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Electrical Inspection Procedures Handbook

PREFACE

This handbook sets forth procedures for MSHA personnel to follow when conducting investigations and inspections of mines and facilities. Volume I provides guidance for electrical specialist, while Volume II provides guidance to MSHA general inspectors who encounter mine electrical systems and electric-powered equipment during the course of their inspections.

Previously issued instructions for this same subject material are superseded by this handbook. Compliance related instructions that are contained in the MSHA Program Policy Manual remain in effect.

Not all procedures and requirements are applicable for all mine types. Any deviation from the procedures outlined in this handbook should be based on the inspector’s professional judgement and discussion with the inspector’s supervisor, and consider conditions, practices, and circumstances specific to the mine.

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VOLUME I

CHAPTER 1 - INTRODUCTION

A. Inspection Schedules

Many of the requirements of 30 CFR concerning electrical circuits and equipment are very technical in nature. A thorough knowledge of electrical theory, mine power systems, and electric equipment is essential if inspection personnel are to properly implement these requirements without creating hazards to themselves or to miners.

When mine inspectors encounter electrical problems that require special electrical expertise, the assistance of an electrical specialist should be requested. The term “electrical specialist” as used in this document refers to a person with an extensive background in mine electrical systems and equipment. Examples include electrical engineers, electrical inspectors, and others who have the education and experience necessary to safely evaluate mine electrical systems and equipment. Requests for assistance from electrical specialists should be forwarded through the inspector's immediate supervisor and should outline the nature of the problem with as much background information as possible.

During each electrical inspection, the electrical specialist shall inspect an adequate portion of the electric circuits, electric equipment, and mechanical equipment at each mine to ascertain that the equipment and circuits are being maintained in accordance with the Federal Mine Safety and Health Act of 1977 (Mine Act), as amended, and MSHA’s standards.

During each electrical inspection, the electrical specialist shall evaluate the examination and maintenance program at the mine to ensure that it is adequate to maintain the electrical equipment and circuits in safe condition. Requirements for examination and maintenance of electrical equipment and circuits in coal mines are listed in 30 CFR 75.512, 75.800, 75.821, 75.832, 75.900, 77.502, 77.800, and 77.900. Requirements for examination and testing of grounding systems in metal and nonmetal mines are listed in 56.12028 and 57.12028. An effective examination and maintenance program should be in place at all mines.

Improvements in electrical technology in the mining industry and the corresponding need for greater expertise by electrical specialists require electrical inspection personnel to continue their education in this technology. In addition to MSHA training, all electrical specialists should keep abreast of the latest developments in mine electrical technology by studying reference material, technical publications, and text books and by attending seminars (with the approval of district management) pertaining to electrical technology.

B. Equipment and Supplies

In addition to the basic safety equipment and supplies required for all mine inspectors, the following equipment and supplies should be provided for electrical specialists:

☐ Electrically-rated safety shoes and safety rubber boots
☐ 100% cotton or fire-resistant (FR) rated coveralls
☐ Class 2 high-voltage gloves with leather protectors
☐ Class 0 low-voltage gloves with leather protectors
☐ Padlock, hasp extender, and suitable tags for lockout/tagout
☐ Non-contact AC voltage detector appropriately rated for the circuits, equipment, and environmental conditions encountered during electrical inspections
☐ Multimeter(s) for measuring voltage, current, and resistance. Meters must be appropriately rated for the circuits, equipment, and environmental conditions encountered during electrical inspections
☐ Earth-resistance tester
☐ Insulation resistance tester appropriately rated for the circuits, equipment, and environmental conditions encountered during electrical inspections
☐ Safety Circuit Tester, Becker/SMC Model C-3100 or equivalent (used to verify compliance with 30 CFR 75.900 and 75.902)
☐ Set of flat feeler gauges (0.003, 0.004, 0.005, 0.007 and 0.009 inch)
☐ Set of round feeler gauges (0.007, 0.009 and 0.011 inch)
☐ Caliper rule
☐ Binoculars

Multimeters and other test equipment should be calibrated and maintained as specified by the manufacturer. Electrical specialists who are exposed to electrical hazards should be provided with appropriate personal protective equipment (PPE). Electrical specialists should be knowledgeable in the selection, use, limitations, inspection, donning, doffing, and maintenance of PPE. PPE should be maintained in a safe, reliable condition and should be inspected or tested as recommended by the manufacturer and required by the Occupational Safety and Health Administration (OSHA). For example, High voltage gloves should be tested every six months in accordance with ASTM F496-97, "Standard Specification for In-Service Care of Insulating Gloves and Sleeves."

District Managers have the authority to determine the specialized equipment their electrical specialist need to conduct on-site activities. Electrical specialists will be provided appropriate training before using such devices to prevent exposing

themselves or others to potential hazards. A standardized list for specialized equipment should be requested from Management & Program Analyst or Management or Procurement Officer.

C. References

Adequate technical reference material should be available at each district and field office for the use of electrical engineers and electrical specialists and should include the following publications at a minimum:

1. *Mine Power Systems* - U.S. Bureau of Mines IC9258
2. *National Electrical Code,* 1968 and later editions as needed
3. *National Electrical Safety Code,* 1968 and later editions as needed
4. *Recommended Practice for Grounding Industrial and Commercial Power Systems* – IEEE Standard 142-1972 and later editions as needed
5. *IEEE Standard Dictionary of Electrical and Electronics Terms* – IEEE Standard 100-1972 and later editions as needed
6. *General Electric Distribution Transformer Manual* - Publication GET-2485B
7. *Ugly's Electrical References* (Jones and Bartlett) or equivalent
8. *Mine Electricity, Metal/Nonmetal Surface and Underground Entry Level Training* – National Mine Health and Safety Academy Publication CI 8

D. Elements of Electrical Inspections

Electrical inspections can vary greatly depending on the type of mine or facility. The following list is not intended to be comprehensive, but may be used as a guide to remind electrical specialists of some of the most common enforcement elements of an electrical inspection.

1. Substations, Transformers, and Switchgear
   a. Fences and enclosures
   b. Vertical and horizontal clearance from live parts
   c. Disconnecting devices
   d. Primary overcurrent protection for transformers
   e. Transformer connections
   f. System grounding (solid grounded, resistance grounded, ungrounded, etc.)
   g. Grounding resistors and connections

- h. Ground fields
- i. Frame grounding of transformers, circuit breakers, etc.
- j. Lightning protection
- k. Circuit breakers and auxiliary devices
  - 1) Overcurrent relays
  - 2) Current transformer ratios
  - 3) Ground check circuits
  - 4) Ground fault relays
  - 5) Undervoltage relays

2. Power Centers
   - a. Frame grounding
   - b. Incoming disconnecting devices
   - c. Primary overcurrent protection of transformers
   - d. Type of neutral connection (direct or derived)
   - e. Grounding resistors
   - f. Circuit breakers and auxiliary devices (grounded phase, undervoltage, etc.)
   - g. Lightning and surge protection
   - h. Disconnecting means for loads served by the power center
   - i. Cable couplers and receptacles
   - j. Ground check circuits

3. General Distribution
   - a. Circuit identification
   - b. Type and capacity of cables or conductors
   - c. Mechanical protection of cables or conductors
   - d. Conductor clearance
   - e. Bushings and fittings where cables enter enclosures
   - f. Splices, terminations, and couplers
   - g. Disconnecting devices
   - h. Switch houses and load centers

4. General Circuit Protection
    a. Ampacity of conductors
    b. Overload and short circuit protection
    c. Proper installation and mounting of fuses, circuit breakers, and other protective devices
5. 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. Cleanliness of equipment
    g. Permissibility of equipment in face areas and return airways
6. Mobile Equipment
    a. Overload and short circuit protection
    b. Frame grounding
    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. Proximity detection systems
7. 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

8. Records
   a. Map of the electrical system (coal mines)
   b. List of qualified electricians (coal mines)
   c. Records of monthly circuit breaker tests (coal mines)
   d. Records of weekly examinations of electric equipment (coal mines)
   e. Record of resistance measurements for grounding systems (metal and nonmetal mines)

9. Work Practices
   a. Lock Out and Tag Out Procedures
   b. Troubleshooting and Testing Practices
   c. Installation and Maintenance Practices

CHAPTER 2 - GROUNDING

A. General

30 CFR contains requirements that relate to both *system grounding* and *equipment grounding*. *System grounding* refers to the way that current carrying conductors in the distribution system are intentionally connected (or not connected) to earth.

Most distribution systems encountered by inspectors will be grounded in some manner. However, ungrounded systems are used at some mines and facilities, and it is important for the inspector to understand the different ways that grounded systems and ungrounded systems respond to fault conditions. In general, ground faults in grounded systems result in current flow that is of sufficient magnitude to operate overcurrent devices. Ground faults in ungrounded systems may not produce sufficient current to operate overcurrent devices, although other means of ground fault detection may be used.

Equipment grounding refers to the way that metallic frames and casings are connected together and to earth. The metal parts of all equipment that can become energized due to insulation failure must be grounded.

B. Approved Grounding Methods

For coal mines, inspectors shall not accept any method of grounding that does not comply with the requirements of Subpart H of 30 CFR Parts 75 and 77. Program Policy Manual (PPM) Volume V provides significant guidance regarding the application of Subpart H and should be consulted by inspectors when questions about the adequacy of different grounding methods arise.

For metal and nonmetal mines, inspectors shall not accept any method of grounding that does not comply with 30 CFR 56.12025, 56.12026, 56.12027, 57.12025, 57.12026, and 57.12027.

Grounded Systems

An inspector shall not approve any method of grounding that does not include a solid connection to a grounding conductor which extends to the grounded point of the power source. The grounded power conductor of a solidly grounded alternating current power system may serve as the equipment grounding conductor only between the grounded point of the power source and the grounded enclosure of the service disconnecting means for a building or other stationary facility. The grounded point of the power source and the metallic enclosure of each service disconnecting means shall be connected to an acceptable grounding medium, such as metal waterlines having low resistance to earth, a low-resistance ground field, etc.

Ungrounded Systems

When multiple units of equipment are supplied by the same ungrounded system, the frames of such equipment must be grounded to the same grounding medium (ground field, grounding electrode, etc.) to ensure that there is no difference in potential between metal enclosures and the earth.

The connecting of different metallic enclosures of electric equipment receiving power from the same ungrounded alternating current system to different, unconnected grounding mediums does not ensure that there is no difference in potential between such enclosures and earth, and has resulted in several electrocutions. Therefore, this method of grounding is not acceptable.

C. Resistance Grounded Systems

Resistance grounded systems are mandated for certain circuits in coal mines. Specific requirements are found in 30 CFR 75.801, 75.802, 75.901, 77.801, 77.802, and 77.901. PPM Volume V also contains additional guidance on grounding resistors and grounding transformers and should be consulted when questions regarding resistance grounding arise.

Resistance grounded systems are not mandated for metal and nonmetal mines. However, when these systems are installed, they must be carefully evaluated by electrical specialists to ensure that they are maintained in safe condition. The information presented in this section is intended to help electrical specialists evaluate the safety of resistance grounded systems and take appropriate enforcement action.

Grounding Resistors

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, depending on the particular system for which the resistor is designed. 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:

$\mathrm{V} = 2{,}400 \text{ volts}, \mathrm{I_R} = 25 \text{ amperes}$

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

$\mathrm{R} = \frac{2{,}400 \text{ volts}}{25 \text{ amperes}} = 96\Omega$

A person standing on the earth while touching the frame of a piece of equipment connected to the grounding circuit is essentially in parallel with the grounding conductor (See Figure 1). During a phase-to-ground fault, most of the voltage drop appearing across the grounding conductor will also appear across the person's body. For this reason, it is critical to keep the grounding conductor resistance as low as possible.

30 CFR 75.801 requires grounding resistors in underground high voltage systems to limit the voltage drop in the grounding circuit external to the grounding resistor to 100 volts. Consequently, if a 25-ampere grounding resistor is used as shown in the circuit in Figure 1, the maximum impedance of the grounding conductor cannot exceed 4.26 ohms.

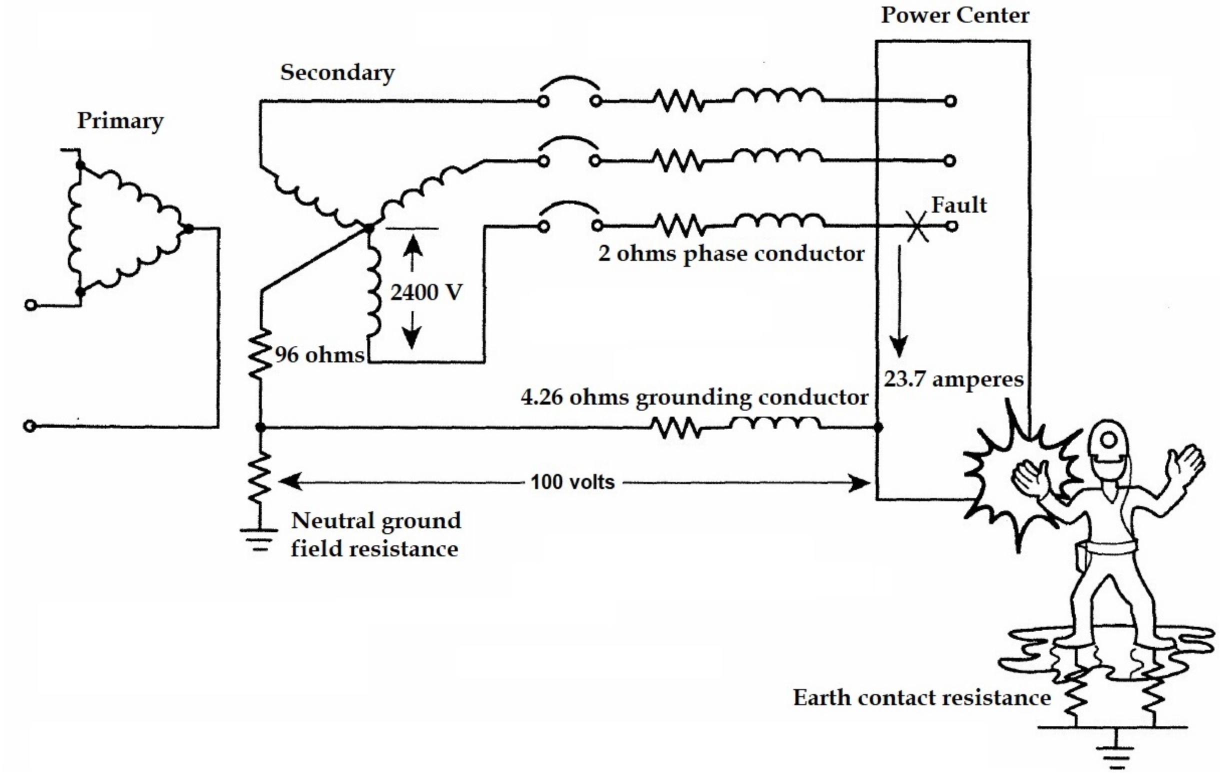


Figure 1 - Touch potential of resistance grounded system under fault conditions (refer to Appendix F for calculations)

