference by parts other than packing.
(c) Packing nuts and stuffing boxes shall be secured against loosening.
(d) Compressed packing material shall be in contact with the cable jacket

for a length of not less than 1/2 inch.

(e) Special requirements for glands in which asbestos-packing material is specified are:

(1) Asbestos-packing material shall be untreated, not less than 3/16 inch diameter if round, or not less than 3/16 inch by 3/16 inch if square. The width of the space for packing material shall not exceed by more than 50 percent the diameter or width of the uncompressed packing material.

(2) The allowable diametrical clearance between the cable and the holes in the stuffing box and packing nut shall not exceed 75 percent of the nominal diameter or width of the packing material.

(f) Special requirements for glands in which a compressible material (example- synthetic elastomers) other than asbestos is specified, are:

(1) The packing material shall be flame-resistant.

18.38 Leads through common walls

(a) Insulated studs will be acceptable for use in a common wall between two explosion-proof enclosures.

(b) When insulated wires or cables are extended through a common wall between two explosion-proof enclosures in insulating bushings, such bushings shall be not less than 1-inch long and the diametrical clearance between the wire or cable insulation and the holes in the bushings shall not exceed 1/16 inch (based on the nominal specified diameter of the cable). The insulating bushings shall be secured in the metal wall.

(c) Insulated wires or cables conducted from one explosion- proof enclosure to another through conduit, tubing, piping, or other solid-wall passageways will be acceptable provided one end of the passageway is plugged, thus isolating one enclosure from the other. Glands of secured bushings with close-fitting holes through which the wires or cables are conducted will be acceptable for plugging. The tubing or duct specified for the passageway shall be brazed or welded into the walls of both explosion-proof enclosures with continuous gas-tight welds.

(d) If wires and cables are taken through openings closed with sealing compounds, the design of the opening and characteristics of the compounds shall be such as to hold the sealing material in place without tendency of the material to crack or flow out of its place. The material also must withstand explosion tests without cracking or loosening.

(e) Openings through common walls between explosion-proof enclosures not provided with bushings or sealing compound, shall be large enough to prevent pressure piling.

18.39 Hose conduit

Hose conduit shall be provided for mechanical protection of all machine cables that are exposed to damage. Hose conduit shall be flame resistant and have a minimum wall thickness of 3/16 inch. The flame resistance of hose conduit will be determined in accordance with the requirements of Section 18.65.

18.40 Cable clamps and grips

Insulated clamps shall be provided for all portable (trailing) cables to prevent strain on the cable terminals of a machine. Also insulated clamps shall be provided to prevent strain on both ends of each cable or cord leading from a machine to a detached or separately mounted component. Cable grips anchored to the cable may be used in lieu of insulated strain clamps.

Supporting clamps for cables used for wiring around machines shall be provided in a manner acceptable to MSHA.

18.41 Plug and receptacle-type connectors

(a) Plug and receptacle-type connectors for use inby the last open crosscut in a gassy mine shall be so designed that insertion or withdrawal of a plug cannot cause incendiary arcing or sparking. Also, connectors shall be so designed that no live terminals, except as hereinafter provided, are exposed upon withdrawal of a plug. The following types will be acceptable:

(1) Connectors in which the mating or separation of the male and female electrodes is accomplished within an explosion-proof enclosure.

(2) Connectors that are mechanically or electrically interlocked with an automatic circuit-interrupting device.

(i) Mechanically interlocked connectors. If a mechanical interlock is provided the design shall be such that the plug cannot be withdrawn before the circuit has been interrupted and the circuit cannot be established with the plug partially withdrawn.

(ii) Electrically interlocked connectors. If an electrical interlock is provided, the total load shall be removed before the plug can be withdrawn and the electrical energy in the interlocking pilot circuit shall be intrinsically safe, unless the pilot circuit is opened within an explosion-proof enclosure.

(3) Single-pole connectors for individual conductors of a circuit

used at terminal points shall be so designed that all plugs must be completely inserted before the control circuit of the machine can be energized.

(b) Plug and receptacle-type connectors used for sectionalizing the cables outby the last open crosscut in a gassy mine need not be explosion-proof or electrically interlocked provided such connectors are designed and constructed to prevent accidental separation.

(c) Conductors shall be securely attached to the electrodes in a plug or receptacle and the connections shall be totally enclosed.

(d) Molded-elastomer connectors will be acceptable provided:

(1) Any free space within the plug or receptacle is isolated from the exterior of the plug.

(2) Joints between the elastomer and metal parts are not less than 1 inch wide and the elastomer is either bonded to or fits tightly with metal parts.

(e) The contacts of all line-side connectors shall be shielded or recessed adequately.

(f) For a mobile battery-powered machine, a plug padlocked to the receptacle will be acceptable in lieu of an interlock provided the plug is held in place by a threaded ring or equivalent mechanical fastening in addition to the padlock. A connector within a padlocked enclosure will be acceptable.

18.42 Explosion-proof distribution boxes

(a) A cable passing through an outside wall(s) of a distribution box shall be conducted either through a packing gland or an interlocked plug and receptacle.

(b) Short-circuit protection shall be provided for each branch circuit connected to a distribution box. The current-carrying capacity of the specified connector shall be compatible with the automatic circuit-interrupting device.

(c) Each branch receptacle shall be plainly and permanently marked to indicate its current-carrying capacity and each receptacle shall be such that it will accommodate only an appropriate plug.

(d) Provision shall be made to relieve mechanical strain on all connectors to distribution boxes.

18.43 Explosion-proof splice boxes

Internal connections shall be rigidly held and adequately insulated. Strain clamps shall be provided for all cables entering a splice box.

18.44 Battery boxes and batteries (exceeding 12 volts)

(a) A battery box (tray) including the cover shall be made of steel the thickness of which is to be based on the total weight of the battery and tray. Materials other than steel that provide equivalent strength will be considered.

(b) Battery-box covers shall be lined with a flame-resistant insulating material, preferably bonded to the inside of the cove, unless equivalent protection is provided.

(c) Battery-box covers shall be provided with a means for securing them in closed position.

(d) Battery boxes shall be adequately ventilated. The size and locations of openings for ventilation shall prevent access to cell terminals.

(e) Battery cells shall be insulated from the battery-box walls and supported on insulating material. Insulating materials that may be subject to chemical reaction with electrolyte shall be treated to resist such action.

(f) Drainage holes shall be provided in the bottom of each battery box.

(g) Cell terminals shall be "burned" on. Bolted connectors (two-bolt type) may be accepted on end terminals.

(h) Battery connections shall be so designed that battery potential will be minimized between adjacent cells, and total battery potential shall not be available between adjacent cells.

(I) Cables within a battery box shall be protected against abrasion of the insulation.

(j) Each wire or cable leaving a battery box on storage-battery-operated equipment shall have short-circuit protection in an explosion-proof enclosure as close as possible to the battery terminals. A protective device installed within an explosion-proof enclosure will be acceptable provided the exposed portion of the cable from the battery box to the enclosure does not exceed approximately 36 inches in length; in addition, special care shall be taken to protect each wire or cable from damage.

18.45 Cable reels

(a) A self-propelled machine, that receives electrical energy through a portable cable and is designed to travel at speeds exceeding 2.5 miles per hour, shall have a mechanically, hydraulically, or electrically driven reel upon which to wind the portable cable.

(b) The enclosure for moving contacts or slip rings of a cable reel shall be explosion-proof.

(c) Cable-reel bearings shall not constitute an integral part of a circuit for transmitting electrical energy.

(d) Cable reels for shuttle cars and locomotives shall maintain positive tension on the portable cable during reeling and unreeling. Such tension shall only be high enough to prevent a machine from running over its own cable(s).

(e) Cable reels and spooling devices shall be insulated with flame-resistant material.

(f) The maximum speed of a travel of a machine when receiving power through a portable (trailing) cable shall not exceed 6 miles per hour.

(g) Diameters of cable reel drums and sheaves should be large enough to prevent undue bending strain on cables.

18.46 Headlights

(a) Headlights shall be constructed as explosion-proof enclosures.

(b) Headlights shall be mounted to provide illumination where it will be most effective. They shall be protected from damage by guarding or location.

(c) Lenses for headlights shall be glass or other suitable material with physical characteristics equivalent to 1/2 inch thick tempered glass, such as "Pyrex". Lenses shall meet the requirements of the tests prescribes in Section 18.66.

(d) Lenses permanently fixed in a ring with lead, epoxy, or equivalent will be acceptable provided only lens assemblies meeting the original manufacturer’s specifications are used as replacements.

(e) If a single lead gasket is used, the contact surface of the opposite side of the lens shall be plane within a maximum deviation of 0.002 inch.

18.47 Voltage limitation

(a) A tool or switch held in the operators hand or supported against his body will not be approved with a nameplate rating exceeding 300 volts direct current or alternating current.

(b) A battery-powered machine shall not have a nameplate rating exceeding 240 volts, nominal (120 lead-acid cells or equivalent).

(c) Other direct-current machines shall not have a nameplate rating exceeding 550 volts.

(d) An alternating-current machine shall not have a nameplate rating exceeding 660 volts, except that a machine may have a nameplate rating greater than 660 volts but not exceeding 4,160 volts when the following conditions are complied with:

(1) Adequate clearances and insulation for the particular voltage(s) are provided in the design and construction of the equipment, its wiring, and accessories.

(2) A continuously monitored, fail-safe grounding system is provided that will maintain the frame of the equipment and the frames of all accessory equipment at ground potential. Also, the equipment, including its controls and portable (trailing) cable, will be deenergized automatically upon the occurrence of an incipient ground fault. The ground-fault-tripping current shall be limited by grounded resistor(s) to that necessary for dependable relaying. The maximum ground-fault-tripping current shall not exceed 25 amperes.

(3) All high voltage switch gear and control for equipment having a nameplate rating exceeding 1,000 volts are located remotely and operated by remote control at the main equipment. Potential for remote control shall not exceed 120 volts.

(4) Portable (trailing) cable for equipment with nameplate rating form 661 volts through 1,000 volts shall include grounding conductors, a ground check conductor, and grounded metallic shields around each power conductor or a grounded metallic shield over the assembly: except that on machines employing cable reel cables without shields may be used if the insulation is rated 2,000 volts or more.

(5) Portable (trailing) cable for equipment with nameplate ratings from 1,001 volts through 4,160 volts shall include grounding conductors, a ground check conductor, and grounded metallic shields around each power conductor.

18.48 Circuit-interrupting devices

(a) Each machine shall be equipped with a circuit-interrupting device by means of which all power conductors can be deenergized at the machine. A manually operated controller will not be acceptable as a service switch.

(b) When impracticable to mount the circuit-interrupting device on a machine, a remote enclosure will be acceptable. When contacts are used as a main-circuit- interrupting device, a means for opening the circuit shall be provided at the machine and at the remote contractors.

(c) Separate two-pole switches shall be provided to deenergize power conductors for headlights or floodlights.

(d) Each hand-held tool shall be provided with a two-pole switch of the "dead-man-control" type that must be held closed by hand and will open when hand pressure is released.

(e) A machine designed to operate from both trolley wire and portable cable shall be provided with a transfer switch, or equivalent, which prevents energizing one from the other. Such a switch shall be designed to prevent electrical connection to the machine frame when the cable is energized.

(f) Belt conveyors shall be equipped with control switches to automatically stop the driving motor in the event the belt is stopped, or abnormally slowed down.

18.49 Connection boxes on machines

Connection boxes used to facilitate replacement of cables or machine components shall be explosion-proof. Portable- cable terminals on cable reels need not be in explosion- proof enclosures provided that connections are well made, adequately insulated, protected from damage by location, and securely clamped to prevent mechanical strain on the connections.

18.50 Protection against external arcs and sparks

Provision shall be made for maintaining the frames of all off-track machines and the enclosures of related detached components at safe voltages by using one or a combination of the following:

(a) A separate conductor(s) in the portable cable in addition to the power conductors by which the machine frame can be connected to an acceptable ground medium, and a separate conductor in a all cables connecting related components not on a common chassis. The cross-sectional area of the additional conductor(s) shall not be less than 50 percent of that of one power conductor unless a ground-fault tripping relay is used, in which case the minimum size may be No. 8 (AWG). Cables smaller than No. 6 (AWG) shall have an additional conductor(s) of the same size as one power conductor.

(b) A means of actuating a circuit-interrupting device, preferably at the outby end of the portable cable.

(c) A device(s) such as a diode(s) of adequate peak inverse voltage rating and current-carrying capacity to conduct possible fault current through the grounded power conductor. Diode installations shall include:

(1) An over-current device in series with the diode, the contacts of which are in the machine's control circuit; and

(2) a blocking diode in the control circuit to prevent operation of the machine with the polarity reversed.

18.51 Electrical protection of circuits and equipment

(a) An automatic circuit-interrupting device(s) shall be used to protect each ungrounded conductor of a branch circuit at the junction with the main circuit when the branch circuit conductor(s) has a current carrying capacity less than 50 percent of the main circuit conductors(s), unless the protective device(s) in the main circuit will also provide adequate protection for the branch circuit. The setting of each device shall be specified. For headlight and control circuits, each conductor shall be protected by a fuse or equivalent. Any circuit that is entirely contained in an explosion-proof enclosure shall be exempt from these requirements.

(b) Each motor shall be protected by an automatic overcurrent device. One protective device will be acceptable when two motors of the same rating operate simultaneously and perform virtually the same duty.

(1) If the overcurrent protection device in a direct current circuit does not open both lines, particular attention shall be given to marking the polarity at the terminals or otherwise preventing the possibility of reversing connections which would result in changing the circuit interrupter to the grounded line.

(2) Three-phase alternating-current motors shall have an overcurrent-protective device in at least two phases such that actuation of a device in one phase will cause the opening of all three phases.

(c) Circuit-interrupting devices shall be so designed that they can be reset without opening the compartment in which they are enclosed.

(d) All magnetic circuit-interrupting devices shall be mounted in a manner to preclude the possibility of their closing by gravity.

18.52 Renewal of fuses

Enclosure covers that provide access to fuses, other than headlight, control-circuit, and hand-held tool fuses, shall be interlocked with a circuit-interrupting device. Fuses shall be inserted on the load side of the circuit interrupter.

Inspections and Tests

18.60 Detailed inspection of components

An inspection of each electrical component shall include the following:

(a) A detailed check of parts against the drawings submitted by the applicant to determine that:

(1) The parts and drawings coincide; and

(2) the minimum requirements stated in this part have been met with respect to materials, dimensions, configuration, workmanship, and adequacy of drawings and specifications.

(b) Exact measurement of joints, journal bearings, and other flame-arresting paths.

(c) Examination for unnecessary through holes.

(d) Examination for adequacy of lead-entrance design and construction.

(e) Examination for adequacy of electrical insulation and clearances between live parts and between live parts and the enclosure.

(f) Examination for weaknesses in welds and flaws in castings.

(g) Examination for distortion of enclosures before tests.

(h) Examination for adequacy of fastenings, including size, spacing, security, and possibility of bottoming.

18.61 Final inspection of complete machine

(a) A completely assembled new machine or a substantially modified design of a previously approved one shall be inspected by a qualified representative(s) of MSHA. When such inspection discloses any unsafe condition or any feature not in strict conformance with the requirements of this part, it shall be corrected before an approval of the machine will be issued. A final inspection will be conducted at the site of manufacture or building, or other locations at the option of MSHA.

(b) Complete machines shall be inspected for:

(1) Compliance with the requirements of this part with respect to joints, lead entrances, and other pertinent features.

(2) Wiring between components, adequacy of mechanical protection for cables, adequacy of clamping of cables, positioning of cables, particularly with respect to proximity to hydraulic components.

(3) Adequacy of protection against damage to headlights, push buttons and any other vulnerable component.

(4) Settings of overload and short circuit protective devices.

(5) Adequacy of means for connecting and protecting portable cable.

18.62 Tests to determine explosion-proof characteristics

(a) In testing for explosion-proof characteristics of an enclosure, it shall be filled and surrounded with various explosive mixtures of natural gas and air. The explosive mixture within the enclosure will be ignited electrically and the explosion pressure developed there from recorded. The point of ignition within the enclosure will be varied. Motor armatures and/or rotors will be stationary in some tests and revolving in others. Coal dust, produced by grinding coal from the Pittsburgh coal bed to a fineness of minus 200 mesh, will be added to the explosive gas-air mixtures in some tests. At MSHA, discretion dummies may be substituted for internal electrical components during some of the tests. Not less than 16 explosion tests shall be conducted; however, the nature of the enclosure and the results obtained during the tests will determine whether additional tests shall be made.

(b) Explosion tests of an enclosure shall not result in:

(1) Discharge of flame.

(2) Ignition of an explosive mixture surrounding the enclosure.

18.66 Tests of windows and lenses

(a) Impact tests. A 4-pound cylindrical weight with a 1-inch diameter hemispherical striking surface shall be dropped (free fall) to strike the window or lens in its mounting, or the equivalent thereof, at or near the center. Windows or lenses of smaller diameter than 1 inch may be tested by alternate methods at the discretion of MSHA.

(b) Thermal-shock tests. Four samples of the window or lens will be heated in an oven for 15 minutes to a temperature of 150 degrees C. (302 degrees F.) and immediately upon withdrawal of the samples from the oven they will be immersed in water having at temperature between 15 degrees C. (59 degrees F.) and 20 degrees C. (68 degrees F.). Three of the four samples shall show no defect or breakage from this thermal-shock test.

18.67 Static-pressure tests

Static-pressure tests shall be conducted by the applicant on each enclosure of a specific design when MSHA determines that visual inspection will not reveal defects in castings or in single seam welds. Such test procedure shall be submitted to MSHA for approval and the specifications on file with MSHA shall include a statement assuring that such tests will be conducted. The static pressure to be applied shall be 150 pounds per square inch (gage) or one and one-half times the maximum pressure recorded in MSHA explosion tests, whichever is greater.

18.68 Tests for intrinsic safety

(a) General:

(1) Tests for intrinsic safety will be conducted under the general concepts of "intrinsically safe" as defined in Subpart A of this part. Further tests or requirements may be added at any time if features of construction or use or both indicate them to be necessary. Some tests included in these requirements may be omitted on the basis of previous experience.

(2) Intrinsically safe circuits and/or components will be subjected to tests consisting of making and breaking the intrinsically safe circuit under conditions judged to simulate the most hazardous probable faults or malfunctions. Tests will be made in the most easily ignitable mixture of methane or natural gas and air. The method of making and breaking the circuit may be varied to meet particular conditions.

(3) The components, which affect intrinsic safety, must meet the following requirements:

(i) Current limiting components shall consist of two equivalent devices each of which singly will provide intrinsic safety. They shall not be operated at more than 50 percent of their ratings.

(ii) Components of reliable construction shall be used and they shall be so mounted as to provide protection against shock and vibration in normal use.

(iii) Semiconductors shall be amply sized. Rectifiers and transistors shall be operated at not more than two-thirds of their rated current and permissible peak inverse voltage. Zener diodes shall be operated at not more than one-half of their rated current and shall short under abnormal conditions.

(iv) Electrolytic capacitors shall be operated at not more than two-thirds of their rated voltage. They shall be designed to withstand a test voltage of 1,500 volts.

(4) Intrinsically safe circuits shall be so designed that after failure of a single component, and subsequent failures resulting from this first failure, the circuit will remain intrinsically safe.

(5) The circuit will be considered as intrinsically safe if in the course of testing no ignitions occur.

(b) Complete intrinsically safe equipment powered by low energy batteries:

(1) Short-circuit tests shall be conducted on batteries at normal operating temperature. Tests may be made on batteries at elevated temperature if such tests are deemed necessary.

(2) Resistance devices for limiting short-circuit current shall be an integral part of the battery, or installed as close to the battery terminal as practicable.

(3) Transistors of battery-operated equipment may be subjected to thermal "run-away" tests to determine that they will not ignite an explosive atmosphere.

(4) A minimum of 1,000 make-break sparks will be produced in each test for direct current circuits with consideration given to reversed polarity.

(5) Tests on batteries shall include series and/or parallel combinations of twice the normal battery complement, and the effect of capacitance and inductance, added to that normally present in the circuit.

(6) No ignition shall occur when approximately 1/2 inch of a single wire strand representative of the wire used in the equipment or device is shorted across the intrinsically safe circuit.

(7) Consideration shall be given to insure against accidental reversal of polarity.

(c) Line-powered equipment and devices:

(1) Line-powered equipment shall meet all applicable provisions specified for battery-powered equipment.

(2) Non-intrinsically safe components supplying power for intrinsically safe circuits shall be housed in explosion-proof enclosures and be provided with energy limiting components in the enclosure.

(3) Wiring for non-intrinsically safe circuits shall not be intermingled with wiring for intrinsically safe circuits.

(4) Transformers that supply power for intrinsically safe circuits shall have the primary and secondary windings physically separated. They shall be designed to withstand a test voltage of 1,500 volts when rated 125 volts or less and 2,500 volts when rated more than 125 volts.

(5) The line voltage shall be increased to 120 percent of nominal rated voltage to cover power line voltage variations.

(6) In investigations of alternating current circuits a minimum of 5,000 make-break sparks will be produced in each test.

(d) The design of intrinsically safe circuits shall preclude extraneous voltages caused by insufficient isolation or inductive coupling. The investigation shall determine the effect of ground faults where applicable.

(e) Identification markings: Circuits and components of intrinsically safe equipment and devices shall be adequately identified by marking or labeling. Battery powered equipment shall be marked to indicate the manufacturer, type designation, ratings, and size of batteries used.

Subpart D - Machines Assembled With Certified or Explosion-Proof Components, Field Modifications of Approved Machines, and Permits To Use Experimental Equipment

18.80 Approval of machines assembled with certified or explosion-proof components

(a) A machine may be a new assembly, or a machine rebuilt to perform a service that is different from the original function, or a machine converted from non-permissible to permissible status, or a machine converted from direct to alternating current power or vice versa. Properly identified components that have been investigated and accepted for application on approved machines will be accepted in lieu of certified components.

(b) A single layout drawing or photographs will be acceptable to identify a machine that was assembled with certified or explosion-proof components. The following information shall be furnished:

(1) Overall dimensions.

(2) Wiring diagram.

(3) List of all components identifying each according to its certification number or the approval number of the machine of which the component was a part.

(4) Specifications for:

(i) Overcurrent protection of motors.

(ii) All wiring between components, including mechanical protection such as hose conduits and clamps.

(iii) Portable cable, including the type, length, outside diameter, and number and size of conductors.

(iv) Insulated strain clamp for machine end of portable cable.

(v) Short-circuit protection to be provided at outby end of portable cable.

(c) MSHA reserves the right to inspect and to retest any component(s) that had been in previous service, as it deems appropriate.

(d) Fees for testing under this subpart shall be consistent with those stated in Section 18.7.

(e) When MSHA has determined that all applicable requirements of this part have been met, the applicant will be authorized to attach an approval plate to each machine that is built in strict accordance with the drawings and specifications filed with MSHA and listed with MSHA formal approval. A design of the approval plate will accompany the notification of approval.

(f) Approvals are issued only Approval and Testing, Pittsburgh Technical Support Center, 4800 Forbes Avenue, Pittsburgh, PA 15213.

18.81 Field modification of approved (permissible) equipment; application for approval of modification; approval of plans for modification before modification

(a) An owner of approved (permissible) equipment who desires to make modifications sin such equipment shall apply in writing to make such modifications. The application, together with the plans of modifications, shall be filed with Approval and Testing, Pittsburgh Technical Support Center, 4800 Forbes Avenue, Pittsburgh, PA 15213.

(b) Proposed modifications shall conform with the applicable requirements of Subpart B of this part, and shall not substantially alter the basic functional

(c) Upon receipt of the application for modification, and after such examination and investigation as may be deemed necessary by MSHA, MSHA will notify the owner and the District office of the miner workers' organization having jurisdiction at the mine where such equipment is to be operated stating the modifications which are proposed to be made and MSHA action thereon.

18.82 Permit to use experimental electric face equipment in a gassy mine or tunnel

(a) Application for permit. An application for a permit to use experimental electric face equipment in a gassy mine or tunnel will be considered only when submitted by the user of the equipment. The user shall submit a written application to the Administrator of MSHA, U.S. Department of the Interior, Washington, D.C. 20240, and send a copy to Approval and Testing, Pittsburgh Technical Support Center, 4800 Forbes Avenue, Pittsburgh, PA 15213.

(b) Fees. The applicable fees for work to be done according to this subpart shall coincide with the fees stated in Section 18.7.

(c) Requirements

(1) Constructional.

(i) Experimental equipment shall be so constructed that it will not constitute a fire or explosion hazard.

(ii) Enclosures designed as explosion-proof, unless already certified, or components of previously approved (permissible) machines, shall be submitted to MSHA for inspection and test and shall meet the applicable design requirements of Subpart B of this part. Components designed as intrinsically safe also shall be submitted to MSHA for investigation.

(iii) MSHA may, at its discretion, waive the requirements for detailed drawings of component parts, inspections, and tests provided satisfactory evidence is submitted that an enclosure has been certified, or otherwise accepted by a reputable testing agency whose standards are substantially equivalent to those set forth in Subpart B of this part.

(2) Specifications. The specifications for experimental equipment shall include a layout drawing or photograph(s) with the components, including overcurrent-protective device(s) with setting(s) identified thereon or separately: a wiring diagram; and descriptive material necessary to insure safe operation the equipment. Drawings already filed with MSHA need not be duplicated by the applicant, but shall be properly identified.

(d) Final inspection. Unless equipment is delivered to MSHA for investigation, the applicant shall notify Approval and Testing, Pittsburgh Technical Support Center, 4800 Forbes Avenue, Pittsburgh, PA 15213, when and where the experimental equipment will be ready for inspection by a representative of MSHA before installing it on a trial basis. Such inspection shall be completed before a permit will be issued.

(e) Issuance of permit. When the inspection discloses full compliance with the applicable requirements of this subpart, the Administrator of MSHA will issue a permit sanctioning the operation of a single unit in a gassy mine or tunnel, as designated in the application. If the applicant is not the assembler of the equipment, a copy of the permit also may be sent to the assembler.

(f) Duration of permit. A permit will be effective for a period of 6 months. For a valid reason, to be stated in a written application, the Administrator of MSHA may grant an extension of a permit for an additional period, not exceeding 6 months. Further extension will be granted only where, after investigation, the Administrator finds that for reasons beyond the control of the user, it has not been possible to complete the experiment within the period covered by the extended permit.

(g) Permit label. With the notification granting a permit, the applicant will receive a photographic copy of a permit label bearing the following:

(1) Emblem of the Mining Enforcement and Safety

Administration.

(2) Permit number.

(3) Expiration date of the permit.

(4) Name of machine.

(5) Name of the user and mine or tunnel.

The applicant shall attach the photographic copy of the permit label, or replica thereof, to the experimental equipment. If a photograph is used, a clear plastic covering shall be provided for it.

(h) Withdrawal of permit. The Administrator of MSHA may rescind, for cause, any permit granted under this subpart.

Subpart E Field Approval of Electrically Operated Mining Equipment

18.90 Purpose

The regulations of this Subpart E set forth the procedures and requirements for permissibility which must be met to obtain MSHA field approval of electrically operated machinery used or intended for use in by the last open crosscut of a coal mine which has not been otherwise approved, certified or accepted under the provisions of this Part 18, Chapter 1, Title 30, Code of Federal Regulations (Bureau of Mines Schedule 2G).

18.91 Electric equipment for which field approvals will be issued

(a) Individual field approvals will be issued by MSHA under the provisions of this Subpart E for electrically operated machines commercially built, or constructed, by the owner- coal mine operator of such machines including any associated electrical equipment, electrical components, and electrical accessories.

(b) Approvals will not be issued under the provisions of this Subpart E for electrically operated mining equipment manufactured or rebuilt primarily for sale or resale to any operator of a coal mine, or for small electrically operated equipment which consumes less than 2,250 watts of electricity, or for instruments and other small devices which employ electric power.

18.93 Application for field approval; filing procedures

(a) (1) Investigation and testing lading to field approval shall be undertaken by MSHA only pursuant to individual written applications for each machine submitted in triplicate on MSHA Form No. 6-1481, by the owner-coal mine operator of the machine.

(2) Except as provided in paragraph (b) of this section, each application shall be accompanied by appropriate photographs, drawings, specifications, and descriptions as required under the provisions of Section 18.94 and each such application shall be filed with the Coal Mine Health and Safety District Manager for the District in which such machine will be employed.

(b) The Coal Mine Health and Safety District Manager may, upon receipt of any application filed pursuant to paragraph (a) of this section, waive the requirements of Section 18.94 with respect to such application if he determines that the submission of photographs, drawings, specifications, or descriptions will place an undue financial burden upon the applicant. In the event a waiver is granted in accordance with this paragraph (b), initial review of the application will be waived and the applicant shall be notified on MSHA Form 6-1481 of such waiver and date, time, and location at which field inspection of the equipment described in the application will be conducted.

(c) Following receipt of an application filed in accordance with paragraph (a) of this section the Coal Mine Health and Safety District Manager shall determine whether the application has been filed in accordance with Section 18.91, and cause the application to be reviewed by a qualified electrical representative to determine compliance with Section 18.92.

(1) If it is determined on the basis of the application or the data submitted in accordance with Section 18.94 that further consideration of a field approval is warranted under this Subpart E or that the machine appears suitable and safe for its intended use, the Coal Mine Health and Safety District Manager shall advise the applicant in writing that further investigation and inspection of the machine will be necessary. The notice issued by the Coal Mine Health and Safety District Manager shall set forth the time and place at which such inspection will be conducted and specify the location and size of any tapped holes required to be made by the applicant to facilitate the pressure testing of enclosures.

(2) If it is determined on the basis of data submitted in accordance with Section 18.94 that the applicant is not qualified to receive an approval or that the machine does not appear to be suitable and safe for its intended use, the Coal Mine Health and Safety District Manager shall so advise the applicant in writing, setting forth the reasons for his denial of the application, and where applicable, the deficiencies in the machine which rendered it unsuitable or unsafe for use.

(3) Rejected applications, together with attached photographs, drawings, specifications and descriptions shall be forwarded by the Coal Mine Health and Safety District Manager to Approval and Testing which shall record all pertinent data with respect to the machine for which field approval was sought.

18.94 Application for field approval; contents of application

(a) Each application for field approval shall, except as provided in Section 18.93(b), include the following information with respect to the electrically operated machine for which field approval is sought:

(1) The trade name and the certification number or other means of identifying any explosion-proof compartment or intrinsically-safe component installed on the machine for which a prior approval or certification has been issued under the provisions of Bureau of Mines Schedules 2D, 2E, 2F, or 2G.

(2) The trade name and the flame resistance acceptance number of any cable, cord, hose, or conveyor belt installed on the machine for which a prior acceptance has been issued under the provisions of Section 18.36, 18.39, 18.64, or 18.65.

(b) Each application for field approval shall be accompanied by:

(1) If the machine is constructed or assembled entirely from components which have been certified or removed from machines approved under Bureau of Mines Schedule 2D, 2E, 2F, or 2G, photographs or a single layout drawing, which clearly depicts and identifies each of the permissible components and its location on the machine.

(2) If the machine contains one or more components required to be permissible which has not been approved or certified under Bureau of Mines Schedule 2 D, 2E, 2F, or 2G, a single layout drawing which clearly identifies all of the components from which it was assembled.

(3) All applications shall include specifications for:

(i) Overcurrent protection of motors;

(ii) All wiring between components, including mechanical protection such as hose conduit and clamps;

(iii) Portable trailing cable for use with the machine, including the type, length, diameter, and number and size of conductors;

(iv) Insulated strain clamp for machine end of portable trailing cable;

(v) Short-circuit protection to be provided at outby end of portable trailing cable.

18.95 Approval of machines constructed of components approved, accepted or certified under Bureau of Mines Schedule 2D, 2E, 2F, or 2G

Machines for which field approval is sought which are constructed entirely from properly identified components that have been investigated and accepted or certified for applications on approved machines under the Bureau of Mines Schedule 2D, 2E, 2F, or 2G, shall be approved following a determination by the electrical representative that the construction of the entire machine is permissible and conforms to the data submitted in accordance with Section 18.94.

18.98 Enclosures, joints, and fastenings; pressure testing

(a) Cast or welded enclosures shall be designed to withstand a minimum internal pressure of 150 pounds per square inch (gage). Castings shall be free from blowholes.

(b) Pneumatic field-testing of explosion-proof enclosures shall be conducted by determining:

(1) Leak performance with a peak dynamic or static pressure of 150 pounds per square inch (gage); or

(2) A pressure rise and rate of decay consistent with unyielding components during a pressure-time history as derived from a series of oscillograms.

(c) Welded joints forming an enclosure shall have continuous gastight welds.

18.99 Notice of approval or disapproval; letters of approval and approval plates

Upon completion of each inspection conducted in accordance with Section 18.97(b), the electrical representative conducting such inspection shall record his findings with respect to the machine examined on MSHA Form no. 6-1481 together with his recommendation of approval or disapproval of the machine.

(a) If the qualified electrical representative recommends field approval of the machine, the Coal Mine Health and Safety District Manager shall forward the completed application form together with all attached photographs, drawings, specifications, and descriptions to Approval and Testing. Approval and Testing shall record all pertinent data with respect to such machine, issue a letter of approval with a copy to the Coal Mine Health and Safety District Manager who authorized its issuance and send the field approval plate to the applicant. The approval plate shall be affixed to the machine by the applicant in such a manner so as not to impair its explosion-proof characteristics.

(b) If the electrical representative recommends disapproval of the machine, he shall record the reasons for such disapproval and the Coal Mine Health and Safety District Manager shall forward the completed application form and other data to Approval and Testing which shall record all pertinent data with respect to such machine and notify the applicant that the application for approval has been rejected and the reasons for rejection.