When the rating of a grounding resistor is unclear, copy the nameplate data and consult with the manufacturer to verify that the resistor is rated for the maximum fault current continuously. Electrical specialists should carefully examine high voltage grounding resistors for improper connection in the circuit, improper rating, broken terminal connections, and broken jumpers between resistor coils. When heat is observed rising from a grounding resistor, the following conditions may exist:

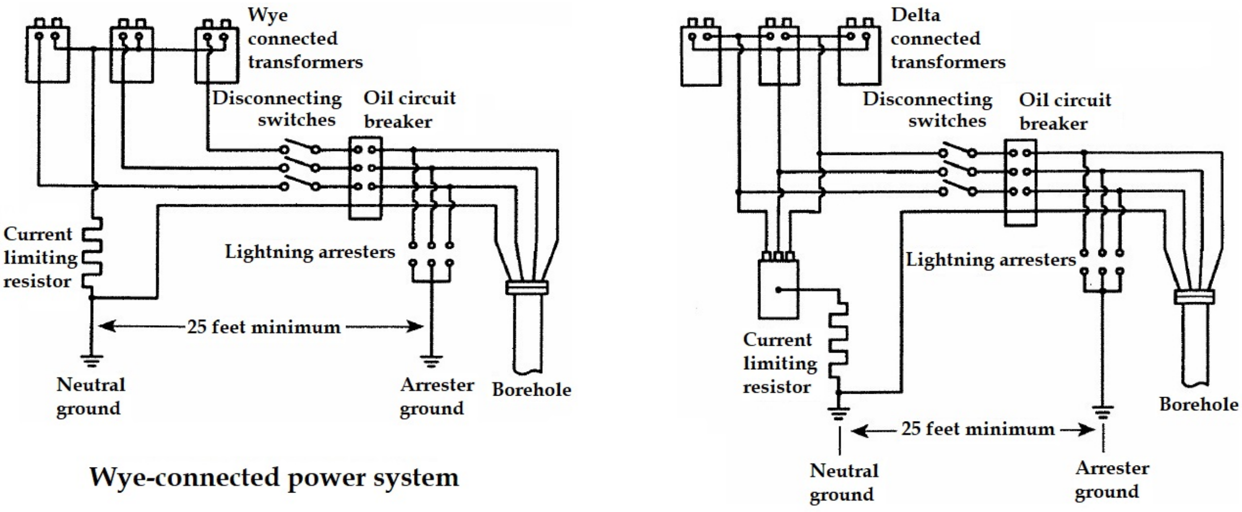
1) a grounded-phase condition, probably in the cable; and
2) an inoperative grounded-phase relay or trip circuit in the circuit breaker.

Analog multimeters or digital multimeters with voltage compensation should be used when measuring grounding resistors, due to possible galvanic interference.

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.

Figures 2 shows in simplified form the proper method of connecting resistance grounded circuits extending underground.



Wye-connected power system

Delta-connected power system with grounding transformer

Figure 2 - Properly connected resistance grounded circuits

The type of grounding transformer most commonly used is a three-phase zigzag transformer. The impedance of the transformer to three-phase currents is high, so that when there is no fault on the system, only a small magnetizing current flows in the transformer windings. The transformer impedance to ground-fault current, however, is low. The transformer divides the ground current into three equal components; these currents are in phase with each other and flow in the three windings of the grounding transformer.

The method of winding is such that when these three equal currents flow, the current in one section of the winding of each leg of the core is in a direction opposite to that in the other section of the winding of that leg. The only magnetic flux that results from the zero-sequence fault currents is the leakage flux about each winding section. This arrangement accounts for the low impedance of the transformer to ground-fault current (See Figure 3). The connections and current distributions in a wye-delta grounding transformer bank are shown in Figure 4.

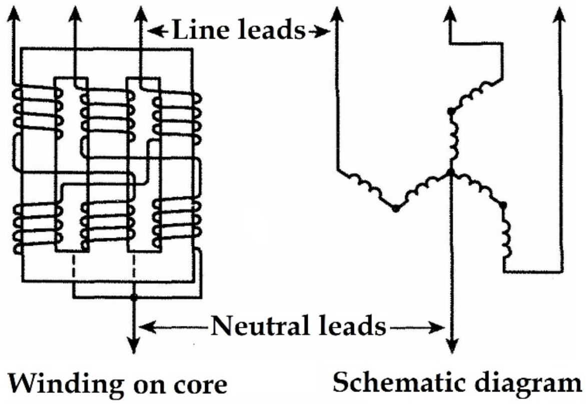


Figure 3 - Zigzag three-phase grounding transformer

Example of how to calculate the proper size grounding transformer:

Transformer kVA $= \frac{\text{VxI}}{1000}$, where

V = phase-to-neutral voltage = 2,400 volts, and

I = rated ground fault current = 25 amperes.

Minimum size grounding transformer = 60 kVA

Transformer banks connected wye on the primary side and supplied power from a resistance-grounded circuit **shall not** have the primary neutral grounded. Such a configuration as shown in Figure 5 would provide the circuit with two neutrals (one resistance grounded and one solidly grounded) and would effectively short circuit the grounding resistor.

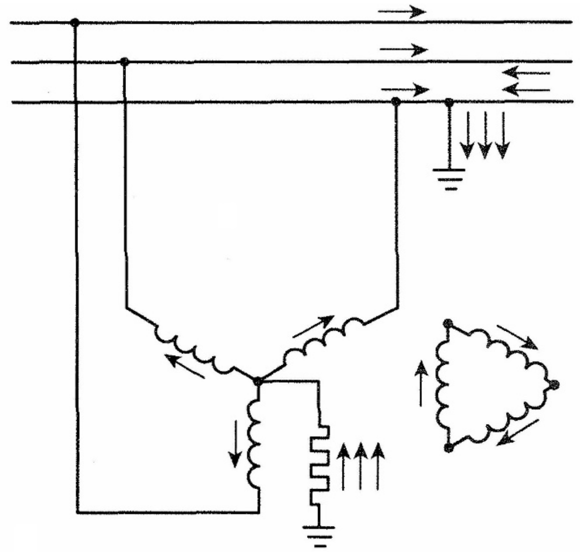


Figure 4 - Connections and current distribution in a wye-delta grounding transformer

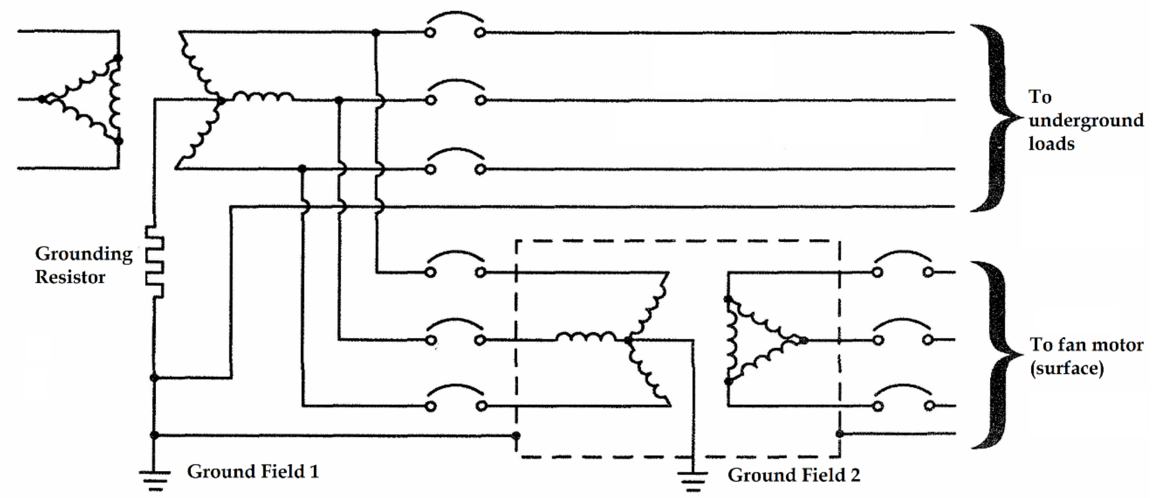
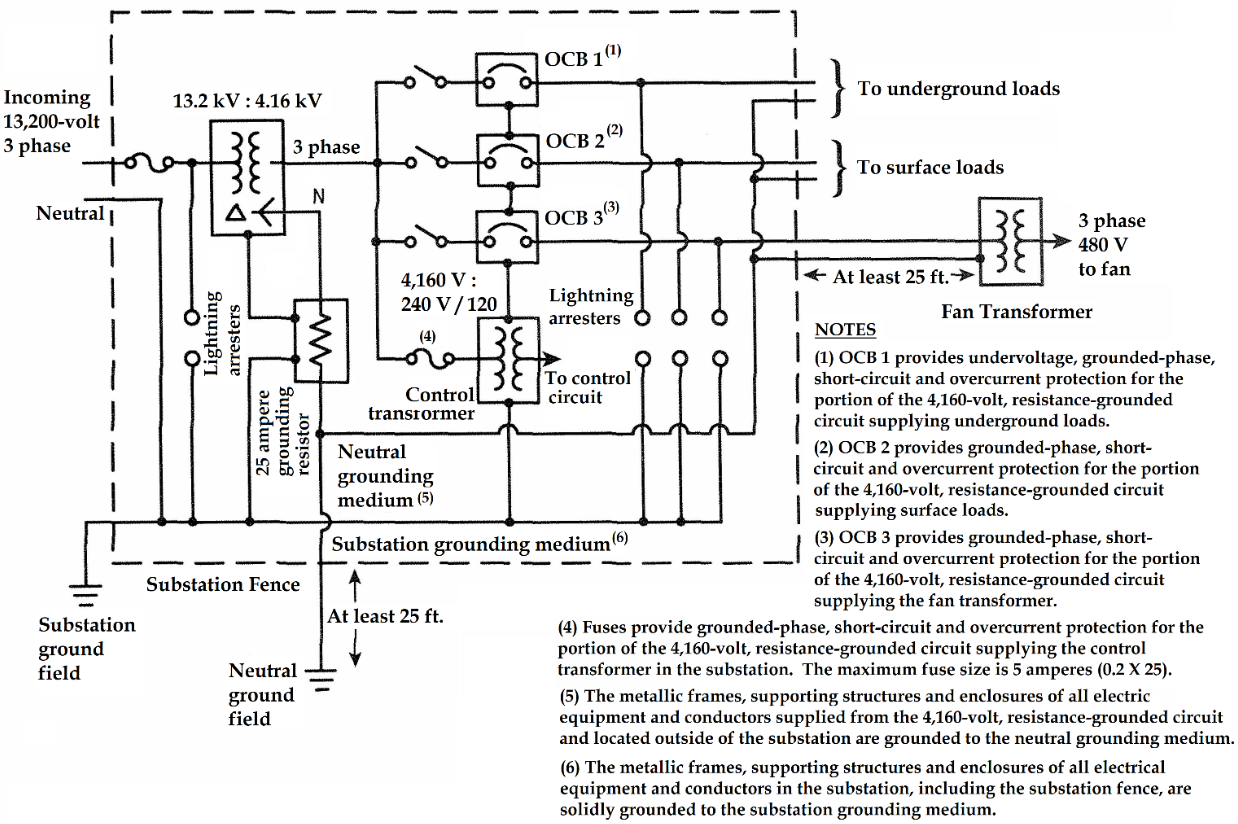


Figure 5 - An ***unacceptable*** *ground fault configuration. This system will not comply since fault current will flow through the second neutral (connected to ground field 2), effectively shorting out the grounding resistor during fault conditions.*

D. Grounded Phase Protection in Resistance Grounded Systems

Inspectors should verify that all three-phase circuits of a resistance grounded system are protected against the harmful effects of a grounded phase in any circuit connected to the same transformer secondary. (See Figure 6.)



NOTES

(1) OCB 1 provides undervoltage, grounded-phase, short-circuit and overcurrent protection for the portion of the 4,160-volt, resistance-grounded circuit supplying underground loads.

(2) OCB 2 provides grounded-phase, short-circuit and overcurrent protection for the portion of the 4,160-volt, resistance-grounded circuit supplying surface loads.

(3) OCB 3 provides grounded-phase, short-circuit and overcurrent protection for the portion of the 4,160-volt, resistance-grounded circuit supplying the fan transformer.

(4) Fuses provide grounded-phase, short-circuit and overcurrent protection for the portion of the 4,160-volt, resistance-grounded circuit supplying the control transformer in the substation. The maximum fuse size is 5 amperes (0.2 X 25).

(5) The metallic frames, supporting structures and enclosures of all electric equipment and conductors supplied from the 4,160-volt, resistance-grounded circuit and located outside of the substation are grounded to the neutral grounding medium.

(6) The metallic frames, supporting structures and enclosures of all electrical equipment and conductors in the substation, including the substation fence, are solidly grounded to the substation grounding medium.

Figure 6 - One-line diagram showing grounding and grounded-phase requirements for a high-voltage resistance grounded circuit supplying both surface and underground loads at a coal mine.

E. Ground Check Monitor Test Procedures

High Voltage

Normally, testing of ground check circuits is necessary for determining compliance, except in instances where it is obvious that the ground check circuit is by-passed or otherwise obviously inoperative. Such testing can be time consuming and can cause unscheduled power interruptions; therefore, management should be consulted, and routine testing of ground check circuits should take place during idle shifts or idle periods when practicable.

Because of the shock hazards involved in testing ground check circuits in underground mines, the following test procedures shall be followed:

1. During routine electrical inspections, the ground check circuits shall be tested by opening the ground check conductor at the extreme (load) end of each branch circuit.

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

   If steps d., e., and f. actuated the ground check relay, the ground check circuit is in compliance. If the above steps did not actuate the ground check relay, part of the ground check current is probably flowing through a parallel path (earth) instead of through the grounding conductor in the high-voltage cable.

3. If opening the grounding conductor as outlined above did not actuate the ground check relay, perform the following steps:
   a. Determine the current rating of the neutral grounding resistor of the system.
   b. Determine the maximum allowable resistance in the grounding circuit that will not exceed a 100-volt drop in the grounding circuit:

$$\text{Allowable Resistance} = \frac{100 \text{ volts}}{\text{current rating of grounding resistor}}$$

$$= 15 \text{ amperes at } 6.67 \text{ ohms}$$
$$= 25 \text{ amperes at } 4 \text{ ohms}$$
$$= 50 \text{ amperes at } 2 \text{ ohms}$$

c. Increase the resistance of the ground check conductor by an amount equal to the allowable impedance. Example: If a 25 ampere grounding resistor is used, insert 4 ohms resistance in series with the ground check conductor.

d. Short out the test resistor and energize the ground check circuit.

e. Remove the shorting wire from the resistor. If the ground check relay actuates, the ground check circuit is in compliance with MSHA regulations. The amount of resistance specified in Step 3 does not take into account the impedance of the system grounding conductor. This impedance is usually small in a typical mine power system, and ignoring it will compensate for possible measurement inaccuracies such as meter tolerances and voltage variations.