TABLE 4.1- PORTABLE POWER CABLE AMPACITIES-600 VOLTS (AMPERES PER CONDUCTOR BASED ON 60 DEGREES C. COPPER TEMPERATURE-40 DEGREES C. AMBIENT)

Cond.size-AWG or MCM	SINGLE cond.	2-cond. round or flat	3-cond. round or flat	4-cond.	5-cond.	6-cond.
8	45	40	35	30	25	20
6	60	50	50	40	35	30
4	85	70	65	55	45	35
3	95	80	75	65	55	45
2	110	95	90	75	65	55
1	130	110	100	85	75	65
1/0	150	130	120	100	90	80
2/0	175	150	135	115	105	95
3/0	205	175	155	130	120	110
4/0	235	200	180	150	140	130
250	275	220	200	160		
300	305	240	220	175		
350	345	240	235	190		
400	375	280	250	200		
450	400	300	270	215		
500	425	320	290	230		

TABLE 4.2-PORTABLE CORD AMPACITIES-600 VOLTS (AMPERES PER CONDUCTOR BASED ON 60 DEGREES C. COPPER TEMPERATURE-40 DEGREES C. AMBIENT)

Cond. size AWG	1-3 Cond.	4-6 Cond.	7-9 Cond.
14	15	12	8
12	20	16	11
10	25	20	14

TABLE 4.3-PORTABLE POWER CABLE AMPACITIES-601 TO 5,000 VOLTS(AMPERES PER CONDUCTOR BASED ON 75 DEGREES C. COPPER TEMPERATURE-40 DEGREES C. AMBIENT)

Cond. size AWG or MCM	3-cond., types G-GC and SIIC-GC 2,000 volts	3-cond., types SHD-GC 2,001 5,000 volts
6	65	65
4	85	85
3	100	100
2	115	115
1	130	130
1/0	145	145
2/0	170	170
3/0	195	195
250	245	245
300	275	275
350	305	305

Part 18 - Permissibility, Electric Motor-Driven Equipment and Accessories

Protective Devices

75.900 Low and Medium Voltage Circuits Serving Three-Phase Alternating Current Equipment; Circuit Breakers

Low and medium voltage power circuits serving three-phase alternating current equipment shall be protected by suitable circuit breakers of adequate interrupting capacity, which are properly tested and maintained as prescribed by the Secretary. Such breakers shall be equipped with devices to provide protection against undervoltage, grounded phase, short circuit, and overcurrent.

75.900-1 Circuit Breakers; Location

Circuit breakers used to protect low and medium voltage circuits underground shall be located in areas which are accessible for inspection, examination, and testing, have safe roofs, and are clear of any moving equipment used in haulage ways.

75.900-2 Approved Circuit Schemes

The following circuit schemes will be regarded as providing the necessary protection to the circuit required by Section 75.900:

(a) Ground check relays may be used for undervoltage protection if the relay coils are designed to trip the circuit breaker when line voltage decreases to 40 to 60 percent of the nominal line voltage.

(b) One undervoltage device installed in the main secondary circuit at the source transformer may be used to provide undervoltage protection for each circuit that receives power from that transformer.

(c) One circuit breaker may be used to protect two or more branch circuits if the circuit breaker is adjusted to afford overcurrent protection for the smallest conductor.

(d) Circuit breakers with shunt trip, series trip or undervoltage release devices may be used if the tripping elements of such devices are selected or adjusted in accordance with the settings listed in the table of the National Electric Code, 1968.

75.900-3 Testing, Examination, and Maintenance of Circuit Breakers; Procedures

Circuit breakers protecting low and medium voltage alternating current circuits serving three-phase alternating current equipment and their auxiliary devices shall be tested and examined at least once each month by a person qualified as provided in Section 75.153. In performing such tests, actuating any of the circuit breaker auxiliaries or control circuits in any manner, which causes the circuit breaker to open, shall be considered a proper test. All components of the circuit breaker and its auxiliary devices shall be visually examined and such repairs or adjustments as are indicated by such tests and examinations shall be carried out immediately.

75.900-4 Testing, Examination, and Maintenance of Circuit Breakers; Record

The operator of any coal mine shall maintain a written record of each test, examination, repair, or adjustment of all circuit breakers protecting low and medium voltage circuits serving three-phase alternating current equipment used in the mine. Such record shall be kept in a book approved by the Secretary.

75.901 Protection of Low and Medium Voltage Three-Phase Circuits Used Underground

(a) Low and medium voltage three-phase alternating-current circuits used underground shall contain either a direct or derived neutral which shall be grounded through a suitable resistor at the power center, and a grounding circuit, originating at the grounded side of the grounding resistor, shall extend along with the power conductors and serve as a grounding conductor for the frames of all the electrical equipment supplied power from that circuit, except that the Secretary or his authorized representative may permit ungrounded low and medium-voltage circuits to be used underground to feed such stationary electrical equipment if such circuits are either steel armored or installed in grounded rigid steel conduit throughout their entire length. The grounding resistor, where required, shall be of the proper ohmic value to limit the ground fault current to 25 amperes. The grounding resistor shall be rated for maximum fault current continuously and insulated from ground for a voltage equal to the phase-to-phase voltage of the system.

75.902 Low and Medium Voltage Round Check Monitor Circuits

On or before September 30, 1970, low and medium voltage resistance grounded systems shall include a failsafe ground check circuit to monitor continuously the grounding circuit to assure continuity which ground check circuit shall cause the circuit breaker to open when either the ground or pilot check wire is broken, or other no less effective device approved by the Secretary or his authorized representative to assure such continuity, except that an extension of time, not in excess of 12 months, may be permitted by the Secretary on a mine-by-mine basis if he determines that such equipment is not available. Cable couplers shall be constructed so that the ground check continuity conductor shall be broken first and the ground conductors shall be broken last when the coupler is being uncoupled.

75.902-1 Maximum Voltage Ground Check Circuits

The maximum voltage used for such ground check circuits shall not exceed 40 volts.

75.902-2 Approved Ground Check Systems not Employing Pilot Check Wires

Ground check systems not employing pilot check wires will be approved only if it is determined that the system includes a fail safe design causing the circuit breaker to open when ground continuity is broken.

75.902-4 Attachments of Ground Conductors and Ground Check Wires to Equipment Frames; Use of Separate Connections

In grounding equipment frames of all stationary, portable or mobile equipment receiving power from resistance grounded systems separate connections shall be used when practicable.

75.903 Disconnecting Devices

Disconnecting devices shall be installed in conjunction with the circuit breaker to provide visual evidence that the power is disconnected.

75.904 Identification of Circuit Breakers

Circuit breakers shall be marked for identification.

75.905 Connection of Single-Phase Loads

Single-phase loads shall be connected phase-to-phase.

75.1001 Overcurrent Protection

Trolley wires and trolley feeder wires shall be provided with overcurrent protection.

C. Permissibility Questions and Answers

Q. What type of material is used for packing permissible packing glands?
A. Untreated asbestos

Q. What distance does compressed packing extend along the cable in a cable entrance gland?
A. ½ inch

Q. What are some things that shall be checked on permissible headlights?
A. Packing gland, conduit, locking screw, lens, proper assembly, and securely mounted

Q. What is the maximum allowable opening of a plane flange joint?
A. .004 inch

Q. What type joint is found on the end bells of most motors?
A. Step flange joint

Q. How far does the step portion of a step flange extend into its opening to qualify as a step flange joint?
A. Greater than 1/8 inch

Q. Flame paths on explosion proof enclosures are designed to __________.
A. Cool flames from an internal explosion

Q. Can the wire size be reduced on permissible equipment?
A. Yes, only after field modification is approved by MSHA

Q. How does air pass in and out of a permissible enclosure?
A. Through a permissible breather

Q. Cable reels are required on equipment traveling in excess of what speed?
A. 2.5 miles per hour (mph)

Q. What is the allowable diametrical clearance for push rods passing through a journal bearing for boxes having a one inch flame path?
A. 0.010 inch

Q. What is the maximum allowable surface temperature of all components

on machines approved under schedule 2G?
A. 150° C or 302° F

Q. How many lock washers can be left off a control cover?
A. None

Q. What does the term permissible equipment mean?
A. Permissible Equipment: completely assembled electrical machine or accessory intended for use into or inby the last open cross cut, for which formal approval has been issued

Q. What is required for cables between machine components?
A. Adequate current carrying capacity, short circuit protection, insulation compatible with impressed voltage, flame resistant properties unless totally enclosed within a flame resistant hose conduit or other flame resistant material

Q. Is it permissible to secure hydraulic hoses and electrical conductors with the same clamp?
A. No

Q. How often is hose conduit required to be stamped with approval markings?
A. Not to exceed 3 feet 18.65 (f) (2)

Q. What does flame resistant as applied to trailing cables and conduit hose mean?
A. Cables and hoses will burn when held in a flame but will cease burning when the flame is removed

Q. When permissible power connection units are not available, where shall all power connection points be made?
A. Intake airways

Q. What does “intrinsically safe” mean?
A. In the course of testing no ignition occurs

D. Permissibility Review

Some Permissibility Inspection Reminders:

Power Center Inspection

- Fire Extinguisher on intake side,
- Start at the cable coupler of the machine to be inspected,
- Circuit breakers and cable couplers should be marked for identification
- De-energize the circuit breaker which supplies power to the trailing cable of the machine
- Cable coupler (cathead) (Ground monitor shall disconnect first, ground lug should disconnect last, coupler shall be grounded)
- Disconnect the cable coupler to assure power is not applied to the trailing cable (Lock out and tag if electrical work is to be preformed)

Trailing Cables

- Trailing cables shall be flame resistant with markings every 12 feet
- When two or more trailing cables junction to the same distribution center, means shall be provided to assure against connecting a trailing cable to the wrong size circuit breaker
- One temporary splice may be used for the next 24 hour working period if made in a workman like manner, mechanically strong and well insulated and not within 25 feet of the machine (except cable reel equipment)
- Permanent splices in trailing cables shall be mechanically strong with adequate conductivity and flexibility, effectively insulated and sealed so as to exclude moisture and vulcanized or otherwise treated with suitable materials to provide flame resistant qualities and good bonding to the outer jacket (Note: the conductor’s insulation shall be electrically rated and the outer cable insulation is mechanically rated and fire resistant)
- Trailing cables shall be adequately protected to prevent damage by mobile equipment
- Trailing cables shall be clamped to machines in a manner to protect the cables from damage and to prevent strain on the electrical connections

Cable Reels

- Any self propelled machine that receives power through a portable trailing cable and travels at speeds exceeding 2.5 M.P.H. must have a cable reel.
- The maximum speed of travel of a machine when receiving power through a portable training cable shall not exceed 6 m.p.h.
- Cable reels for shuttle cars must maintain positive tension on the portable cable during reeling and unreeling. Tension shall be only high enough to prevent a machine from running over its own cable.
- Cable reels and spooling devices shall be insulated with flame resistant material.
- Trailing cables should be connected to the reel at the clamp
- Inspect the cable reel for loose connections and check the ground wire and ground check circuit for positive connection
- Cable guides should be insulated from the frame and reel

Strain Clamps

- Insulated clamps shall be provided for all portable trailing cables to prevent strain on the cable terminals of a machine. In addition, insulated clamps shall be provided to prevent strain on both ends of each cable or cord leading from a machine to a detached or separately mounted component.
- Cable grips (kellen grips) anchored to the cable may be used in lieu of insulated strain clamps

Threaded Straight Stuffing Box and Packing Gland Lead Entrance

- Stuffing boxes are machined or fabricated openings, which permit electrical conductors to pass through an explosion proof enclosure. The enclosure wall is drilled so that a bushing can be seated against the shoulder of the enclosure and packing material can be placed around the cable. Whenever the packing gland nut is screwed into the threaded portion of the opening and tightened, the packing material is compressed forcing it tightly against the cable. This minimizes the possibility of a flame path where the conductor passes through the wall of the enclosure.
- Stuffing boxes shall be designed and the amount of packing used shall be such, that with the packing properly compressed, the gland nut still has a clearance distance of 1/8 inch or more to travel without meeting interference by parts other that packing.
- Compressed packing material shall be in contact with the cable

jacket for a length of not less than ½ inch.

- Packing nuts and stuffing boxes shall be secured against loosening.
- Asbestos packing material shall be untreated, not less than 3/16 inch in diameter if round or not less than 3/16 inch by 3/16 inch if square.

Slip-Fit Stuffing Box and Packing Gland Lead Entrance

Volume of Empty Enclosures-more than 124 cubic inches

- Minimum length of flame arresting path is 1 inch
- Packing nuts and stuffing boxes shall be secured against loosening
- Stuffing boxes shall be designed and the amount of packing used shall be such, that with the packing properly compressed, the gland nut still has a clearance distance of 1/8 inch or more to travel without meeting interference by parts other that packing.
- Maximum radial clearance is .003 inch.
- Maximum diametrical clearance is .006 inch (Note: the wire gage size used to check clearance between journal and bearing surface is .007 inch)
- Compressed packing material shall be in contact with the cable jacket for a length of not less than ½ inch.

Plane Flange Joint

A plane flange joint is formed when two surfaces, such as a cover and enclosure meet in parallel planes. This type of joint applies particularly to flat covers such as ones used on controller or connection boxes.

Volume of empty enclosure-more than 124 cubic inches

- Maximum clearance of plane flange joint is .004 inches and is checked with a .005 inch feeler gage (Note: The feeler gage can extend into the opening, as long as 1 inch flame path is maintained)
- A minimum of 1/8 inch stock must be left at the center of the bottom of each hole drilled for fastenings
- Lock washers shall be provided for all bolts, screws and studs that secure parts of explosion-proof enclosures (Note: Machine approval may allow a lock washer, flat and lock washer, star washer, or flat with star washer; Repairman should check machine approval and maintain as approved)
- Minimum diameter of bolt for fastening (without regard to type of joint) is 3/8 inch

- Minimum thread engagement of bolt is 3/8 inch (**Note: In general, minimum thread engagement shall be equal to or greater than the diameter of the bolt specified; If a ¾ inch diameter bolt is used to fasten a cover to the enclosure, then thread engagement must be ¾ inch into the enclosure**)
- Minimum width of plane flange joint is 1 inch
- Minimum distance from the interior of enclosure to the edge of a bolt hole is 7/16 inch (Note: Sometimes a bolt hole is stripped out. If so there are three common methods of repairing the hole: weld the hole and retap, retap to the next larger size hole, or use a helicoil. All three methods are acceptable provided the minimum distance from the interior of the enclosure to the edge of the bolt hole is 7/16 inch)

Step Flange Joint

A step flange joint is formed when two surfaces, such as a cover and enclosure, meet at right angles or form a step with each other
End bells on motors and reset switches are typical examples of components, which have step flange joints

Volume of empty enclosure-more than 124 cubic inches

- Maximum clearance of step flange joint is .006 inches and is checked with a .007 inch feeler gage
- A minimum of 1/8 inch stock must be left at the center of the bottom of each hole drilled for fastenings
- Lock washers shall be provided for all bolts, screws and studs that secure parts of explosion-proof enclosures (Note: Machine approval may allow a lock washer, flat and lock washer, star washer, or flat with star washer; Repairman should check machine approval and maintain as approved)
- Minimum diameter of bolt for fastening (without regard to type of joint) is 3/8 inch
- Minimum thread engagement of bolt is 3/8 inch (**Note: In general, minimum thread engagement shall be equal to or greater than the diameter of the bolt specified; If a ¾ inch diameter bolt is used to fasten a cover to the enclosure, then thread engagement must be ¾ inch into the enclosure**)
- Minimum width of plane flange joint is ¾ inch (total flame path including step must be ¾ inch)

Explosion Proof Control Panel Box

- Check for missing bolts or lock washers
- Most steel covers use a bolt with a lock washer underneath to secure the cover
- Aluminum covers use a bolt with a star washer or a lock washer underneath to secure the cover
- Bolts with two lock washers underneath are improperly assembled
- Check for burned holes in explosion proof enclosures
- Examine for requirements of plane/step flange joints (most control boxes are plane flange)
- Examine for requirements for packing glands and lead entrances
- Holes in enclosures, provided for lead entrances but which are not in use shall be closed with a secured metal plug (spot welded, brazed or equivalent)
- Fastenings used for joints on explosion proof enclosures shall not be used for attaching non-essential parts or for making electrical connections

Access Openings and covers

- Examine inspection covers on motors and contactor compartments for damaged flame paths (Note: if the threads of screw type covers are damaged, the cover must be replaced)
- Covers for access openings shall meet the same requirements as any other part of an enclosure except that threaded covers shall be secured against loosening, preferably with screws having threads requiring a special tool

Explosion Proof Headlight Enclosure

- Examine the headlight for loose or broken lens
- Mounting bolts should bolt he headlight solidly to the frame of the machine
- Many headlights use a screw on type of lens ring to secure the lens in place. The ring should be mechanically tight and sealed or padlocked
- Lens on headlights shall be glass or other suitable material with physical characteristics equivalent to ½ inch thick tempered glass such as Pyrex
- A headlight and red light reflecting material shall be provided on both front and rear of each mobile transportation unit that travels as

a speed greater than 2.5 miles per hour. Red light reflecting materials shall be provided on each end of other mobile machines

- Headlights shall be mounted to provide illumination where they will be most effective
- Headlights will be protected from damage by guarding or location
- Examine for the requirements for packing glands and lead entrances

Explosion Proof Connection Box

A junction box is an enclosure with a cover and serves to join different runs of cable. The box provides space for connecting and branching the enclosed conductors. A junction box used on permissible equipment is used for splicing conductors in an explosion proof enclosure.

- Examine for missing bolts and lock washers
- Examine the cable packing glands for tightness
- Packing nuts shall be secured against loosening
- Examine for requirements for packing glands and lead entrances
- Examine for missing or loose hose conduit clamps
- Hose conduit shall be flame resistant (examine the hose conduit for nicks and cuts)

Explosion Proof Motors

- Motor end bells are step flange joints (maximum opening for plane portion of a step flange joint is .006 inch)
- Examine for evidence of chisel marks in the end bell (a chisel is frequently used to pry the end bell from the motor housing, which causes damage to the flame path of the step flange joint)
- Examine for requirements for covers for access openings
- Examine for requirements for packing glands and lead entrances

Battery Boxes and Batteries

- Battery box covers shall be lined with flame resistant insulating material, preferably bonded to the inside of the cover, unless equivalent protection is provided
- Battery box covers shall be provided with a means for securing them in a closed position
- Battery boxes shall be well ventilated (the size and locations of openings for ventilation shall prevent access to the cell terminals)
- Batteries shall be insulated from the battery box walls and supported on insulating material

- Drainage holes shall be provided in the bottom of each battery box
- Cell terminals shall be burned on (bolted connections (two bolt type) may be accepted on end terminals)
- Cables within the battery box shall be protected against abrasion
- Each wire leaving a battery box on storage battery operated equipment shall have short circuit protection in and explosion proof enclosure as close as practicable to the battery terminals.

Miscellaneous

- Coal dust, including float coal dust deposited on rock dusted surfaces, loose coal, and other combustible materials, shall be cleaned up and not be permitted to accumulate in active workings or on electrical equipment therein (75.400)
- Moving parts, such as rotating saws, gears, and chain drives shall be guarded to prevent personal injury
- An audible warning device shall be provided on each mobile machine that travels at a speed greater than 2.5 m.p.h.
- The temperature of the external surfaces of mechanical or electrical components shall not exceed 150°C (302°F) under normal operating conditions

18.65 Marking of accepted hose conduit.

18.45 Insulation of cable reels and spooling devices.

18.40 Strain clamps.

18.31 Minimum length of flame arresting path on a plane flange.

18.82 Maximum length of a given size trailing cable.

18.37 Minimum length of contact of packing material on the cable.

18.31 Acceptable sizes for and spacings of fastenings for explosion proof enclosures.

18.31 Maximum clearance of a step flange joint.

18.33 Non-hardening preparation to inhibit rusting.

18.27 Gaskets between two surfaces forming a flame-arresting path.

18.20 Need for an audible warning device.

18.69 Brazing, spot welding, or equivalent of metal plugs in unused lead entrances.

18.31 Minimum width of joint to qualify as a step flange.

18.33 Finish of surface joint forming a flame-arresting path.

18.36 Clamping of cables between machine components.

18.46 Protection of headlights from damage.

18.64 Marking of accepted cables.

18.32 Use of fastenings on an explosion proof enclosure.

18.44 Insulation of battery box covers.

18.20 Moving parts such as gears, saws, and chain drives.

18.32 Fastenings used to secure explosion proof enclosures being used to make electrical connections.

18.20 Headlights fastened solid to the frame of the machine.

18.64 Marking of accepted trailing cable.

18.32 Holes for fastenings shall not penetrate to the interior of an enclosure.

Chapter 8
Diesel Equipment Permissibility

A. Introduction Diesel Equipment

The number of diesel units used in underground coal mines is growing rapidly. The increased use can be attributed to diesel powered equipment being versatile, safe and productive. Diesel equipment use has reduced electrical hazards and minimized other hazardous tasks.

Diesel powered equipment shall not be permitted underground without receiving approval from the Chief of the Division of Mines and MSHA. The Virginia Mine Safety Act under section § 45.1-161.206 (Diesel Powered Equipment) establishes regulations governing the use of diesel powered equipment in underground coal mines.

Virginia's Safety and Health Regulations for Coal Mines (Regulations Governing the Use of Diesel-Powered Equipment in Underground Coal Mines) establishes the requirements that diesel powered equipment shall not be permitted underground without receiving the approval from the Chief. The regulations establish compliance with 30 CFR Part 7 Subpart E, Subpart F and Part 36.

Part 7 Subpart E, (Diesel Engines Intended for Use in Underground Coal Mines) establishes the specific engine performance and exhaust emission requirements for MSHA approval of diesel engines for use in areas of underground coal mines where permissible electric equipment is required and areas where non-permissible electric equipment is allowed.

Part 7 Subpart F (Diesel Power Packages Intended for Use in Areas of Underground Coal Mines Where Permissible Electric Equipment is Required) establishes the specific requirements for MSHA approval of diesel power packages intended for use in approved equipment in areas of underground coal mines where electric equipment is required to be permissible.

Part 36 establishes approval requirements for permissible mobile diesel powered equipment and Part 75 Subpart T (75.1900) establishes requirements concerning diesel fuel and outby diesel equipment use in underground coal mines.

Regulations require permissible and emission components of diesel-powered equipment shall be inspected weekly by a certified diesel engine mechanic in accordance with the instructions of the manufacturer and all applicable federal and state requirements. The person responsible for maintenance should be acquainted with State and MSHA requirements and the manufacturer recommendations. The four major component areas are the electrical light system, engine intake system, engine exhaust system and the fuel system.

B. Virginia Mine Safety Act

§ 45.1-161.206 Diesel Powered Equipment

Diesel powered equipment may be utilized underground with the written approval of the Chief. The Chief shall promulgate regulations necessary to carry out the provisions of this section. The regulations shall require that the air in each travelway in which diesel equipment is used, and in any active workings, connected thereto, be of a quality necessary for a safe, healthful working environment. The minimum quantity of ventilating air that must be supplied for a permissible diesel machine in a given time shall conform to that shown on the approval plate attached to the machine. All diesel machines and equipment shall be maintained in such manner that the exhaust emissions meet the same standards to which the machine or equipment was manufactured.

(Review Chapter 7 Permissibility)

Virginia's Safety and Health Regulations for Coal Mines (Chapter 90: Regulations Governing the Use of Diesel-Powered Equipment in Underground Coal Mines) establishes the requirements that diesel powered equipment shall not be permitted underground without receiving the approval from the Chief.

4 VAC 25-90-20 of Virginia's regulations establish compliance with 30 CFR Part 7 Subpart E, Subpart F and Part 36. 4 VAC 25-90-40 of the regulations require permissible and emission components of diesel-powered equipment be inspected weekly by a certified diesel engine mechanic in accordance with the instructions of the manufacturer and all applicable federal and state requirements.

C. 30 CFR (Code of Federal Regulations) Part 36

Part 36 Approval Requirements for Permissible Mobile Diesel Powered Transportation Equipment Review

36.2(h) A diesel engine is a compression ignition, internal combustion engine that utilizes a low-volatile hydrocarbon (diesel) fuel

36.2(n) A flame arrestor is a device so constructed that flame or sparks from the diesel engine cannot propagate an explosion of a flammable mixture through the flame arrestor

36.11(c) Without an approval plate, diesel equipment is not considered permissible

36.21 Electric starting of a permissible diesel engine shall not be accepted. Engines burning fuel other than diesel fuel are not considered for testing for certification as a permissible engine

36.22 The fuel system is constructed so that the fuel injected is at a desired maximum value and fixed so that the adjustment can only be changed after breaking a seal or unlocking a compartment

36.23(b) The intake system shall include a flame arrestor that will prevent an explosion within the system from propagating to a surround flammable mixture

36.23(b)(2) A flame arrestor of the spaced plate type, the spacing between the plates shall not exceed .018 inch; and the plates forming the flame path shall be at least 1 inch wide. Corrosion resistant metal must be used to construct flame arrestors

36.23(c) The engine intake system must include a valve, operable from the operator's compartment, to shut off the air supply to the engine

36.23(d) An air cleaner must be included in the engine intake system and arranged so that only clean fresh air will enter the engine

36.24 Joints in the engine intake system shall be formed by metal flanges fitted with metal or metal clad gaskets

36.25(b)(3) When a cooling box scrubber is used as a flame arrestor, one safety device may be accepted provided it controls a safe minimum water level in the cooling box scrubber

36.25(f)(2) The final diluted exhaust mixture must be discharged so that it is directed away from the operator's compartment

36.26(a) An engine submitted for approval must have the fuel injection rate such that the exhaust will not contain black smoke

36.27(a) A vent opening must be provided in the fuel filler cap so that only atmosphere pressure is maintained inside the tank

36.27(a)(1) Fuel can only be added to the fuel tank by a self closing valve

36.27(b) Fuel lines shall be installed to protect them against damage in ordinary use, and they shall be designed, fabricated, and secured to resist breakage from vibration

36.27(c) A shutoff valve must be provide in the fuel system

36.28 Warning devices, such as a horn or bell shall be operated manually or pneumatically

36.29 All mobile diesel powered equipment must be equipped with adequate brakes acceptable to MSHA

36.31 Each permissible diesel unit must be equipped with a fire extinguisher carried in a location easily accessible to the operator

36.32 Electrical components on mobile diesel powered transportation equipment shall be approved under Part 18, 20 or 27

36.33(a) Headlights must be protected from external damage by recessing in the equipment frame, enclosing them within a shield of substantial construction, or by some other method, that provides equivalent protection

[illegible]

A [illegible]

[illegible]

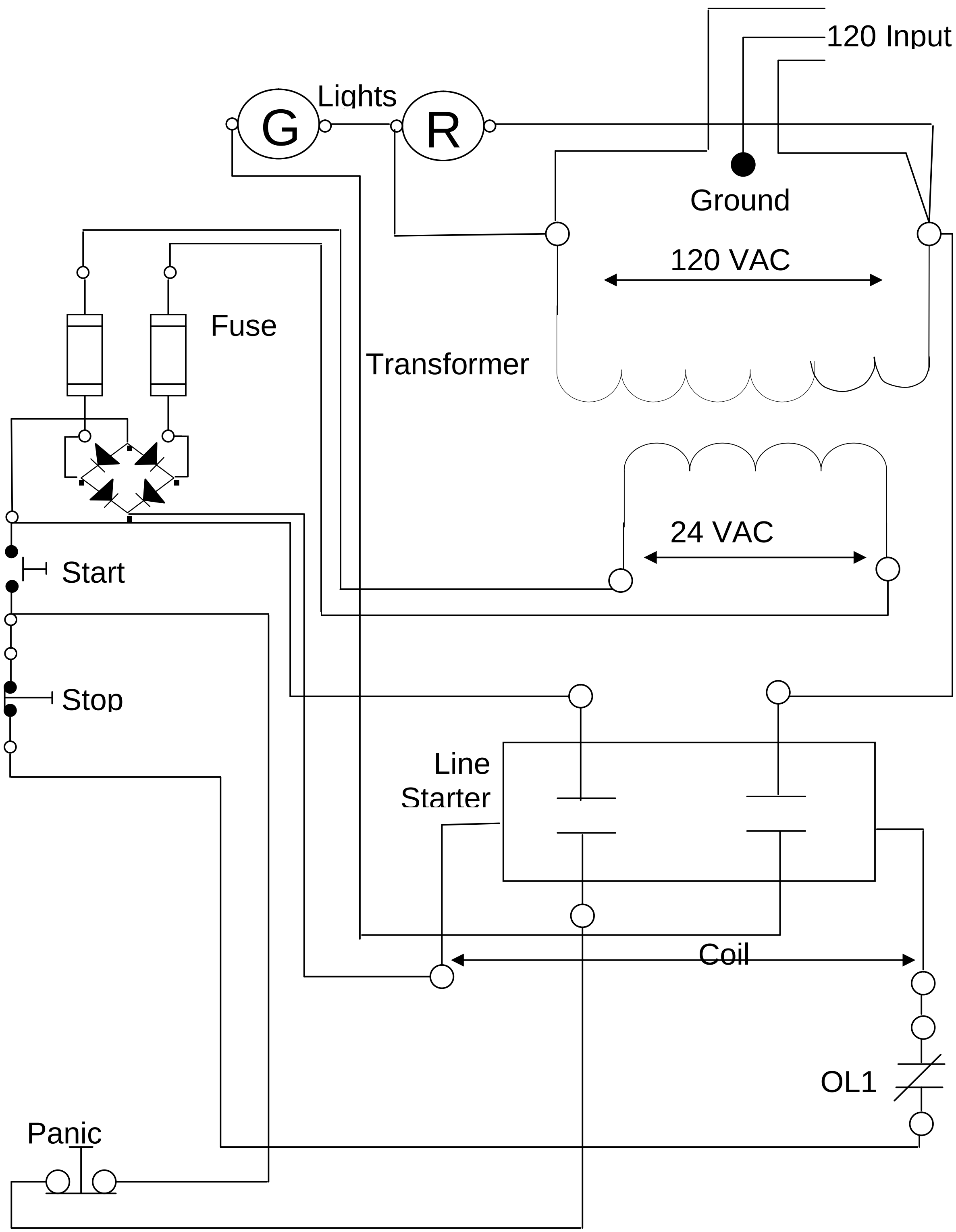
[illegible]

This station will require the applicant to be able to read a basic control circuit schematic and demonstrate safe testing/troubleshooting procedures on a 24-volt AC control circuit panel board.

The student will be required to read an electrical schematic that is provided and properly install jumper wires in the proper location in the control circuit panel board so the circuit will operate properly. The line starter contactors will close and the green indicator light will come on when the start switch is depressed if the circuit has been properly connected. You will be allowed to use any test equipment provided to complete this station. You will have twenty-five (25) minutes to complete this station.

Enclosed is a schematic of a basic control circuit similar to the one that you will be tested on.

Control Circuit Troubleshooting and Schematic Reading



B [illegible]

ELECTRICAL REPAIRMAN EXAMINATION

You are required to identify all of the following conditions in the two sections of cable: phase to phase, phase to ground, ground-to-ground monitor, open phase, open ground, open ground monitor. Only three (3) conditions are present in each section of cable. Student has twenty-five (25) minutes to complete this station.

Mark the appropriate blocks for applicable conditions.

[illegible]

- ❑ phase to phase
- ❑ phase to ground
- ❑ ground to ground monitor
- ❑ open phase
- ❑ open ground
- ❑ open ground monitor

[illegible]

- ❑ phase to phase
- ❑ phase to ground
- ❑ ground to ground monitor
- ❑ open phase
- ❑ open ground
- ❑ open ground monitor

C [redacted]

[redacted]

STUDENT TRAINING GUIDE

You are required to examine the circuit breaker, cathead, and trailing cable. Mark only the appropriate blocks of the <u>deficiencies</u> that you find. Inappropriate blocks marked will be discounted. Student has twenty-five (25) minutes to complete this station.
When student begins this station the circuit breaker will be energized and the magnetic trip settings will be on HI. You will be provided necessary meters, gloves and safety glasses to perform this station. You will be given a list of conditions selected from below to identify by both visual observations and with meter test equipment. Students are required to de-energize this energized circuit breaker before disconnecting the cathead.

- ❑ If not set properly, you are <u>required</u> to adjust the magnetic trip (short circuit protection) to the proper setting based on the attached cable size
- ❑ Strain relief clamp securely clamped to trailing cable
- ❑ Ground wire is connected to a phase lug in receptacle
- ❑ Jumper wire from ground to ground monitor in receptacle
- ❑ Latching plate missing on top of cat-head
- ❑ The ground monitor conductor is connected to the wrong lug in the cat-head
- ❑ Ground conductor connected to a phase lug in cat-head
- ❑ The cat-head frame is grounded
- ❑ The ground conductor is connected to the wrong lug in the receptacle
- ❑ Ground lug in cat-head is missing
- ❑ The circuit breaker panel is marked for identification
- ❑ The cat-head is marked for identification
- ❑ One phase lug is loose in the receptacle
- ❑ Magnetic trip (short circuit) setting is incorrect
- ❑ Trailing cable has an exposed power conductor
- ❑ One phase lug is loose in the cat-head
- ❑ The cat-head will remain latched when coupled
- ❑ The circuit breaker handle has a hole drilled through it
- ❑ The circuit breaker handle is broken
- ❑ Jumper wire connected from ground monitor to receptacle
- ❑ Exposed power conductor where trailing cable enters cat-head
- ❑ Trailing cable is too long
- ❑ Ground monitor lug is installed in the wrong location in the cat-head
- ❑ The resistance between the ground and ground monitor is too high
- ❑ Trailing cable is flame resistant
- ❑ Open phase conductor between end of cable and cat-head
- ❑ The ground lug in the receptacle is missing
- ❑ The ground conductor will connect before any phase lead when the cathead is coupled

[illegible]

[illegible] [illegible] SIZE	[illegible] [illegible] SETTING	LENGTH	AMPACITY	RATING DE
14	50	---	15	15
12	75	---	20	20
10	150	---	25	25
8	200	---	50	50
6	300	550	65	70
4	500	600	90	90
3	600	650	105	110
2	800	700	120	125
1	1000	750	140	150
1/0	1250	800	170	175
2/0	1500	850	195	200
3/0	2000	900	225	225
4/0	2500	1000	260	300

[illegible]

(Trailing Cable Short Circuit Protection)

(Trip Ranges)	Lo	1	2	3	4	5	6	7	Hi
150 – 480 Amps	150	191	232	274	315	356	397	439	480
300 – 700 Amps	300	350	400	450	500	550	600	650	700
500-1000 Amps	500	562	625	687	750	812	875	937	1000
750-1500 Amps	750	844	938	1031	1125	1219	1313	1407	1500
800-1600 Amps	800	900	1000	1100	1200	1300	1400	1500	1600
1500-3000 Amps	1500	1688	1875	2063	2250	2438	2625	2813	3000
2000-4000 Amps	2000	2250	2500	2750	3000	3250	3500	3750	4000
2500-5000 Amps	2500	2812	3125	3437	3750	4062	4375	4687	5000

Lo	1	2	3	4	5	6	7	8	9	10	11	12	Hi
50 - 150 Amps	50	58	65	73	80	88	95	103	111	118	126	134	142
66 - 190 Amps	66	75	85	94	104	113	123	132	142	151	161	170	180
150-480 Amps	150	175	200	225	250	275	300	325	350	375	400	425	450

[illegible]

ELECTRICAL REPAIRMAN EXAMINATION

STUDENT TRAINING GUIDE

A panel board display consisting of four permissible enclosures and some adjoining conduit will be used to test on this station. Each of the four units will have permissible deficiencies. Discrepancies may include but not limited to enclosure flange openings, bolts and washers, packing gland installation, conduit clamps, safety plugs, safety wire, etc.