Low- and Medium-Voltage

If opening the grounding conductor opens the circuit breaker, the performance requirements of the ground check circuit are satisfied. If the device does not trip the circuit breaker when the ground wire is broken, perform the following steps:

1. Determine the current rating of the neutral grounding resistor of the system.
2. Determine the maximum allowable resistance in the grounding circuit that will not exceed a 40-volt drop in the grounding circuit:

$$\text{Allowable Resistance} = \frac{\text{40 volts}}{\text{current rating of grounding resistor}}$$

$$\begin{aligned} &= \text{5 amperes-8 ohms} \\ &= \text{10 amperes-4 ohms} \\ &= \text{15 amperes-2.7 ohms} \\ &= \text{25 amperes-1.6 ohms} \end{aligned}$$

To compensate for voltage variations, instrument error, and other measurement inaccuracies, the value of allowable resistance shall be multiplied by 125 percent to determine the actual amount of resistance to be inserted in the ground check conductor. Insert the resistor in series with the ground check conductor, place a shorting jumper across the resistor, and energize the ground check circuit. Remove the shorting jumper. If the circuit breaker opens when the jumper is removed, the performance requirements for the ground check circuit are satisfied.

When an arc suppression device is installed in a power center, the ground check circuit should be connected on the machine side of the device. Monitoring through an arc suppression device preloads the device and reduces its effectiveness in suppressing intermachine arcing and may also cause false tripping of the ground check circuit.

F. Lightning Arrester Ground Fields

Lightning arrester ground fields shall be maintained with as low a resistance to earth as possible, preferably less than 5 ohms and never more than 25 ohms. The separation of lightning arrester ground fields from neutral ground fields prevents lightning surges from being transmitted to the neutral ground field where they could momentarily energize the frames of equipment grounded to the neutral ground field. (See Figures 7 and 8.)

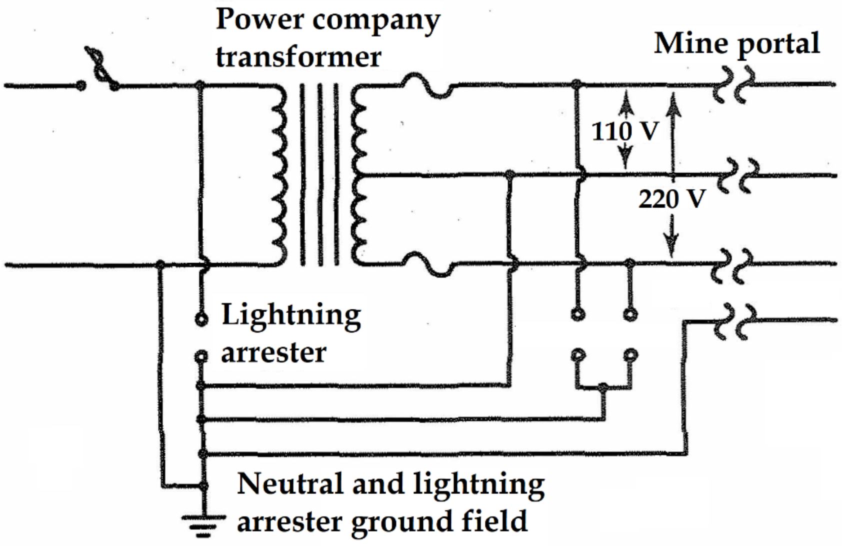


*Figure 7 - **Unacceptable** lightning arresters for single-phase circuits. Single-phase circuits, such as the one shown above, are not acceptable to supply power to underground loads since the neutral and lightning arrester grounds are not separated by at least 25 feet.*

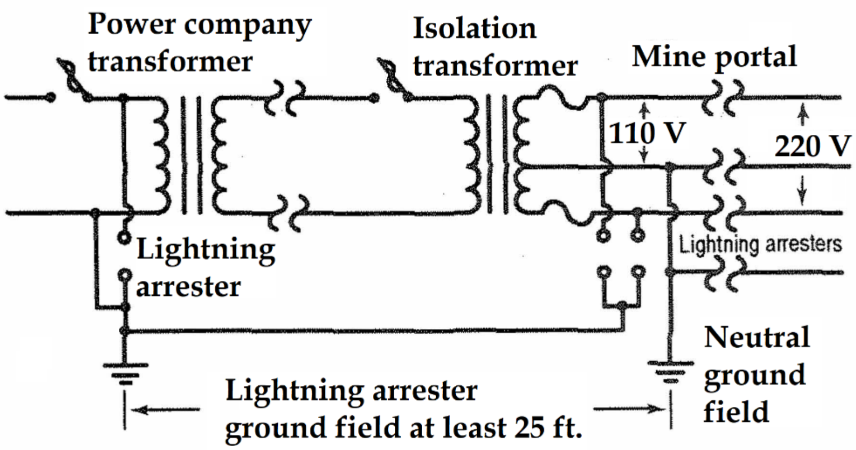


*Figure 8 - **Acceptable** lightning arresters for single-phase circuits. This circuit, with an isolation transformer installed, is acceptable since the neutral and lightning arrester grounds are separated by at least 25 feet.*

G. Silicon Diode Grounding Test Procedures

Diode grounding of equipment is not acceptable on direct-current systems which have both the positive and negative polarities ungrounded. Two suggested procedures for testing silicon diode grounding circuits, as required weekly by 30 CFR 75.512, are as follows:

1. Running Test. (Suitable precautions should be exercised during this test to avoid the danger of electrical shock.)
    a. Start the pump motor on the machine being tested. Using a resistance, such as a resistance type DC welder set to a low amperage, pass current from the ungrounded source 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 if the ground trip relay is operating as it should.
    b. Reverse the trailing cable connections. Extreme caution shall be used during this step because the frame of the machine will become energized if the grounding diode is shorted. Check to make certain that the frame is not energized to verify that the grounding diode is functioning as it should. If the frame is found to be energized, proceed to test 2 (voltmeter test).
    c. If the frame is not energized, attempt to start the machine. The machine will not start with the trailing cable connected in reverse if the polarizing diode is operative and properly connected in the control circuit.
2. Voltmeter test for rubber-tired equipment.

    When silicon diodes are used for frame grounding of off-track, direct-current powered equipment, the diode grounding circuit shall be maintained in such manner that not more than .005 amperes of current can flow from the ungrounded power conductor to the equipment frame when the polarity of the trailing cable is inadvertently reversed. The procedure for determining if diodes will pass more than .005 amperes of leakage current is as follows:

    a. Reverse the trailing cable connections.
    b. Connect a suitable multimeter in shunt to a 1,000 ohm resistor as shown in Figure 9.
    c. Measure the voltage across the 1,000 ohm resistor using the multimeter.

$$\text{Diode Leakage Current (in amperes)} = \frac{\text{voltage across resistor}}{\text{1,000 ohms}}$$

    d. A voltage reading in excess of 5 volts will indicate that the diode under test is passing excessive reverse current and must be replaced.

e. Inspectors should familiarize themselves with the above testing procedures so that they will be able to determine whether the proper weekly tests are being conducted. During electrical inspections, inspectors should be present while a representative number of diode grounding circuits are being tested.

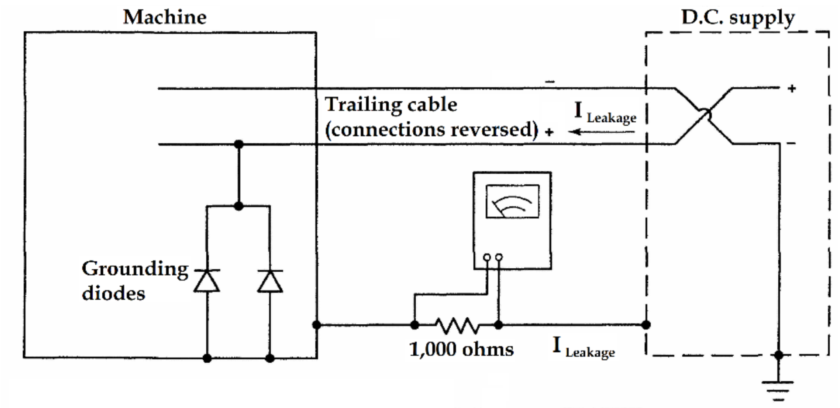


Figure 9 - Testing silicon diodes for leakage current.

H. Metal Battery Connector Housings

Metal Battery trays shall be effectively grounded to the battery charger frame during charging. Technical Support's Mine Electrical Systems Division conducted tests on two-pole battery connectors to evaluate the effectiveness of the electrical connection between the connector housings as the means of grounding the battery trays. These tests indicate that the tolerance fit between the male and female connector housings does not provide an effective electrical connection, particularly when the connectors are contaminated with water, rock dust, or mud.

In view of these test results, enforcement personnel shall not accept the use of the tolerance fit between male and female connection housings to ground battery trays to the battery charger frame during charging. Section 75.703 also requires that metal battery connector housings be effectively grounded to the battery charger frame during charging. Consequently, mine operators must also make provisions to effectively ground metal battery connector housings during charging. The grounding requirements for two-pole battery connectors and battery trays are summarized in Figure 10.

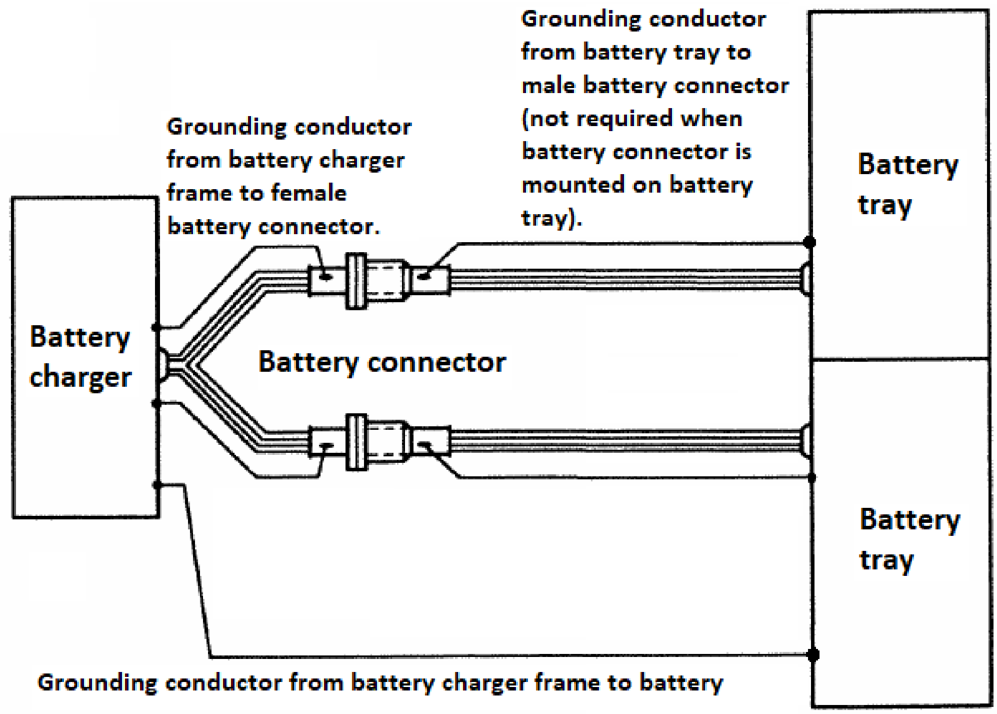


Figure 10 - Battery connector tray grounding requirements when two-pole battery connectors are used.

I. Testing of Grounding Systems in Metal and Nonmetal Mines

30 CFR 56.12028 and 57.12028 require periodic testing of equipment grounding conductors, ground electrode conductors, and grounding electrodes/ground fields. PPM Volume IV provides significant guidance on the testing of grounding systems and should be consulted by inspectors in making enforcement decisions.

Equipment Grounding Conductors and Ground Electrode Conductors

Periodic tests of grounding conductors must demonstrate that the conductors are intact and that, where distribution systems are grounded, the resistance is low enough to facilitate operation of overcurrent or ground fault protective devices. In most cases, a simple calculation can determine the expected current flow in the event of a ground fault.

$$\text{Ground Fault Current} = \frac{\text{Phase to Ground Voltage}}{\text{Ground Wire Resistance}}$$

Furthermore, many circuits encountered will be protected by circuit breakers or other devices that have time overcurrent characteristics (thermal circuit breakers, time delay fuses, etc.). These devices may require many multiples of their rated current to trip quickly enough to protect personnel from the harmful effects of ground faults.

Grounding Electrodes and Ground Fields

Periodic testing of grounding electrodes and ground fields must demonstrate that a low resistance connection to earth is established and maintained. 30 CFR does not specify a maximum acceptable value for resistance to earth, but there are several consensus publications that can provide guidance on acceptable values. The National Electrical Code specifies a maximum value of 25 ohms for a single driven rod electrode, and IEEE Standard 142-1972 recommends a value of 5 ohms for a typical substation ground field.

CHAPTER 3 - CABLE INSULATION, PROTECTION, AND SPLICING

A. General

The outer jacket of a cable is intended to protect the internal conductors from cuts, abrasion, moisture, etc., and must be intact for the cable to be fully protected. Electrical cables must have outer jackets that are suitable for the environment in which they are used.

Inspectors should verify that cables exposed to direct sunlight have an outer jacket that is resistant to the damaging effects of ultraviolet light. Inspectors should also verify that cables installed or used outdoors are of a type suited for wet locations (SOW, SOOW, etc.). Cables supplying power to dredges, floating pond pumps, and similar equipment must be suitable for submersion in water.

B. Outer Jacket or Insulation Damage in Cables

Underground Mines

Inspectors should take appropriate enforcement action under 30 CFR 57.12004 or 75.517 when they observe insulation or outer jacket damage that is not located in a splice. Inspectors should specify one of the following in the citation:

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

When inspectors observe damaged outer jackets or conductor insulation in cable splices, appropriate enforcement action should be taken under 30 CFR 57.12013, 75.514, 75.603, or 75.604.

Surface Mines

Inspectors should take enforcement action under 30 CFR 56.12004, 56.12030, or 77.502 when they observe cable insulation or outer jacket damage that is not located in a splice.

Damaged splices in cables at surface metal and nonmetal mines should be cited under 30 CFR 56.12013. Damaged splices in surface coal mines should be cited under 77.602 for trailing cables, and 77.502 for all other cables.