You are required to examine the explosion-proof enclosures and identify permissible deficiencies on the four units (numbered 1 through 4) and associated conduit. Student has twenty-five (25) minutes to complete this station.

EXAMPLES

[illegible]

1. Opening exceeding .004 inch in enclosure
2. No safety wire on packing gland
3. No locking device on plug

UNIT 2

1. Inadequate packing in packing gland
2. Opening exceeding .006 inch in enclosure
3. Damaged conduit

UNIT 3

1. No bolt in enclosure
2. No lock washer on two bolts in enclosure
3. Conduit hose clamp is missing

UNIT 4

1. Opening exceeding .006 inch in enclosure
2. Damaged conduit
3. Lock washer missing from enclosure bolt

[redacted]

[redacted]

This two part exercise is designed to test your knowledge on the use of electrical safety equipment and the proper steps involved after being instructed to add or remove a section of high voltage cable from the electrical system and move the section transformer to the preferred location, reconnect the high voltage cable to the section transformer, and then energize the high voltage power and test for proper high voltage phase polarity.

The following is a suggested sequence procedure for moving a section power center and the installation and removal of high voltage cables.

- On the day of the move, all affected personnel should be thoroughly briefed on planned work procedures and their assigned duties.

- Any equipment affected by de-energizing the section high voltage power should be repositioned to the preferred location.

- The certified electrical repairman performing the work must:
  - De-energize, tag and lock out the high voltage circuit on the surface or other suitable location.
  - Visual evidence must be provided to assure the power is de-energized.

- With the required safety equipment, bleed any potential capacitive charge and ground each high voltage phase lead to the system ground terminal at a location outby the affected equipment/cable being installed or removed with suitable grounding leads.

- With the required safety equipment, prior to performing work within the electrical equipment (*e.g. section transform, belt transformer, splice box or high voltage splitter*), bleed any potential capacitive charge from each phase lead terminal inside the electrical equipment with suitable equipment. This will ensure that there is no capacitive charge on the leads that will be removed.

- Add or remove the section of high voltage cable and install the appropriate equipment needed to complete the installation or removal.

- Move the section power center to the preferred location.

- The high voltage cable should be placed or positioned in a manner to prevent strain or damage.

- The high voltage cable should be hung on insulators or placed in a location to protect from mechanical damage and from contact with low and medium voltage circuits.

- Guard the high voltage cable where miners work and travel, unless hung at least six and one-half feet above the mine floor.

- Excess high voltage cable should be looped in a figure eight pattern to prevent forming an electro-magnetic field.

- Reconnect the ground, ground monitor and high voltage phase leads.

- Reposition all covers and secure with in place

- Ensure/verify that all mining personnel are clear of the section power center and not handling the high voltage cable prior to energizing the high voltage power.

- Disconnect the grounding leads at the location where the high voltage leads were grounded

- Energize the high voltage power.

- Check the high voltage phase polarity by energizing a unit of section equipment to ensure proper phase rotation.

- You have checked high voltage phase polarity.
    - If the phase polarity is correct, skip the following procedures.
    - If the phase polarity is backwards; followed the next sequence procedures:

  <u>Sequence procedures for correctly reversing phase polarity:</u>
    - Certified electrical repairman performing the work must:
        - De-energize, lock out and tag the high voltage power.
        - Visual evidence must be provided to assure the power is de-energized

    - With the required safety equipment, bleed any potential capacitive charge and ground each high voltage phase lead to the system ground terminal at a location outby the affected equipment/cable previously installed or removed with suitable grounding leads.

    - With the required safety equipment, prior to performing work within the electrical equipment, bleed any potential capacitive charge from each phase lead terminal inside the electrical equipment with suitable equipment. This will ensure that there is no capacitive charge on the leads that will be removed.

    - Reverse two-phase leads inside the section transformer.

    - Reposition all covers and secure in place.

    - Ensure/verify that all mining personnel are clear of the section power center and not handling the high voltage cable prior to energizing the high voltage power.

    - Disconnect the grounding leads at the location where the high voltage leads were grounded the second time.

    - Energize the high voltage power the second time.

- Upon completion of the power move, the high voltage ground monitoring system should be checked by activating the emergency stop switch on the section transformer.

- Insulating mats, danger signs and fire extinguisher should be properly located.
- Section equipment cables should be properly routed to the power center, hung and anchored at the proper locations.

[redacted]

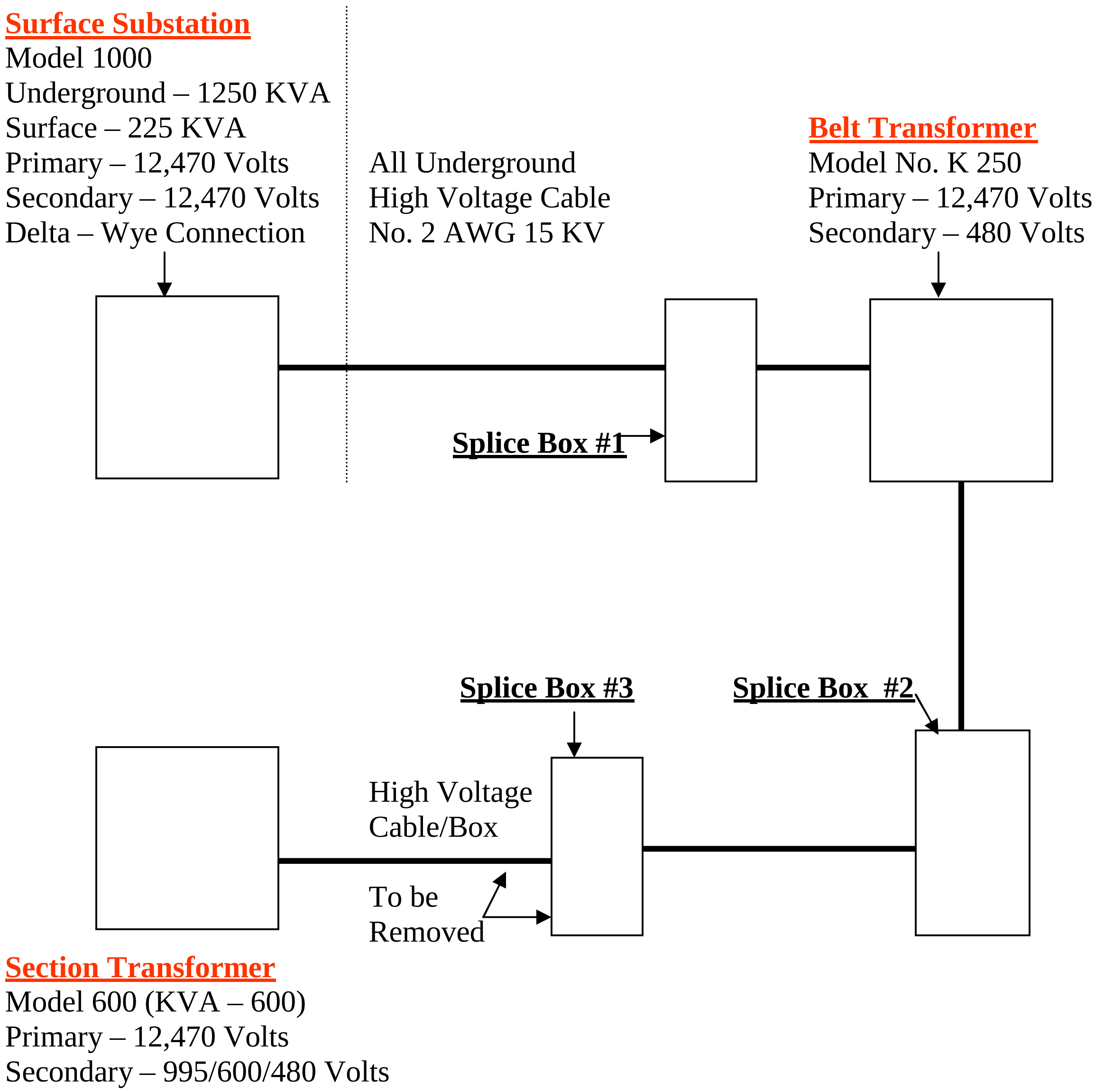
Part II

The following safety equipment should be used to complete a section high voltage power move that involves removing or adding high voltage cable, splice boxes, etc.

1. Proper protective gloves or high voltage gloves
2. Proper grounding cables
3. Lock and tag
4. Hot stick/insulating stick
5. Safety glasses

5 POINTS FOR EACH CORRECT ANSWER

[redacted]


Surface Substation
Model 1000
Underground – 1250 KVA
Surface – 225 KVA
Primary – 12,470 Volts
Secondary – 12,470 Volts
Delta – Wye Connection
All Underground
High Voltage Cable
No. 2 AWG 15 KV
Belt Transformer
Model No. K 250
Primary – 12,470 Volts
Secondary – 480 Volts
Splice Box #1
Splice Box #3
Splice Box #2
High Voltage
Cable/Box
To be
Removed
Section Transformer
Model 600 (KVA – 600)
Primary – 12,470 Volts
Secondary – 995/600/480 Volts

ELECTRICAL EXAMINATIONS – RECORD KEEPING-WEEKLY EXAMINATION OF ELECTRICAL EQUIPMENT

The following information is provided for you to identify electrical equipment examination deficiencies and correctly complete the attached weekly electrical equipment examination record book. Student has twenty-five (25) minutes to complete this station.

You are a certified repairman at Gold Mine Coal Company, Mine # 2, 002 section, located on Meade Fork in Wise County. On November 5, 2007, you have conducted a weekly examination of the following equipment located on the 002 Section:

EQUIPMENT	SERIAL NUMBER
Joy Continuous Miner	J55432
21 SC Shuttle Car	BR549
Fletcher Roofbolter	AZ5101
S/S Battery Scoop	SS4955
Conveyor Feeder	CB1010
Section Transformer	FM2041

During your weekly electrical equipment examination, you have observed the following conditions on each unit of equipment, however only hazardous conditions are required to be recorded.

Please complete the “Weekly Examination of Electrical Equipment” record book while identifying the hazardous conditions required to be recorded and the action that you would take to correct these conditions.

Joy Continuous Miner - Serial No. J55432: (1) Hand tools are located on top of the miner frame. (2) The methane monitor warning light comes on at 1% and de-energizes the miner at 1.5%. (3) The right ripper motor junction box (plane flange joint) has an opening of .005 inch. (4) The methane monitor enclosure (plane flange joint) has three bolts missing and has an opening of .005 inch.

21 SC Shuttle Car – Serial No. BR549: (1) Three bolts are missing from the pump motor junction box (plane flange joint) and the junction box has an opening exceeding .005 inch. (2) Six permanent splices are visible in the trailing cable. (3) The right front headlight is inoperative. (4) The tram foot switch linkage is defective causing the shuttle car to hang on point.

Fletcher Roofbolter – Serial No. AZ5101: (1) The roofbolter operators have complained that the ATRS is operating slower than normal. (2) The cable reel is operating slower than normal but, will take the cable up. (3) The trailing cable has six (6) permanent splices in the cable. (4) The offside control (start-stop switch) plane flange enclosure has an opening of .005 inch.

S/S Battery Scoop – Serial No. SS4955: (1) The left side battery cover is bent on one corner. (2) Rock dust is stacked on top of the battery scoop covers. (3) The main panel board enclosure (plane flange) has an opening of .005 inch. (4) The scoop motor has rock dust on it.

Conveyor Feeder – Serial No. CB1010: (1) Loose coal, three inches in depth, is present in front and on both sides of the feeder. (2) Only 7 of 10 pick breaker water sprays are operating. (3) An insulating mat is not provided at the main panel board where the circuit breaker is energized/de-energized. (4) The offside conveyor start/stop switch has an exposed conductor where the cable enters the switch.

Section Transformer – FM2041: (1) A danger sign is hung from the mine roof approximately 8 feet from the transformer. (2) Only 200 pounds of rock dust is located 10 feet from the transformer. (3) Conveyor belt material is used as insulating mats for all shock hazard locations. (4) Circuit breaker mounting bolts are missing and one energized circuit breaker assembly has partially fallen out of the transformer.

DEPARTMENT OF MINES, MINERALS AND ENERGY
DIVISION OF MINES

ELECTRICAL REPAIRMAN EXAMINATION
STATION NO. 2
STUDENT TRAINING GUIDE – Answer Key

NAME: ______________________________ **DOB:** ______________________________

DATE: ______________________________

WEEKLY EXAMINATION OF ELECTRICAL EQUIPMENT

Date	Location	Equipment	Serial/Co.No.	Condition	Action Taken
1. 11/05/07	002 Section	Joy Miner	J55432	Opening in right ripper motor junction box	Resealed junction box to less than .005 inch
2. 11/05/07	002 Section	Joy Miner	J55432	Methane Monitor enclosure opening and three bolts missing	Replaced three missing bolts and resealed enclosure
3. 11/05/07	002 Section	Shuttle Car	BR549	Pump motor junction box - three bolts missing and opening	Replaced three missing bolts and resealed junction box
4. 11/05/07	002 Section	Shuttle Car	BR549	Tram foot switch - hanging on point	Repaired tram foot switch linkage
5. 11/05/07	002 Section	Fletcher Roofbolter	AZ5101	Offside start-stop control, start-stop switch has opening	Removed cover, cleaned and resealed to less than .005 inch
6. 11/05/07	002 Section	S/S Scoop	554955	Main panel board - opening	Removed cover, cleaned and resealed to less than .005 inch
7. 11/05/07	002 Section	Feeder	CB1010	Offside – start/stop switch has an exposed conductor	Restocked cable in switch
8. 11/05/07	002 Section	Section Transformer	FM2041	Circuit breaker assembly – mount belts are missing and circuit breaker has partially fallen out	Deenergized power and installed mounting bolts

WEEKLY CALIBRATION OF METHANE MONITORS

Calibrated miner – methane monitor with 2.5% calibration gas, operated properly.

EXAMINER John Davis **COUNTERSIGN** ______________________________

Electrical Examinations – Record Keeping
Monthly Examination of Electrical Equipment
Station No. 1
10 Point Discount for each incorrect answer

The following information is provided for you to identify electrical equipment hazardous conditions and correctly complete the attached monthly electrical equipment examination record book.

You are a certified repairman assigned to conduct a monthly examination at the surface area of an underground mine. On October 23, 2006, you have conducted a monthly examination of the following electrical equipment.

EQUIPMENT	SERIAL NUMBER
#1 Belt Drive	BR-549
Stacker Belt- Belt Drive	BR-600
Fan Installation	BR-750
#1 Battery Charger	BG-501
#2 Battery Charger	BC-300
Stamler 240 Volt Pump	ST-101
Shop 110 Volt Disc Grinder	DG-202
Shop 220 Volt Heater	HE-303

During your monthly electrical equipment examination, you have observed the following 16 conditions.

However, only 8 of these conditions are classified as hazardous conditions and required to be recorded in the monthly examinations record book.

#1 Belt Drive; Serial No. BR-549

(1) The belt drive motor has exposed conductors where the 480-volt phase leads enter the motor.
(2) Hand tools are located on top of the belt-drive starter box.

Stacker Belt – Belt Drive; Serial No. BR-600

(1) A small amount of coal dust has accumulated near the stacker belt-tail roller.
(2) The handrail located along the entire length of the stacker belt walkway needs some welding.

Main Fan Installation; Serial No. BR-750

(1) An insulating mat is not provided at the fan-circuit breaker located near the main fan.
(2) The cover of the fan circuit breaker had been removed exposing energized conductors..

#1 Battery Charger; Serial No. BG-501

(1) The charger circuit breaker is not marked (labeled) for identification.
(2) The charger top cover is missing exposing energized 120-volt conductors.

#2 Battery Charger; Serial No. BC-300

(1) The manufacturer identification tag normally installed on the side of the charger is missing.
(2) The battery charger is charging the scoop battery and has an exposed conductor in the charger cable where the cable enters the connector plug (receptacle).

Stamler 220-Volt Water Pump; Serial No. ST-101

(1) The energized pump has 120 volts as measured on the pump frame with a volt–ohmmeter.
(2) A manufacturer identification tag is not provided on the pump frame.

Shop 110-Volt Disc Grinder; Serial No. DG-202

(1) An extension cord attached to the grinder power cord had an exposed energized conductor.
(2) The grinder disc is worn on the edges of the disc.

Shop 220-Volt Heater; Serial No. HE-303

(1) The heater does not have a cover over the front of the heater.
(2) The heater has exposed energized conductors in the power source cable located ten feet from the heater.

[redacted]

10 POINT DISCOUNT FOR EACH INCORRECT ANSWER

[redacted] John Doe **3/21/1955**

[redacted] [redacted] **10-23-06**

[redacted]

Date	Equipment	Serial/Co.No.	Hazardous Condition	Action Taken
10/23	#1 Belt Drive	BR-549	Exposed conductor in belt motor cable	Repaired cable
10/23	Stacker Belt Belt Drive	BR-600	Use handrail along stacker belt	Welded handrail
10/23	Main Fan Installation	BR-750	Circuit breaker cover was missing exposing energized conductors	Replaced cover on circuit breaker.
10/23	#1 Battery Charger	BG-501	Top cover is missing - exposing energized conductors	Replaced top cover
10/23	#2 Battery Charger	BC-300	Charger cable has exposed conductor	Repaired cable
10/23	Stamler Water Pump	ST-101	Voltage (120 volts) measured on pump frame	Found source of frame voltage and removed voltage from pump frame
10/23	Shop Disc Grinder	DG-202	Extension cord used with grinder has exposed energized conductor	Repaired extension cord
10/23	Shop 220 Volt Heater	HE-303	Heater cable (power source) has exposed energized conductors	Repaired heater cable

Electrical Examinations
Monthly Examinations of Surface High Voltage Circuit Breakers/Substations

The following information is provided for you to identify hazardous conditions and correctly complete the attached monthly examination of high voltage circuit breakers record book.

During your monthly examination of high voltage circuit breakers, you have observed the following conditions.

Only 4 of these conditions are classified as hazardous conditions and required to be recorded in the monthly examinations record book.

You are a certified repairman assigned to conduct a monthly examination of the surface high voltage circuit breakers. On October 23, 2006, you have conducted a monthly examination and have observed the following:

1. The substation fence is intact and the gate is locked.
2. Danger high voltage signs are provided
3. The lightning arrestors are intact.
4. You conducted a visual examination of circuit breaker/auxiliary devices and observed that the cover installed around the high voltage circuit breaker has been removed exposing energized conductors.
5. The substation area is free of combustible material.
6. Insulating mats are provided at shock hazard locations inside the substation area.
7. A fire extinguisher is provided inside the substation fence.
8. Visual disconnects are provided.
9. You manually activated the induction discs on two overcurrent relays to actuate tripping of the high voltage circuit breaker and the high voltage circuit breaker tripped.
10. You rotated the induction disc on the 59G (ground fault relay) and the high voltage circuit breaker failed to trip.
11. The frame grounds are intact on the gate, transformers and ground resistor. The fence delivers an electrical shock when touched and has 110 volts on the fence frame when measured with a volt-ohm meter.
12. You activated the ground check monitoring circuit (emergency stop button) at the farthest point from the surface substation inside the mine and usually at the section transformer – power center. The high voltage circuit breaker failed to trip when this test was conducted.

STUDENT PRACTICE EXAM

SURFACE ELECTRICAL REPAIRMAN EXAMINATION

NAME: John Doe **DOB:** 3/21/1955

DATE: 10-23-06

10 POINT DISCOUNT FOR EACH INCORRECT ANSWER

MONTHLY EXAMINATION OF SURFACE HIGH VOLTAGE CIRCUIT BREAKERS/SUBSTATION

EXAMINATIONS:	YES	CORRECTIVE ACTION TAKEN
Rotate the Induction Disc on Two Overcurrent Relays to Actuate Tripping of the High Voltage Circuit Breaker	x	
Station Fence Intact and Gate Locked	x	
Danger High Voltage Signs	x	
Frame Grounds Intact on Fence, Gate, Transformers and Ground Resistors	x	Fence-Stray voltage on fence. Found source and removed stray voltage from fence frame.
Lightning Arrestors Intact	x	EITHER ANSWER ↓
Activated the Ground Check Monitoring circuit (emergency stop button)	x	1. Loose connection – tightened – operates properly 2. Contact tips not making contact - adjusted or replaced relay – operates properly
Visual exam of circuit breaker/auxiliary devices	x	Cover – over circuit breaker missing – reinstalled cover
Station Free of Combustible Material	x	
Insulating Mats in Place	x	
Fire Extinguisher	x	
Visual Disconnects	x	EITHER ANSWER ↓
Rotate the Induction Disc on the Ground Fault Relay	x	1. Defective emergency stop switch – replaced. 2. Improper ground or ground monitor connection – reconnected properly. 3. Ground – ground monitor wires shorted together – found short and repaired. 4. Defective ground monitor unit repaired or replaced.

John Doe
Examiner

Countersign

Chapter 10
Electrical Systems Review

A. Basic Electrical Principles

Electricity provides energy for operating equipment, lighting, heating and mine electrical motors. (Figure 1)

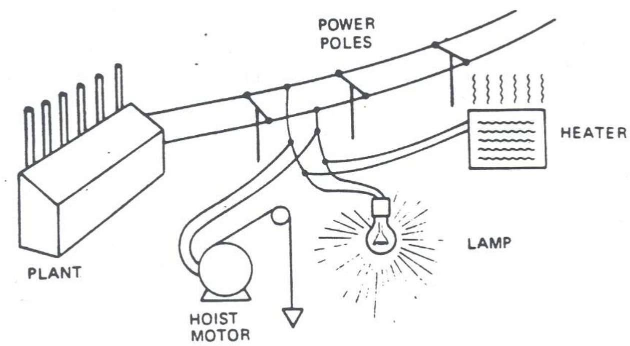


Figure 1

Like other forms of energy, electricity, if not carefully controlled, can cause injuries to people and damage to equipment. Knowledge of the material in this unit will assist the electrical repairman with maintaining electrical equipment with a high degree of safety from electrical hazards.
ELECTRICITY:

Electrical energy is created by a flow of negatively charged atomic particles called electrons. If there are more electrons at point A (Figure 2) than there are at point B, and there is a current path (conductor) through which the electrons can flow, electrons will move from point A to B

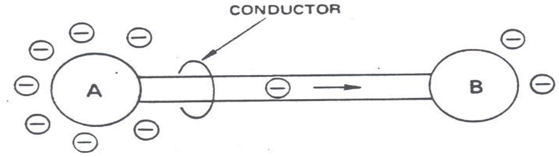


Figure 2

until an equal number are at each point (Figure 3).

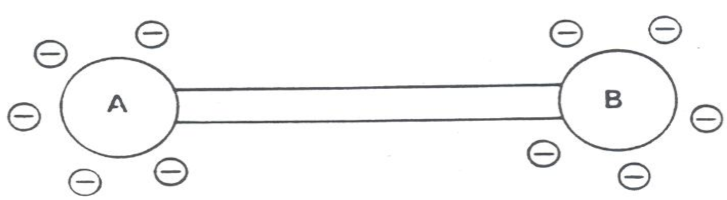


Figure 3

The excess number of electrons at A in Figure 2 created a pressure, causing the electrons to flow to point B. You can compare the action to the two tanks of water in Figure 4.

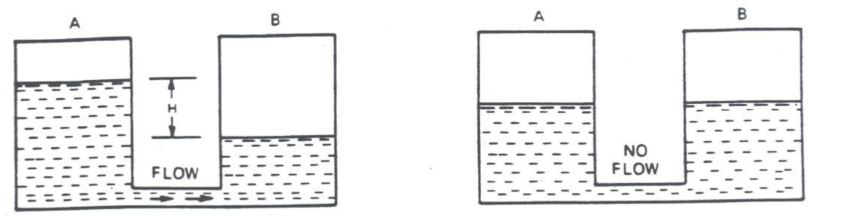


Figure 4

The greater water pressure caused by the greater height of the water in A (H) will cause water to flow into B until the water in each tank is at the same height.

PRESSURE AND CURRENT

Volts and Amperes: In electricity the "pressure", causing the flow is called voltage. The rate of flow of electrons is called current. A unit of voltage is one Volt. Its symbol is E. A unit of current is one Ampere. Its symbol is I. It is important to remember that if there is a difference in voltage and a path along which electricity will flow (conductor) between two points, current will flow from the high voltage to the low voltage point.

RESISTANCE – OHMS

In the water system, resistance is a restriction that opposes the flow of water. For example, if we use a smaller pipe between the two tanks, the rate of flow of the water will be less than if we use a larger pipe. With the smaller pipe, we have put a resistance to the flow of water in the path (See Figure 5).

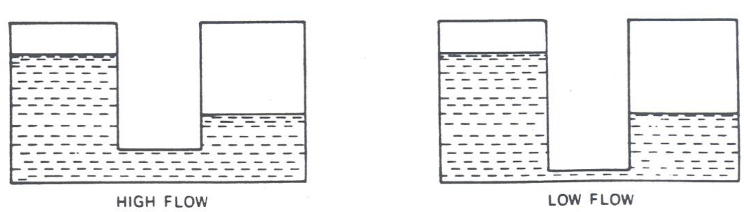


Figure 5

If we put a resistance in the path of the electrons (a smaller conductor or a conductor of a material that does not allow electrons to flow as well), Figure 6, the rate of flow of electrons will be reduced.

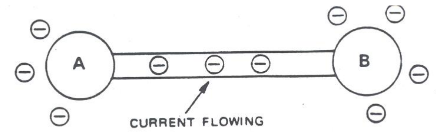


Figure 6

In an electrical circuit, a unit of resistance to flow is an <u>Ohm</u>. Its symbol is <u>R</u>. There is a relationship between the number of volts, amperes and ohms in an electrical circuit. It is called <u>Ohm's Law</u>. Here are the relationships:

	<u>Symbols</u>
Volts = Amperes x Ohms	E = IR
Amperes = $\frac{\text{Volts}}{\text{Ohms}}$	$I = \frac{E}{R}$
Ohms = $\frac{\text{Volts}}{\text{Amperes}}$	$R = \frac{E}{I}$

These relationships enable us to find one unknown value if two others is known. For example, if we have 5 amperes flowing through a circuit with 10 ohms resistance, what is the voltage?

E (Volts) = I (Amperes) x R (Ohms)
E = 5 x 10 = 50 Volts.
The circuit would look like Figure 7.

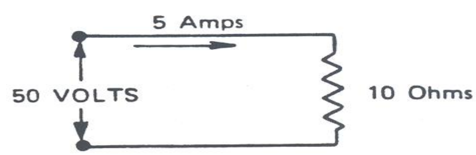


Figure 7

If we have 100 volts across a 5 ohm resistance (Figure 8), how many amperes are there?

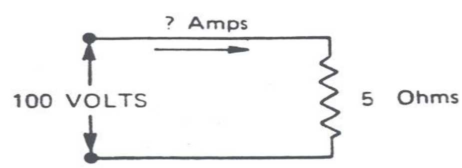


Figure 8

The current flow will be
$I = \frac{E}{R} = \frac{100}{5} = 20$ Amperes

If we have 75 volts causing 25 amperes to flow in a circuit (Figure 9), what is the resistance in the circuit?

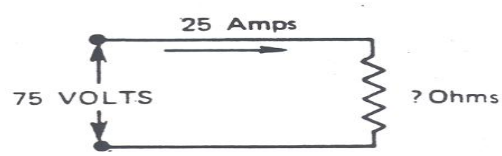


Figure 9

$$R = \frac{E}{I} = \frac{75}{25} = 3 \text{ Ohms.}$$

SERIES AND PARALLEL CIRCUITS

There are two types of circuits: series and parallel (Figure 10).

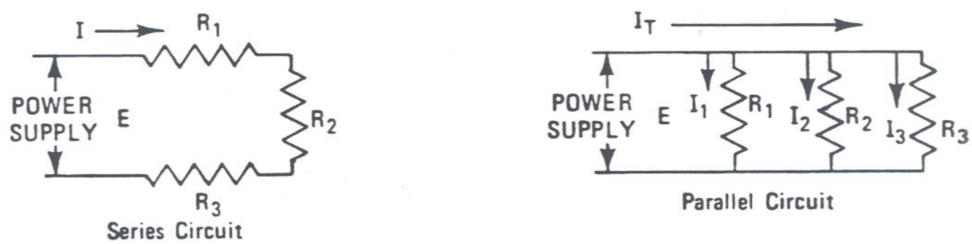


Figure 10

In a series circuit the same amount of current flows through each resistance (or load) in the circuit. The total resistance in the circuit is equal to the sum of the resistances, that is $R_T = R_1 + R_2 + R_3$. The current flowing through each resistance is equal to the total voltage (E) divided by the total resistance: $I = \frac{E}{R_1 + R_2 + R_3}$

In a parallel circuit, the amount of current flowing through each resistance (or load) is equal to the voltage (E) divided by that resistance: $I_1 = \frac{E}{R_1}$ or $I_2 = \frac{E}{R_2}$ or $I_3 = \frac{E}{R_3}$

The total current $I_T = I_1 + I_2 + I_3$.

For example, in a 100 volt series circuit there are 3 resistances, one of 5 ohms, one of 8 ohms and one of 12 ohms. What is the total current flow?

$$I_T = \frac{E}{R + R + R} = \frac{100}{5 + 8 + 12} = \frac{100}{25} = 4 \text{ Amperes.}$$

In a 100 volt parallel circuit we have three resistances (or loads), one of 5 ohms, one of 10 ohms and one of 20 ohms. How much current flows through each one? What is the total current?

$$I_1 = \frac{E}{R_1} = \frac{100}{5} = 20 \text{ amps}$$

$$I_2 = \frac{E}{R_2} = \frac{100}{10} = 10 \text{ amps}$$

$$I_3 = \frac{E}{R_3} = \frac{100}{20} = 5 \text{ amps}$$

$$I_T = I_1 + I_2 + I_3 = 20 + 10 + 5 = 35 \text{ amps}$$

CONDUCTORS AND INSULATORS

Practically every substance will conduct electricity to some extent. Those that have low resistance are called Conductors; those that have high resistance are called Non-conductors. Non-conductors are used as Insulators.

Commonly used conductors are listed below from lowest to highest resistance: Silver, Copper, Gold, Aluminum, & Carbon

Silver, of course, is used only in rare cases, and in very limited amounts because of its cost.

The best and most commonly used non-conductors are Rubber, Porcelain, Glass, & Some Plastics

Conductors and non-conductors are not perfect. Most conductors are in the form of wire, made of copper or aluminum.

The diameter of the wire is given in thousandths of an inch or Mils. A wire with a diameter of 5 thousandths of an inch is 5 Mil wire. The cross-section of the wire in Figure 11 is 5 Circular Mils.

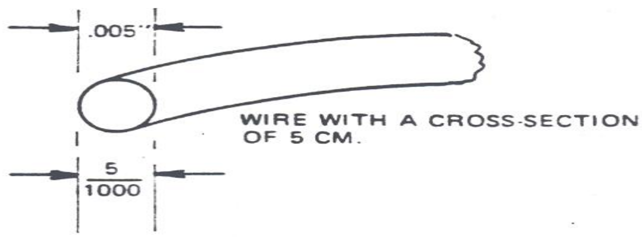


Figure 11

ELECTRICAL POWER SYSTEMS

We cannot actually see electricity flow through a wire and do work for us. We can, however, readily understand its basic operating principles by comparing it to a simple power system hat is easily understood.

An electrical power system is similar to a water power system. Figure 12 is a sketch of a water powered system. Water is stored behind the dam and creates a pressure to force water through the pipe. When the valve is opened, water flows through the pipe and turns the water wheel. The greater the pressure the greater the rate of flow of water. The greater the flow or water the greater the amount of power generated by the turning wheel.

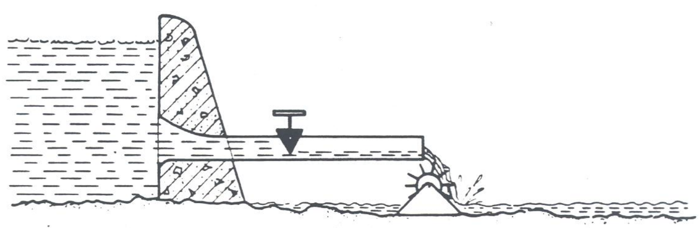


Figure 12

In an electrical power system, Figure 13, we have a similar situation. Electricity is like the water. It comes from a battery or generator and flows through wires or conductors. Remember that the pressure that forces it through the conductors is the voltage and the rate of flow of electricity is the current.

Voltage is measured with a voltmeter; current is measured with an ammeter. (Figure 14) The greater the number of volts, the greater the number of amperes and the greater the amount of power, light or heat that is generated.

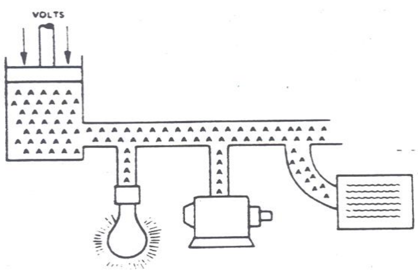


Figure 13

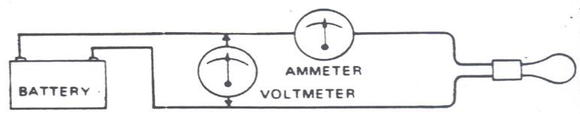


Figure 14

Too much pressure in a water system will increase the flow of water to the point that the pipes or equipment will be damaged (Figure 15).

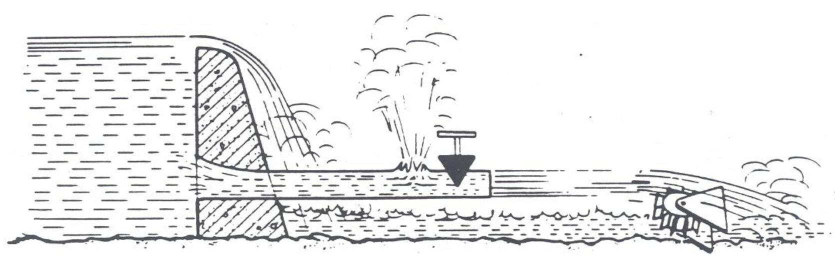


Figure 15

Too much voltage in an electrical system will increase the current to the point that the conductors or equipment will be damaged (Figure 16).

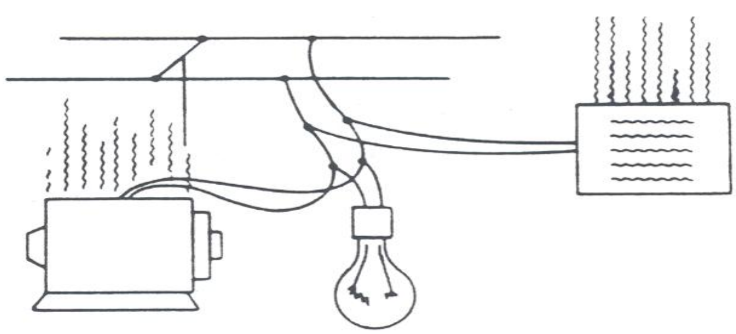


Figure 16

POWER/WATTS

For our purpose, Power is the rate at which a motor or engine does work. Power is equal to the pounds lifted times the number of feet the pounds were lifted, divided by the number of seconds that it took to do the lifting.

$$\text{Power} = \frac{\text{Pounds x Feet}}{\text{Seconds}}$$

A basic unit of power is foot-pound per second. If a hoist lifts one pound one foot in one second it exerted one foot pound per second of power (Figure 17).

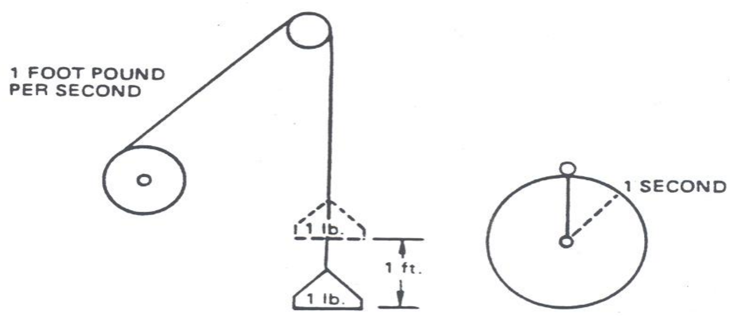


Figure 17

If the hoist lifts 5 pounds 10 feet in 2 seconds, it used 25 foot-pounds per second of power (Figure 18).

$$\text{Power} = \frac{\text{5 pounds x 10 feet}}{\text{2 seconds}} = \text{25 foot pounds per second}$$

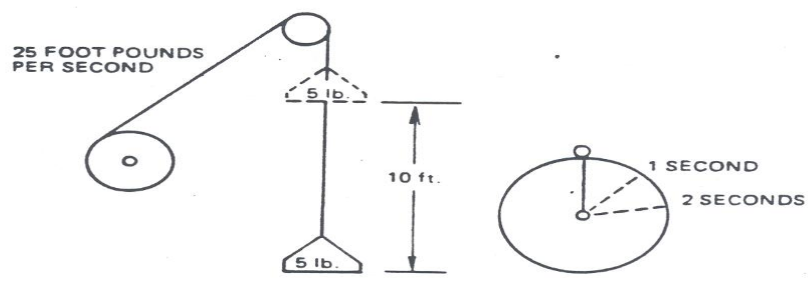


Figure 18

WORK

The work done by the motor or engine is equal to the pounds that were lifted or force that was exerted, times the distance the pounds were lifted, or distance through which the fore was exerted.
(Work = Pounds x Feet)

If we lift 1 pound 1 foot, we do 1 foot-pound of work. If we lift 1 pound 3 feet, we do 3 foot-pounds of work. If we lift 2 pounds 3 feet, we do 6 foot-pounds of work (Figure 19).

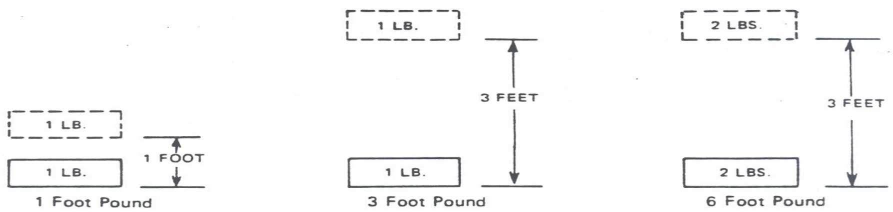


Figure 19

WORK AND POWER

We can also determine the amount of work done by multiplying the power exerted by a motor or engine by the time that it operated
(Work = Power x Seconds). For example, the hoist in Figure 18 raised 5 pounds 10 feet in 2 seconds. It did 50 foot pounds of work in 2 seconds, or 25 foot pounds each second.
(25 foot pounds per second of power) X (2 seconds) = 50 foot pounds of work

HORSEPOWER

Horsepower is a common term used to express power. One horsepower is the power needed to do 550 foot pounds of work in one second or 33, 000 foot pounds of work in one minute. If a hoist has a 100 horsepower motor, it could do (550 x 100) foot-pounds of work in one second, that is, 55,000 foot pounds. It might lift a 550 pound weight 100 feet in one second or a 55,000 pound weight one foot in one second (Figure 20).

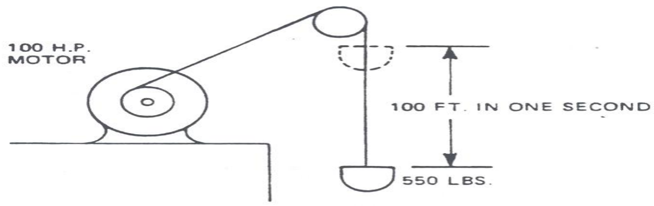


Figure 20

In one minute the 100 HP, motor could hoist a 33,000 pound weight 100 feet.

Suppose your production hoist has, two skips and tail ropes. The hoist will lift 15, 000 pounds of ore at a speed of 2,200 feet per minute. If you ignore friction losses, how many horsepower are needed to run the hoist? The work to be done in one minute is:

15,000 pounds x 2,200 feet = 33,000,000 foot pounds.

To convert the 33,000,000 foot-pounds per minute to horsepower, divide the 33,000,000-foot pounds per minute by 33,000 foot pounds per minute for each horsepower.

$$\text{Power required is} = \frac{33{,}000{,}000}{33{,}000} = 1{,}000 \text{ horsepower}$$

We can find out how much work the motor has done by multiplying the power by the time that the power is used. For example, if the above hoist operates for 10 minutes, it will do (1,000 x 33,000 x 10) or 330,000,000 foot pounds of work.

WATTS, KILOWATTS AND KILOWATT HOURS

Power for electrical machinery is expressed in Watts. One horsepower is equal to 746 watts.

When one volt causes a one-ampere current to flow in an electrical circuit, one watt of power is used. The symbol for Power is P. The power may hoist ore, turn a fan, pump water, light a lamp or provide heat. Since the watt machine operates for one hour, it will do one Kilowatt, that is, 1,000 watts. If a one-watt machine operates for one hour it will do one-watt hour of work, or you can say that it used or expended one-watt hour of energy. If a 10 Kilowatt machine operates for one hour, it does 10 Kilowatt-hours of work.

Electric power used can be calculated by multiplying the voltage times the current flow, that is P = E x I. If 100 volts causes 5 amperes to flow in a circuit, the power used is P = E x I = 100 x 5 = 500 watts. If the voltage and current flow continues for 2 hours, 1,000 watt hours of work (or one Kilowatt hour) are done. The power company bills the consumer on the number of Kilowatt-hours of energy used.

WATT HOUR METER

A Watt Hour Meter is used to measure the power or energy used. The watt-hour meter actually measures the voltage and the amperage and combines the two measurements along with a time factor through a mechanical linkage in the meter. Thus work or energy used = Volts x Amperage x Hours

RESISTANCE AND POWER

We can use the Ohm's Law relationships to develop a similar formula for determining power. For example, we had: P = E x I or 1^2 x R. Thus if we have 5 amperes flowing through a circuit with 40 ohms resistance, the power used in the circuit is:

$$P = 1^2 \times R = 5 \times 5 \times 40 = 1000 \text{ Watts}$$

The power that is used when current flows through the resistance in conductors turns into heat and is usually wasted. This fact creates two problems: one problem is the loss of power in transmission from the power company to the customer; the other problem is the creation of a fire hazard.

TRANSMISSION OR LINE LOSSES

Suppose the mine receives power from the power company. The power company sends 100,000 watts at 1,000 volts and 100 amperes. Assume that the power lines have a resistance of 2 ohms.

In this case, there will be a power transmission loss (line loss) of $I^2 \times R = 100 \times 100 \times 2$, or 20,000 watts. Thus while the power company sent 100,000 watts, we only receive 80,000.

If the power company sent the power at 2,000 volts and 50 amperes, the transmission or line loss would only be:

Power = $I^2 \times R = 50 \times 50 \times 2$, or 5,000 watts, and 95,000 watts would be received instead of 80,000.

Since line losses increase very rapidly as we increase the current, electricity is usually transmitted at very high voltage and low amperage. The problem of a fire hazard is created when there is a poor connection, too small a conductor, or a damaged conductor between the power supply and the load that creates additional resistance. For example, a motor draws 10 amperes at normal load. If there is a bad connection in the conductor to the motor controls or switch boxes, the resistance at that point increases. For each ohm that it increases, 100 watts of power are lost and turn into heat.

$$P = I^2 \times R = 10 \times 10 \ 1 = 100$$

The heat may burn the insulation off the conductor, ignite flammable materials in the vicinity and start a fire.

B. Electricity and Magnetism

The electric motor and motor generator operate as they do because of certain relationships between electricity and magnetism. This section will explain those relationships.

If direct current electricity flows through a coil of wire that is wrapped around a piece of iron ("core") in the direction shown by the arrow, the iron will become a magnet. The magnetic lines of force are indicated. The magnet's North and South Poles will be as indicated by N and S. (Figure 21). This kind of magnet is called an electromagnet since it is created by electricity.

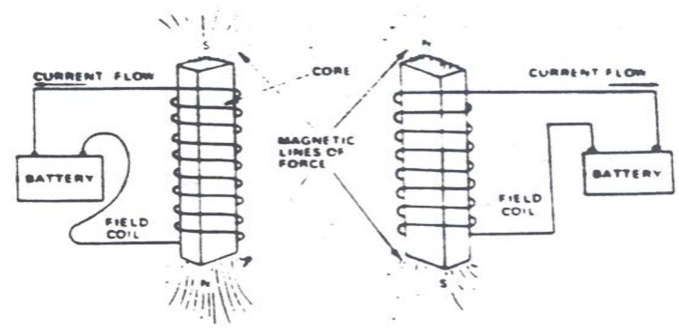


Figure 21

If the number of wire turns or the current flow through the turns is increased, the strength of the magnetic field will be increased (Figure 22).

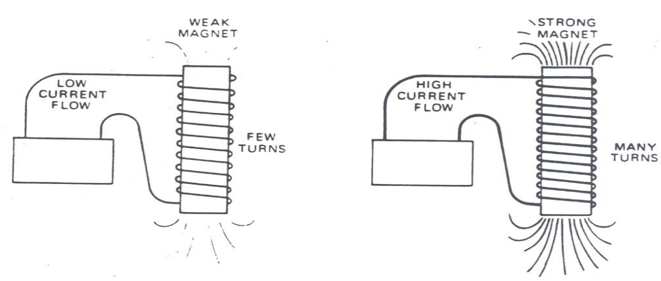


Figure 22

Opposite poles, N and S, attract each other (Figure 23). Like poles, N and N or S and S repel each other (Figure 24).

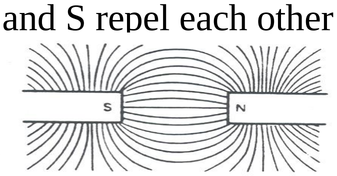


Figure 23

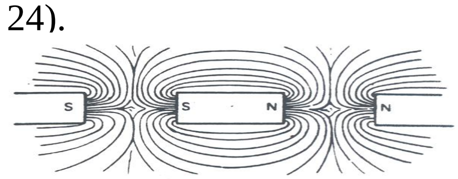


Figure 24

There are electromagnets inside the mine electrical motors. The attracting and repelling forces between the magnets cause the shaft of the electric motor to turn.

In Figure, 25A a wire is passed from left tot right through the magnetic field. A voltage is generated in the wire. If the two ends of the wire are connected, current will flow. In Figure 25B the direction of motion of the wire through the magnetic field is from right to left. The current flow is in the opposite direction from Figure 25A. In Figure 25C the position of the poles of the magnetic field are opposite to those in Figure 25A. Changing the position of the poles changes the direction of current flow. If the strength of the field is increased and/or the speed of the wire passing through the field is increased the voltage generated is increased.

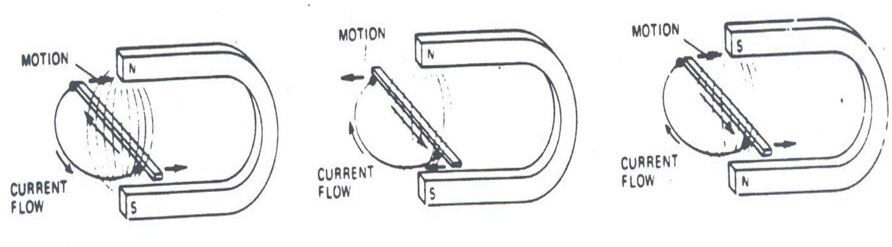


Figure 25A Figure 25B Figure 25C

The voltage in the wire changes as the wire passes through a magnetic field. It is low on entering the field, at a peak in the center of the field, low on leaving the field (Figure 26).

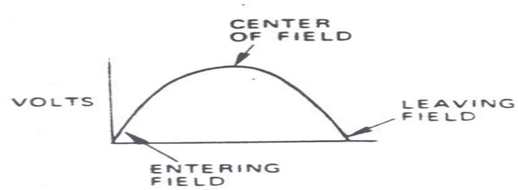


Figure 26

The generator that supplies power to the hoist motor operates on these principles. Control of the hoist motor is also affected by these principles.

There are two kinds of electricity: <u>Direct Current</u> and Alternating Current. With direct current, the voltage causes the current to flow in one direction only. The voltage may vary in the amount but not in the direction.

For alternating current, the voltage causes current to flow first in one direction, then in the opposite direction. The voltage starts at zero, rises to a peak in one direction, drops to zero then to a peak in the opposite direction, and then rises back to zero. (Figure 28).

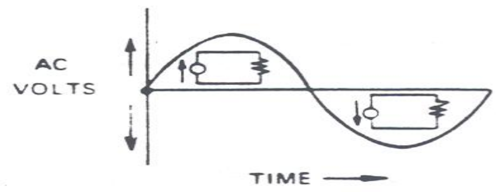


Figure 28

Most commercial electricity is generated and transmitted to the customer as alternating current. Some mine equipment operates on alternating current and some operates on direct current. Where direct current is used, the alternating current must be changed to direct current. A motor generator set (alternating current motor driving a direct current generator) or a rectifier is used for this purpose. (Figure 29)

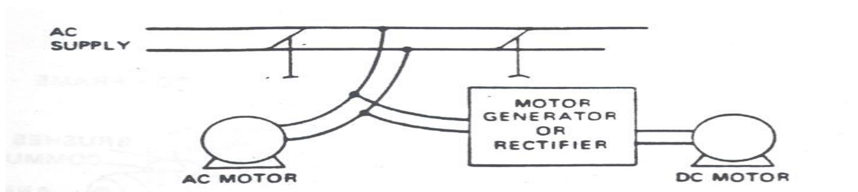


Figure 29

DIRECT CURRENT VS ALTERNATING CURRENT

There are advantages and disadvantages in using both AC and DC current:

Alternating current is more dangerous: 1/10 ampere of alternating current gives a fatal shock: however, it takes five times as much direct current (1/2 ampere) to give the same shock.

The voltage of alternating current can be raised or lowered with very little loss in a simple transformer; changing direct current or direct current voltage requires complex electronic circuits (invertors).

Direct current voltage can b e lowered by passing it through a Rheostat, a resistance whose value can be changed; however, this procedure wastes power.

The speed and power output of direct current motors can be adjusted and varied much more simply and efficiently than the speed and power output of alternating current motors.

C. Electric Motors and Generators

The electric motor changes electrical energy into rotary motion. The generator that supplies power to the hoist changes rotary motion into electricity. A generator may also be called a dynamo. Since there are differences between alternating current and direct current motors and generators, we will describe them separately.

Direct Current Motor has four principal parts (Figure 30).

• the field magnets which are mounted in the motor frame. The field magnets are electromagnets (that is, cores wrapped in coils of wire).

• the armature that is the rotating part of the motor and mounted inside the motor frame. The armature consists of several electromagnets (cores with their coils) mounted on a shaft.

• the commutator, which is a series of segments of a circle, arranged around and attached to the armature shaft. Each segment is connected to one of the armature's electromagnet coils.

• the brushes are attached to the motor frame and touch the commutator. They provide a path for electricity from the power supply through the commutator to the electromagnet coils in the armature. (Figure 31)

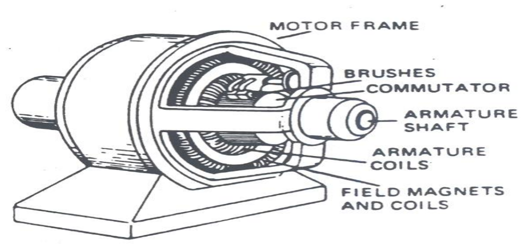


Figure 30

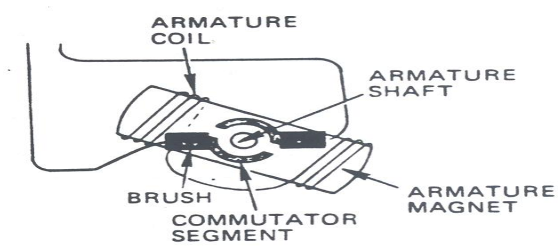


Figure 31

A Direct Current Motor operates on these principles: If we reverse the flow of current through the coil of an electromagnet, the poles of the magnet are reversed. (Opposite poles attract each other and like poles repel each other).

Industrial motors, like this one in Figure 30, have several armature magnets with two commutator segments for each one. They may also have more than one field magnet. In order to explain the operation of a direct current motor we will use a simple motor, which has only these parts, (one field magnet, one armature magnet and two commutator segments).

Note in Figures 32 through 34 that the poles of the field magnet do not change.

In Figure 32 the armature, poles are the same. The nearest field poles, therefore, are being repelled, causing a clockwise rotation of the armature.

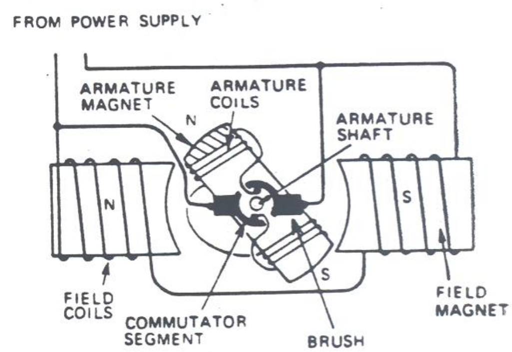


Figure 32

In Figure 33 the armature has continued its clockwise movement and the armature poles are being attracted by the opposite field poles.

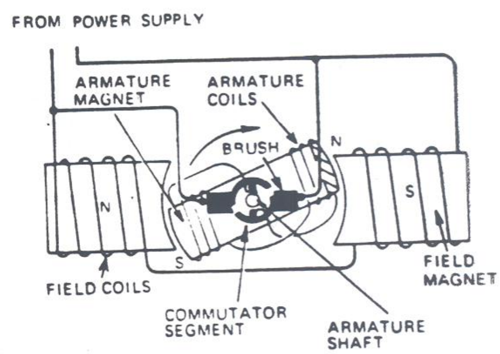


Figure 33

In Figure 34 the armature has passed through the horizontal position and the brushes have switched to opposite segments of the commutator. Current flow in the armature coils is reversed: the armature poles are reversed and are now being repelled by the field poles to continue the clockwise motion. The rotary motion of the armature can be used to turn the electric motor, hydraulic pump and other machinery.

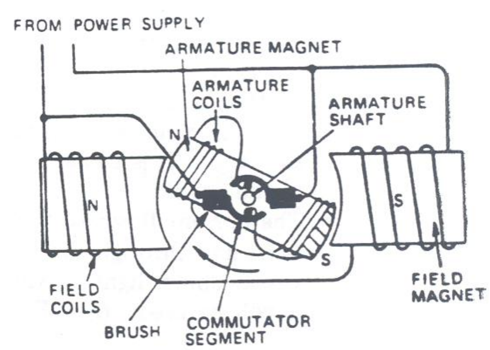


Figure 34

Increasing or decreasing the armature current will increase or decrease the magnetic forces, which turn the armature and therefore, increase or decrease the power output of the motor (Figure 35). A direct current motor is reversed by changing the direction of current flow in either the armature or the field coils.

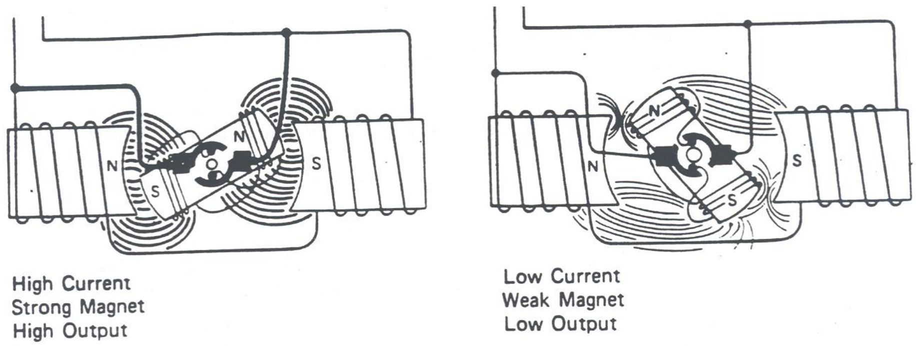


Figure 35

The brushes of a DC motor are made of either carbon or copper. Copper is a better conductor and wears longer. However, it is hard and causes more wear on the motor commutator. Carbon brushes cause little commutator wear; however, they do chip and cause sparking, and they need to be replaced more often. Each brush usually has a wire (Pigtail) attached, which is connected to the power supply.

The position of the brushes is very critical. If the voltage on the brush and the voltage of the commutator segment passing under the brush are nearly equal, sparking will occur. Changing position of the brush will help correct this defect. A worn commutator or broken brush will also cause sparking.

DIRECT CURRENT GENERATOR

A direct current generator has the same parts as a direct current motor. Direct current from an outside source flows through the field coils. A power source, turbine, diesel or gasoline engine, or motor turns the armature. As the armature coils pass through the magnetic fields, a voltage is generated in the coils. This causes current to flow in the coils. The current flows to the commutator and through the brush circuit to the machine, light or appliance where it will be used. (Figure 36)

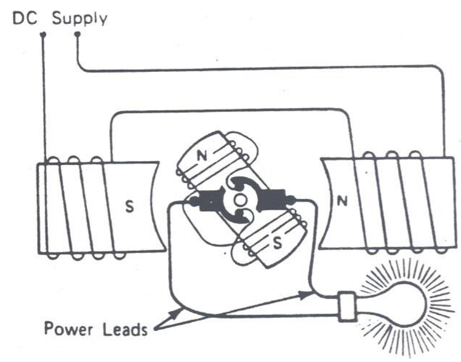


Figure 36

Increasing the strength of the magnetic field and/or increasing the speed of the armature increases the generated voltage. (Figure 37)

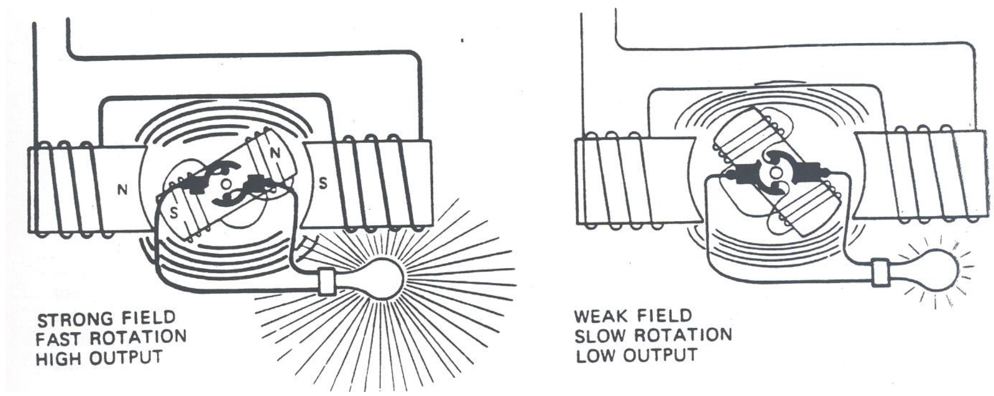


Figure 37

The voltage generated in the coils reverses itself each time that it passes a different pole. This would cause alternating current to flow. (Figure 38)

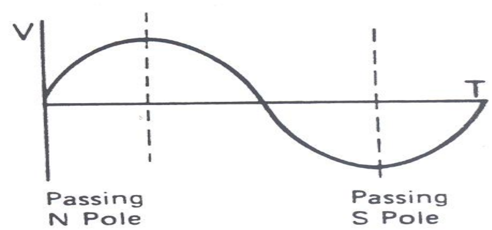


Figure 38

However, the commutator switches the end of the coils from one power lead to another as the voltage reverses itself. The switching keeps the voltage in the power leads going in the same direction. (Figure 39)

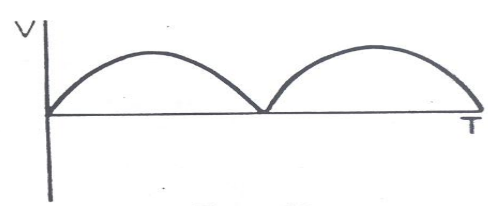


Figure 39

Industrial generators have many armature coils and the current flows into the power leads at peak voltage. The output has little more than a slight ripple. (Se Figure 40)

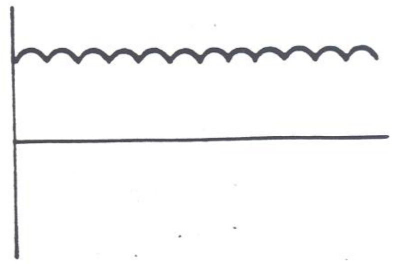


Figure 40

In a direct current generator a magnetic field was created in the field coils and voltage was generated in the armature coils. (See Figure 41)

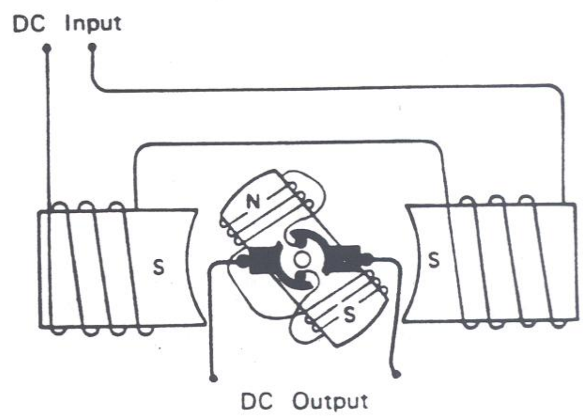


Figure 41

In an alternating current generator the magnetic field is created in the armature. DC current flows into the armature coils through slip rings. As the armature turns voltage is generated in the field coils. (See Figure 42)

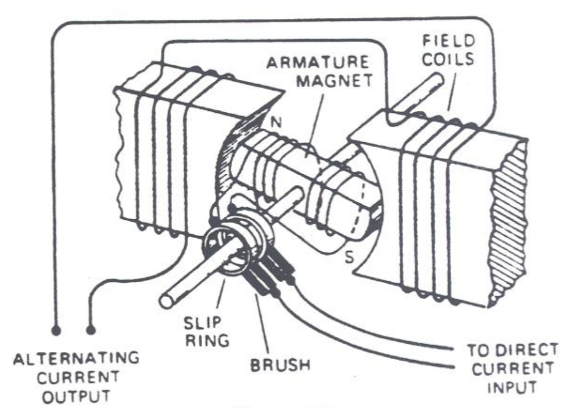


Figure 42

The output of a simple AC generator is shown in Figure 43.

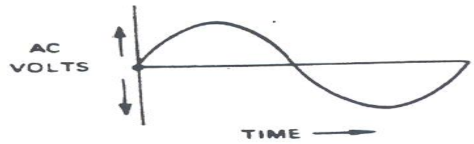


Figure 43

An industrial AC generator has 3 pairs of poles (See Figure 44). Each pair is independent of the other pairs. The output of each pair (Figure 44) is called a phase. The output of each phase is like Figure 43.

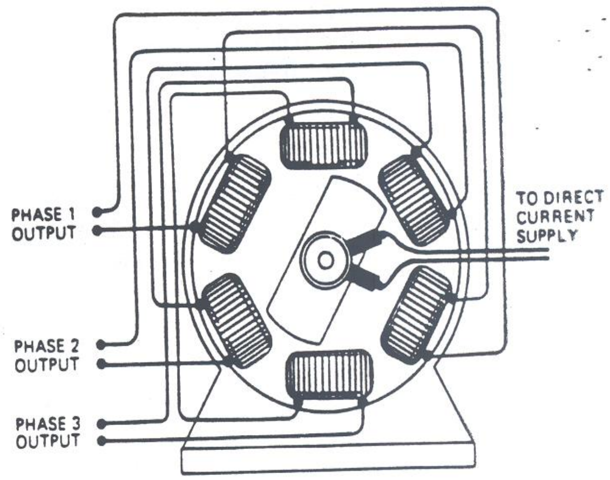


Figure 44

The output of the three phases looks like Figure 45.

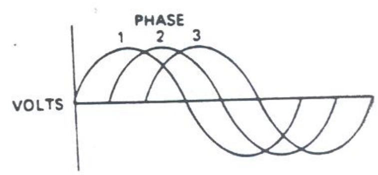


Figure 45

The stronger the magnetic field and the faster the armature rotation, the higher the voltage and current flow. (Figure 46)

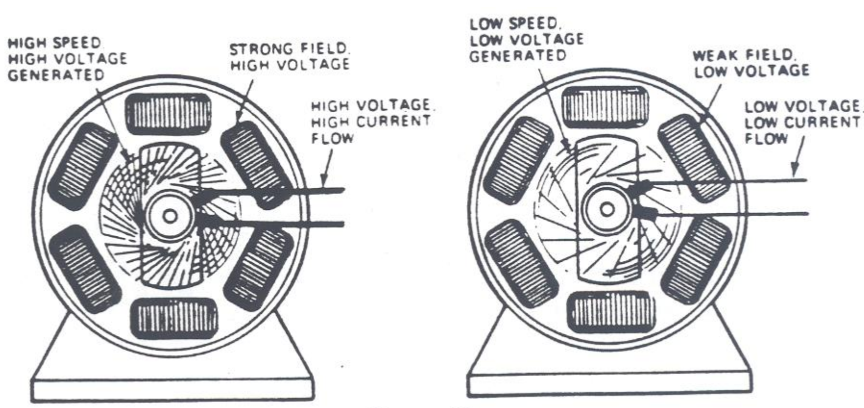


Figure 46

ALTERNATING CURRENT MOTOR

An alternating current motor has a frame and field coils that are just like those of an alternating current generator (See Figure 44).

The coils of a large alternating current motor would be connected to the corresponding coils of the generator.