C. Trailing Cables

Mechanical Protection

Citations involving trailing cables should include a description of any damage that has been caused by mobile equipment or any practice that is causing damage, such as improper anchorage or routing. Inspectors should ensure that trailing cables are placed where they will not be run over by mobile equipment. This can be accomplished by hanging cables with suitable hangers, or covering cables with substantial bridges where equipment crossing is unavoidable.

Evaluation of Permanent Splices in Trailing Cables – Metal and Nonmetal Mines, Surface Coal Mines, and Surface Areas of Underground Coal Mines

The following is intended as a general guide for evaluation of trailing cable splices and failure to comply with any of these requirements should be cited under the applicable section of 30 CFR.

1. Each power conductor shall be joined by suitable mechanical connections (30 CFR 56.12013, 57.12013, or 77.504).
2. Each power conductor shall be reinsulated to the same degree of insulation as the power conductors in the cable (30 CFR 56.12013, 57.12013, or 77.601).
3. Semi-conducting tape, where provided, shall be replaced over each power conductor and shall be continuous across the splice (30 CFR 56.12030, 57.12030, or 77.804(b)).
4. Metallic shielding, where provided, shall be replaced around each power conductor and shall be continuous across the splice (30 CFR 56.12030, 57.12030, or 77.804(b)).
5. All grounding conductors shall be individually spliced (30 CFR 56.12013, 57.12013, or 77.804(b)).
6. The ground check conductor shall be spliced and reinsulated to the same degree of insulation as the ground check conductor in the cable (30 CFR 56.12013, 57.12013, or 77.601).
7. An outer jacket comparable to the original shall be placed over the completed splice (30 CFR 56.12013, 57.12013, or 77.602(c)).
8. Splices made in low-voltage trailing cables shall provide continuity of all components (30CFR 56.12030, 57.12030, or 77.906).

Evaluation of Permanent Splices Made with Flame Resistant Materials

30 CFR 75.604(d) requires permanent splices in trailing cables in underground coal mines to be made using splice kits that are approved or accepted by MSHA as flame resistant. 30 CFR Part 57, Subpart T requires that cables approved or accepted by MSHA as flame resistant be used in specific categories of underground metal and nonmetal mines. Where approved or accepted flame resistant cables are required, permanent splices must be made with components that preserve the flame resistance of the original cable.

An acceptance number will generally be provided on the outer sleeve or jacket of permanent splices. The MSHA Approval and Certification Center tests permanent splice kits and materials for the sole purpose of determining the flame-resistant qualities. An approval number will generally be provided on the outer sleeve or jacket of permanent splices. Approval numbers will be of the form 07-KA#######. Legacy markings include ###, 7K-######, SC-###, SC-###/#, 7K-SC-######, and 7K-SK-#####. Each approval number is unique and will not be the same number as the cable. Splice kits approved by MSHA shall be applied without substitution or alteration of parts in order to duplicate the conditions under which the materials were tested and approved.

The inspector must determine whether the splice is effectively insulated and sealed so as to exclude moisture. Particular attention should be given to splices that are made with lapped tape to insure compliance.

Particular attention shall be given to the manner in which permanent splices are made in trailing cables. Manufacturers' specifications on all permanent splice kits emphasize the importance of proper cable preparation, which includes cleaning the cable to insure that the splice sleeves bond to the conductors and cable jackets. Inspectors shall take advantage of every opportunity to observe cable splicing underground to insure that the completed splice will not constitute a fire or shock hazard to miners.

If cables are not well cleaned, the splice's outer jacket will have a tendency to slip on the cable and fray at the ends. These frayed ends will catch on protruding objects such as ribs, chunks of coal, and cable reel guides and cause further damage to the cable. Permanent splices that are damaged to the extent that water is not excluded or splices that have an outer jacket that is not bonded in its entirety to the original cable are not acceptable.

D. Continuity of Shielding in Cable Splices

Electrical inspectors shall check a representative number of splices in shielded cables with a suitable non-contact voltage detector (TIC tracer), using the following precautions.

1. Appropriately rated electrical gloves shall be worn at all times while using the instrument.
2. The sensing element shall only be held close to the splice and under no circumstances allowed to contact the splice.
3. If the instrument indicates the presence of voltage, there is a high probability that the shielding is either missing or not continuous.

Non-contact voltage detectors must be suitable for the voltage and the location of the cable being tested. If tests are performed in areas where permissibility requirements apply, then the detector must be approved by MSHA.

Non-contact voltage detectors principally work by exploiting the effect of capacitance inherent to electrical circuits. When an alternating electric field is present, the inherent capacitance results in a small current flow, with this current flow being proportional to field strength. Non-contact voltage detectors sense this current flow and give an indication (usually audible) that voltage is present. It should be noted that this type of detector requires the presence of a changing electric field for proper operation; therefore it will not detect the presence of voltage in direct current circuits.

CHAPTER 4 – OVERCURRENT PROTECTION

A. General

Electrical specialists and inspectors should understand and use the following terms when discussing electrical circuit protection:

1. Overcurrent – Overcurrent is a general term that describes any current in excess of the rated current of equipment or the ampacity of a conductor. Overcurrent may result from overload, short circuit, or ground fault.
2. Overload – Overload refers to the operation of equipment in excess of normal, full load rating, or of a conductor in excess of rated ampacity that, when it persists for a sufficient length of time, would cause damage or dangerous overheating. A fault, such as a short circuit or ground fault, is not an overload.
3. Short Circuit – A short circuit is a type of fault that involves an abnormal connection of relatively low impedance between two points of different potential. This type of fault typically results in very high levels of current.
4. Ground Fault - Ground fault, sometimes referred to as "grounded phase", is a type of fault involving an abnormal connection between a normal current-carrying conductor and ground or a metallic object connected to ground.
5. Ampacity – Ampacity describes the maximum current, in amperes, that a conductor can carry continuously under the conditions of use without exceeding its temperature rating.

B. Cable and Conductor Ampacity

The general purpose of 30 CFR 56.12004, 57.12004, 75.513, and 77.503 is to ensure that conductors at all mines are of sufficient ampacity to prevent overheating and insulation damage during normal use. Specific methods for ampacity determination will vary based on the type of mine and the characteristics of the conductor or cable.

Metal and Nonmetal Mines

30 CFR Parts 56 and 57 do not specify the method for determining the minimum ampacity of conductors used in metal and nonmetal mines. The National Electrical Code (NEC) provides the most commonly accepted method for ampacity determination and may be used as a guide when evaluating conductors for proper ampacity. Ampacity tables published by the Insulated Cable Engineers Association (ICEA) may be used to determine proper ampacity for power cables manufactured in accordance with ICEA standards. Cables supplying power to permissible equipment must have

ampacities consistent with the requirements of 30 CFR Part 18 or the appropriate schedule of the Bureau of Mines.

Underground Coal Mines

Inspectors shall use ICEA tables when evaluating the ampacity of the power cables manufactured in accordance with ICEA standards (see PPM Volume V regarding 75.513). The ampacity of trailing cables supplying power to permissible equipment shall comply with the requirements of 30 CFR Part 18 or the appropriate Bureau of Mines schedule. All other power cables used in underground coal mines shall comply with the ampacity requirements of the 1968 edition of the NEC.

Surface Coal Mines, Facilities, and Surface Areas of Underground Mines

The ampacity of surface power cables and conductors, other than trailing cables, must generally be in accordance with the provisions of the 1968 NEC. However, other methods of determining ampacity may be used if they provide an equivalent or greater level of safety (see PPM Volume V regarding 77.503). The ampacity of surface trailing cables must be in accordance with ICEA standards.

Power Cables Manufactured in Accordance with ICEA Standards

Appendix A contains ampacity tables derived from ICEA publications for several types of power cables commonly used in mining. These tables may be used in evaluating the ampacity of cables manufactured in accordance with ICEA standards. Portable cords such as types S, SO, ST, STO, SJ, SJO, SJT, SJTO, and portable power cables and mine power cables such as types G, G-GC, W, SH, SHG-GC, SHD, SHE-GC, MP, and MP-GC are considered to be manufactured in accordance with ICEA standards.

C. Conductor Ampacity for Motor Circuits

The following discussion and example use the method of conductor selection prescribed in Article 430 of the 1968 NEC. The basic method is substantially the same in subsequent editions of the NEC. However, in applications where the 1968 edition is not explicitly required by 30 CFR or program policy, other editions may be more appropriate.

Basic NEC Method for Motor Circuit Conductors

Conductors supplying a single motor shall have an ampacity not less than 125 percent of the full load current rating of the motor (NEC Section 430-22). The ampacity of conductors for a motor used for short-time, intermittent, periodic, or varying duty shall be calculated according to NEC Table 430-22(a).

Conductors supplying two or more motors shall have an ampacity equal to the sum of the full-load current ratings of all the motors, plus 25 percent of the highest rated motor in the group (NEC Section 430-24). Where one or more motors of a group of motors are used for short-time, intermittent, periodic, or varying duty, the ampacity of the conductors shall be calculated according to NEC Section 430-24(a), (b), and (c).

NEC Section 430-6(a) requires that the values of motor full-load current used in calculating motor circuit conductor ampacity and motor circuit overcurrent (short circuit) protection be taken from NEC Tables 430-147 through 430-150 rather than the motor nameplate. However, the full-load current on the motor nameplate shall be used in determining motor overload protection.

NEC ampacity tables are included in Appendix B and NEC values for motor full-load current are included in Appendix C of this handbook.

Example Using the Basic NEC Method for Motor Circuit Conductors

Determine the proper size of copper feeder conductors and branch conductors (75˚C insulation) for the motor circuit depicted in Figure 11. For this example, assume an ambient temperature of 30˚C and that the motors are supplied by conductors which are not manufactured in accordance with ICEA standards.

1. Determine the full load current of each motor using Table C-3 in Appendix C.
    - Branch Circuit #1 (60 horsepower motor) = 77 amperes
    - Branch Circuit #2 (60 horsepower motor) = 77 amperes
    - Branch Circuit #3 (25 horsepower motor) = 34 amperes

2. Determine the ampacity required for each branch circuit.
    - Minimum ampacity for Branch Circuit #1 = 1.25 X 77 = 96.25 amperes
    - Minimum ampacity for Branch Circuit #2 = 1.25 X 77 = 96.25 amperes
    - Minimum ampacity for Branch Circuit #3 = 1.25 X 34 = 42.5 amperes

3. Determine the minimum size of the conductors for each branch circuit by selecting the value in Table B-1 that is equal to or greater than the minimum required ampacity.
    - Minimum size conductors for Branch Circuit #1 = #3 AWG
    - Minimum size conductors for Branch Circuit #2 = #3 AWG
    - Minimum size conductors for Branch Circuit #3 = #8 AWG

4. Determine the minimum ampacity of the feeder conductors supplying power to the three branch circuits.
    - Minimum feeder ampacity = (1.25 X 77) + 77 + 34 = 207.25 amperes

5. Determine the minimum size of the feeder conductors by selecting the value in Table B-1 that is equal to or greater than the minimum required ampacity.
    - Minimum size feeder conductors = #4/0 AWG

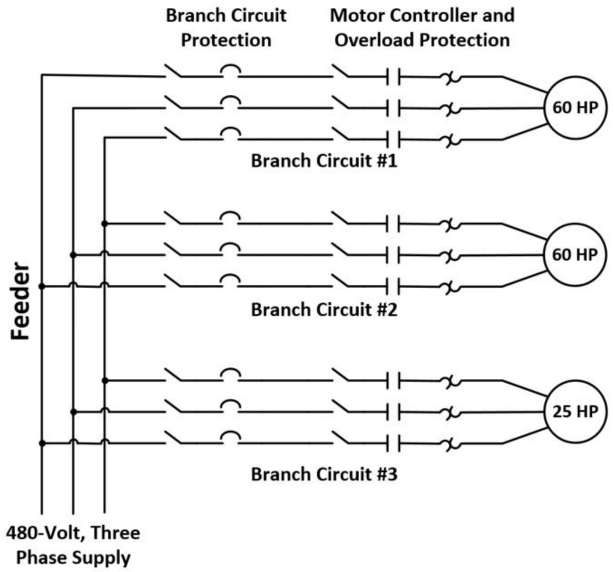


Figure 11 – Motor Circuit

D. General Overcurrent Protection for Electric Equipment and Circuits

The purpose of overcurrent protection is to prevent damage to conductors and equipment caused by excessive current. Excessive heat generated by overloads or short circuits in equipment and conductors can cause mine fires, which pose a grave danger to miners, especially in underground mines. Insulation damage caused by overcurrents can subject miners to electrical shock hazards. The sudden release of energy in arc flashes caused by short circuits can cause severe burns. Therefore, it is essential that inspectors ensure that appropriate overcurrent protection is provided for equipment and circuits at all mines.

Specific methods for determining proper overcurrent protection will vary depending on the characteristics of the circuit and the type of mine.

Metal and Nonmetal Mines

30 CFR Parts 56 and 57 do not specify the method for determining proper fuse sizes or circuit breaker settings in metal and nonmetal mines. The National Electrical Code (NEC) provides the most commonly accepted method for determining proper overcurrent protection and may be used as a guide when evaluating circuit protection. Overcurrent protection for permissible equipment must be in accordance with the requirements of 30 CFR Part 18 or the appropriate Bureau of Mines schedule.

Coal Mines

30 CFR Parts 75 and 77 generally require overload and short circuit protective devices to conform to the requirements of the 1968 NEC. Overcurrent protection for permissible equipment must be in accordance with the requirements of 30 CFR Part 18 or the appropriate Bureau of Mines schedule.

Location of Overcurrent Protection

In general, short circuit protection shall be provided at the beginning of each feeder and branch line, unless an interrupting device located in the same circuit outby the beginning of the branch line will deenergize the circuit when a short circuit occurs. However, it is acceptable to connect branch circuit conductors directly to feeder conductors (feeder tap) if the feeder tap requirements of Article 240 of the NEC are strictly followed. Overload protection may be provided at the beginning or end of a branch line.

Direct Current Circuits

A fuse or an overcurrent trip unit of a circuit breaker shall be provided for each ungrounded power conductor. Therefore, for direct-current systems that are either ungrounded or in which a resistance grounded neutral point is provided, protective elements shall be provided for both positive and negative lines. This requirement necessitates the use of either a two-pole circuit breaker or a fuse in each polarity.

E. Overload and Short Circuit Protection for Motor Circuits

The following discussion and example use the method of motor short circuit and overload protection prescribed in Article 430 of the 1968 NEC. The basic method is substantially the same in subsequent editions of the NEC. However, in applications where the 1968 edition is not explicitly required by 30 CFR or program policy, other editions may be more appropriate.

The NEC requires that the full-load current listed on the motor nameplate be used when determining motor overload protection. However, when determining short circuit protection for motor circuits, the full-load current information from the tables found in NEC Article 430 must be used. NEC full-load current information is included in Appendix C.

Overload Protection in Motor Circuits

The detailed requirements for motor overload protection are found in Section 430-32 of the NEC. A typical motor used in mining, having a service factor of 1.15 and a temperature rise not greater than 40˚C, would require overload protection set at not more than 125 percent of the full-load current. However, many other factors must be considered when determining overload protection, so inspectors should carefully review the requirements of Section 430-32 when evaluating motor overload protection.

Overload protection in motor circuits is typically provided by heater type or electronic devices installed as part of a motor controller. Some overload charts published by manufacturing companies include the motor full-load current factor (115 percent to 140 percent) in their charts. If this is the case, inspectors should select the proper overload device or setting directly from the manufacturer's charts using the motor nameplate full-load current rating.

Short Circuit Protection in Motor Circuits

An adjustable instantaneous trip circuit breaker may be installed at the beginning of a motor branch circuit to provide short circuit and grounded phase protection. Such circuit breaker should be set just above the starting current of the motor and not more than 700 percent of the full-load current of the motor. However, if the motor will not start, the setting may be increased to a value that will allow the motor to start, provided that such setting does not exceed 1300 percent of the full-load current of the motor (NEC Section 430-52).

Time-limit type circuit breakers and fuses (where permitted by 30 CFR) may also be used to provide short circuit protection for motor branch circuits. The rating of these devices depends on the type and code letter of the motor, but is typically 250 percent of the full-load current of the motor. Time-limit circuit breakers or fuses with higher ratings may be used to permit motor starting, as long as the rating does not exceed 400 percent of the full-load current of the motor (NEC Section 430-52).

If the setting or rating of the branch short circuit protective device determined using the preceding method does not correspond to one of the standard ratings listed in Section 240-5(b) of the NEC, then the next higher standard rating may be used.

Short circuit protection for a motor feeder circuit shall not be greater than the rating or setting of the branch short circuit protective device for the largest motor in the group plus the sum of the full-load currents of all other motors in the group (NEC Section 430-62).

The tables in Appendix D to this handbook show the minimum wire size, the maximum instantaneous branch circuit protection, and the maximum overload (running) protection for common motors and branch circuit conductors encountered in mining.

Example Using the Basic NEC Method for Motor Circuit Protection

Determine the proper short circuit and overload (running) protection for the motor circuit depicted in Figure 12. For this example, assume that branch and feeder circuit protection will be provided by molded case circuit breakers with adjustable instantaneous trip units and that all motors have a temperature rise of less than 40˚C.

1. Using the full-load current from Table C-3 in Appendix C, determine the short circuit protection for each branch circuit.
    - Short circuit protection for Branch Circuit #1 = 7 X 40 = 280 amperes (next higher standard rating is 300 amperes)
    - Short circuit protection for Branch Circuit #2 = 7 X 52 = 364 amperes (next higher standard rating is 400 amperes)
    - Short circuit protection for Branch Circuit #3 = 7 X 34 = 238 amperes (next higher standard rating is 250 amperes)

2. Determine the short circuit protection for the feeder circuit.
    - Feeder short circuit protection = 400 + 40 + 34 = 474 amperes

3. Using the full-load current from the motor nameplate, determine the overload protection for each branch circuit.
    - Overload protection for Branch Circuit #1 = 36 X 1.25 = 45 amperes
    - Overload protection for Branch Circuit #2 = 47 X 1.25 = 58.75 amperes
    - Overload protection for Branch Circuit #3 = 31 X 1.25 = 38.75 amperes

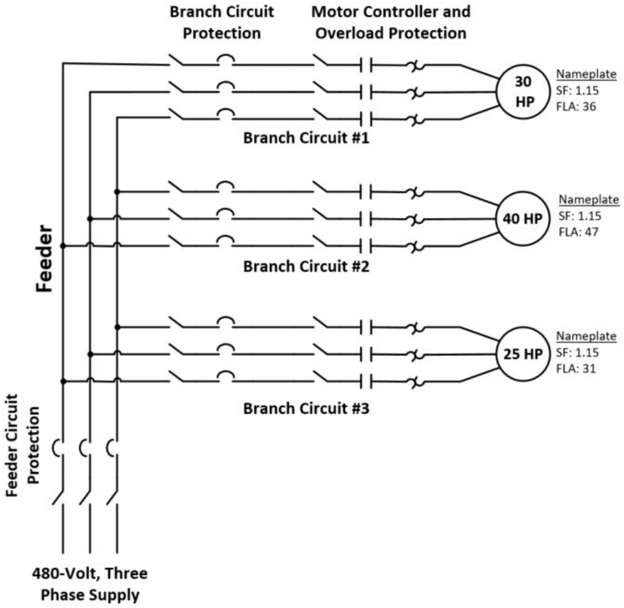


Figure 12 – Motor Circuit

F. Short Circuit Protection for Trailing Cables

The specific requirements for trailing cable short circuit protection vary depending on the type of mine and whether the cable is located underground or on the surface of the mine. However, each trailing cable shall be protected by a suitable circuit breaker or fuse (where permitted) that can detect and interrupt the current resulting from a short circuit at any point between the short circuit protective device and the machine to which the cable is supplying power.

Fuses or circuit breakers must be capable of safely interrupting the current when a fault occurs at any point in the protected circuit. The voltage rating of a circuit breaker or fuse must not be less than the maximum voltage of the circuit in which it is installed.

In instances where a molded case circuit breaker is used to provide short circuit protection for a DC trailing cable, it may be necessary to connect two or more poles of the circuit breaker in series in order to achieve the required voltage rating. When two or more poles of a molded case circuit breaker are connected in series, the poles of the circuit breaker should be wired so the bottom of one pole is connected to the top of the next pole, to decrease the voltage stresses between adjacent poles when the circuit breaker opens under load. It is not acceptable to connect fuses in series to achieve a higher voltage rating.

In mines and locations where 30 CFR does not specify a particular value or setting for trailing cable short circuit protection, a citation should only be issued if no short circuit protection is provided, or if a short circuit analysis of the system indicates that the protective device will not interrupt the current under all short circuit conditions.

G. Examples of Noncompliance

The following conditions are examples of noncompliant overcurrent protection:

a) failure to provide either a fuse or automatic circuit breaker to protect wiring and equipment against overloads and short circuits,

b) fuse ratings or circuit breaker settings that are greater than those required by 30 CFR,

c) defective circuit breakers or line starters, and

d) improper overload devices in line starters.

CHAPTER 5 – HIGH VOLTAGE CIRCUIT BREAKERS AND SUBSTATIONS

A. Safety Precautions for High Voltage Testing

Electrical specialists shall take the following precautions during the testing of high-voltage circuit breakers and associated equipment in substations.

1. Only electrical specialists who have received special training and who are experienced in testing high-voltage circuits and equipment shall be assigned to high-voltage substation testing. Such persons shall demonstrate their competence and knowledge to the district's electrical supervisor before performing high-voltage testing, unless under the direct supervision of the supervisor.
2. There shall be a minimum of two qualified electrical specialists present, and both shall actively participate in the testing at all times. No activities shall begin without the complete concurrence of both persons, who shall remain in full view of each other or have confirmed two-way communication during the entire testing process. Electrical specialists shall, as far as practicable, be responsible for each other's safety.
3. Electrical specialists shall wear properly rated high-voltage gloves while energizing, deenergizing, or grounding high-voltage circuits or equipment. Electrical specialists shall wear properly rated rubber boots or overshoes in areas where step potentials may exist.
4. Electrical specialists shall discuss the nature of the testing to be performed with mine officials and all other persons participating in the tests, and determine the voltage level and purpose of all incoming and outgoing circuits.
5. Electrical specialists shall make a visual observation of the substation before entering the substation gate. During this observation, those people involved in the testing shall familiarize themselves with the layout of the substation and the high voltage circuits. Each person shall identify the high-voltage disconnects and determine how the substation can be property deenergized. Inspectors shall check for proper clearance of live unguarded high-voltage parts and lines; proper grounding of substation equipment, fences, and gates; heating of the grounding resistor; blown fuses; damaged lightning arresters; and other unusual or abnormal conditions.
6. Remember, when testing high-voltage equipment:
   - Be sure you understand the circuit!
   - Take your time – don't rush!
   - Take a second look!

- Watch out for your co-workers!
- If it isn't grounded, it isn't dead!

Safeguards for Testing Totally Enclosed Substations

Totally enclosed substations are often used to provide power to small mines. These substations are completely enclosed in a metal box and contain transformers, resistors, circuit breakers, relays, and switches. Clearance and visibility inside these enclosed units are extremely limited; therefore, the following safeguards are needed to safely test this type of equipment:

1. Disconnect and ground all incoming high-voltage conductors before any testing is performed by using the following procedure:
   a. Remove all loads on the substation by opening the appropriate circuit breaker(s) and load breaking device(s).
   b. Deenergize the incoming high-voltage conductors by opening overhead visible disconnects or gang-operated air break (GOAB) switches. Lockout and tag the handles of GOAB switches. Use a non-contact voltage detector to verify that the power is deenergized on the load side of the opened disconnecting devices.
   c. Ground the high-voltage conductors on the load side of the opened disconnecting devices to the station ground using properly rated grounding clamps. Connect the grounding leads to the station ground before they are connected to the high-voltage conductors.
2. Connect the frame of the test generator directly to the substation ground.
3. Ground all outgoing high-voltage conductors unless such conductors are otherwise protected against accidental contact.
4. Be especially cautious around high-voltage capacitors, which can store a lethal charge. Capacitors are normally equipped with internal resistors to bleed off the charge in approximately 5 minutes. After allowing at least 5 minutes for the charge to bleed off, ground the capacitor terminals to the station ground.
5. Ground the primary terminals of the control transformer.
6. Disconnect the control circuit from the control transformer secondary terminals and make sure it is completely isolated to prevent feedback into the system. Ground the control transformer secondary terminals to the station ground. The control circuit leads should be marked for proper reconnection after the testing is completed.
7. Connect the generator leads to the substation control circuit leads and ensure that the connection is insulated to prevent accidental contact with the control

transformer secondary terminals. Persons shall not be present within the substation while any circuit is energized.

8. Conduct the necessary tests. Advise appropriate mine officials of any major adjustments needed to substation equipment.
9. Disconnect the generator leads from the substation control leads and reconnect the substation control leads to the control transformer.
10. Remove the grounding conductors from the primary and secondary terminals of the control transformer.
11. Remove the grounding conductors from the high-voltage capacitors.
12. Remove the grounding conductors from the outgoing high voltage conductors and reconnect the outgoing high voltage conductors.
13. Remove the grounding conductor from the station ground to the generator frame.
14. Remove grounding leads from the incoming high-voltage conductors.
15. Close the overhead disconnect switches or GOAB switches.
16. Reenergize the substation.

Safeguards for Testing Open-Type Substations

Whenever practicable, the entire substation shall be deenergized prior to any testing within an open-type high-voltage substation. In this case, the safeguards for testing totally enclosed substations shall be followed. When it is not practicable to deenergize an entire open-type substation for testing, the following safeguards shall be followed:

1. Disconnect and ground all high-voltage conductors associated with the circuit to be tested. Disconnect and ground all other high-voltage conductors that are not guarded or are physically isolated by elevation of at least 8.5 feet above the work space in the substation. Use the following procedure to disconnect and ground high voltage conductors:
    a. Remove all loads on high-voltage conductors by opening the appropriate circuit breaker(s) and load breaking device(s).
    b. Deenergize the incoming high-voltage conductors by opening overhead visible disconnects or gang-operated air break (GOAB) switches. Lockout and tag the handles of GOAB switches. Use a non-contact voltage detector to verify the power is deenergized on the load side of the opened disconnecting devices.
2. Ground the high-voltage conductors on the load side of the opened disconnecting devices to the station ground using properly rated grounding

clamps. Connect the grounding leads to the station ground before they are connected to the high-voltage conductors.

3. Connect the frame of the test generator directly to the substation ground.
4. Visibly disconnect all outgoing high-voltage conductors associated with the circuit under test. Ground all outgoing high-voltage conductors associated with the circuit under test, unless such conductors are otherwise protected against contact.
5. Be especially cautious around high-voltage capacitors, which can store a lethal charge. Capacitors are normally equipped with internal resistors to bleed off the charge in approximately 5 minutes. Unless high-voltage capacitors and the associated circuits are physically isolated by an elevation of at least 8.5 feet above the work space in the substation, disconnect all capacitors, wait at least 5 minutes for the charge to bleed off, and then use high voltage gloves and a hot stick to ground all circuits extending from the capacitors.
6. Open the primary disconnects for the control transformer. Ground the primary terminals of the control transformer to the station ground, unless both the control transformer and the control transformer primary circuits are physically isolated by an elevation of at least 8.5 feet above the work space in the substation.
7. Disconnect the control circuit from the control transformer secondary terminals. Ground the control transformer secondary terminals to the station ground, unless both the control transformer and the control transformer primary circuits are physically isolated by an elevation of at least 8.5 feet above the work space in the substation. The control circuit leads should be marked for proper reconnection after the testing is completed.
8. Connect the generator leads to the substation control circuit leads and ensure that the connection is insulated to prevent accidental contact with the control transformer secondary conductors.
9. Conduct the necessary tests. Advise appropriate mine officials of any major adjustments necessary to substation equipment.
10. Disconnect the generator leads from the substation control leads and reconnect the substation control leads to the control transformer secondary terminals.
11. Remove the grounding conductors from the primary bushings of the control transformer and close the primary disconnects for the control transformer.
12. Remove the grounding conductors from the high-voltage capacitors and reconnect the high-voltage capacitors.
13. Remove the grounding conductors from the outgoing high-voltage conductors and reconnect the outgoing high-voltage conductors.

14. Remove the grounding conductor from the station ground to the generator frame.
15. Remove the remaining grounding leads from the high-voltage conductors.
16. Close the overhead disconnect switches or GOAB switches.
17. Reenergize the substation.

B. Protection of High Voltage Circuits

High voltage circuit breakers used in mining applications are typically equipped with devices to provide protection against undervoltage, grounded phase, short circuit, and overload. The following information is provided to assist inspection personnel in the evaluation of these protective devices.

C. Undervoltage Protection

The principal purpose for undervoltage protection is to prevent automatic restarting of equipment when power is restored after an outage. Undervoltage protection can be provided by an undervoltage trip coil on the circuit breaker, or by an undervoltage relay or a ground-check relay connected into the circuit breaker trip circuit. When an undervoltage relay or ground-check relay is used to operate the shunt trip coil on a circuit breaker, a stored-energy tripping source must be provided (i.e., capacitor trip or battery trip) to ensure that the circuit breaker will trip during a power outage. The undervoltage relay may either be an induction or attraction type, and must trip the circuit breaker when the line voltage decreases to 40 percent of nominal or less when power is lost.