The voltage in the generator coils will cause current to flow through the motor coils and create magnetic fields. The fields will change poles successively and create a rotating field inside the motor frame. (See Figures 47A through 47D)

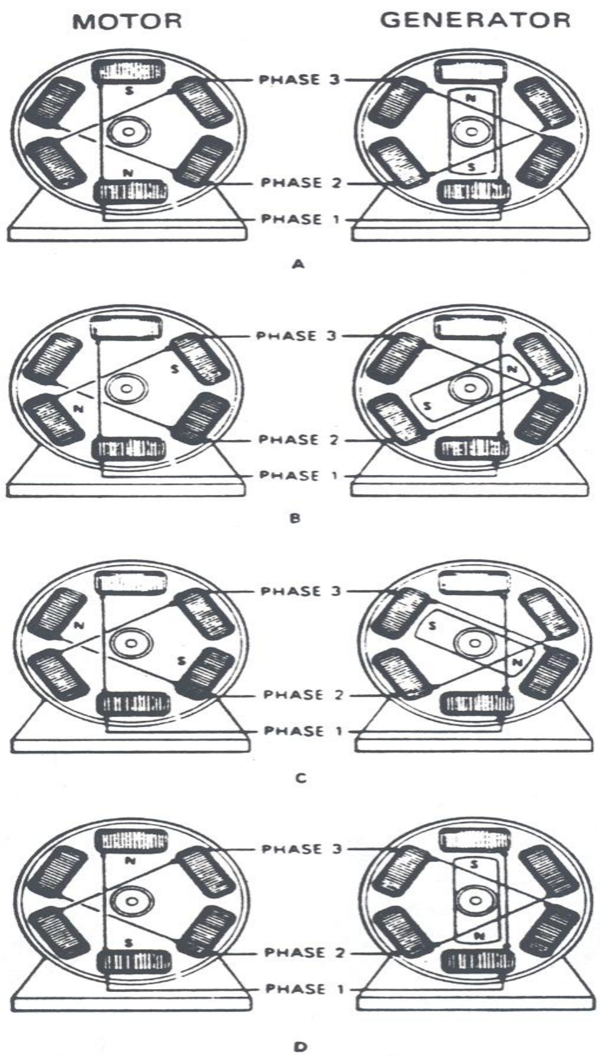


Figure 47

The armature of an alternating current motor is a core with a coil of wire. The ends of the coil are connected together. (See Figure 48)
As the motor field passes over the armature, a voltage is generated (or induced) in the armature coil, and current flows and creates a magnet. The magnet is attracted by the rotating field and rotates with it. The voltage is induced in the armature coil only if the rotating field rotates faster than the armature does. The difference in armature rotation speed and field rotation speed is called Slip. The more slip the more voltage is generated, and the stronger the armature magnet becomes. If the magnet is stronger, the motor rotates faster or with more force.

Slip	Armature Voltage Generated	Armature Current Flow	Armature Magnet Strength	Power Output
High	High	High	High	High
Medium	Medium	Medium	Medium	Medium
Low	Low	Low	Low	Low

MOTOR SPEED CONTROL

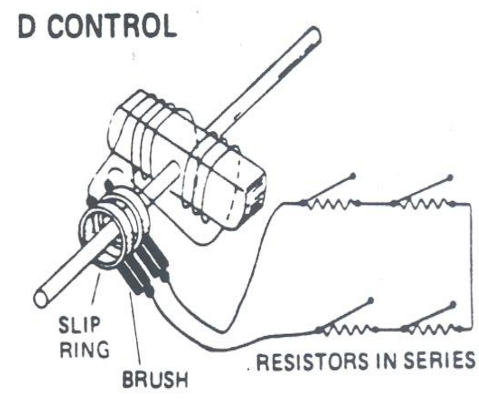


Figure 48

The speed of a electrical motor needs to be controlled. The speed of the alternating current motor, like the direct current motor, depends on armature current. In an AC motor, armature resistances are placed in the armature, coil circuits. The resistances can be bypassed by closing switches. (See Figure 37)

When starting the AC motor, all of the switches a open and the armature circuit has maximum resistance. At this time, slip is at a maximum and the generated voltage is high. The high resistance keeps the armature current low. If the resistance were not in the circuit, the armature current might get too high and damage the motor.

As the armature picks up speed, slip, the voltage and the current flow declines. The switches are closed, one by one, to allow additional current to flow through the armature coils. The armature continues to pick up speed until all of the switches are closed. The motor is then running at its best speed for the amount of work that it is doing.

To slow the armature the switches are opened one by one. This action:
- increases the resistance of the armature circuit.
- reduces the flow of current through the armature coils.
- reduces the strength of the armature magnets.
- causes the armature to slow down.

In an electrical motor, the resistances are normally located in the control panel. The switches are in the motor control box and are opened or closed by turning the motor controller. The switches and resistances are connected to the armature coils through slip rings and brushes.

If we exchange the connections of two phases of the motor with two phases of the generator, the direction of rotation of the magnetic field will be reversed. This is how an AC motor is reversed.

STARTING DIRECT CURRENT MOTORS

When the armature of a DC motor is turning, a voltage is generated in the armature coil as the coil passes through the motor's magnetic field. This voltage opposes the voltage from the power supply. The voltage causing current to flow in the armature coils is equal to the difference between the power supply voltage and that being generated in the armature coils.

When the armature is not turning all of the power supply voltage is causing current to flow. If the power supply voltage is too high, too much current will flow. Therefore, the voltage first applied to the armature should be low. It is increased slowly as the motor picks up speed and begins to generate the opposing voltage.

The motor is at full speed when the power supply voltage is at its maximum.

If the voltage to a running DC motor drops, the armature may slow down and stop. In this condition, there may be enough voltage remaining to force enough current through the armature to burn the armature coils.

The voltage to the armature in a mine hoist motor is increased or decreased by strengthening or weakening the magnetic field of the DC generator, or by changing the output voltage of the rectifier.

Types of Direct Current Motors: A Shunt motor is show in Figure 49. The field coil and armature (through the brushes) are both connected across the power supply. They are in parallel.

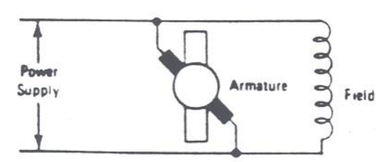


Figure 49

A Series motor is shown in Figure 50. One terminal of the field coil is connected to one terminal of the armature. The two are then connected across the power supply. The armature and field coils are in series.

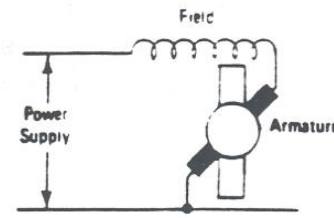


Figure 50

A Compound motor is shown in Figure 51. The motor has two fields, a shunt field and a series field. If the connections of the series field in a compound motor becomes reversed, as the motor starts it will rotate in one direction. As the armature current and the series field current increases, the series field will overpower the shunt field and cause the motor to reverse itself.

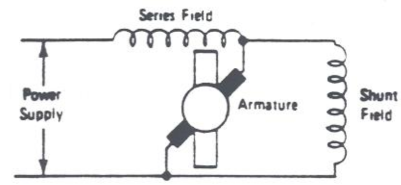


Figure 51

HOIST OPERATION

Figure 52 shows a sample sketch of a mine hoist electrical system with an alternating current motor. It functions as follows:

• Alternating current power comes form the power company to the switch board and through the hoist power switch to the hoist control.

• the hoist control hoes two things:

- It sends power to the alternating current motor fields, and
- It controls the amount of resistance in the circuit that includes the armature coils and the resistor sets.

• when the hoist motor starts there is a high resistance in the armature and resistor circuit. The resistance is lowered as the motor picks up speed.

ALTERNATING CURRENT HOIST MOTOR OPERATION

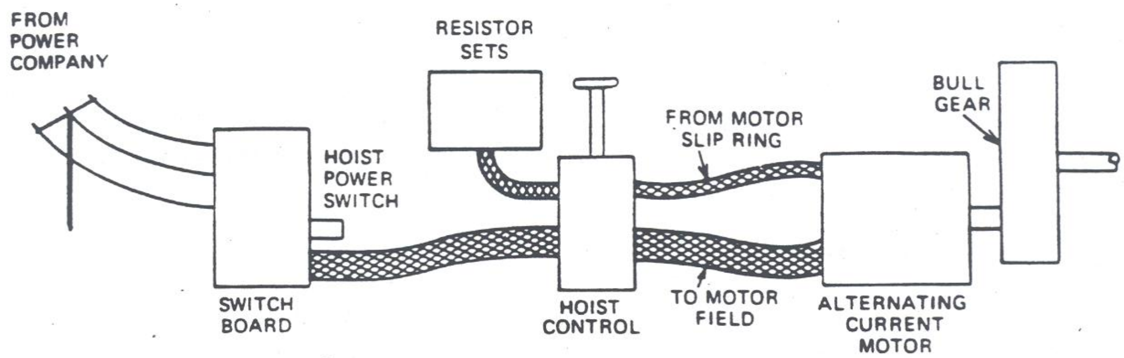


Figure 52

Figure 53 is a simple sketch of a mine hoist electrical system with a direct current hoist motor and a motor generator set. It functions as follows:

• Alternating current power from the power company goes to the switchboard and through the hoist power switch to the alternating current motor of the motor generator set.

• the alternating current motor drives the direct current generator and the exciter generator.

TYPICAL MINE HOIST INSTALLATIONS
DIRECT CURRENT HOISTS FOR MOTOR GENERATOR

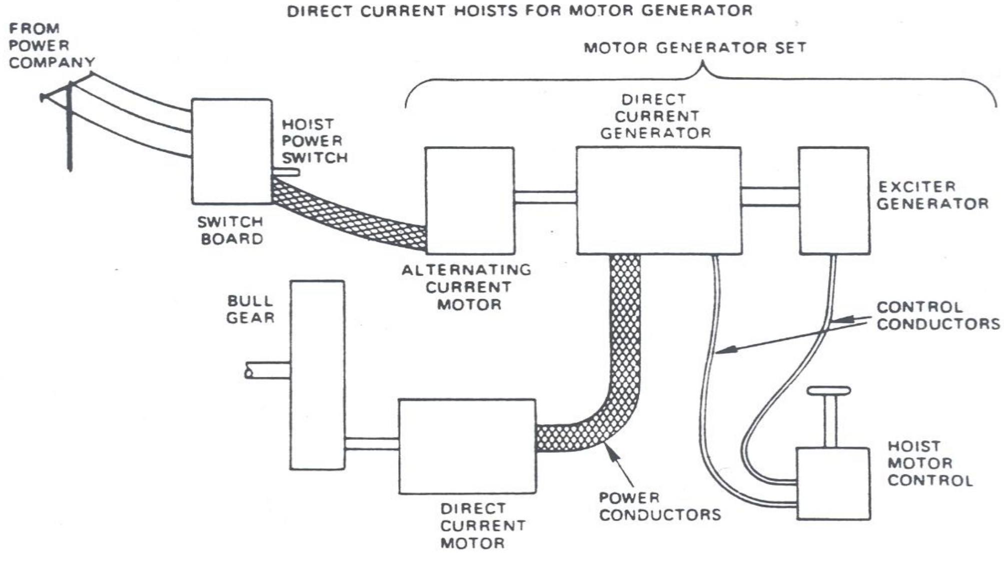


Figure 53

•The exciter generator is a small direct current generator that provides the current for the main generator magnetic fields.
• the output of the exciter generator goes to the hoist motor control then to the direct current generator fields.
• the hoist motor control is a switch that controls the direction and the amount of current that goes to the generator fields.
• the condition of the DC generator fields will determine the direction and amount of current that will be delivered to the hoist motor.
• the output of the main generator drives the hoist motor.

Figure 54 shows a simple sketch of a mine hoist electrical system with a direct current motor and a rectifier power supply. It functions as follows:
• Alternating current power goes through the switchboard to the hoist power switch, then to the rectifier.
• the rectifier changes the alternating current to direct current.
• the hoist motor control causes the rectifier to send current at the required voltage and in the proper direction to the hoist motor.

DIRECT CURRENT HOIST MOTOR RECTIFIER POWER SUPPLY

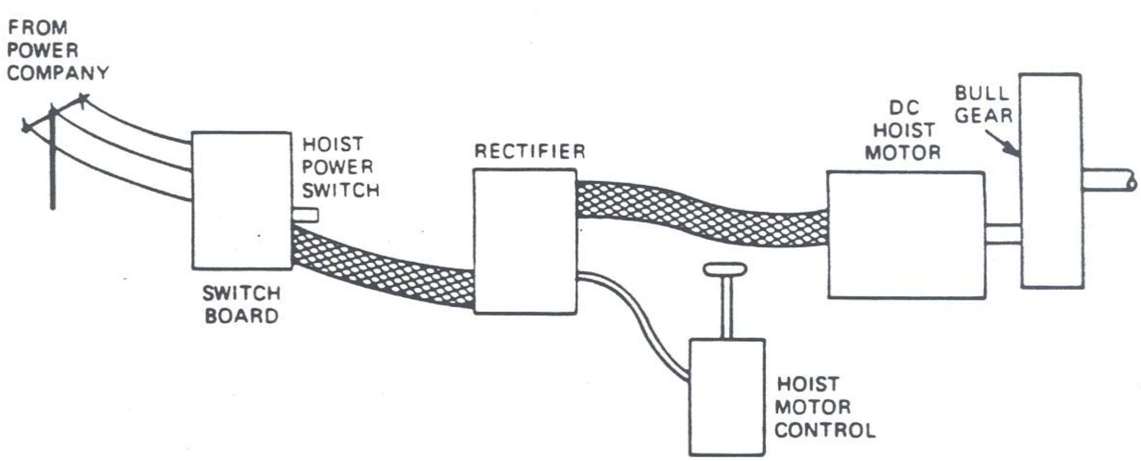


Figure 54

USING THE MOTOR AS A BRAKE

An electric motor may be used as a brake to control the speed of the machine that it drives. This feature may be used in a mine hoist, for example, to slow the conveyance when lowering a heavy load and when approaching the designated landing.

In a direct current motor, the armature voltage is reduced below that of the opposing voltage being generated in the motor armature. The overall voltage then is forcing current to flow out of the motor armature rather than into it. In effect, the motor is now a generator. The energy required to generate the current acts as a brake on the motor armature and causes it to slow. The current that flows back can be sent back to the power company through the motor generator.

In some alternating current motors, the motor is simply reversed. When lowering, for example, the hoist motor control is placed in the hoist position. The rotating field starts to rotate in the opposite direction and will slow the rotation speed of the armature.

In other alternating current motors, a switch is provided to substitute direct current for alternating current in one or two of the phases. Voltage is then generated in the armature coils as they rotate in the newly created magnetic field. The voltage is absorbed in the starting resistances. The energy thus absorbed acts as a brake on the motor armature.

The use of the motor as a brake is sometimes referred to as Dynamic Braking.

D. Transformers

The relationships between electricity and magnetism are used in another electrical machine called a "transformer." The transformer changes the voltage of alternating current. If it raises the voltage, it is a stop-up transformer. If it lowers the voltage, it is a step-down transformer.

You might ask "Why do we want to change the voltage?" We want to change voltage because for some applications high voltage is preferred and for others, low voltage. For example, transmission losses are lower if electric power is transmitted at high voltage and low current (we covered that in a previous section). However, at the point where electricity is used, that is, generated and/or handled, this high voltage is more dangerous than low voltage. Remember that voltage is the pressure causing current to flow. High pressure/voltage may cause current to flow in places where it is not wanted, such as between poorly insulated conductors or from conductors to the machinery frame. High voltage may also cause sparking on motor commutators. It may also be a source of fire or damage to motors, heaters, lights, controls and other equipment. Therefore, it is safer and more economical to have low voltage where the power is generated and used, and to have high voltage where power is transmitted.

Here is what the inside of a transformer looks like. (Figure 55)

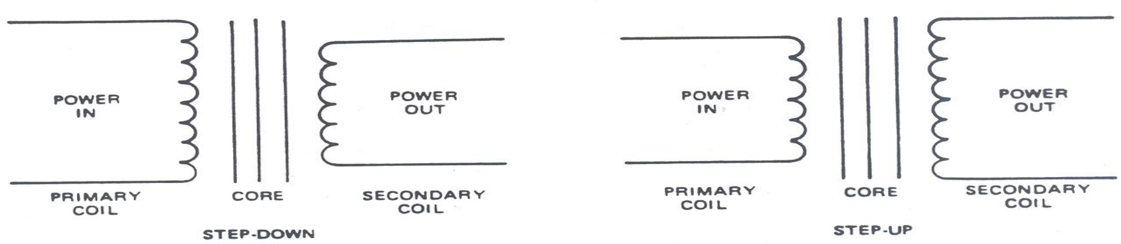


Figure 55

A transformer consists of two coils with a common core. Alternating current flows into the primary coil in one direction and makes a magnet out of the core. The build up of magnetism in the core causes a voltage to be generated in the secondary coil. As the current reverses itself in the primary coil, the magnet is reversed and causes a reverse voltage to be generated in the secondary coil. Thus, the alternating current flowing into the primary coil generates a voltage, which causes current to flow in the secondary coil.

Since power losses in a transformer are very small, for the purpose of this explanation, we will consider them zero, the power flowing into the primary coil (Pp) is equal to the power flowing out of the secondary coil (Ps).

The voltage going into the primary coil (Ep) and the voltage going out of the secondary coil (Es) are proportional to the number of turns of wire in each coil (Np for the primary and Ns for the secondary). Suppose we have a transformer like this one, Figure 56.

Primary

P_P - Power = 1000 Watts
N_P - Turns = 100
E_P - Volts = 100
I_P - Amperes = ?

Secondary

P_S - Power = ?
N_S - Turns = 10
E_S - Volts = ?
I_S - Amperes = ?

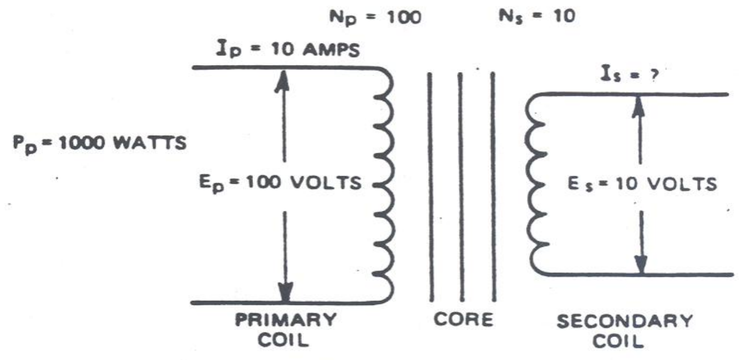


Figure 56

Since we know the power and volts into the primary, and the number of turns in both the primary (Np) and secondary (s), we can solve for the unknown values.

Primary current (Ip): 1000 watts going into the primary at 100 volts;

$P_P = E_P \text{ X } I_P$; $P_P = 1000$; $E_P = 100$

Then; $I_P = \frac{P_P}{E_P} = \frac{1000}{100} = 10$

Secondary Power (P_S): Since there are 1000 watts of power going into the primary P_P , there must be approximately 1000 watts of power from the secondary Ps. ($P_P = P_S$; $P_S = 1000$ watts)

Since there are 100 volts and 100 turns in the primary Ep and Np, and 10 turns in the secondary Ns.

$\frac{E_P}{N_P} = \frac{E_S}{N_S}$ or $\frac{100}{100} = \frac{E_S}{10}$ or $E_S = \frac{100}{100} \text{ X } 10 = 10$ volts.

Secondary current (Is): Since there are 1000 watts of power in the primary (P_P), there are also (for our purpose) 1000 watts in the secondary (P_S).

$P_P = P_S = 1000$ watts.

Also $P_S = E_S \times I_S$ or $1000 = 10 \times I_S$ or

$$I_S - \frac{1000}{10} = 100 \text{ amperes.}$$

In summary then, remember these relationships about transformers

$P_P = P_S$ (approximately)

Therefore: $E_P \times I_P = E_S \times I_S$

$$\frac{E_P}{N_P} = \frac{E_S}{N_S}$$

Use of Laminations

The magnetizing and demagnetizing that occur in transformers, motors and generators cause stray currents, called eddy currents, to flow through the magnet itself. The power that is used by this current flow ($I^2 \times R$) comes from the power supply and is a loss.

In order to reduce these losses to a minimum the cores for electric motor and generators and for transformers are not made of solid iron. Instead, they are made of thin, soft iron plates (laminations), stacked together and insulated from each other, usually by insulating varnish (See Figure 57). The laminated construction reduces the flow of the eddy currents.

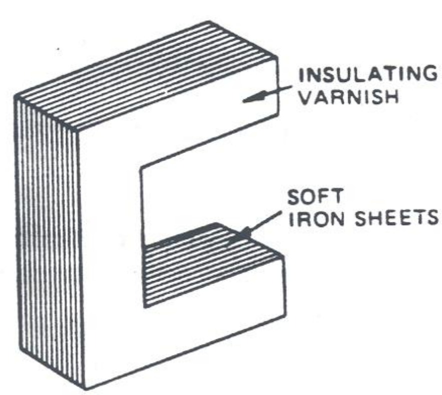


Figure 57

E. Electrical Safety

Electricity can be dangerous if not properly controlled. If electrical machinery is used near flammable materials, vapors, or gases, sparks may be given off and cause a fire. If the current flowing through a conductor is greater than the conductor can carry safely, the conductor may overheat and cause a fire or otherwise damage the machines. If just 1/10 of an ampere passes through your body, the shock could kill you.

State and Federal safety laws and regulations require that steps be taken to prevent such accidents. Electrical machinery that is used in mines and other areas where flammable dust, gas, or vapors may be present must be permissible. This will prevent sparks, such as occur on motor commutators, switches, and at loose connections, from igniting the flammable materials.

Every electrical circuit must use conductors that are large enough to carry the normal current flow of the circuit, plus an acceptable overload without overheating. For most circuits a 25% overload is allowed. They interrupt the current flow if the normal load plus the overload is exceeded.

OVER CURRENT PROTECTION

Electrical equipment and conductors can only carry a limited amount of current without being damaged. Fuses or circuit breakers prevent too much current from flowing through the conductors or through the equipment.

FUSE

A fuse is a piece of metal that is placed in the circuit, in series with the load. When too many amperes flow through the fuse, the heat generated (I X R) cases the metal to melt and breaks the circuit. A new fuse must be installed to restore power.

CIRCUIT BREAKER

A circuit breaker is a magnetic switch that is also placed in the circuit, in series with the load. When too much current flows through the conductors, the magnetic switch opens and stops the flow. The circuit breaker may then be reset that is, the switch closed and the circuit re-energized.

Conductors supplying power to a mine or other facility are protected by circuit breakers of ruses, before they enter the mine. In addition, a very large fuse or circuit breaker (lightning arrester) is installed to break the circuit if lightning strikes the power lines. A ground wire is also provided to lead the lightning to ground.

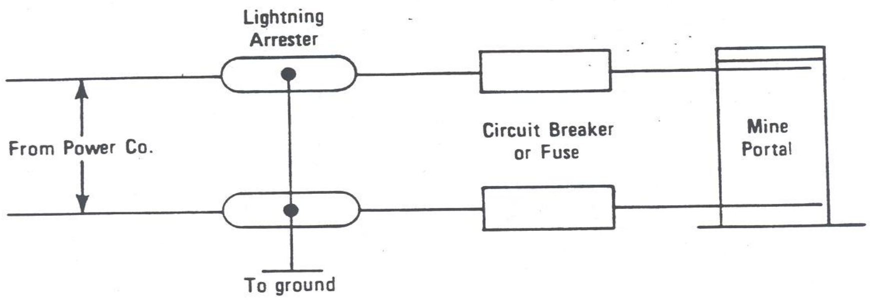


Figure 58

ELECTROLYSIS

When an electric current flows through a mixture of water and dissolved metallic compounds, that is, iron oxide (rust). Corroded metal, clay, etch, chemical changes take place. Oxygen and hydrogen may be generated, and metals with which the current comes in contact may be eroded away and deposited elsewhere. This action can severely damage metal structures that are in contact with the moist material. Good grounding of all equipment can help to keep the voltage difference between the structures to a minimum and reduce the possibility of damage.
(Figure 59)

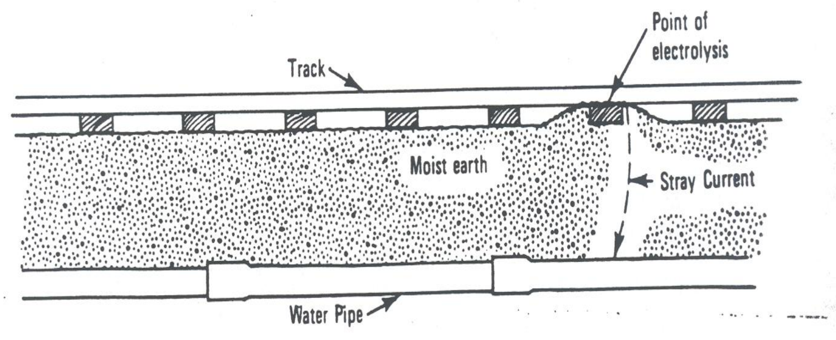


Figure 59

Conductors and other current-carrying parts of the machines shall be insulated or enclosed to prevent persons from touching them. In addition, some areas restrict the maximum voltage permitted on exposed conductors such as trolley wires.

Exposed metal parts of electrical machinery that do not carry current normally, the frames, strands, enclosures, must be connected to the ground. Normally, the conductors and parts of electrical machines through which the current flows are insulated from the frames and other structural parts of the machines. If the insulation is damaged these parts may carry current. If a person touches one of the current carrying parts, his/her body will provide a path for the current to flow to the ground. The person will receive a shock and may be killed. The ground connection provides a path of current to flow to the ground. Thus, if a break occurs in the insulation, current will flow to ground in sufficient quantity to open the overcurrent protection device.

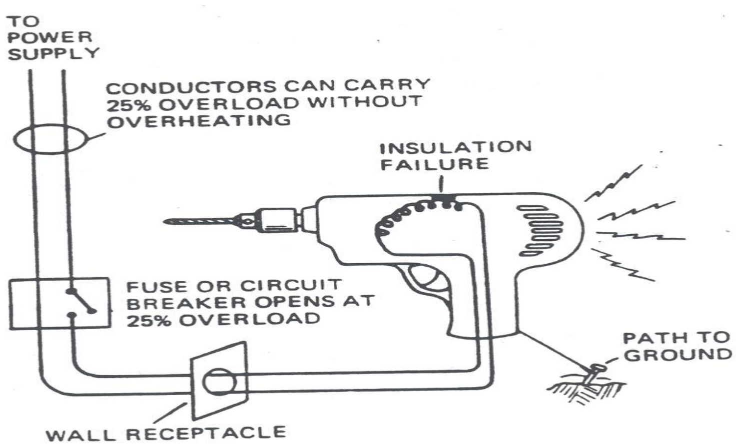


Figure 60

DE-ENERGIZING EQUIPMENT

Prior to having personnel work on electrical equipment, the power shall be cut off from that equipment and measures taken to prevent its being turned back on until the work is completed.

Repairs to circuits and electric equipment.

No electrical work shall be performed on low-voltage, medium-voltage, or high-voltage distribution circuits or equipment, except by a certified person or by a person trained to perform electrical work and to maintain electrical equipment under the direct supervision of a certified person.

All high-voltage circuits shall be grounded before repair work is performed.

Disconnecting devices shall be locked out and suitably tagged by the persons who perform electrical or mechanical work on such circuits or equipment connected to the circuits, except that in cases where locking out is not possible, such devices shall be opened and suitably tagged by such persons.

Locks and tags shall be removed only by the persons who installed them or, if such persons are unavailable, by certified persons authorized by the operator or his agent. However, miners may, where necessary, repair energized trolley wires if they wear insulated shoes and lineman's gloves.

This section does not prohibit certified electrical repairmen from making checks on or troubleshooting energized circuits or the performance of repairs or maintenance on equipment by authorized persons once the power is off and the equipment is blocked against motion, except where motion is necessary to make adjustments.

Always de-energize, disconnect, lockout, tag and ground electrical circuits, prior to performing electrical repairs!

Section II
Maintenance Foreman Study Guide

Chapter 1
Electrical Inspection, Testing, and Examination

BOARD OF COAL MINING EXAMINERS
CERTIFICATION REQUIREMENTS
http://www.dmme.virginia.gov/dm/default.htm

ELECTRICAL MAINTENANCE FOREMAN (SURFACE AND UNDERGROUND)

Article 3 of the **Coal Mine Safety Laws of Virginia** establishes requirements for certification of coal mine workers. The certification requirements are included in §45.1-161.24 through §45.1-161.41 in which the Board of Coal Mining Examiners is established for the purpose of administering the certification program. The Board has promulgated certification regulations 4 VAC 25-20, which set the minimum standards and procedures required for Virginia coal miner examinations and certifications.

CERTIFICATION CLASSIFICATION: ***Electrical Maintenance Foreman (Surface and UG)***
This certification authorizes the holder to:

- Perform electrical work and inspections at all surface areas of underground, surface and underground coal mines
- Make examinations on electrical equipment
- Conduct and record results of electrical examinations

APPLICATION/EXPERIENCE REQUIREMENTS:

- Application (BCME-1) and $40.00 fee 5 working days prior to examination
- Hold a valid Electrical Repairman
- Three years of electrical experience as applied to underground mining or appropriately related work experience approved by the Chief of the Division of Mines
- Current first aid training (MSHA 5000-23 Annual Retraining or New Miner Inexperienced Training acceptable)

EXAMINATION REQUIREMENTS: A score of 80% on each element of the examination.

ELEMENTS OF EXAM	NUMBER OF QUESTIONS
▪ Electrical Maintenance Foreman (MT)	50
Alternating Current	
Direct Current	
Circuits & Equipment	
Cable Splicing	
High Voltage	
Legal Requirements	
Permissibility	
▪ First Aid (FA)	20
▪ National Electrical Code (not implemented)	20
▪ Practical Stations (not implemented	
▪ Records – practical (not implemented)	

- continued on back -

RECOMMENDED REFERENCE/STUDY MATERIALS:

- Electrical Study Guide
- Coal Mine Safety Laws of Virginia
- BCME Requirements
- First Aid For Miners Study Guide
- Title 30 CFR Part 18, 75, 78

The above mentioned study materials are available at the Department of Mines, Minerals and Energy's Big Stone Gap Office, Customer Assistance Center (276) 523-8233 and Keen Mountain Field Office (276) 498-4533.

***8 hours annual Electrical Repairman continuing education will update this certification.**

CHAPTER 1

ELECTRICAL INSPECTION, TESTING, AND EXAMINATION

A. **Virginia Mine Safety Act**

§ 45.1-161.195.A

Electric equipment and wiring shall be inspected by a certified person at least weekly if located underground, and at least monthly if located on the surface, and more often if necessary to assure safe operating conditions, and any hazardous condition found shall be promptly corrected or the equipment or wiring shall be removed from service. Records of such examination shall be maintained at the mine for a period of one year.

§ 45.1-161.206

Diesel Powered Equipment

Diesel powered equipment may be utilized underground with the written approval of the Chief. The Chief shall promulgate regulations necessary to carry out the provisions of this section. The regulations shall require that the air in each travel way in which diesel equipment is used, and in any active workings connected thereto, be of a quality necessary for a safe, healthful working environment. The minimum quantity of ventilating air that must be supplied for a permissible diesel machine in a given time shall conform to that shown on the approval plate attached to the machine. All diesel machines and equipment shall be maintained in such manner that the exhaust emissions meet the same standards to which the machine or equipment was manufactured.

B. CFR REQUIREMENTS

§ 75.153 and75.512

All underground electrical equipment shall be examined and tested at least weekly by a coal mine electrician that has been qualified by a state approved program. Permissible equipment shall be examined to see that it is in permissible condition (75.153 and 75.512).

Circuit breakers and their auxiliary devices protecting underground high voltage circuits shall be tested and examined at least one each month by a qualified person. These tests shall include: breaking continuity of the ground check conductor, actuating at least two of the auxiliary protective relays. Examinations shall include visual observation of all components of the circuit breakers (75.800.3).

Circuit breakers protecting surface high voltage circuits shall be tested and examined at least monthly. The test shall include breaking continuity and actuating any auxiliary protection relay.

§75.900-1 Circuit Breakers; Location

Circuit breakers used to protect low and medium voltage circuits underground shall be located in areas which are accessible for inspection, examination, and testing, have safe roofs, and are clear of any moving equipment used in haulage ways.

§75.900.2 Approved Circuit Schemes

The following circuit schemes will be regarded as providing the necessary protection to the circuit required by Section 75.900:

(a) Ground check relays may be used for undervoltage protection if the relay coils are designed to trip the circuit breaker when line voltage decreases to 40 to 60 percent of the nominal line voltage.

(b) One undervoltage device installed in the main secondary circuit at the source transformer may be used to provide undervoltage protection for each circuit that receives power from that transformer.

(c) One circuit breaker may be used to protect two or more branch circuits if the circuit breaker is adjusted to afford overcurrent protection for the smallest conductor.

(d) Circuit breakers with shunt trip, series trip or undervoltage release devices may be used if the tripping elements of such devices are selected or adjusted in accordance with the settings listed in the table of the National Electric Code, 1968.

§75.900-3 Testing, Examination, and Maintenance of Circuit Breakers; Procedures

Circuit breakers protecting low and medium voltage alternating current circuits serving three-phase alternating current equipment and their auxiliary devices shall be tested and examined at least once each month by a person qualified as provided in Section 75.153. In performing such tests, actuating any of the circuit breaker auxiliaries or control circuits in any manner, which causes the circuit breaker to open, shall be considered a proper test. All components of the circuit breaker and its auxiliary devices shall be visually examined and such repairs or adjustments as are indicated by such tests and examinations shall be carried out immediately.

§75.900-4 Testing, Examination, and Maintenance of Circuit Breakers; Record

The operator of any coal mine shall maintain a written record of each test, examination, repair, or adjustment of all circuit breakers protecting low and medium-voltage circuits serving three-phase alternating current equipment used in the mine. Such record shall be kept in a book approved by the Secretary.

§75.903 Disconnecting Devices

Disconnecting devices shall be installed in conjunction with the circuit breaker to provide visual evidence that the power is disconnected.

§75.904 Identification of Circuit Breakers

Circuit breakers shall be marked for identification.

Chapter 2
Electrical Theory Review

CHAPTER 2

ELECTRICAL THEORY REVIEW

The repairman's study guide material includes Ohm's Law, basic electricity and basic formulas for the Maintenance Foreman's review. The Maintenance Foreman should have knowledge of basic and advanced electrical circuits.

A. SERIES CIRCUITS

$R_T = R_1 + R_2 + R_3 + R_4$ = ohms

$E_T = E_1 + E_2 + E_3 + E_4$ = volts

$I_T = I_1 = I_2 = I_3 = I_4$ = Amps

$P = E_T \times I_T$ = watts

Power = 1000 watts = 1 kilowatt

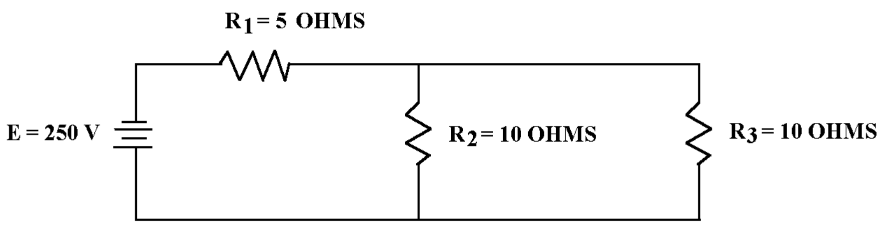
B. PARALLEL CIRCUITS

$$R_T = \frac{R_1 \times R_2}{R_1 + R_2}$$

$E_T = E_1 = E_2 = E_3$

$$I_T = \frac{E_T}{R_T}$$

C. SERIES/PARALLEL CIRCUIT



Step 1 Resistor 2 and 3 are in parallel

$$R_{2\text{ and }3} = \frac{R_2 \times R_3}{R_2 + R_3} = \frac{10 \times 10}{10 + 10} = \frac{100}{20} = 5 \text{ ohms}$$

Step 2 Resistor 1 is in Series with $R_{2\ \&\ 3}$

$$R_T = R_1 + R_{23} = 5 + 5 = 10 \text{ ohms}$$

Step 3 $I_T = \frac{E_T}{R_T} = \frac{250}{10} = 25$ amps

Step 4 $P = E_T \times I_T = 250 \times 25 = 6{,}250$ watts

Power = 6,250 watts = 6.250 kilowatts

Step 5 $E_1 = I_T \times R_1 = 25 \times 5 + 125$ volts

$E_{2\text{ and }3} = E_T - E_1 = 250 - 125 = 125$ volts

Step 6 $I_2 = \frac{E_2}{R_2} = \frac{125}{10} = 12.5$ amps

$P_2 = E_2 \times I_2 = 125 \times 12.5 = 1562.5$ watts

Power = 1562.5 watts = 1.5625 kilowatts

Chapter 3
Power Sources: Batteries, Rectifiers and Transformers

CHAPTER 3

POWER SOURCES: BATTERIES, RECTIFIERS, AND TRANSFORMERS

Three common types of power sources used in mining are batteries, rectifiers and transformers. The Maintenance Foreman should have knowledge of the mine power distribution system including the state and federal requirements for protection.

A. MINE SAFETY ACT REQUIREMENTS

§ 45.1-161.183 Underground Transformers

All transformers used underground shall be air-cooled or filled with nonflammable liquid or inert gas.

§ 45.1-161.184 Stations and Substations

A. Suitable danger signs shall be posted conspicuously at all transformer stations.
B. All transformer stations, substations, battery-charging stations, pump stations, and compressor stations shall be kept free of nonessential combustible materials and refuse.
C. Reverse-current protection shall be provided at storage-battery- charging stations to prevent the storage batteries from energizing the power circuits in the event of power failure.

§ 45.1-161.205 Storage and Use of Flammable Fluids and Materials

A. Underground storage places for oil, grease and flammable hydraulic fluid shall be of fireproof construction.
B. Oil, grease and flammable hydraulic fluid kept underground for current use shall be in closed metal containers.
C. Provisions shall be made to prevent accumulation of spilled oil or grease at the storage places or at the locations where such materials are used.
D. Oily rags, oily waste, and wastepaper shall be kept in closed metal containers until removed for disposal.
E. No gasoline, benzene, kerosene or other flammable oils shall be used underground in powering machinery.

F. All oxygen and acetylene bottles used underground shall be secured while in use. When stored underground, oxygen and acetylene bottles shall be placed in a safe location, protected from physical damage, with caps in place where provided for on the tank, and secured upright or elevated, whichever mine heights allow.

§ 45.1-161.221 Coursing of Air

C. Underground transformer stations, battery-charging stations, substations, rectifiers, and water pumps shall be housed in noncombustible structures or areas, or be equipped with an approved fire suppression system. These installations shall be ventilated with intake air that is coursed into a return air course or to the surface, and that is not used to ventilate working places. This requirement does not apply to: (i) rectifiers, power centers with transformers that are either dry-type or contain nonflammable liquid, or battery-charging stations, if they are located at or near the working section and are moved as the working section advances or retreats, (ii) submersible pumps, (iii) permissible pumps and associated permissible switch gear, (iv) pumps located at or near the working section that are moved as the working section advances or retreats, and (v) small portable pumps. Such equipment shall be installed and operated only in well ventilated locations.

B. RECTIFIERS

HALF-WAVE RECTIFIER

$E_{out} = E_{in} \times .5$

FULL-WAVE RECTIFIER

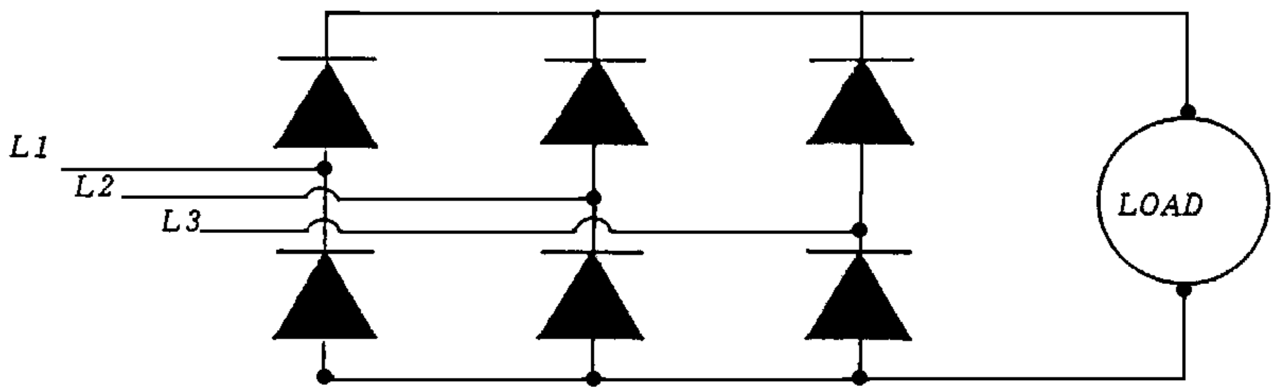
$E_{out} = E_{in} \times .9$

THREE-PHASE RECTIFIER

$E_{out} = E_{in} \times 1.35$

$E_{out} = 250 \text{ Volts} \times 1.35 = 337.5 \text{ Volts DC}$

Example: Three-phase rectifier has an input voltage of 250 volts phase to phase. What is the output voltage?



$E_{LL} = 250$ Volts AC
Volts $DC_{out} = 337.5$

Figure: Three-Phase Rectifier

C. SINGLE PHASE TRANSFORMERS

Single-phase transformers are used throughout the mine electrical system. Most single-phase transformers windings are marked (H_1, H_2) for the high side and (X_1, X_2) for the low side. The transformer primary windings and secondary windings are insulated from each other with a class H insulating varnish. Therefore, the resistance between the primary and secondary windings is infinity. The primary winding is a continuous coil of wire. Therefore, the resistance between terminal H_1 and H_2 is near zero. The secondary terminals will also read near zero resistance. The voltage and current is transformed from the primary to the secondary of a step down transformer by using the number of turns on the primary to the number of turns on the secondary.

$$E_{primary} = E_{secondary} \text{ x turns ratio}$$

$$E_{secondary} = \frac{E_{primary}}{\text{Turns ratio}}$$

$$I_{primary} = \frac{I_{secondary}}{\text{Turns ratio}}$$

$$I_{secondary} = I_{primary} \text{ x turns ratio}$$

D. THREE PHASE TRANSFORMERS

Three single-phase transformers can be connected in various configurations to supply the mine with the required voltage current and power.

Characteristics of a delta-connected transformer are:

$$\text{Voltage}_{\text{Line to Line}} = \text{Voltage}_{\text{Phase}}$$

$$E_{\text{Line to Line}} = E_{\text{Phase}}$$

$$I_{\text{Line}} = \sqrt{3} \text{ X } I_{\text{Phase}}$$

$$I_{\text{Line}} = 1.73 \text{ X } I_{\text{Phase}}$$

Characteristics of a wye-connected transformer are:

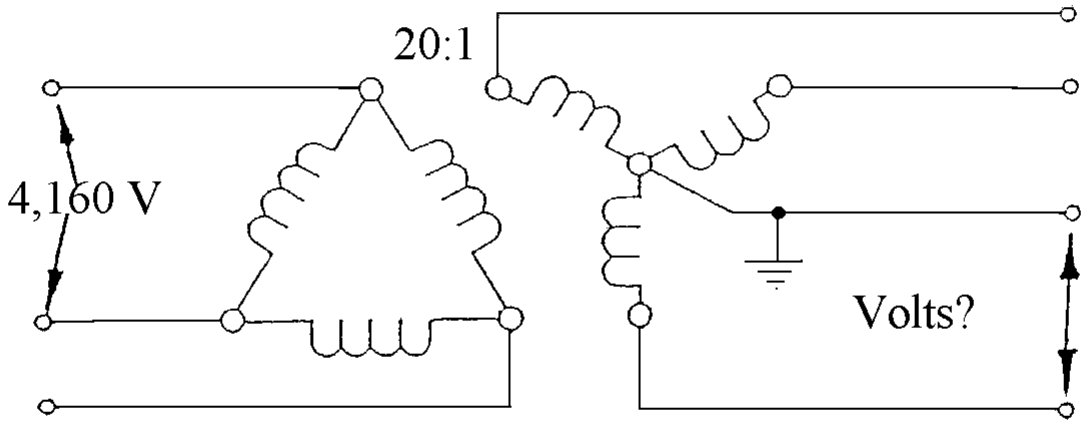
$E_{\text{Line to Line}} = E_{\text{Phase}} \times 1.73$

$I_{\text{Line}} = I_{\text{Phase}}$

Delta to Wye

Deltas to wye-connected transformers are common in mine power systems because of the load advantages of the delta connection of the primary, which is the load for the incoming power. The neutral of the wye-connected secondary provides a grounding point for the outgoing system from the transformer.

An example of how to calculate secondary voltage and secondary current of a three-phase Delta to wye connected transformer is as follows: Ratio = 20 to 1.



Primary: $E_{LL} = 4160 = E_{\text{Phase}}\ 4160$

Primary Line Current = 20 amps

$E_{\text{Phase Secondary}} = \dfrac{E_{\text{Phase Primary}}}{\text{ratio}}$

$E_{\text{Phase Secondary}} = \dfrac{4160}{20} = 208$ volts

$E_{LL\ \text{secondary}} = \sqrt{3} \times E_{\text{Phase}} = 1.73 \times (208) = 360$ volts

$I_{L\ \text{Primary}} = 20$ amps

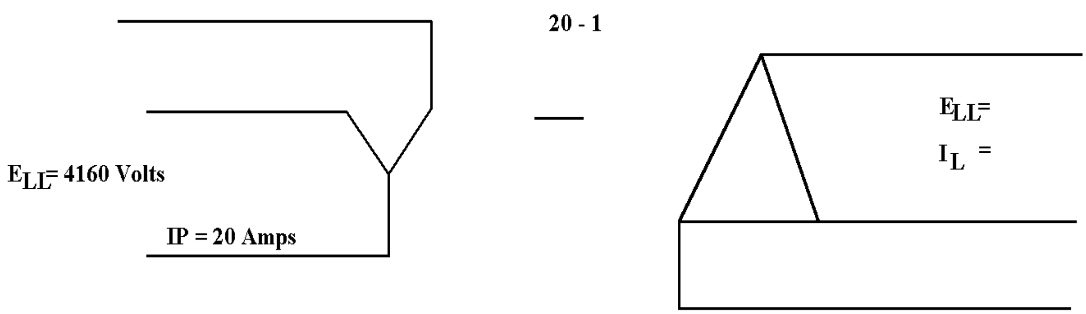
$I_{P\ \text{(phase primary)}} = \dfrac{I_{L\ \text{primary}}}{\sqrt{3}} = \dfrac{20}{1.73} = 11.56$ amps

$I_{P\ secondary} = I_{P\ primary}$ X ratio = 11.56 X (20) = 231.21 amps
$I_{P\ secondary} = I_{L\ secondary}$ = 231.21 amps

Wye to Delta

Wyes to Delta connected transformers are also used in the mining industry. The Delta connected secondary does not have a neutral for grounding purposes, but that problem is corrected by installing a zigzag-grounding transformer.

An example of how to calculate secondary voltage and secondary current of a three-phase wye to delta-connected transformer is as follows:
Ratio 20 to 1.



Primary: $E_{phase} = \frac{E_{LL}}{\sqrt{3}} = \frac{4160}{1.73} = 2400$ volts

Secondary: $E_{phase\ secondary} = \frac{E_{phase}}{Ratio} = \frac{2400}{20} = 120$ volts

$E_{phase\ secondary} = E_{LL\ secondary}$ = 120 volts

Primary: $I_L = I_{phase}$ = 20 amps

Secondary: $I_{phase\ secondary} = I_{phase\ primary}$ x Ratio = 20 X 20 = 400 amps

$I_L = \sqrt{3} \times I_{phase\ secondary}$ = 1.73 X (400) = 692 Amps

Chapter 4
Grounding and Ground Monitoring

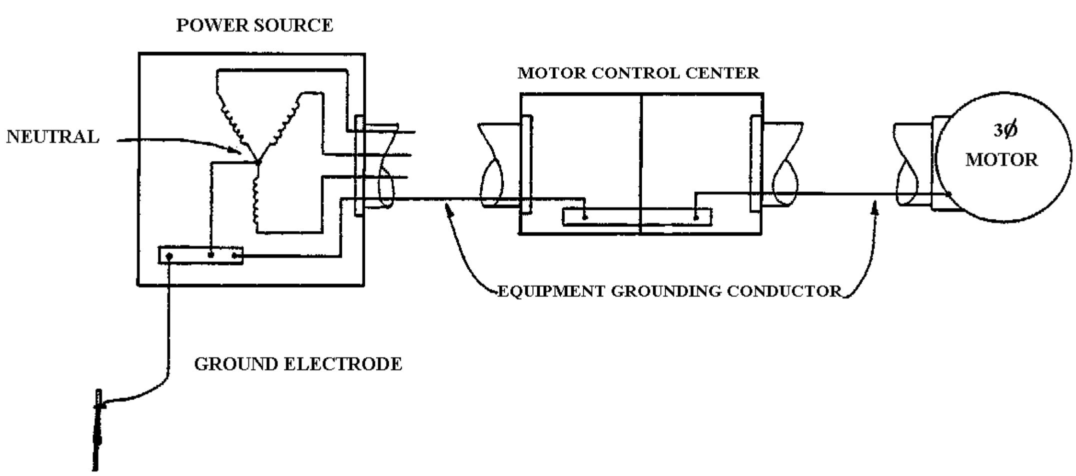
CHAPTER 4

GROUNDING AND GROUND MONITORING

A. SYSTEM GROUNDING

System grounding is accomplished when one conductor of the circuit, such as the neutral, is intentionally connected to earth. The system ground can cause the circuit breaker to automatically open the circuit if an accidental or ground fault occurs at one of its ungrounded conductors. This is different from the equipment ground in that an equipment ground must have at least two faults, each on a different phase, to cause a circuit breaker or fuse to open the circuit.

The figure shows a system with an equipment-grounding conductor connected at the neutral point of the wye-connected transformer. This circuit has the transformer load connected phase-to-phase. The equipment-grounding conductor extends from the neutral point of the wye transformer to the frame of the motor (load). Notice that this system has only four conductors.



Wye-Connected Neutral Ground

Mining Application

Most underground mining equipment uses trailing cable to furnish electrical power to its electrical motors. Trailing cables are difficult to maintain, especially with the abuse that is given to them in today's mines. It is important, then, that the motors and frames of electrically driven equipment be maintained at ground potential (0 volts) at all times.

Mining machines are grounded to avoid unnecessary and dangerous differences of potential between the mining machine and other machines or to earth. This statement is more clearly illustrated by looking at a few low voltage secondary circuits, typical of the conditions that might be found in the average mine.

The circuit in this figure illustrates a three-phase wye connection for a mining machine. The voltage between any phase and ground is 277 volts.

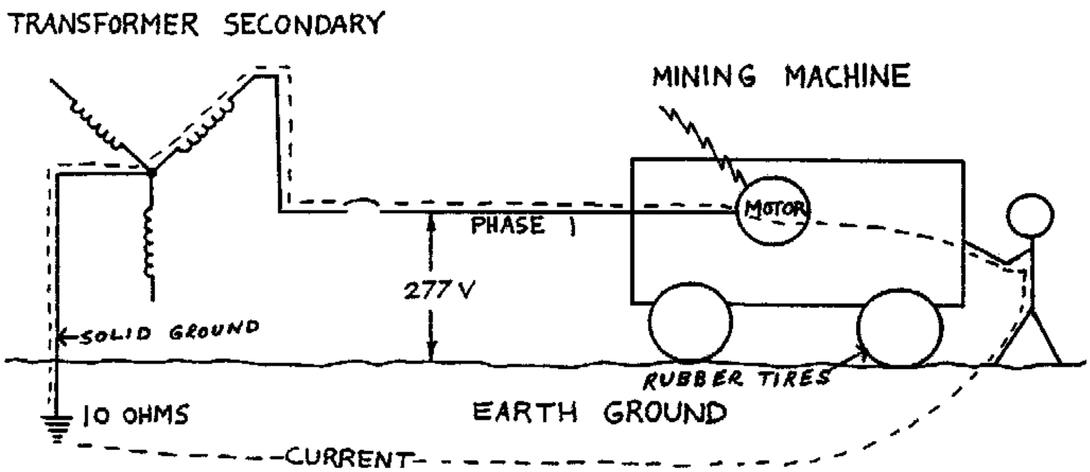


Figure: Wye-Connected transformer (No Ground Wire)

Assume that Phase I becomes grounded to the motor frame inside the mining machine, thereby energizing the mining machine. The machine is now at the same potential as Phase I (277 volts to ground).

With no frame, ground conductor on the machine there would be no fault current, and the machine would remain at 277 volts to ground indefinitely. When someone standing on the earth touches the frame of the machine, the current passes through his body, through the earth, back to the source through the ground electrode conductor and back through the circuit again.

The current will continue indefinitely because there is not enough fault current to cause the circuit breaker to interrupt. The individual exposed to this machine would experience a shock--perhaps fatal.

This figure shows a circuit grounded at the neutral of the transformer and the mining machine with a frame ground.

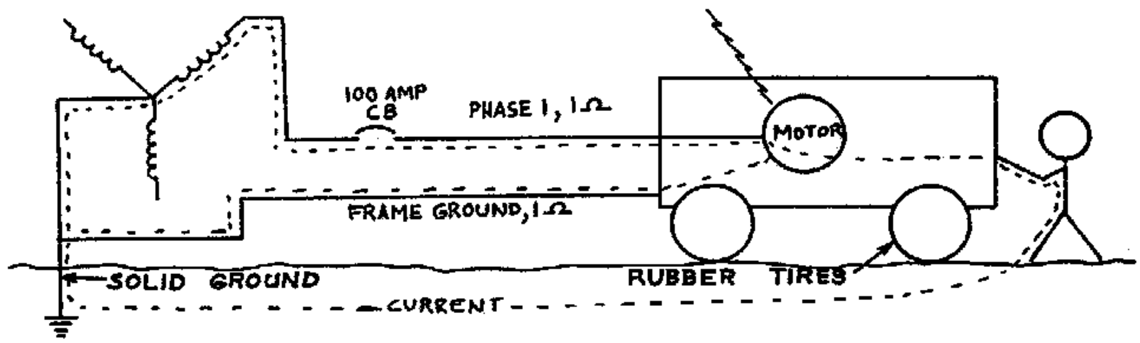


Figure: Wye Connected Transformer (No Grounding Resistor)

What happens to the circuit when a frame ground conductor is added to the circuit? Whenever a fault develops between Phase I and the motor frame, there is a fault circuit through the frame ground conductor and back to the source. A voltage of 277 volts begins to force current through the phase wire and back through the frame ground wire. The resistance of the phase conductor is 1 ohm, and the resistance of the frame ground conductor is 1 ohm. Total resistance is 2 ohms. The current that flows is:

$$I = \frac{E}{R} = \frac{277}{2} = 138.5 \text{ amperes}$$

The current, 138.5 amperes is enough to trip the circuit breaker--if set properly.

What would happen if the circuit breaker were bridged out? The fault current could not trip the circuit breaker. The voltage across the frame ground conductor is:

$$E = I \times R$$
$$E = 138.5 \text{ amperes} \times 1 \text{ ohm}$$
$$E = 138.5 \text{ volts}$$

This is an unsafe voltage. Anyone touching the machine frame may be electrocuted.

This figure represents the following three conditions:

1. Circuit grounded at machine
2. Mining machine with frame ground
3. Neutral grounding resistor

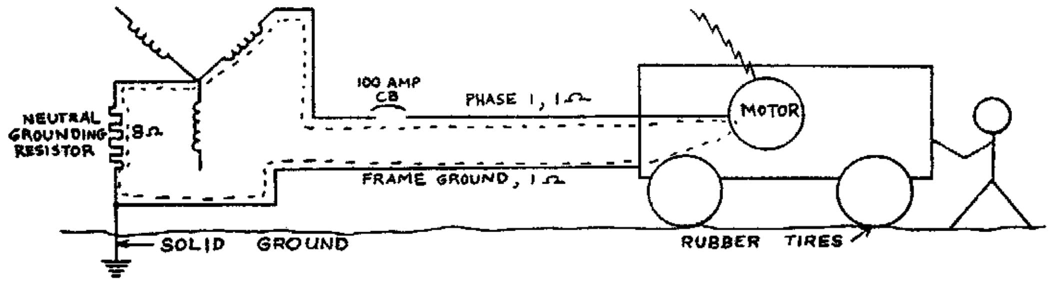


Figure: Mining Machine with Phase to Frame Fault and Neutral Grounding Resistor in Circuit

The circuit above has an 8-ohm neutral grounding resistor added to the circuit. When an electrical fault occurs at the motor, the fault current travels through Phase I conductor, machine frame, frame ground conductor, neutral grounding resistor, transformer winding and back through the circuit again. The fault current is:

$$I_{fault} = \frac{E}{R} = \frac{277}{10} = 27.7 \text{ amperes}$$

The addition of an 8-ohm neutral grounding resistor changes the value of the voltage, which can exist on the machine frame. The voltage on the frame of the machine is:

E = I x R
E = (27.7 amperes) (1 ohm)
E = 27.7 volts

Most of the supply voltage is dropped across the 8-ohm neutral grounding resistor. The voltage dropped across the resistor is:

E = I x R
E = (27.7 amperes) (8 ohms)
E = 221.6 volts

B. Neutral Ground

A neutral ground is connected between the earth and the neutral point of a wye-connected transformer or to the neutral point of a grounding transformer. The neutral grounding resistor is located inside a power center. This protects the individual from a shock or burn hazard.

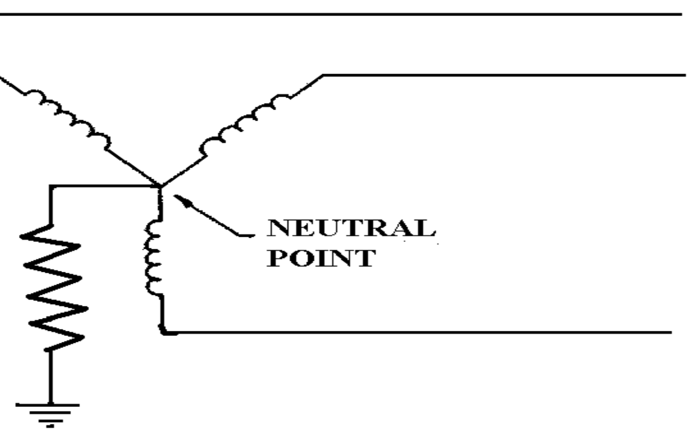


Figure: Neutral Ground with Neutral Grounding Resistor
(CFR 30) 75.802(a)

High-voltage circuits extending underground and supplying portable, mobile, or stationary high-voltage equipment shall contain either a direct or derived neutral which shall be grounded through a suitable resistor at the source transformers, and a grounding circuit, originating at the grounding site of the grounding resistor, shall extend along with the power conductor and serve as a grounding conductor for the frames of all high-voltage equipment supplied power from the circuit.

C. Ground Monitor Circuits

Occasionally, phase to ground faults occur on underground electrical equipment. Protection of persons exposed to this equipment depends on a continuous ground wire from the power source to the equipment frame. If the ground wire is broken when a ground fault occurs, a person would be exposed to line-to-neutral voltage. For this reason, the condition of the ground wire is monitored continuously.

One method to monitor the ground wire is to connect an insulated wire in the cable with
the ground wire to form a circuit as shown in the picture below.

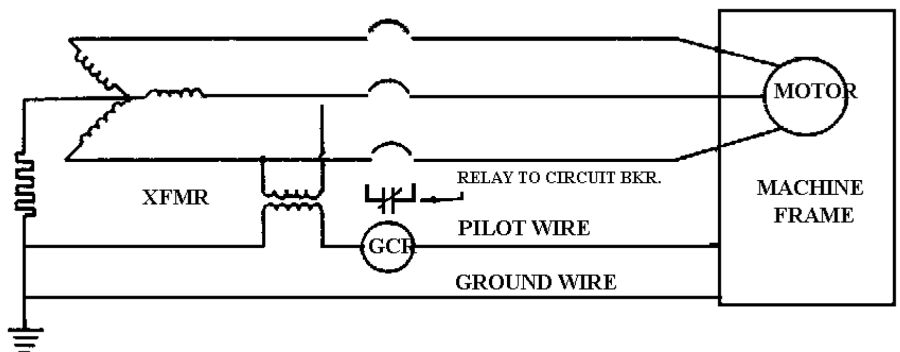


Figure: Ground Check Circuit

The monitor circuit consists of:

A. Ground wire
B. Pilot wire
C. Ground check relay coil
D. Transformer (supplies power to monitor circuit)

The voltage generated by the transformer causes current to flow through the ground wire, pilot wire, and the ground monitor relay coil. During normal operation, the relay coil keeps the relay contacts closed. The relay contacts are connected to an undervoltage release inside the main circuit breaker. Normally open contacts may be used for shunt trip type circuit breakers. The shunt trip contacts are normally in parallel with the undervoltage release and when the shunt trip coil is energized the contracts short out the undervoltage release coil, thus opening up the circuit breaker.

What happens when the ground wire or pilot wire is broken? If either of these wires is broken, the ground check relay will be deenergized. The deenergized relay contacts open, thus causing the undervoltage release to trip the main circuit breaker. This deenergizes the voltage to the machine and removes the shock hazard.

Another method to monitor the ground wire is illustrated below.

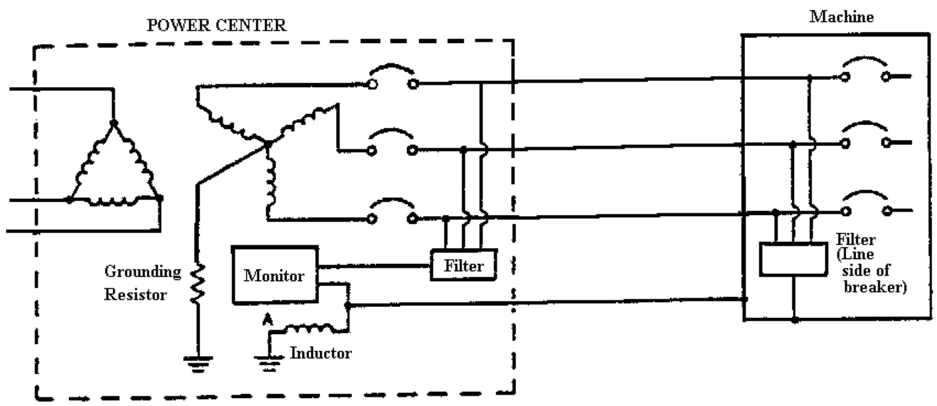


Figure: Continuity-Type Monitor with Inductor-Type Suppressor

The monitor circuit consists of:

A. Ground wire
B. Monitor
C. Filters
D. Parallel path suppression device

A signal generated by the monitor is passed through a filter, which is connected, to each phase for the load side of the circuit breaker. The signal is transmitted on the phase conductors to the machine where it passes through another filter and returns to the monitor on the ground wire. If the signal path is interrupted (open ground wire) relay contacts in the monitor, which are connected to the circuit breaker trip unit, causes the circuit to be deenergized.

Due to the possibility of the signal returning to the monitor through the earth or means other than the ground wire, a parallel path suppression device is often installed in the power center.

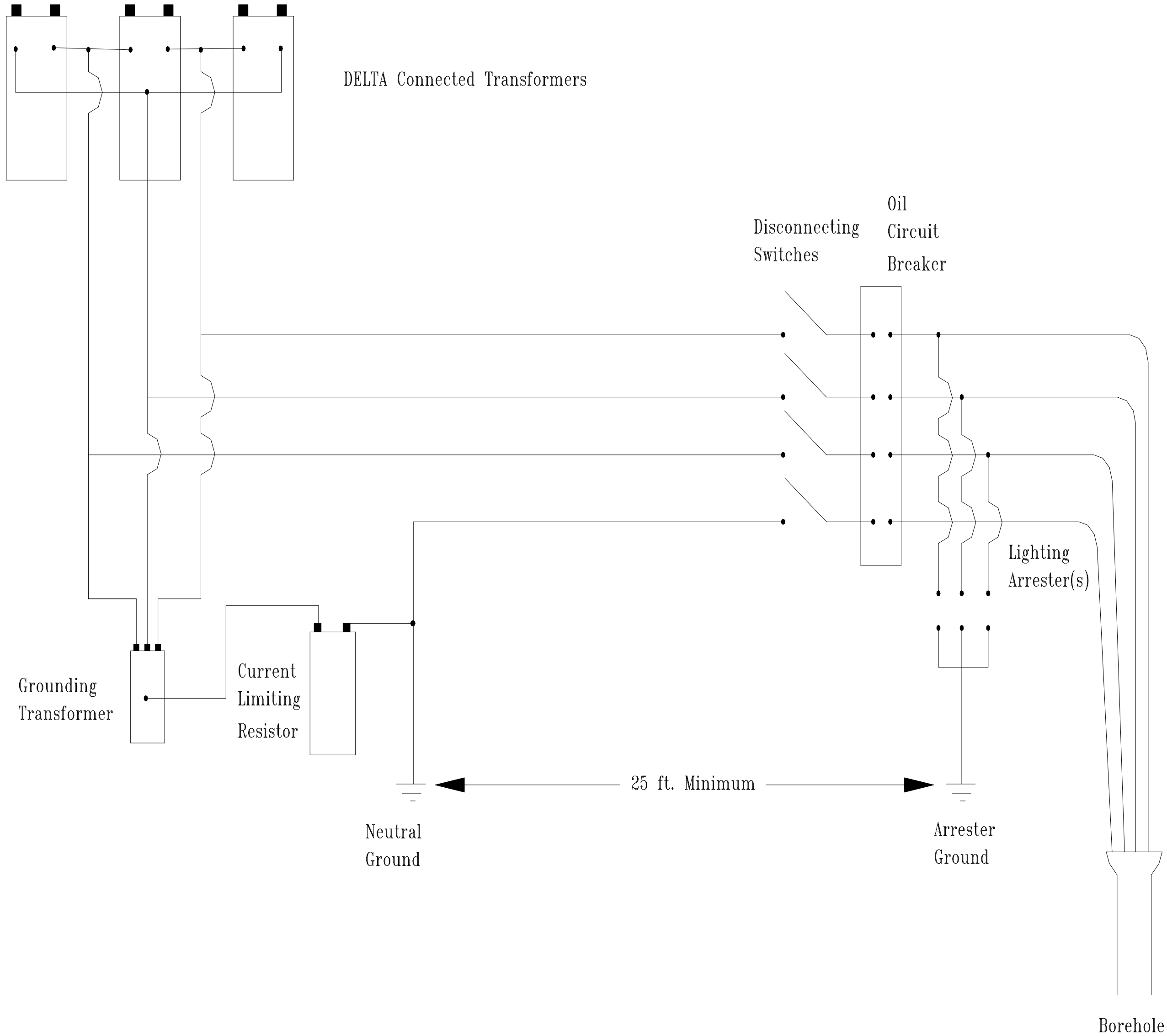


Figure: Delta Connected Secondary

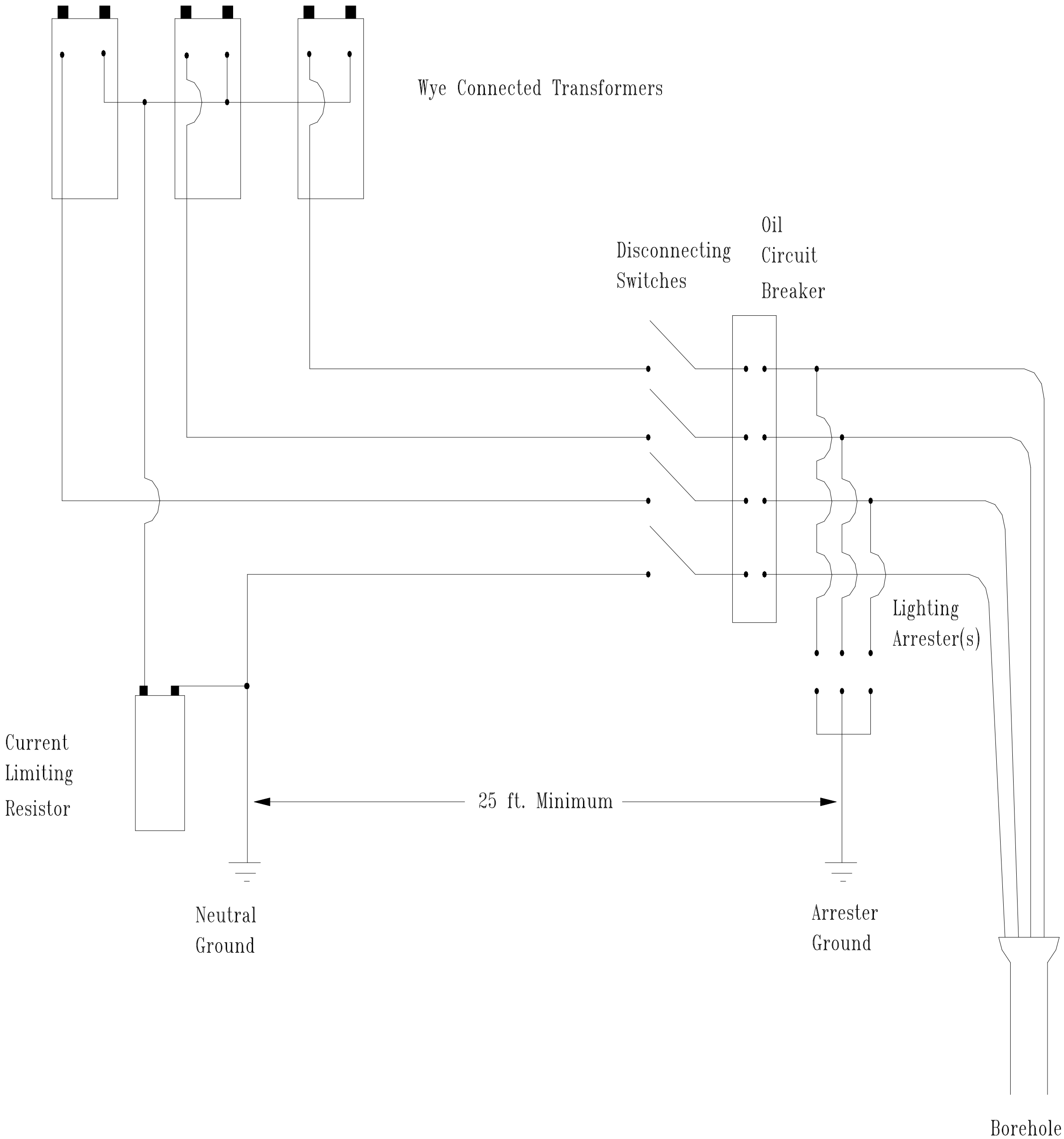


Figure: Wye Connected Secondary

Chapter 5
Electric Motors

CHAPTER 5

ELECTRIC MOTORS

A. DC MOTORS

Series Motors

The commonly used DC motors are series shunt and compound.