D. Grounded-Phase Protection

There are four common methods of accomplishing grounded-phase protection:

Direct Relaying

In this method, grounded-phase current is detected directly with a current transformer (CT) installed in the grounded neutral conductor. The current transformer must not be installed in the equipment grounding conductor (See Figure 13).

Example:
CT ratio – 50/5 or 10/1
Grounded-phase relay pickup – 1.0 ampere
Grounded-phase protection – 10 x 1.0 = 10.0 amperes

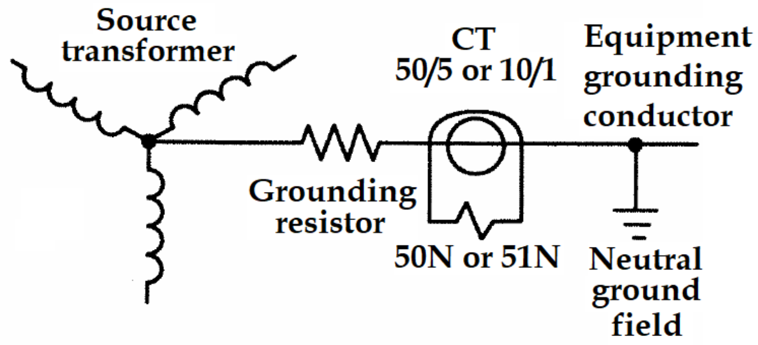


Figure 13. - Direct relaying to provide grounded-phase protection

Balance Flux Relaying

In this method, grounded-phase current is detected by a doughnut-type current transformer installed around the three phase conductors. The equipment grounding conductors (including conductor shields) must not be installed through the current transformer (See Figure 14).

Example:
CT ratio – 50/5 or 10/1
Grounded-phase relay pickup – 0.5 ampere
Grounded-phase protection – 10 x 0.5 = 5.0 amperes

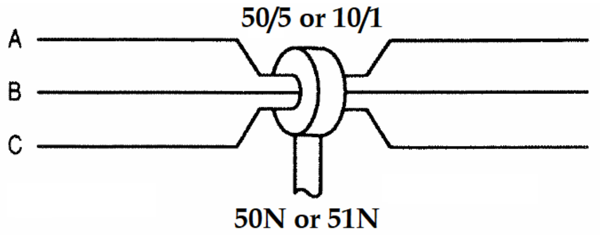


Figure 14. - Balanced flux relaying to provide grounded-phase protection.

Residual Trip Relaying

In this method, grounded-phase current is detected as the unbalance in the currents produced by the phase current transformers (See Figure 15.). This can also be accomplished in software on some electronic relays.

Example:
CT ratio – 100/5 or 20/1
Ground-phase relay pickup – 0.5 ampere
Grounded-phase protection – 20 x 0.5= 10.0 amperes

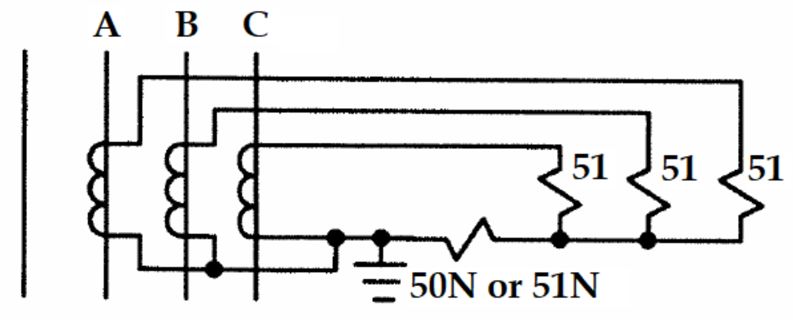


Figure 15. - Residual trip relaying to provide grounded-phase protection

Potential Relaying

In this method, grounded-phase current is detected as the voltage drop across the grounding resistor. (See Figure 16.) An advantage of this method over the three previous methods is that grounded-phase protection is still provided even if the grounding resistor is open. For this reason, potential relaying is often used to provide backup grounded-phase protection for resistance-grounded systems.

Example:
Potential transformer ratio – 7200/120 or 60/1
Overvoltage relay coil rating – 120 volts
Overvoltage relay tap (40% Grounded-phase protection) 60 x 120 x 40%= 2880 volts

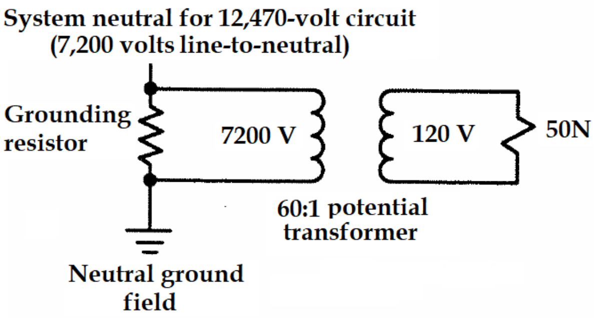


Figure 16. - Potential relaying to provide grounded-phase protection.

Where an ungrounded high-voltage circuit is accepted for use underground under the provisions of 30 CFR 75.802(b), the circuit must be provided with grounded-phase protection. (See Figure 17.)

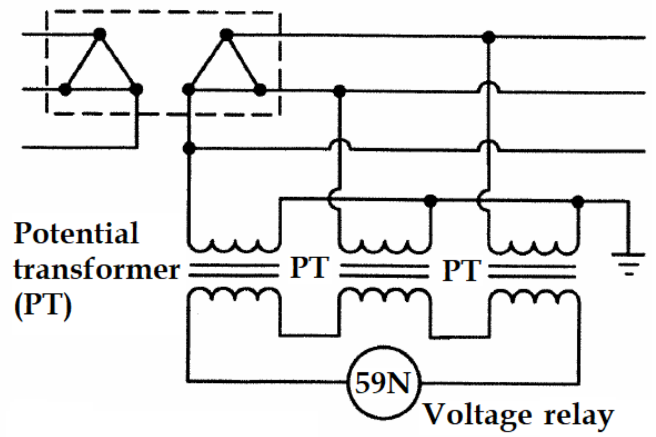


Figure 17. - Grounded-phase protection scheme for ungrounded systems.

E. Current Transformers and Relay Burden

There have been recent examples of hazards where high-voltage circuit breakers failed to trip on ground faults due to a mismatch of the current transformers and the grounded-phase relays. In several instances, the ratio of the current transformers was too high for the relays to operate. In other cases, the burden of the grounded-phase relay coil was too great, causing the current transformer to saturate below the relay's pickup.

Normally, current transformers are used to provide a common base current, usually 5 amperes, on the secondary for relaying ground faults and overcurrents. Current transformers obtain their rating based on their ability to produce a fixed ratio of the primary current in the secondary without saturating when connected to a given burden. When a current transformer saturates, the secondary current and voltage level off and are not directly proportional to the current in the primary, thus leading to relaying inaccuracies.

The voltage required to be produced in the current transformer to operate a given relay is the relay pickup current times the burden of the circuit. The burden is the impedance of the grounded-phase relay coil (or the grounded-phase relay coil in series with the overcurrent relay coil when the residual grounded-phase protection scheme is used), the current transformer secondary winding and the leads connecting the current transformer to the relay. A typical overcurrent relay burden range is 0.3 to 0.8 ohms, while a typical grounded-phase relay burden range is 18 to 22 ohms.

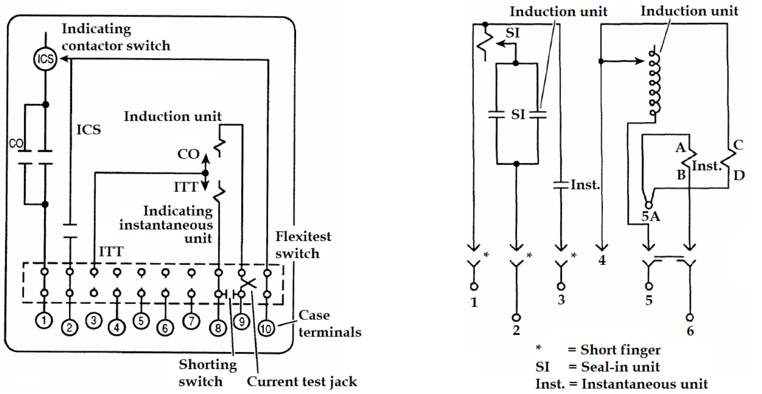
The voltage required to be produced by the current transformer to operate a given relay is the relay pickup current times the burden of the circuit. It then follows that a typical grounded-phase relay would require higher current transformer voltage output than a typical overcurrent relay for reliable relaying.

F. How to Calculate Short Circuit Protection

Short circuit protection can be provided by using the instantaneous units of overcurrent relays, or by using inverse-time overcurrent relays with minimal time dial settings. The pickup of the instantaneous unit of an overcurrent relay is independent of the pickup of the inverse-time unit and is determined by the position of the top of the screw on the instantaneous unit of most electromechanical relays and in the internal settings or dial settings of most electronic relays.

Example:
Current transformer ratio – 100/5 or 20/1
Instantaneous unit pickup – 20 amperes
Instantaneous setting – 20 x 20 = 400 amperes

G. How to Calculate Overcurrent Protection

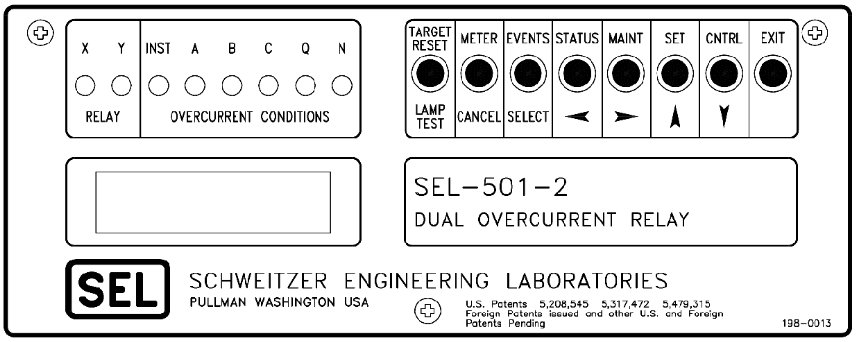


Westinghouse Type CO **GE Type IAC51B (front view)**

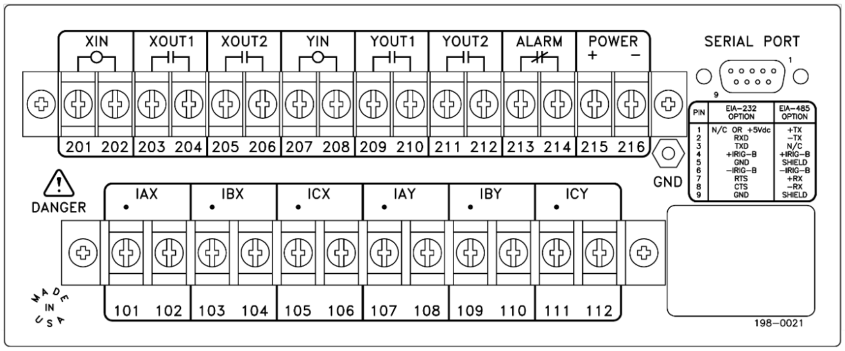
Figure 18. - Schematic diagrams of common electromechanical relays

Overcurrent protection is provided to protect conductors and conductor insulation from thermal damage due to excessive currents. The temperature rise of the conductor is proportional to the current squared, times the resistances 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 function of time and current, an inverse time current relay is used for overcurrent protection.

Two electromechanical relays commonly used in mining are the Westinghouse CO relay and the General Electric IAC relay (see Figure 18). A common electronic relay is the Schweitzer SEL 501 (see Figure 19).



Front View



Rear View

Figure 19 –SEL 501 electronic relay

To determine whether the overcurrent relays on a circuit breaker are properly adjusted, the following information is required:

1) the ratio of the current transformers;
2) the pickup current of the overcurrent relays; and
3) the ampacity of the high-voltage cable.

Some protective relays have optional settings or terminal connections which specify the secondary current rating (usually 1 ampere or 5 amperes) of the current transformer(s) driving the relay. Electrical specialists should verify that this optional setting matches the secondary current rating of the current transformer(s) connected to the relay.

The current transformer ratio is normally found on the current transformer nameplate. Some current transformers have tapped secondary windings, and the tap wires are usually routed to a terminal block to permit selection of different turns ratios. Care should be taken to ensure that the locations of the tap screws do not short out the secondary of the current transformers. The different turns ratios based on typical taps for a 600/5 current transformer are provided in the following table.

Typical Current Transformer Tap Block

Nominal Primary Rating – 600 amperes
Nominal Secondary Rating – 5 amperes

Taps	Turns Ratio
BC	10/1
AB	20/1
AC	30/1
DE	40/1
CD	50/1
BD	60/1
AD	80/1
CE	90/1
BE	100/1
AE	120/1

The protection provided by the overcurrent relay is determined by the setting on the relay and the ratio of the current transformer driving the relay. If the current transformer has a tapped secondary winding, then the turns ratio can be selected as depicted in Figures 20, 21, 22, and 23.

The 1968 NEC, Article 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. Therefore, the ratio of the current transformers and the tap setting of the overcurrent relays must be selected so that the circuit breaker trip current does not exceed 125 percent of the cable ampacity.

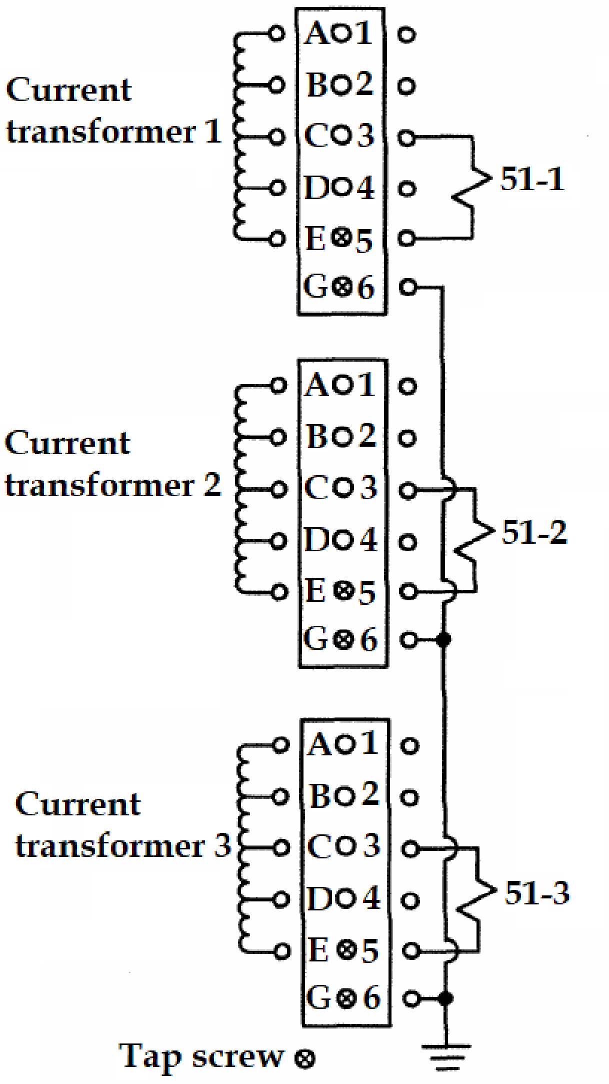


Figure 20. - Terminals C and E are connected to the relay coils. From the table, the ratio of primary to secondary current in the transformers is 90/1. Notice that the tap screws short E to G which effectively grounds one side of the transformer secondaries.

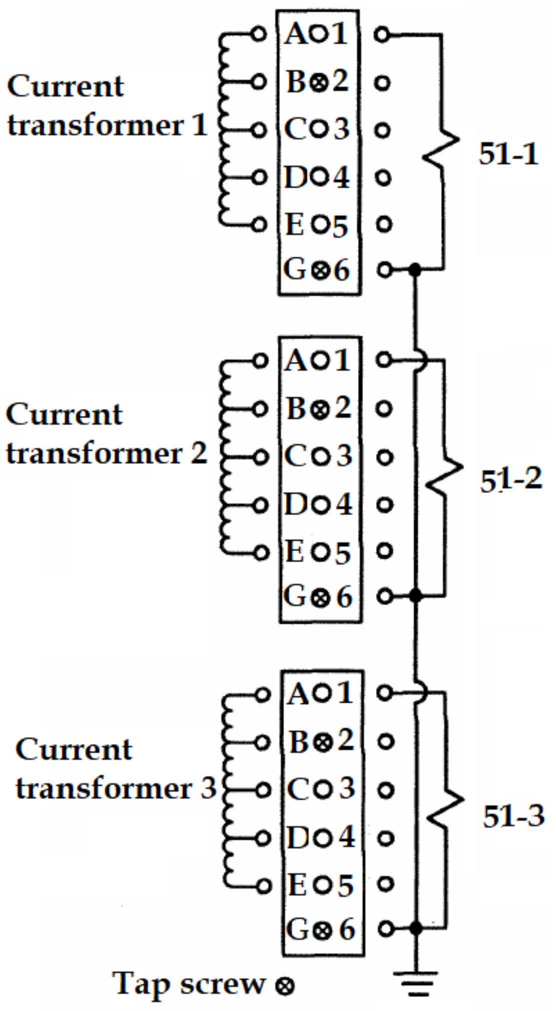


Figure 21. - The tap screws short B to G, so the relay is across terminals AB. From the table, the ratio of primary to secondary current in the transformer is 20/1. With this wiring method, any turns ratio can be obtained by changing only one wire and the tap screw.

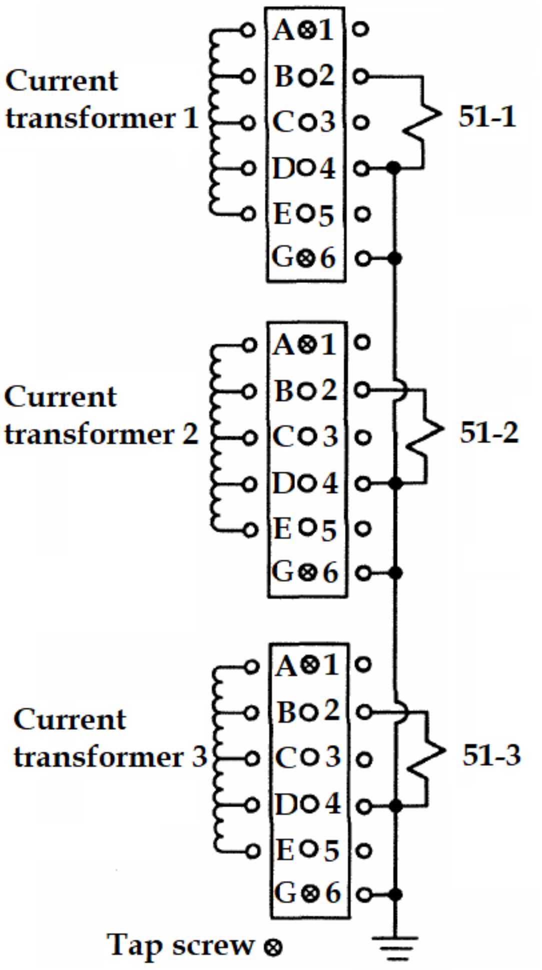


Figure 22. - Terminals D and G are connected together and to one side of the relay coils. Terminal B is connected to the other side of the relay coils. However, the tap screws short A to G and thus effectively short out the current transformer secondaries.

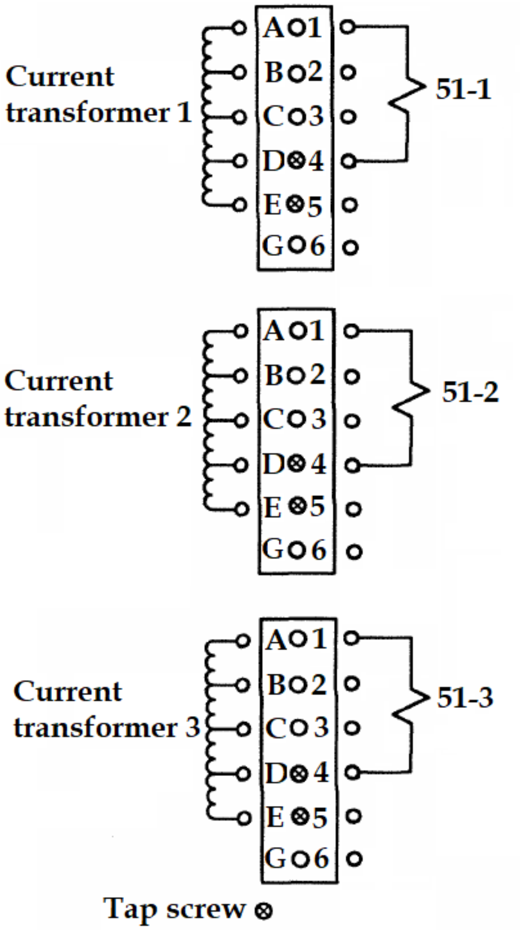


Figure 23. - Terminals A and D are connected to the relay coils. However, since D and E are shorted and they are both terminals of the current transformer secondaries, the current transformers are effectively shorted. Any two or more terminals of a current transformer that are shorted will short out the entire secondary. Also, the current transformer secondaries are not properly grounded.

Example:

Select a current transformer ratio and relay setting to provide proper overcurrent protection for a #3/0 AWG, 3-conductor, 15kV, copper mine power cable with 90˚C insulation. Assume an ambient temperature of 20˚C.

1. The cable ampacity based on Table A-6 in Appendix A is 334 amperes.
2. The maximum allowable trip current is 334 x125% = 418 amperes.
3. The following current transformer ratio and relay setting will provide the required protection.

- current transformer ratio = 80/1
- Relay setting = 5 amperes
- Trip current = 5 x 80 = 400 amperes

4. If an electromechanical relay (Westinghouse Type CO or General Electric Type IAC) is being used, the screw tap on the front of the relay should be set on 5.
5. If a SEL 501-2 electronic relay is being used, the settings can be viewed using the following procedure.
    - Press the EXIT button until you are at the main screen.
    - Press the SET button and navigate left or right using the STATUS (left) or MAINT (right) buttons to select which relay you want to observe (X or Y). Press the SELECT button to confirm.
    - Navigate to the right to select the SHOW option and then press SELECT.
    - Use the SET (up) and CNTRL (down) buttons to navigate to the phase time overcurrent pickup parameter (51PP). The 51PP parameter should be set to 5.
    - Navigate up or down to view the current transformer ratio (CTR). The CTR parameter should be set to 80.

The preceding example is greatly simplified and does not apply to all of the different types of relays used in the mining industry. Electrical specialists should consult the documentation provided by the relay manufacturer for detailed instructions on how to verify or set specific parameters.

All protective relay contacts must be properly connected into the circuit breaker control circuit for the circuit breaker to function properly. Figures 24 depicts a typical circuit breaker control circuit.

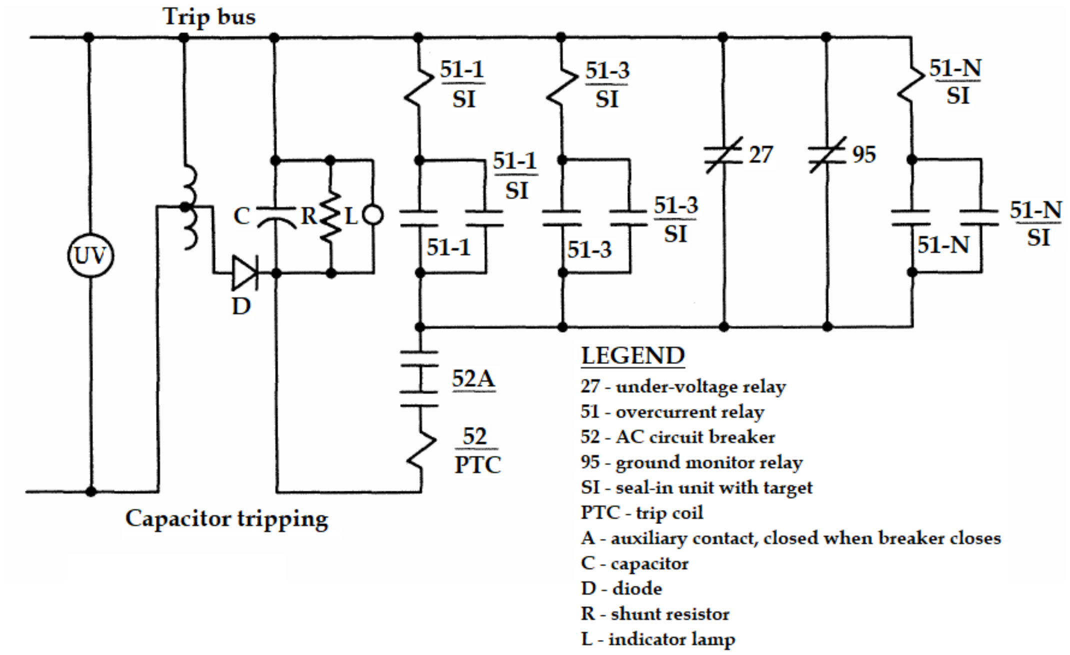


Figure 24 - Typical AC control circuit for high-voltage circuit breaker

H. Testing Methods

The following methods are commonly used to test overcurrent and grounded phase protection for high voltage circuit breakers:

Primary Injection Test

This test method involves passing sufficient current to cause the circuit breaker to trip through at least two current transformers associated with the circuit breaker. Since this method requires that test connections be made on high-voltage conductors or terminals, the stringent safety procedures listed at the beginning of this chapter must be followed. This method simultaneously tests the current transformer ratio, the current transformer secondary wiring, the operation and calibration of the relays, and the operation of the circuit breaker tripping circuit.

Secondary Injection Test

This test method involves passing sufficient current to cause the circuit breaker to trip through at least two of the protective relays associated with the circuit breaker. This method simultaneously tests the operation and calibration of the relays and the operation of the circuit breaker trip circuit.

Activation Test

This test method involves manually activating at least two of the protective relays associated with the circuit breaker. This method tests the operation of the circuit breaker trip circuit.

I. Surface Transformer Station Guidelines

The interior of transformer stations, both in a fenced enclosure or transformer vault or house, must be designed to prevent any person from inadvertently contacting energized parts. Therefore, all wiring and other exposed energized parts must be installed at least 8 feet above the work area or walking surface. Otherwise the wiring, transformer bushings, or other exposed parts must be properly guarded to prevent accidental contact. Conductor insulation is not acceptable in lieu of guarding in high-voltage installations. Shielded cable maybe considered as guarding.

CHAPTER 6 - PERMISSIBILITY

A. Inspection Procedures

Caution: An inspector shall not examine a machine for permissibility until the trailing cable supplying power to the machine has been de-energized. The inspector will request the disconnection of power and proper lock out/tag out before the permissibility examination.

The inspector should observe the following items when inspecting permissible-type electric face equipment:

1. Note the type and capacity of trailing cable short circuit protection and overload protection. Check settings of circuit breakers and the rating of dual element fuses and verify that these devices conform to 30 CFR 75.601-1, 75.601-3, and 57.12003.
2. Check the type, size, electrical rating, length, and condition of trailing cables, and determine if the cable is flame resistant. The inspector can achieve this by noting the embossed acceptance number. The embossed acceptance number will reference the Bureau of Mines (USBM), MESA, or MSHA.
3. Examine the trailing cable strain clamps for effectiveness and insulation at the entrance to the machine, at each end of a cable leading to a separately detached component, and where a cable exits a battery enclosure.
4. Examine the equipment for broken rollers and sheaves, and determine if they are working properly. Ensure that metallic rollers and sheaves are insulated from the trailing cable. Ungrounded metallic rollers and sheaves shall be isolated to prevent contact by workers.
5. Examine the flame-resistant material on spooling devices and cable reels. The MSHA Approval and Certification Center (A&CC) maintains a list of accepted insulating materials for cable reels. Inspectors should contact A&CC for guidance when questions arise regarding cable reel insulation.
6. Examine the cable reels closely for holes burned into the collector ring compartment and for sharp edges on flanges that may damage the cable.
7. Check to ensure that cable reels maintain positive tension on the trailing cable during reeling and unreeling. Such tension should only be high enough to prevent the machine from running over its own cable. Hydraulic pressure controlling cable reel tension should be adjusted to the manufacturer’s specifications.

8. Check to ensure that a temporary splice is not within 25 feet of a machine, except on equipment using a cable reel.
9. Check each explosion-proof enclosure for a USBM, MESA, or MSHA certification plate or marking.
10. Check to see if the powered dust collector system on bolting machines is identified by a USBM, MESA, or MSHA approval number.
11. Check the plane flange joints of explosion-proof compartments for excessive openings. (Example: contactor compartments, controller boxes, resistor cases.)
12. Check the step flange joints for excessive openings. (Example: motor end bells, some switches.)
13. Check the diametrical clearance of push rods for excessive clearance. (Examples: control stations, foot switches.)
14. Check for missing bolts or lock washers on covers of explosion-proof enclosures.
15. Check the breathers in explosion-proof enclosures for cleanliness.
16. Check the inspection covers on motors and contactor compartments for damaged flame paths. Replace damaged screw-type covers.
17. Check all screw-type inspection covers. Verify a means to secure against loosening.
18. Check for burned holes in explosion-proof enclosures, especially on rubber-tired cutting machines and roof bolters.
19. Examine all cable packing glands for tightness. Verify a means to secure against loosening. Verify that the packing gland is tight against the packing material, has a minimum 3 thread engagement, and still has a clearance of not less than (minimum) 1/8 inch between the packing glands and the stuffing boxes.
20. Verify that cables between machine components are either flame-resistant, as noted by the presence of a USBM, MESA, or MSHA acceptance number on the outer jacket, or are totally enclosed within a flame-resistant hose conduit or other flame-resistant material.
21. Verify that cables between machine components are clamped in place to prevent undue movement and do not contain splices.
22. Examine the condition of mechanical protection for cables, such as guards, conduit hose, and check for missing or loose hose clamps.
23. Check the headlights for loose or broken lenses, loose packing glands, missing or broken lock wires, and improper assembly.
24. Verify that all headlights, resistance boxes, connection boxes, and other electric components are solidly attached to the frame of the machine. Verify proper means of grounded light fixtures.