The series motor consists of a series field winding (S_1 and S_2) and an armature winding (A_1 and A_2). The series field winding is connected in series with the armature. All current must flow through both windings; therefore, the series motor has high starting current and high starting torque. The starting current must be limited with a starting resistance. As the motor speed is required to be increased, the starting resistance is gradually by-passed and the motor increases in speed. After the entire starting resistance is by-passed, the series motor will continue to increase in speed. If there is no load on the motor, the motor will increase to dangerous speeds. Therefore, series motors are used in applications where there are constant loads. A series motor may be reversed by reversing the series leads (S_1, S_2) <u>or</u> the armature leads (A_1, A_2).

Shunt Motor

The shunt motor consists of a shunt field winding (F_1, F2) and an armature winding (A_1, A2). The shunt winding is connected in parallel to the armature winding. Current flows through two different paths creating less starting current and less starting torque. The shunt motor has good speed control. Once the motor reaches running speed, the shunt motor runs at a constant speed. The shunt motor is reversed by reversing the shunt field (F_1, F_2) <u>or</u> the armature (A_1, A_2).

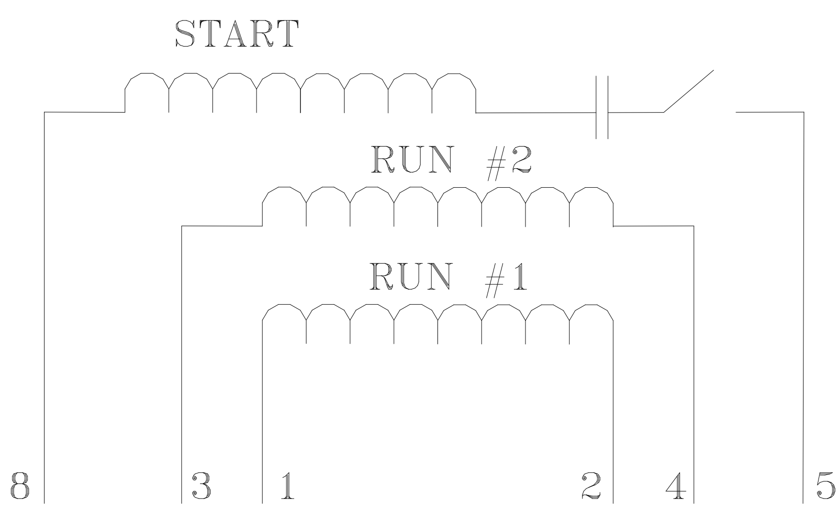
Compound Motor

The compound motor consists of a series field winding, an armature winding and a shunt field winding. The compound motor has characteristics common to the series and shunt motor. The compound motor has good starting torque, but not as good as the series motor and good speed control. If resistance is added in series with the armature, the motor speed will decrease. As the resistance is decreased, then the motor speed will increase. The shunt field will hold the compound motor to a consistent speed. The compound motor is reversed by changing the series leads (S_1, S_2) <u>or</u> the armature leads (A_1, A_2). If the shunt field opens, then the compound motor becomes a series motor and speed will increase. In addition, if resistance is added to the shunt field, the compound motor speed will increase.

B. AC MOTORS

Single Phase Motors

Single-phase motors are constructed different than three phase motors. A single-phase motor has two different sets of windings. They are the start windings and the <u>run</u> windings. The start winding is used to start the motor. Once the motor gets near operating speed (RPM), a centrifugal switch will open and disconnect the start windings from the circuit. The run windings will keep the motor running. To reverse the rotation of a single-phase motor, the leads going to the <u>start or the run</u> windings must be changed.



Chapter 6
Inductance, Capacitance and Impedance

CHAPTER 6

INDUCTANCE, CAPACITANCE AND IMPEDANCE

A. INDUCTANCE

Inductance is placed in the mine electrical system through cables, windings of transformers and windings of large motors. Inductance opposes change in current and can reduce the efficiency or power factor of the system. Inductance is measured in henries and can be converted to inductive reactance with the formula $X = 2 \pi F L$ = ohms. For example, a .10 henry coil is converted to ohms by:

$$X_L = 2 \pi F L$$

$$X_L = 2 (3.14) (60) (.10)$$

$$X_L = 37.68 \text{ ohms}$$

B. CAPACITANCE

The Maintenance Foreman needs an understanding of how capacitance affects electrical circuits and equipment. Capacitance can be added to mine electrical circuits to improve the power factor and the efficiency and effectiveness of the mine electrical system. Capacitance can offset the inductance of the large motors and transformers that are used in mining.

The Maintenance Foreman should understand and instruct repairman to the dangers involved when working with capacitors. The repairman should know that capacitors would remain charged to the source voltage for an indefinite time. Before work is initiated on a circuit containing capacitors, the circuit should be de-energized, disconnected, locked out and tagged and the capacitors discharged.

Capacitance is measured in farads. Capacitance is the <u>opposite</u> of resistors, when determining the total capacitance in series and parallel. For example, if two ten-farad capacitors are connected in parallel, the total capacitance will equal 20 farads. If two ten-farad capacitors were connected in series, then the total capacitance would equal five farads.

To determine the capacitive reactance from capacitance, the formula is:

$$X_C = \frac{1}{2 \pi F C} = \text{ohms}$$

For example, if a 10-microfarad capacitor is used, changing the microfarads to farads and then using the formula can determine the capacitive reactance

$$X_C = \frac{1}{2 \pi F C} = \text{ohms}$$

10 microfarads = .000010 farads

$$X_C = \frac{1}{2 \pi F C}$$

$$X_C = \frac{1}{2 \pi F (.000010)}$$

$$X_C = \frac{1}{2 (314)(60)(.00010)}$$

$$X_C = \frac{1}{.03768}$$

$$X_C = 26.59 \text{ ohms}$$

C. IMPEDANCE

From your study of inductance and capacitance, you know how inductive reactance and capacitive reactance act to oppose the flow of current and voltage in an AC circuit. However, there is another factor, the resistance, which also opposes the flow of the current. Since in practice, AC circuits containing reactance also contain resistance; the two combine to oppose the flow of current. This combined opposition by the resistance and the reactance is called the IMPEDANCE, and is represented by the symbol Z measured in ohms.

Since the values of resistance and reactance are both given in ohms, it might at first seem possible to determine the value of the impedance by simply adding them together. However, it cannot be calculated that easily. In an AC circuit, which contains only resistance, the current and the voltage will be in step (that is, in phase), and will reach their maximum values at the same instant. In addition, in an AC circuit containing only reactance the current will either lead or lag the voltage by one-quarter of a cycle of 90 degrees. Therefore, the voltage in a purely reactive circuit will differ in phase by 90 degrees from that in a purely resistive circuit and for this reason reactance and resistance are not combined by simply adding them.

When reactance and resistance are combined, the value of the impedance will be greater than either. It is also true that the current will not be in step with the voltage nor will it differ in phase by exactly 90 degrees from the voltage, but it will be somewhere between the in-step and the 90-degree out-of-step conditions. The larger the reactance compared with the resistance, the more nearly the phase difference will approach 90 degrees. The larger the resistance compared to the reactance, the more nearly the phase difference will approach zero degrees.

If the value of resistance and reactance cannot simply be added together to find the impedance, or Z, how is it determined? Because the current through a resistor is in step with the voltage across it and the current in a reactance differs by 90 degrees from the voltage across it, the two are at right angles to each other. They can therefore be combined by means of the same method used in the construction of a right-angle triangle.

Assume you want to find the impedance of a series combination of 8 ohms resistance and 5 ohms inductive reactance. Start by drawing a horizontal line, R, representing 8 ohms resistance, as the base of the triangle. Since the effect of the reactance is always at right angles or 90 degrees to that of the resistance, draw the line X, representing 5 ohms inductive reactance as the altitude of the triangle.

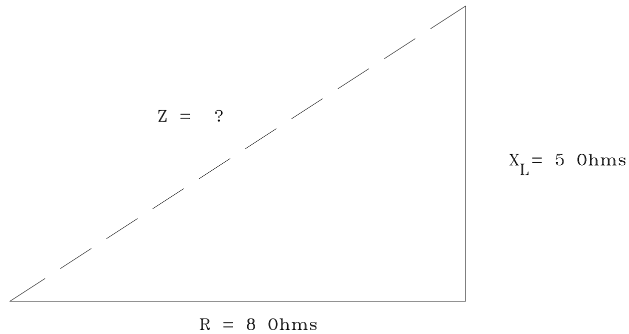


Figure: Impedance

One of the properties of a right triangle is:

$(\text{hypotenuse})^2 = (\text{base})^2 + (\text{altitude})^2$
or,
$\text{hypotenuse} = \sqrt{(\text{base})^2 + (\text{altitude})^2}$

Applied to impedance, this becomes,

$(\text{impedance}) = \sqrt{(\text{resistance})^2 + (\text{reactance})^2}$
or,
$\text{impedance}^2 = (\text{resistance})^2 + (\text{reactance})^2$

$Z = \sqrt{R^2 + X^2}$

Now suppose you apply this equation to check your results in the example given above:

Given: R = 8

$X_L = 5$

Solution: $Z = \sqrt{R^2 + X_L^2}$

$Z = \sqrt{8^2 + 5^2}$

$Z = \sqrt{64 + 25}$
$Z = \sqrt{89}$
Z = 9.4 ohms

When you have a capacitive reactance to deal with instead of inductive reactance as in the previous example, it is customary to draw the line representing the capacitive reactance in a downward direction.

When a circuit has an inductive reactance of 10 ohms and capacitive reactance of 15 ohms, the total reactance is the difference. For example:

$X_{Total} = X_C - X_L$

$X_{Total} = 15 - 10$

$X_{Total} = 5$ ohms (capacitive reactance)

D. True Power in A. C. Circuits

As mentioned before, the true power of a circuit is the power actually used by resistance in the circuit. This power, measured in watts, is the power associated with the total resistance in the circuit. To calculate true power, the voltage and current associated with the resistance must be used. Since the voltage drop across the resistance is equal to the resistance multiplied by the current through the resistance, true power can be calculated by the formula:

True Power = $I^2 R$

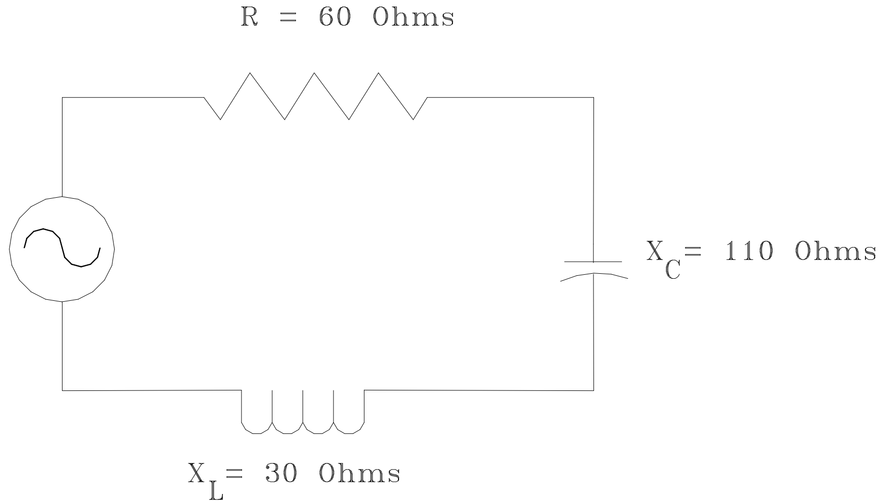
Where: True Power is measured in watts, I_R is resistive current in amperes, R is resistance in ohms.

Given: R = 60 ohms

$X_L = 30$ ohms

$X_C = 110$ ohms

E = 500 volts



Solution: $X_{Total} = X_C - X_L$

$X_{Total} = 80$ (capacitive reactance)

$Z = \sqrt{R^2 + X^2}$

$Z = \sqrt{(60)^2 + (80)^2}$

$Z = \sqrt{3600 + 6400}$

$Z = \sqrt{10{,}000}$

Z = 100

$$I = \frac{E}{Z}$$

$$I = \frac{500}{100}$$

I = 5 Amps

Since the current in a series circuit is the same in all parts of the circuit:

True Power = I^2 R

True Power = $(5)^2 \times 60$

True Power = 1500 watts

Recall that current in a series is the same in all parts of the circuit.

Solution: Apparent power = $I^2 Z$

Apparent power = $(5)^2 \times 100$

Apparent power = 2500 V A

or

Given: True power = 1500 watts

Reactive Power = 2000 VAR

Apparent power = $\sqrt{(\text{True power})^2 + (\text{reactive power})^2}$

Apparent power = $\sqrt{(1500\text{ W})^2 + (2000\text{ VAR})^2}$

Apparent power = $\sqrt{2{,}250{,}000 + 4{,}000{,}000}$

Apparent power = 2500 V A

E. Power Factor

The POWER FACTOR is a number (represented as a decimal or a percentage) that represents the portion of the apparent power dissipated in a circuit.

Therefore, $PF = \frac{\text{True Power}}{\text{Apparent Power}} = \frac{1500}{2500} = .6$ or 60%

If true power and apparent power are known, you can use the formula shown above.

Going one step further, another formula for power factor can be developed. By substituting the equations for true power and apparent power in the formula for power factor, you get:

$$PF = \frac{I_R^2\ (R)}{I_R^2\ (Z)}$$

Since current in a series circuit is the same in all parts of the circuit, I equal I. Therefore, in a series, circuit.

$$PF = \frac{R}{Z}$$

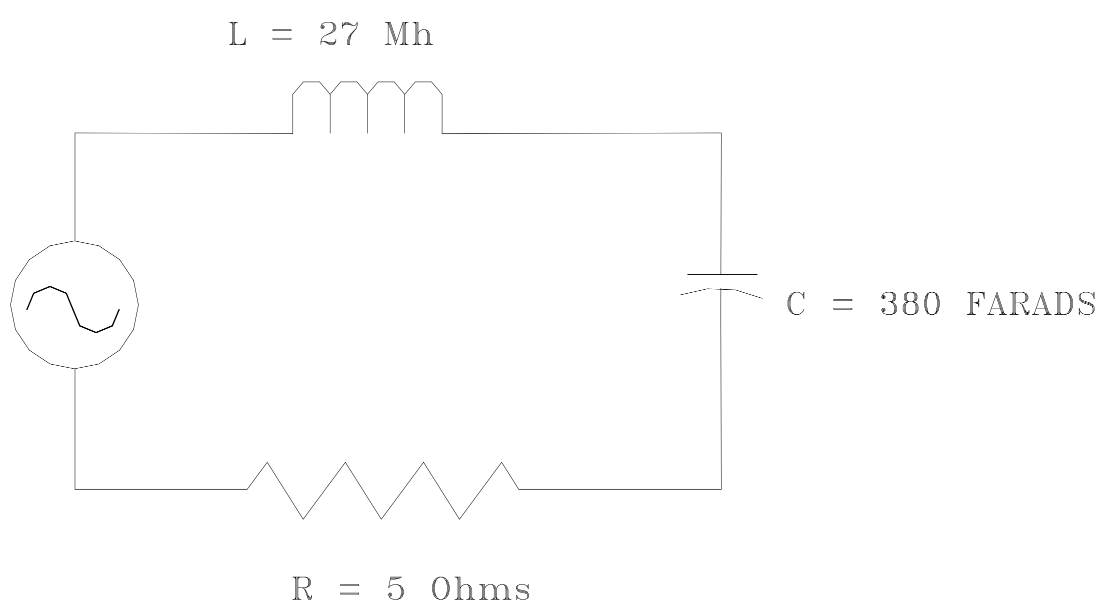
F. Series R L C Circuits

The principles and formulas that have been presented in this topic are used in all AC circuits. The examples given have been series circuits.

This section of the topic will not present any new material, but will be an example of using all the principles presented so far. You should follow each example problem step by step to see how each formula used depends upon the information determined in earlier steps.

The example series R L C circuit will be used to solve for X_L, X_C, X, Z, I_T, true power, reactive power, apparent power, and power factor.

The values solved will be rounded off to the nearest whole number.



First, solve for X_L and X_C .

Given: f = 60 Hz

L = 27 mh (millihenries) = .027 henries

C = 380 F

Solution: $X_L = 2 \pi f L$

$X_L = 6.28 \times 60 \text{ Hz} \times 27 \text{ mH}$

$X_L = 6.28 (60) (.027)$

$X_L = 10$ ohms (Inductive Reactance)

Solution: $X_C = \frac{1}{2 \pi f C}$

$X_C = \frac{1}{6.28 \times 60 \text{ Hz} \times 380 \text{ F}}$

$X_C = \frac{1}{0.143}$

$X_C = 7$ ohms (Capacitive reactance)

Solution: $Z = \sqrt{R^2 + (X_L - X_C)^2}$

$Z = \sqrt{5^2 + (10 - 7)^2}$

$Z = \sqrt{5^2 + 3^2}$

$Z = \sqrt{25 + 9}$

$Z = \sqrt{34}$

Z = 5.83 ohms (impedance)

Solution: $I_T = \frac{E_{ins}}{Z}$

$I_T = \frac{120}{5.83}$

I_T = 20.58 Amps

Solution: True Power = I_R^2 R

True Power = $(20.58)^2$ (5)

True Power = 2118 watts

Solution: Reactive Power = I^2 $(X_L - X_C)$

Reactive Power = $(20.58)^2$ (10-7)

Reactive Power = $(20.58)^2$ (3) = 1271 VAR

Solution: Apparent Power = $\sqrt{2118^2 + 1271^2}$

Apparent Power = $\sqrt{4{,}485{,}924 + 1{,}615{,}441}$

Apparent Power = $\sqrt{6{,}101{,}365}$

Apparent Power = 2470 VA

Solution: Power Factor (pF) = $\frac{\text{True Power}}{\text{Apparent Power}}$

Power Factor (pF) = $\frac{2118}{2470}$

Power Factor (pF) = .859 = 86%

pF = $\frac{R}{2} = \frac{5}{5.83}$ = .86 = 86%

Section III
Chief Electrician Study Guide

Chapter 1
Electrical Inspection, Testing and Examinations

DIVISION OF MINES

BOARD OF COAL MINING EXAMINERS
CERTIFICATION REQUIREMENTS
Website: http://dmme.virginia.gov/dm/default.htm

CHIEF ELECTRICIAN (SURFACE AND UNDERGROUND)

Article 3 of the **Coal Mine Safety Laws of Virginia** establishes requirements for certification of coal mine workers. The certification requirements are included in §45.1-161.24 through §45.1-161.41 in which the Board of Coal Mining Examiners is established for the purpose of administering the certification program. The Board has promulgated certification regulations 4 VAC 25-20, which set the minimum standards and procedures required for Virginia coal miner examinations and certifications.

CERTIFICATION CLASSIFICATION: ****Chief Electrician (Surface and Underground)***
This certification authorizes the holder to:

- Perform electrical work and inspections at all surface areas of underground, surface and underground coal mines
- Make examinations on electrical equipment
- Conduct and record results of electrical examinations

APPLICATION/EXPERIENCE REQUIREMENTS:

- Application (BCME-1) and $40.00 fee 5 working days prior to examination
- Hold a valid Electrical Repairman and Electrical Maintenance Foreman certification
- Five years of electrical experience as applied to underground mining or appropriately related work experience approved by the Chief of the Division of Mines
- Current first aid training (MSHA 5000-23 Annual Retraining or New Miner Inexperience Training acceptable)

EXAMINATION REQUIREMENTS: A score of 80% on each element of the examination.

ELEMENTS OF EXAM	NUMBER OF QUESTIONS
Chief Electrician Exam (CH) ▪ Alternating Current ▪ Direct Current ▪ Circuits & Equipment ▪ Cable Splicing ▪ High Voltage ▪ Legal Requirements ▪ Permissibility	50
▪ First Aid (FA)	20
▪ National Electrical Code (not implemented)	20
▪ Practical Stations (not implemented)	
▪ Records – practical (not implemented)	

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RECOMMENDED REFERENCE/STUDY MATERIALS:

- Title 30 CFR Part 75, 77
- Coal Mine Safety Laws of Virginia
- BCME Requirements
- Electrical Study Guide
- First Aid For Miners Study Guide

The above mentioned study materials are available at the Department of Mines, Minerals and Energy's Big Stone Gap Office, Customer Assistance Center (276) 523-8233 and Keen Mountain Field Office (276) 498-4533.

***8 hours annual Electrical Repairman continuing education will update this certification.**

Revised 06/25/07

CHAPTER 1

ELECTRICAL INSPECTION, TESTING AND EXAMINATIONS

A. Virginia Mine Safety Act

Underground Hoisting

§ 45.1-161.158 Inspecting of Hoisting Equipment

A. Before hoisting or lowering miners in a shaft, the hoisting engineer shall operate empty cages up and down each shaft at least one round trip at the beginning of each shift and after the hoist has been idle for one hour or more.
B. Before hoisting or lowering miners in slope and surface incline hoisting, the hoisting engineer shall operate empty cages at least one round trip at the beginning of each shift and after the hoist has been idle for one hour or more.
C. The hoisting engineer, at the time the inspections required by subsections A and B are performed, shall (i) inspect all cable or rope fastenings at all cages, buckets, or slope cars; (ii) inspect hammer locks and pins, thimbles, and clamps; (iii) inspect safety chains on buckets, cage or slope cars; (iv) inspect the braking system for malfunctions; (v) clean all excess oil and extraneous materials from the hoist housing construction; (vi) inspect the overwind, overtravel, and lilly switch or control from stopping at the collar and within 100 feet of the work deck; and (vii) check communications between the top house, work deck and work deck tugger house.
D. Hoisting rope on all cages or trips shall be inspected at the beginning of each shift by the hoisting engineer.
E. A test of safety catches on cages shall be made at least once each month. A written record shall be kept of such tests, and such record shall be available for inspection by interested persons.
F. Hoisting equipment including the headgear, cages, ropes, connections, links and chains, shaft guides, shaft walls, and other facilities shall be inspected daily by an authorized person designated by the operator. Such person shall also inspect all bull wheels and lighting systems on the head frame. Such person shall report immediately to the operator, or his agent,

any defects found, and any such defect shall be corrected promptly. The person making such examination shall make a daily permanent record of such inspection, which shall be available for inspection by interested persons. If a hoist is used only during a weekly examination of an escapeway, then the inspection required by this subsection shall only be required to be completed weekly before the examination occurs.
G. Subsections A, B, C, and D shall not apply to automatically operated elevators.

Illumination

§ 45.1-161.171 Portable Illumination

A. All miners underground shall use only permissible electric cap lamps that are worn on the person for portable illumination.
B. Light bulbs on extension cables shall be guarded adequately.
C. The requirements of subsection A shall not precede the use of other type of permissible electric lamps, permissible flashlights, permissible safety lamps, or any other permissible illumination device.

§ 45.1-161.172 Underground Illumination

A. Electric-light wires shall be supported by suitable insulators or installed in conduit, fastened securely to the power conductors and shall not contact combustible materials.
B. Electric lights shall be installed so that they do not contact combustible materials.

§ 45.1-161.173 Inspection of Electric Illumination Equipment

All electric illumination equipment located underground shall be inspected by an authorized person at least once per week, and more often if necessary, to ensure safe operating conditions. Such equipment located at the surface shall be inspected by an authorized person at lease once per month, and more often if necessary, to ensure safe operating conditions. Any defect found shall be corrected.

§ 45.1-161.181 Surface Electrical Installations

A. Overhead high potential power lines shall be placed at least fifteen feet above the ground and twenty feet above driveways shall be installed on insulators, and shall be supported and guarded to prevent contact with other circuits.

B. Surface transmission lines including trolley circuits shall be protected against short circuits and lighting. Each exposed power circuit that leads underground shall be equipped with approved lightning arrestors at the point where the circuit enters the mine.

C. Electric wiring in surface buildings shall be installed to prevent fire and contact hazards.

§ 45.1-161.182 Surface Transformers

A. Surface transformers which are not isolated by elevation of eight feet or more above the ground shall be enclosed in a transformer house or surrounded by a suitable fence at least six feet high. If the enclosure or fence is of metal, it shall be grounded effectively. The door to the enclosure or the gate to the fence shall be kept locked at all times unless persons authorized to enter the gate or enclosure is present.

B. Surface transformers containing flammable oil and installed near mine openings, in or near combustible buildings, or at other places where they present a fire hazard shall be provided with means to drain or to confine the oil in the event of rupture of the transformer casing.

§ 45.1-161.183 Underground Transformers

All transformers used underground shall be air-cooled or filled with nonflammable liquid or inert gas.

§ 45.1-161.184 Stations and Substations

A. Suitable danger signs shall be posted conspicuously at all transformer stations.

B. All transformers stations, substations, battery-charging stations, pump stations, and compressor stations shall be kept free of nonessential combustible materials and refuse.

C. Reverse-current protection shall be provided at storage-battery charging stations to prevent the storage batteries from energizing the power circuits in the event of power failure.

§ 45.1-161.186 Power Circuits

A. All underground power wires and cables shall have adequate current-carrying capacity, shall be guarded from mechanical injury, and shall be installed in a permanent manner.
B. Wire and cables not encased in armor shall be supported by well-installed insulators and shall not touch combustible materials, roof, or ribs; however, this shall not apply to ground wires, grounded power conductors, and trailing cables.
C. Power wires and cables installed in belt-haulage slopes shall be insulated adequately and buried in a trench not less than 12 inches below combustible materials, unless encased in armor or otherwise fully protected and trailing cables.
D. Splices in power cable shall be made in accordance with the following:
   1. Mechanically strong with adequate electrical conductivity;
   2. Effectively insulated and sealed so to exclude moisture; and
   3. If the cable has metallic armor, mechanical protection and electrical conductivity equivalent to that of the original armor.
E. All underground transmission cables shall be:
   1. Installed only in regularly inspected airways;
   2. Covered, buried, or placed on insulators to afford protection against damage by derailed equipment if installed along the haulage road;
   3. Guarded where miners regularly work or pass under them under them unless they are 6 1/2 feet or more above the floor or rail,
   4. Securely anchored, properly insulated, and guarded at ends; and
   5. Covered, installed or placed to prevent contact with trolley circuits and other low-voltage circuits.
F. New high-voltage disconnects installed on or after January 1, 2007, on all underground electrical installations shall automatically ground all three power leads when in the open position.
G. All power wires and cables shall be insulated adequately where they pass into or out of electrical compartments, where they pass through doors and stoppings, and where they cross bare power wires.
H. Where track is used as a power conductor:
   1. Both rails of main-line tracks shall be welded or bonded at every joint, and cross bonds shall be installed at intervals of not more than 200 feet. If the rails are paralleled with a feeder circuit of like polarity, such

paralleled feeder shall be bonded to the track rails at intervals of not more than 1,000 feet;

2. At least one rail on secondary track-haulage roads shall be welded or bonded at every joint, and cross bonds shall be installed at intervals of not more than 200 feet;

3. Track switches on entries shall be well bonded; and

§ 45.1-161.188 Grounding

A. All metallic sheaths, armors, and conduits enclosing power conducts shall be electrically continuous throughout and shall be grounded effectively.

B. Metallic frames, casing, and other enclosures of stationary electric equipment that can become "alive" through failure of insulation or by contact with energized parts shall be grounded effectively, or equivalent protection shall be provided.

§ 45.1-161.189 Circuit Breakers and Switches

A. Automatic circuit breaking devices or fuses of the correct type and capacity shall be installed so as to protect all electric equipment and power circuits against excessive overload; however, this shall not apply to locomotives operated regularly on grades exceeding five percent. Wires or other conducting materials shall not be used as a substitute for properly designed fuses, and circuit breaking devices shall be maintained in safe operating condition.

B. An automatic circuit breaker of correct type and capacity shall be installed on each resistance grounded circuit used underground. Such circuit breaker shall be located at the power source and equipped with devices to provide protection against under-voltage, grounded phase, short circuit and overcurrent.

C. Operating controls, such as switches, starters, and switch buttons, shall be so installed that they are readily accessible and can be operated without danger of contact with moving or live parts.

D. Disconnecting switches shall be installed underground in all main power circuits within approximately 500 feet of the bottoms of shafts and boreholes, and at other places where main power circuit enter the mine.

E. Electric equipment and circuits shall be provided with switches or other controls of safe design, construction and installation.

F. Electric equipment and circuits shall be provided with switches or other controls of safe design, construction and installation.
G. Insulating mats or other electrically nonconductive material shall be kept in place at each power-control switch and at stationary machinery where shock hazards exist.
H. Circuit breakers, disconnecting devices and switches shall be marked for identification.

§ 45.1-161.195 Inspection of Electric equipment and Wiring; Checking and Testing Methane Monitor

A. Electric equipment and wiring shall be inspected by a certified person at least weekly if located underground, and at least monthly if located on the surface and more often if necessary to assure safe operating conditions, and any hazardous condition found shall be promptly corrected or the equipment or wiring shall be removed from service. Records of such examination shall be maintained at the mine for a period of one year.
B. A functional check of methane monitors on electrical face equipment shall be conducted to determine that such monitors are de-energizing the electrical face equipment properly. Such check shall be made on each production shift and shall be conducted by the equipment operator in the presence of a mine foreman, and shall be recorded in the on-shifts report of the mine foreman.Weekly calibration tests on methane monitors on electrical face equipment to determine the accuracy and operation of such monitors shall be conducted with a known mixture of methane at the flow rate recommended by the methane monitor manufacturer. A record of results shall be maintained.
D. Required methane monitors shall be maintained in permissible and proper operating condition.

§ 45.1-161.196 Repairs to Circuits and Electric Equipment

No electrical work shall be performed on low-voltage, medium-voltage, or high-voltage distribution circuits or equipment, except by a certified person or by a person trained to perform electrical work and to maintain electrical equipment under the direct supervision of a certified person. All high-voltage circuits shall be grounded before repair work is performed. Disconnecting devices shall be locked out and suitably tagged by the persons who perform electrical or mechanical work on such circuits or equipment connected to the circuits, except that in cases where locking out is not possible, such devices shall be opened and suitably tagged by such persons. Locks and tags shall be removed only by the persons who installed them or, if such persons are unavailable, by certified persons authorized by the operator or his agent. However, miners may, where necessary, repair energized trolley wires if they wear insulated shoes and lineman's gloves. This section does not prohibit certified electrical repairmen from making checks on or troubleshooting energized circuits or the performance of repairs or maintenance on equipment by authorized persons once the power is off and the equipment is blocked against motion, except where motion is necessary to make adjustments.

§ 45.1-161.206 Diesel Powered Equipment

Diesel powered equipment may be utilized underground with the written approval of the Chief. The Chief shall promulgate regulations necessary to carry out the provisions of this section. The regulations shall require that the air in each travelway in which diesel equipment is used, and in any active workings, connected thereto, be of a quality necessary for a safe, healthful working environment. The minimum quantity of ventilating air that must be supplied for a permissible diesel machine in a given time shall conform to that shown on the approval plate attached to the machine. All diesel machines and equipment shall be maintained in such manner that the exhaust emissions meet the same standards to which the machine or equipment was manufactured.

Surface Areas of Underground and Surface Mines

§ 45.1-161.279 Overhead High-Potential Power Lines; Surface Transmission Lines; Electric Wiring in Surface Buildings

A. Overhead high-potential power lines shall be placed at least fifteen feet above the ground and twenty feet above driveways and haulage roads, shall be on insulators, and shall be supported and guarded to prevent contact with other circuits.
B. Surface transmission lines shall be protected against short circuits and lightning.
C. Electric wiring in surface buildings shall be installed, to prevent fire and contact hazards.

§ 45.1-161.280 Transformers

A. Unless surface transformers are isolated by elevation (eight feet or more above the ground), they shall be enclosed in a transformer house or surrounded by a suitable fence at least six feet high. If the enclosure or fence is of metal, it shall be grounded effectively. The gate or door to the enclosure shall be kept locked at all times, unless authorized persons are present.
B. Surface transformers containing flammable oil and installed where they present a fire hazard shall be provided with means to drain or to confine the oil in the event of rupture of the transformer casing.
C. Suitable danger signs shall be posted conspicuously at all transformer stations on the surface.
D. All transformer stations on the surface shall be kept free of nonessential combustible materials and refuse.
E. No electrical work shall be performed on low-voltage, medium-voltage, or high-voltage distribution circuits or equipment, except by a certified person or by a person trained to perform electrical work and to maintain electrical equipment under the direct supervision of a certified person. All high-voltage circuits shall be grounded before repair work is performed. Disconnecting devices shall be locked out and suitably tagged by the persons who perform electrical or mechanical work on such circuits or equipment connected to the circuits, except that in cases where locking out is not possible, such devices shall be opened and suitably tagged by such persons. Locks and tags shall be removed only by the persons who installed them or, if such persons are unavailable, by certified persons authorized by the operator or his agent. However, employees may, where necessary, repair energized trolley wires if they wear insulated shoes and lineman's gloves. This section does not prohibit certified electrical repairmen from making checks on or troubleshooting energized circuits or the performance of repairs or maintenance on equipment by authorized persons once the power is off and the equipment is blocked against motion, except where motion is necessary to make adjustments.

§ 45.1-161.281 Grounding

A. All metallic sheaths, armors, and conduits enclosing power conductors shall be electrically continuous throughout and shall be grounded effectively.

B. Metallic frames, casing, and other enclosures of stationary electric equipment that can become "alive" through failure of insulation or by contact with energized parts shall be grounded effectively or equivalent protection shall be provided.

C. When electric equipment is operated from three-phase alternating current circuits originating in transformers connected to provide a neutral point, a continuous grounding conductor of adequate size shall be installed and connected to the neutral point and to the frames of the power-utilizing equipment. Such grounding conductors shall be grounded at the neutral point and at intervals along the conductor if feasible. A suitable circuit breaker or switching device shall be provided having a ground-trip coil connected in series with the grounding conductor to provide effective ground-fault tripping.

S 45.1-161.282 Circuit Breakers and Switches

A. Automatic circuit breaking devices or fuses of the correct type and capacity shall be installed so as to protect all electric equipment and power circuits against excessive overload. Wires or other conducting materials shall not be used as a substitute for properly designed fuses, and circuit breaking devices shall be maintained in safe operating condition.

B. Operating controls, such as switches, starters, and switch buttons, shall be so installed that they are readily accessible and can be operated without danger of contact with moving or live parts.

C. Electric equipment and circuits shall be provided with switches or other controls of safe design, construction and installation.

D. Insulating mats or other electrically nonconductive material shall be kept in place at each power-control switch and at stationary machinery where shock hazards exist.

E. Suitable danger signs shall be posted conspicuously at all high- voltage installations.

F. All power wires and cables shall have adequate current-carrying capacity, shall be guarded from mechanical injury and installed in a permanent manner.

G. Power circuits shall be labeled to indicate the unit or circuit they control.

H. Persons shall stay clear of an electrically powered shovel or other similar heavy equipment during an electrical storm.

I. All devices installed on or after July 1, 2005, which provide either short circuit protection or protection against overload, shall conform to the minimum requirements for protection of electric circuits and equipment of the National Electric Code in effect at the time of their installation.
J. All electric conductors installed on or after July 1, 2005, shall be sufficient in size to meet the minimum current-carrying capacity provided for in the National Electric Code in effect at the time of their installation.
K. All trailing cables purchased on or after July 1, 2005, shall meet the minimum requirements for ampacity provided in the standards of the Insulated Power Cable Engineers Association - National Electric Manufacturers Association in effect at the time such cables are purchased.

§ 45.1-161.283 Electrical Trailing Cables

A. Trailing cables shall be provided with suitable short-circuit protection and means of disconnecting power from the cable.
B. Temporary splices in trailing cables shall be made in a workmanlike manner, mechanically strong, and well insulated.
C. The number of temporary, unvulcanized splices in a trailing cable shall be limited to one.
D. Permanent splices in trailing cables shall be made as follows:
   1. Mechanically strong with adequate electrical conductivity and flexibility.
   2. Effectively insulated and sealed to exclude moisture.
   3. The finished splice shall be vulcanized or otherwise treated with suitable materials to provide flame-resistant properties and good bonding to the outer jacket.
E. Trailing cables shall be protected against mechanical injury.

B. 30 CFR Requirements

§ 75.503 Permissible Electric Face Equipment; Maintenance

The operator of each coal mine shall maintain in permissible condition all electric face equipment required by § 75.500, § 75.501, § 75.504 to be permissible which is taken into or used inby the last open crosscut of any such mine.

§ 75.508 Map of Electrical System

The location and the electrical rating of all stationary electric apparatus in connection with the mine electric system, including permanent cables, switchgear, permanent pumps, and trolley wires and trolley feeder wires, and settings of all direct-current circuit breakers protecting underground trolley circuits, shall be shown on a mine map.

Any changes made in a location, electric rating, or setting shall be promptly shown on the map when the change is made. Such map shall be available to an authorized representative of the Secretary and to the miners in such mine.

§ 75.708-2 Changes in Electric System Map; Recording

Changes made in location, electrical rating or setting within the mine electrical system shall be recorded on the map of such system no later than the end of the next workday following completion of such changes.

§ 75.509 Electric Power Circuit and Electric Equipment; De-Deenergization

All power circuits and electric equipment shall be de-energized before work is done on such circuits and equipment, except when necessary for trouble shooting or testing.

§ 75.510 Energized Trolley Wires; Repair

Energized trolley wires may be repaired only by a person trained to perform electrical work and to maintain electrical equipment and the operator of a mine shall require that such person wear approved and tested insulated shoes and wireman's gloves.

Subpart H - Grounding

§ 75.700 Grounding Metallic Sheaths, Armors, and Conduits Enclosing Power Conductors

All metallic sheaths, armors, and conduits enclosing power conductors shall be electrically continuous throughout and shall be grounded by methods approved by an authorized representative of the Secretary.

§ 75.700-1 Approved Methods of Grounding

Metallic sheaths, armors, and conduits in resistance grounded systems where the enclosed conductors are a part of the system will be approved if a solid connection is made to the neutral conductor; in all other systems, the following methods of grounding will be approved:

(a) A solid connection to a borehole casing having low resistance to earth;
(b) A solid connection to metal waterlines having low resistance to earth;
(c) A solid connection to a grounding conductor, other than the neutral conductor of a resistance grounded system, extending to a low resistance ground field located on the surface;
(d) Any other method of grounding, approved by an authorized representative of the Secretary, which ensures that there is no difference in potential between such metallic enclosures and the earth.

§ 75.701 Grounding Metallic Frames, Casings, and Other Enclosures of Electric Equipment

Metallic frames, casings, and other enclosures of electric equipment that can become "alive" through failure of insulation or by contact with energized parts shall be grounded representative of the Secretary.

§ 75.701-1 Approved Methods of Grounding of Equipment Receiving Power from Underground Alternating Current Power Systems

For purpose of grounding metallic frames, casings, and other enclosures of equipment receiving power from ungrounded alternating current power systems, the following methods of grounding will be approved:

(a) A solid connection between the metallic frame, casing, or other metal enclosure and the grounded metallic sheath, armor, or conduit enclosing the power conductor feeding the electrical equipment enclosed;
(b) A solid connection to a boreholes casing having low resistance to earth;
(c) A solid connection to metal waterlines having low resistance to earth;
(d) A solid connection to a grounding conductor extending to a low resistance ground field located on the surface;
(e) Any other method of grounding, approved by an authorized representative of the Secretary, which ensures that there is no difference in potential between such metal enclosures and the earth.

§75.701-2 Approved Method of Grounding Metallic Frames, Casings, and Other Enclosures Receiving Power from Single-Phase 110-220-Volt Circuit

In instances where single-phase 110-220-volt circuits are used to feed electrical equipment, the only method of grounding that will be approved is the connection of all metallic frames, casings, and other enclosures of such equipment to a separable grounding conductor which establishes a continuous connection to a ground center tap of the transformer.

§ 75.701-3 Approved Methods of Grounding Metallic Frames, Casings, and Other Enclosures of Electric Equipment Receiving Power from Direct Current Power Systems with One Polarity Grounded

For the purpose of grounding metallic frames, casings, and enclosures of any electric equipment or device-receiving power from a direct- current power system with one polarity grounded, the following methods of grounded will be approved:
(a) A solid connection to the mine track;
(b) A solid connection to the grounded power conductor of the system;
(c) Silicon diode grounding; however, this method shall be employed only when such devices are installed in accordance with the requirements set forth in paragraph (d) of § 75.703-3; and
(d) Any other method, approved by an authorized representative of the Secretary, which insures that there is no difference in potential between such metal enclosures and the earth.

§ 75.701.4 Grounding Wires; Capacity of Wires

Where grounding wires are used to ground metallic sheaths, armors, conduits, frames, casings, and other metallic enclosures, such grounding wires will be approved if:

(a) The cross-sectional area (size) of the grounding wire is at least one-half the cross-sectional area of the power conductor where the power conductor used is NO. 6 A.W.G. or larger.

(b) Where the power conductor used is less than NO. 6 A.W.G., the cross-sectional area of the grounding wire is equal to the cross-sectional area of the power conductor.

§ 75.701-5 Use of Grounding Connectors

The attachment of grounding wires to a mine track or other grounded power conductor will be approved if separate clamps, suitable for such purpose, are used and installed to provide a solid connection.

§ 75.702 Protection Other Than Grounding

Methods other than grounding which provide no less effective protection may be permitted by the Secretary or his authorized representative.

§ 75.702-1 Protection Other Than Grounding; Approved by an Authorized Representative of the Secretary

Under this subpart no method other than grounding may be used to ensure against a difference in potential between metallic sheaths, armors, and conduits, enclosing power conductors and frames, casings, and metal enclosures of electric equipment, and the earth, unless approved by an authorized representative of the Secretary.

§ 75.703 Grounding Offtrack Direct-Current Machines and the Enclosures of Related Detached Components

The frames of all offtrack direct-current machines and the enclosures of related detached components shall be effectively grounded, or otherwise maintained at no less safe voltages, by methods approved by an authorized representative of the Secretary.

§ 75.703-1 Approved Method of Grounding

In instances where the metal frames both of an offtrack direct-current machine and of the metal frames of its component parts are grounded to the same grounding medium the requirements of § 75.70 will be met.

§ 75.703-2 Approved Grounding Mediums

For the purpose of grounding offtrack direct-current machines, the following grounding mediums are approved:

(a) The grounded polarity of the direct-current power system feeding such machine; or

(b) The alternating current grounding medium where such machines are fed by an underground direct-current power system originating in a portable rectifier receiving its power from a section power center. However, when such a medium is used, a separate grounding conductor must be employed.

§ 75.703-3 Approved Methods of Grounding Offtrack Mobile, Portable and Stationary Direct-Current Machines

In grounding offtrack direct-current machines and the enclosures of their components parts, the following methods of grounding will meet the requirements of § 75.703:

(a) The use of a separate grounding conductor located within the trailing cable of mobile and portable equipment and connected between such equipment and the direct-current grounding medium;

(b) The use of a separate ground conductor located within the direct-current power cable feeding stationary equipment and connected between such stationary equipment and the direct-current-grounding medium;

(c) The use of separate external ground conductor connected between stationary equipment and the direct-current grounding medium; or,

(d) The use of silicon diodes; however, the installation of such devices shall meet the following minimum requirements:

1. Installation of silicon diodes shall be restricted to electric equipment receiving power from a direct-current system with one polarity grounded;

2. Where such diodes a nominal voltage rating of 250, they must have a forward current rating of 400 amperes or more and a peak inverse

voltage rating of 400 or more;

3. Where such diodes are used on circuits having a nominal voltage rating of 550, they must have a forward current rating of 250 amperes or more, and have a peak inverse voltage rating of 800 or more:
4. Where fuses approved by the Secretary are used at the outby end of a trailing cable connected to electrical equipment employing silicon diodes, the rating of such fuses must not exceed 150 percent of the nominal current rating of the grounding diodes;
5. Where circuit breakers are used at the outby end of a trailing cable connected to electrical equipment employing silicon diodes, the instantaneous trip setting shall not exceed 300 percent of the nominal current rating of the grounding diode;
6. Overcurrent devices must be used and installed in such a manner that the operating coil circuit of the main contactor will open when a fault current with a value of 25 percent or less of the diode rating flows through the diode;
7. The silicon diode installed must be suitable to the grounded polarity of the power system in which it is used and its threaded base must be solidly connected to the machine frame on which it is installed;
8. In addition to the grounding diode, a polarizing diode must be installed in the machine control circuit to prevent operation of the machine when the polarity of a trailing cable is reversed;
9. When installed on permissible equipment, all grounding diodes, overcurrent devices, and polarizing diodes must be placed in explosion proof compartments;
10. When grounding diodes are installed on a continuous miner, their nominal diode current rating must be at least 750 amperes or more; and,
11. All grounding diodes shall be tested examined and maintained as electrical equipment in accordance with the provisions of § 75.512.

§ 75.703-4 Other Methods of Protecting Offtrack Direct-Current Equipment; Approved by an Authorized Representative of the Secretary

Other methods of maintaining safe voltage by preventing a difference between the frames of offtrack direct-current machines and the earth must be approved by an authorized representative of the Secretary.

§ 75.704 Grounding Frames of Stationary High Voltage Equipment Receiving Power from Underground Delta Systems

The frames of all stationary high-voltage equipment receiving power from underground delta systems shall be grounded by methods approved by an authorized representative of the Secretary.

§ 75.704-1 Approved Methods of Grounding

The methods of grounding stated in § 75.701-1 will also be approved with respect to the grounding of frames of high-voltage equipment referred to in § 75.704.

§ 75.705 Work on High-Voltage Lines; De-energizing and Grounding

High-voltage lines, both on the surface and underground, shall be de-energized and grounded before work is performed on them, except that repairs may be permitted, in the case of energized surface high- voltage lines, if such repairs are made by a qualified person in accordance with procedures and safeguards, including, but not limited To, a requirement that the operator of such mine provide, test, and maintain protective devices in making such repairs, to be prescribed by the Secretary prior to March 30, 1970.

§ 75.705-1 Work on High-Voltage Lines

(a) Section 75.705 specifically prohibits work on energized high-voltage lines underground;

(b) No high-voltage line, either on the surface or underground, shall be regarded as de-energized for the purpose of performing work on it, until it has been determined by a qualified person (as provided in § 75.153) that such high-voltage line has been de-energized and grounded. Such qualified person shall by visual observation

(1) determine that the disconnecting devices on the high-voltage circuit are in open position and
(2) ensure that each underground conductor of the high-voltage circuit upon which work is to be done is properly connected to the

system-grounding medium. In the case of resistance grounded or solid wye-connected systems, the neutral wire is the system-grounding medium. In the case of an underground power system, either the steel armor or conduit enclosing the system or a surface grounding field is a system grounding medium;

(c) No work shall be performed on any high-voltage line on the surface which is supported by any pole or structure which also supports other high-voltage lines until;

(1) All lines supported on the pole or structures are de-energized and grounded in accordance with all of the provisions of this section, which apply to the repair of energized surface high-voltage lines; or

(2) the provisions of § 75.705-2 through § 75.705-10, inclusive.

§ 75.705.5 Installation of Protective Equipment

Before repair work on energized high-voltage surface lines is begun, protective equipment shall be used to cover all bare conductors, ground wires, guys, telephone lines, and other attachments in proximity to the area of planned repairs. Such protective equipment shall be installed from a safe position below the conductors or other apparatus being covered. Each rubber protective device employed in the making of repairs shall have a di-electric strength of 20,000 volts, or more.

§ 75.705-6 Protective Clothing: Use and Inspection

All persons performing work on energized high-voltage surface lines shall wear protective rubber gloves, sleeves, and climber guards if climbers are worn. Protective rubber gloves shall not be worn wrong side out or without protective leather gloves.

Protective devices worn by a person assigned to perform repairs on high voltage surface lines shall be worn continuously from the time he leaves the ground until he returns to the ground, and, if such devices are employed for extended periods, such person shall visually inspect the equipment assigned him for defects before each use and, in no case, less than twice each day.

§ 75.705-7 Protective Equipment; Inspection

Each person shall visually inspect protective equipment and clothing provided him in connection with work on high-voltage surface lines before using such equipment and clothing, and any equipment or clothing containing any defect or damage shall be discarded and replaced with proper protective equipment or clothing prior to the performance of any electrical work on such lines.

§ 75.705-8 Protective Equipment: Testing and Storage

(a) All rubber protective equipment used on work energized high-voltage surface lines shall be electrically tested by the operator in accordance with ASTM standards, Part 28, published February 1968, and such testing shall be conducted in accordance with the following schedule:
   (1) Rubber gloves, once each month;
   (2) Rubber sleeves, once every three (3) months;
   (3) Rubber blankets, once every six (6) months;
   (4) Insulator hoods and line hose, once a year; and
   (5) Other electric protective equipment, once a year.

(b) Rubber gloves shall not be stored wrong side out. Blankets shall be rolled when not in use, and line hose and insulator hoods shall be stored in their natural position and shape.

§ 75.705-9 Operating Disconnecting or Cutout Switches

Disconnecting or cutout switches on energized high-voltage surface lines shall be operated only with insulated sticks, fuse tongs, or pullers which are adequately insulated and maintained to protect the operator from the voltage to which he is exposed. When such switches shall wear protective rubber gloves.

Subpart I - Underground High-Voltage Distribution

§ 75.800 High-Voltage Circuits; Circuit Breakers

High-voltage circuits entering the underground area of any coalmine shall be protected by suitable circuit breakers of adequate interrupting capacity, which are properly tested and maintained as prescribed by the Secretary. Such breakers shall be equipped with devices to provide protection against under-voltage grounded phase, short circuit, and overcurrent.

§ 75.800-1 Circuit Breaker; Location

Circuit breakers protecting high-voltage circuits entering an underground area of any coal mine shall be located on the surface and in no case installed either underground or within a drift.

§ 75.800-2 Approved Circuit Schemes

The following circuit schemes will be regarded as providing the necessary protection to the circuits required by § 75.800:

(a) Ground check relays may be used for undervoltage protection if the relay coils are designed to trip the circuit breaker when line voltage decreases to 40 percent to 60 percent of the nominal line voltage;

(b) Ground trip relays on resistance grounded systems will be acceptable as grounded phase protection;

(c) One circuit breaker may be used to protect two or more branch circuits, if the circuit breaker is adjusted to afford overcurrent protection for the smallest conductor.

§ 75.800-3 Testing, Examination and Maintenance of Circuit Breakers; Procedures

(a) Circuit breakers and their auxiliary devices protecting underground high-voltage circuits shall be tested and examined at least once each month by a person qualified as provided in § 75.153;

(b) Tests shall include:

(1) Breaking continuity of the ground check conductor, where ground check monitoring is used.

(c) Examination shall include visual observation of all components of the circuit breaker and its auxiliary devices, and such repairs or adjustments as are indicated by such tests and examinations shall be carried out immediately.

§ 75.800-4 Testing, Examination and Maintenance of Circuit Breakers; Record

The operator of any coal mine shall maintain a written record of each test, examination, repairs, or adjustment of all circuit breakers protecting high voltage circuits, which enter any underground area of the coal mine. Such record shall be kept in a book approved by the Secretary.

§ 75.801 Grounding Resistors

The grounding resistor, where required shall be of the proper ohmic value to limit the voltage drop in the grounding circuit external to the resistor to not more than 100 volts under fault conditions. The grounding resistor shall be rated for maximum fault current continuously and insulated from ground for a voltage equal to the phase-to-phase voltage of the system.

§ 75.802 Protection of High-Voltage Circuits Extending Underground

(a) Except as provided in paragraph (b) of this section, high voltage circuits extending underground and supplying portable, mobile, or stationary high-voltage equipment shall contain either a direct or derived neutral which shall be grounded through a suitable resistor at the source transformers, and a grounding circuit, originating at the grounding side of the grounding resistor, shall extend along with the power conductors and serve as a grounding conductor for the frames of all high-voltage equipment supplied power from that circuit.

(b) Notwithstanding the requirements of paragraph (a) of this section, the Secretary or his authorized representative may permit underground high-voltage circuits to be extended underground to feed stationary electric equipment if:

(1) Such circuits are either steel, armored or installed in the grounded, rigid steel conduit throughout their entire length; or,

(2) The voltage of such circuits is nominally 2,400 volts or less phase-to-phase and the cables used in such circuits are equipped with metallic shields around each power conductors, and contain one or more ground conductors having a total cross sectional area of not less than one-half half the power conductor; and

(3) Upon a finding by the Secretary or his authorized representative that the use of the circuits described in paragraph (b) (1) and (2) of this section does pose a hazard to the miners.

(c) Within 100 feet of the point on the surface where high- voltage circuits enter the underground portion of the mine, disconnecting devices shall be installed and so equipped or designed in such a manner that it can be determined by visual observation that the power is disconnected, except that the Secretary or his authorized representative may permit such devices to be installed at a greater distance from such area of the mine if he determines, based on existing physical conditions, that such installation will be more accessible at a greater distance and will not pose any hazard to the miners.

§ 75.803 Fail Safe Ground Check Circuits on High-Voltage Resistance Grounded Systems

On and after September 30, 1970, high-voltage, resistance grounded systems shall include a fail safe ground check circuit to monitor continuously the grounding circuit to assure continuity and the fail safe ground check circuit shall cause the circuit breaker to open when either the ground or pilot check wire is broken, or other no less effective device approved by the Secretary or his authorized representative to assure such continuity, except that an extension of time, not in excess of 12 months, may be permitted by the Secretary on a mine-by-mine basis if he determines that such equipment is not available.

§ 75.803-1 Maximum Voltage Ground Check Circuits

The maximum voltage used for ground check circuits under § 75.803 shall not exceed 96 volts.

§ 75.803-2 Ground Check Systems Not Employing Pilot Check Wires; Approval by the Secretary

Ground check systems not employing pilot check wires will be approved only if it is determined that the system includes a fail safe design causing the circuit breaker to open when ground continuity is broken.

§ 75.804 Underground High-Voltage Cables

(a) Underground high-voltage cables used in resistance grounded systems shall be equipped with metallic shields around each power conductor with one or more ground conductors having a total cross sectional area of not less than one-half the power conductor, and with an insulated external conductor not smaller than No. 8 (A.W.G.) or an insulated internal ground check conductor not smaller than No. 10 (A.W.G.) for the ground continuity check circuit.

(b) All such cables shall be adequate for the intended current and voltage. Splices made in such cables shall provide continuity of all components.

§ 75.805 Couplers

Couplers that are used with medium-voltage or high-voltage power circuits shall be of the three-phrase type with a full metallic shell, except that the Secretary may permit, under such guidelines as he may prescribe, no less effective couplers constructed of materials other than metal. Couplers shall be adequate for the voltage and current expected. All exposed metal on the metallic couplers shall be grounded to the ground conductor in the cable.

The coupler shall be constructed so that the ground check continuity conductor shall be broken first and the ground conductor shall be broken last when the coupler is being uncoupled.

§ 75.806 Connection of Single-Phase Loads

Single-phased loads, such as transformer primaries, shall be connected phase-to-phase.

§ 75.807 Installation of High-Voltage Transmission Cables

All underground high-voltage transmission cables shall be installed only in regularly inspected air courses and haulage ways, and shall be covered, buried, or placed so as to afford protection against damage, guarded where men regularly work or pass under them unless they are 6 and 1/2 feet or more above the floor or rail, securely anchored, properly insulated, and guarded at ends, and covered, insulated, or placed to prevent contact with trolley wires and other low-voltage circuits.

§ 75.808 Disconnecting Devices

Disconnecting devices shall be installed at the beginning of branch lines in high-voltage circuits equipped or designed in such a manner that it can be determined by visual observation that the circuit is de- energized when the switches are open.

§ 75.809 Identification of Circuit Breakers and Disconnecting Switches

Circuit breakers and disconnecting switches underground shall be marked for identification.

§ 75.810 High-Voltage Trailing Cables; Splices

In the case of high-voltage cables used as trailing cables, temporary splices shall not be used and all permanent splices shall be made in accordance with § 75.604. Terminations and splices in all other high- voltage cables shall be made in accordance with the manufacturer's specifications.

§ 75.811 High-Voltage Underground Equipment; Grounding

Frames, supporting structures and enclosures of stationary, portable, or mobile underground high-voltage equipment and all high-voltage equipment supplying power to such equipment receiving power from resistance grounded systems shall be effectively grounded to the high-voltage ground.

Subpart J - Underground Low and Medium Voltage Alternating Current Circuits

§ 75.900 Low and Medium Voltage Circuits Serving Three-Phase Alternating Current Equipment; Circuit Breakers

Low and medium voltage power circuits serving three-phase alternating current equipment shall be protected by suitable circuit breakers of adequate interrupting capacity, which are properly tested and maintained as prescribed by the Secretary. Such breakers shall be equipped with devices to provide protection against undervoltage, grounded phase, short circuit, and overcurrent.

§ 75.900-1 Circuit Breakers; Locations

Circuit breakers used to protect low and medium-voltage circuits underground shall be located in areas, which are accessible for inspection, examination, and testing, have safe roofs, and are clear of any moving equipment used in haulageways.

§ 75.900-2 Approved Circuit Schemes

The following circuit schemes will be regarded as providing the necessary protection to the circuit required by § 75.900:

(a) Ground check relays may be used for undervoltage protection if the relay coils are designed to trip the circuit breaker when line voltage decrease to 40 to 60 percent of the nominal line voltage.

(b) One undervoltage device installed in the main secondary circuit at the source transformer may be used to provide undervoltage protection for each circuit that receive power from that transformer.

(c) One circuit breaker may be used to protect two or more branch circuits if the circuit breaker is adjusted to afford overcurrent protection for the smallest conductor.

(d) Circuit breakers with shunt trip, series trip or undervoltage release devices may be used if the tripping elements of such devices are selected or adjusted in accordance with the settings listed in the tables of the National Electric Code, 1968.

§ 75.900-3 Testing, Examination, and Maintenance of Circuit Breakers; Procedures

Circuit breakers protecting low and medium-voltage alternating current circuits serving three-phase alternating current equipment and their auxiliary devices shall be tested and examined at least once each month by a person qualified as provided in § 75.153. In performing such tests, actuating any of the circuit breaker axillaries or control circuit breaker to open, shall be considered proper test. All components of the circuit breaker and its auxiliary devices shall be visually examined and such repairs or adjustments as are indicated by such test and examinations shall be carried out immediately.

§ 75.901 Low and Medium Voltage Ground Check Monitor Circuits

On or before September 30, 1970, low and medium voltage resistance grounded systems shall include a fall-safe ground check circuit to monitor continuously the grounding circuit to assure continuity which ground check circuit shall cause the circuit breaker to open when either the ground or pilot check wire is broken, or other no less effective device approved by the Secretary or his authorized representative to assure such continuity, not in excess of 12 months, may be permitted by the Secretary on a mine-by-mine basis if he determines that such equipment is not available. Cable couplers shall be constructed so that the ground check continuity conductor shall be broken first and the ground conductors shall be broken last when the coupler is being uncoupled.

§ 75.902-1 Maximum Voltage Ground Check Circuits

The maximum voltage used for such ground check circuits shall not exceed 40 volts.

§ 75.902-2 Approved Ground Check Systems Not Employing Pilot Check Wires

Ground check systems not employing pilot check wires will be approved only if it is determined that the system includes a fall safe design causing the circuit breaker to open when ground continuity is broken.

§ 75.902-4 Attachment of Ground Conductors and Ground Check Wires to Equipment Frames; Use of Separate Connections

In grounding equipment frames of all stationary, portable or mobile equipment receiving power from resistance grounded systems separate connections shall be used when practicable.

Chapter 2
Circuits, Equipment and High Voltage

A. Single Phase Transformers

Turn Ratio: Relationship between the primary and secondary of a single phase transformer.

Primary: The input side of a transformer.

Secondary: The output side of a transformer.

Step-down transformer: The primary turns are higher than the secondary turns and the voltage on the primary is larger than the secondary voltage. The primary current is less than the secondary current. The primary wiring is normally smaller with more turns, than the larger wiring on the secondary. The primary terminals are usually labeled H_1 and H_2 and the secondary terminals are labeled X_1 and X_2.

$$\text{Ratio} = \frac{\text{turns primary}}{\text{turns secondary}} = \frac{\text{voltage primary}}{\text{voltage secondary}} = \frac{\text{current secondary}}{\text{current primary}}$$

Example: A single-phase step-down transformer has a ratio on 10 to 1, with an input voltage of 120 volts and a secondary load of 2 amps.

What is the secondary voltage?

$$\text{Ratio} = \frac{E_{\text{primary}}}{E_{\text{secondary}}} \text{ therefore } 10 = \frac{120}{E_{\text{secondary}}} \ \& \ E_{\text{secondary}} = \frac{120}{10} = 12 \text{ volts}$$

What is the primary current?

$$\text{Ratio} = \frac{I_{\text{secondary}}}{I_{\text{primary}}} = 10 = \frac{2}{I_{\text{primary}}} = I_{\text{primary}} = \frac{2}{10} = .2 \text{ amps}$$

What is transformer KVA?

$$VA = (E_{\text{primary}} \text{ x } I_{\text{primary}}) = E_{\text{secondary}} \text{ x } I_{\text{secondary}}$$
$$VA = 120 \text{ x } .2 = 12 \text{ x } 2 = 24$$
$$KVA = \frac{24}{1000} = .024$$

B. Three Phase Transformers

Delta Connected Transformers: Coil or phase voltage is equal to voltage line to line.

$E_{\text{line to line}} = E_{\text{phase}}$

I: Line Current is equal to phase current times $\sqrt{3}$ = (1.73) I_{phase}

$I_{\text{Line}} = \sqrt{3}\ I_{\text{phase}}$

Wye Connected Transformers: Coil or phase voltage is equal to voltage line to line divided by $\sqrt{3}$ or 1.73.

$E_{\text{phase}} = E_{\text{line to line}} : \sqrt{3}$

$E_{\text{phase}} = \frac{E_{\text{line to line}}}{1.73}$

$I_{\text{line secondary}} = I_{\text{phase secondary}}$

$I_{\text{phase secondary}} = I_{\text{phased primary}}$ X ratio

Example: A three-phase transformer is connected Delta on the primary and wye on the secondary. The incoming voltage from line to line is 7,200 volts. The ratio is 10. The secondary load current is 50 amps.

What is the secondary phase to ground voltage?
What is the secondary line-to-line voltage?
What is the primary phase current?
What is the primary line current?
What is the transformer KVA rating?

$E_{\text{line to line primary}} = E_{\text{phase primary}} = 7{,}200$ volts

$E_{\text{phase to ground secondary}} = \frac{E_{\text{primary}}}{\text{Ratio}}$

$E_{\text{phase to ground secondary}} = \frac{E_{\text{primary}}}{\text{Ratio}} = \frac{7200}{10}$ = 720 volts

$E_{\text{line to line secondary}} = E_{\text{phase to ground secondary}} \text{ X } \sqrt{3}$

E = 720 x 1.73 + 1245.6 volts

$I_{\text{line secondary}} = 50$ amps

$I_{\text{phase secondary}} = I_{\text{line secondary}} = 50$ amps

$I_{\text{phase primary}} = \dfrac{I_{\text{phase secondary}}}{\text{Ratio}} = \dfrac{50}{10} = 5$ amps

$I_{\text{line primary}} = I_{\text{phase primary}} \text{ X } \sqrt{3} = 5 \text{ x } 1.73 = 8.65$ amps

$\text{KVA} = \dfrac{E_{\text{phase primary}} \text{ X } I_{\text{phase primary}}}{1{,}000}$

$\text{KVA} = \dfrac{E_{\text{phase secondary}} \text{ X } I_{\text{phase secondary}}}{1{,}000}$

$\text{KVA}_{\text{primary}} = \dfrac{7{,}200 \text{ x } 5}{1{,}000} = \dfrac{1{,}440}{1{,}000} = 1.440$

$\text{KVA}_{\text{secondary}} = \dfrac{720 \text{ x } 50}{1{,}000} = \dfrac{1{,}440}{1{,}000} = 1.440$

$\text{KVA}_{\text{primary}} = \text{KVA}_{\text{secondary}}$

C. Alternating Current Values

In reviewing the alternating current values from Chapter 2, the chief electrician should understand the values of the voltages of a sine wave.

$E_{effective} = .707\ E_{peak}$

$E_{peak} = \sqrt{2}\ X\ E_{effective} = 1.414\ E_{effective}$

$E_{peak\ to\ peak} = 2\ X\ E_{peak}$

Example: If 120 AC volts is measured with a voltmeter. What is the peak-to-peak voltage?

$E_{peak} = E_{effective}\ X\ 1.414$

$E_{peak} = 120\ X\ 1.414 = 169.68$ volts

$E_{peak\ to\ peak} = E_{peak}\ X\ 2$

Answer: $E_{peak\ to\ peak} = 169.68 \times 2 = 339.36$