25. Verify proper working condition of all circuit breakers and other overload protection devices. (Opening the main circuit interrupting device on-board the machine should de-energize the complete machine, except the methane monitor and control conductors.)
26. Verify that guards and “safe-off” devices on buttons are maintained in proper working order.
27. Check the equipment for any accumulations of loose coal, float coal dust, or other combustible materials.
28. Determine if the machine is properly frame grounded or provided with equivalent protection. If separate grounding conductors are used to ground the frames of direct-current-powered equipment, the return and frame ground conductors must be connected to the rail or grounded power conductor by separate clamps. Diode grounding is acceptable only for direct current-powered equipment receiving power from direct-current systems having one polarity permanently grounded.
29. Verify that all hose conduits used on machines approved under schedule 2G is flame resistant by noting if the USBM, MESA, or MSHA acceptance number is molded or stamped on the hose.
30. Verify that all mobile equipment that travels more than 2.5 miles per hour is provided with a functioning audible warning device.
31. Verify that all mobile machines are provided with functioning parking brakes, unless design of the driving mechanism will preclude accidental movement of the machine when parked.
32. Verify that a headlight and red light reflecting material are provided on both front and rear of each mobile transportation unit that travels at a speed greater than 2.5 miles per hour.
33. Check to ensure that machines with nameplate ratings from 661 to 1000 volts have a shielded trailing cable or, where a cable reel is employed, the cable insulation is rated at 2000 volts or more.
34. Check to ensure that battery covers are secured in a closed position.
35. Check battery plugs and receptacles for padlocks or equivalent, explosion proof properties, or interlock design.
36. Check to ensure that fastenings used for joints on explosion-proof enclosures are not used for attaching nonessential parts or for making electrical connections.
37. Check to ensure that ground wires and pilot wires are separately terminated.
38. Check to ensure that trailing cable is minimum 4 AWG for direct-current haulage units, minimum 6 AWG for alternating-current haulage units, and minimum 14

AWG for face equipment. Size 14 AWG cables shall be constructed with heavy jackets.

39. Check to ensure moving parts are guarded to prevent personal injury.
40. Check to ensure that unused cable guard entrances are closed with metal plugs secured by spot-welding, brazing, or equivalent.
41. Check to ensure that headlight/luminaire lenses are held in place with sealing compounds (RTV, epoxy, etc.) using the following procedures:
    a. Finger tap around the perimeter of each lens to determine if the lens bond is intact. If the lens hits the internal metal fastenings (stopper), the bond between the lens and the housing has failed, and the headlight/luminaire needs to be replaced.
    b. If there is no evidence of the lens hitting the stopper, nominal thumb pressure should be applied around the perimeter of each lens while inspecting the bond between the lens and housing. Any separation in the bond between the sealing compound and the lens or between the sealing compound and the housing indicates a failure in the bond, and the headlight/luminaire needs to be replaced.
    c. If any of the sealing compound is missing from between the lens and the housing, the headlight/luminaire needs to be replaced.
    d. Under no circumstances should feeler gages, screw drivers, or pointed objects be used to inspect for separation in the bond since this practice could adversely affect the original integrity of the bond.
42. Citations involving permissibility should include the approval number of the machine on which the permissibility deficiency is observed. If an approval plate is missing on a machine that is being cited for a permissibility deficiency, the citation should note the absence of the permissibility plate.
43. Check for any unauthorized changes in permissible equipment.

B. Field Modification Procedures

The proposed modification shall comply with the applicable requirements of Part 18 (Schedule 2G), Subpart B (Construction and Design Requirements), and shall not substantially alter the basic functional design that was originally approved for the machine.

The electrical inspector shall inspect each machine listed in an application for a field modification.

The inspection of the machine shall include the following elements:

1. a general inspection of the entire machine to determine if it is being operated in a permissible condition;
2. a detailed inspection of all components and cables listed in the modification bill of materials (components added) and the original machine components that were involved in the modification, including all certified components such as head lights, push-button stations, diffuser fan motors, and the original machine components such as the starter of control station; and
3. a written field modification report giving a description of the modification

C. Field Modification Reports

The field modification report should consist of a memorandum containing the following:

1. identification of the applicant;
2. a description of the machine;
3. a brief statement that the changes were completed:
    a. as submitted by the operator, or
    b. as submitted by the operator except for ... (identify the changes that were not in agreement with the operator's application); and
4. the finished report should close with the following signed statement:

    The modifications described above have been personally examined by me and are judged not to increase the fire and explosion hazards involved in the operation of this machine in gassy or dusty mines.

    Signed: ________________________________ *Date:* ________________
    (Electrical Specialist)
    Reviewed by: ____________________________ *Date:* ________________
    (Supervisor)

D. District Field Changes

The following field changes may be made without sending an application letter to the Approval and Certification Center (A&CC), without processing a written field change report and acceptance letter, and without a visual inspection at the time of installation. However, mine operators are required to notify the district office in writing that these changes will be or have been made in accordance with 30 CFR Part 18. A copy of all notifications shall be maintained in the appropriate mine file. Inspection of such changes shall be made as soon as practicable, but never later than one month after receipt of the notification. A record of such inspection shall be maintained in the electronic mine file (EMF):

1. Installation of methane monitors.
2. Field modifications duplicating the original equipment manufacturer's approved design of an essentially identical machine. For example, a shuttle car with approval number 2G-2000 may have been originally approved without an emergency stop switch. Subsequently, the manufacturer filed an application and received approval from A&CC to install a certain switch X/P-1000 on all new shuttle cars, which would bear approval number 2G-2000-1, or the first extension of the original approval. An operator owning a shuttle car with the original approval 2G-2000 and wishing to add an emergency stop switch should contact the manufacturer. If the switch X/P-1000 is installed as approved under the first extension, it is not necessary to notify A&CC.
3. Field modifications duplicating previously accepted field changes for machines of the same type and with the same approval number, at the same mine or under the direction of the same maintenance supervisor(s).
4. Installation of silicon diode grounding equipment in existing explosion-proof enclosures on machines, provided no cable gland openings are made in the machine and provided the installation meets the requirements of 30 CFR 75.703-3(d), which refers to voltage and current ratings and overcurrent protection for such devices.
5. Removal of non-safety-related electrical components from a machine. For example, the relocation of the headlight resistors to the machine control box would eliminate the headlight resistor enclosures. All unused cable entrances must be plugged, and plugs must be secured in place in accordance with 30 CFR Part 18.29 (c).
6. Changes that are made within explosion proof enclosures and do not conflict with permissibility requirements. Circuit breakers, overload relays, and fuse protection must be retained as originally approved.
7. Change of trailing cables on machines with cable reels having external trailing cable connections from flat to round, or vice versa from a G to GC (G – Ground, GC – Ground Check) or vice versa, and changes to a larger cable size, provided the insulated trailing cable strain clamp still grips the cable properly and provided no changes are made to the entrance glands.
8. Change of trailing cable from G to GC or vice versa on machines with direct cable entry into an enclosure. Changes in the physical cable size (outside diameter) require cable entry modification and a field change application and report. Cables that are the same size electrically may not have the same outside diameters due to insulation differences.

9. Change in the length of the trailing cable to the maximum allowable, as shown in Table 9 of 30 CFR, Part 18, if previously approved for that machine.
10. Installation of illumination systems that have been accepted under a Statement of Test and Evaluation (STE), or the interchanging of alternate lighting fixtures of STE lighting systems that have been found by A&CC to have similar photometric patterns.
11. Installation of any electrical components of a braking system required by 30 CFR 75.523-3.
12. Insulation of cable reels or battery box lids with material that has been accepted by MSHA. The A&CC maintains a list of accepted insulating materials for cable reels and battery box covers. Inspectors should contact A&CC for guidance when questions arise regarding cable reel or battery box cover insulation.
13. Interchanging of certified headlights that meet Part 18 requirements and are designed to accept the same size cable. Replacement lamps in these headlights must be in conformance with the headlight certification.
14. Substitution of a certified battery and tray assembly for an assembly on an existing machine
15. Relocation of electrical components on a machine, provided the interconnecting cables meet the requirements of 30 CFR 18.36(b).

NOTE: Headlights and cables between machine components must be protected from damage by location and/or guarding

CHAPTER 7 – GENERAL

A. Guidelines for Using the National Electrical Code

The National Electrical Code (NEC) is the most widely accepted standard for the installation of electrical wiring and equipment in the United States. 30 CFR refers to the NEC in the following standards:

56.12045 – overhead power lines
57.12045 – overhead power lines
56.12048 – communication conductors on power poles
57.12048 – communication conductors on power poles
75.513-1 – conductor size
75.518-1 – short circuit and overload protection
75.900-2(d) – trip units for circuit breakers
77.503-1 – conductor size
77.506-1 – short circuit and overload protection
77.516 – installation of electrical equipment and wiring
77.901(c) – circuits supplying stationary equipment

The references in 30 CFR Parts 56 and 57 do not specify the edition of the NEC. However, the 1984 NEC was available to the public when these 30 CFR standards became effective in 1985. Therefore, the latest edition of the NEC that inspectors should use when enforcing 30 CFR 56.12045, 57.12045, 56.12048, and 57.12048 is the 1984 NEC. There are several additional standards in 30 CFR Parts 56 and 57 for which the NEC can be used as a technical reference to support enforcement decisions. When the NEC is used for this purpose, the edition of the NEC in effect at the time of installation is the most appropriate one to use.

Most of the NEC references found in 30 CFR Parts 75 and 77 specify the 1968 edition explicitly. When the 1968 NEC is specified in a 30 CFR standard, inspectors must base enforcement actions on the 1968 NEC. 30 CFR 77.516 and 77.901(c) do not specify a particular edition to be used, but past guidance from the Solicitor's Office indicates that enforcement actions involving these sections should be based on the 1968 NEC as well.

In cases where 30 CFR and the NEC present conflicting information, the requirements of 30 CFR shall take precedence.

B. Guidelines for Determining Portable, Mobile, and Stationary Electric Equipment Located on the Surface

If electric equipment is capable of moving under its own power, the equipment is considered to be mobile equipment. Mobile electric equipment includes stripping shovels, draglines, drills, coal loaders, etc. If the equipment is occasionally moved or could be readily moved from one place to another, the equipment is considered to be portable equipment. Portable electric equipment also generally receives its power through a portable cable (trailing cable) or portable cord, and should not be moved while energized. All equipment that is not wired in a permanent manner shall be considered to be portable, and also may be mobile.

Examples of portable electric equipment include electric hand tools, electric pumps, and air compressors that receive power through a portable cable and are designed to be moved from place to place in a strip pit; electric welders which receive power through a portable cable and are designed to be moved from place to place in preparation plant or onboard a unit of mobile electric equipment, etc.; and a skid mounted substation that receives its power through a portable cable.

If the electric equipment is installed in a fixed location and is wired in a permanent manner, the equipment is considered stationary equipment. Examples of stationary electric equipment include pendant type lighting fixtures, even though the fixtures are suspended from the ceiling by a portable cord; electric welders that are installed in fixed locations and wired using permanent wiring methods; electric pumps installed in fixed locations in preparation plants and wired using permanent wiring methods; and skid mounted substations that are installed and grounded in a permanent manner and receive power directly from overhead power lines.

Certain electric equipment such as rail-mounted and pivoting coal stackers, traveling shop cranes, and small traveling hoists on I beams, cannot be strictly classified as portable, mobile, or stationary. For the purposes of circuit protection and system and enclosure grounding, such equipment shall be considered stationary.

C. Guidelines for Permitting Non-Explosion-Proof Air Heating Units in Hazardous Locations on the Surface

In accordance with Article 90-4 of the 1968 NEC, MSHA permit the use of non-explosion-proof heaters for heating large hazardous locations. These types of heaters may be used only if the following minimum safety precautions are followed:

1. The heating unit shall be located outside the hazardous location and connected by at least 5 feet of horizontal air ducting between the heating unit and the

hazardous location. Air ducting systems shall be designed to prevent accumulations of dust within the air ducts.

2. Flame heating units shall contain a sealed combustion chamber with no direct flame or combustion gases entering the air stream to the hazardous location. Electric heating elements may be placed directly in the airstreams.
3. Air in the ducting shall not exceed 150˚ C at the point where the ducting enters the hazardous location.
4. All makeup air for the heating unit shall be from a clean outside location and filtered to keep out dust, leaves, and other combustible material. For example, the air will not be obtained from an outside dusty location nor will any air be recirculated from the hazardous location to the heating unit.
5. The heater shall have a purge cycle that provides at least six air changes in the heating unit and in that portion of the air duct between the heating unit and the hazardous location, before ignition of flame or energization of electric heating elements.
6. A spark arrester must be provided in the air duct within 18 inches outside of the point where the air duct connects to the heating unit. The spark arrester shall be made of a substantial heat and corrosion resistant metal with 1/8-inch or smaller openings. The spark arrester installation shall facilitate frequent inspection and necessary replacement.
7. A back draft damper shall be provided within 18 inches outside of where the air duct enters the hazardous location. The, damper must close automatically when there is no forward air movement in the air duct.
8. If the area being heated is a Class I hazardous location[1], a gas vent of at least two square inches must be provided at the highest point in the ducting between the heating unit and the hazardous location. This vent may be provided with a damper that closes when the heater is in operation. However, this damper must open automatically when there is no forward air movement in the duct.

Each installation must be inspected by MSHA before it is accepted. To have a reasonable assurance that a system will be acceptable, installation plans should be reviewed by an MSHA electrical specialist before the installation begins.

D. Electrical Switch Evaluation Criteria

All electric equipment must be equipped with a suitable means of starting, stopping, and deenergizing. Devices used to accomplish these features must be properly rated,

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[1] Class I locations are those in which flammable gases or vapors are or may be present in the air in quantities sufficient to produce explosive or ignitable mixtures.

well-built both electrically and mechanically, and properly installed, maintained, and used.

A switch is a device for opening and closing or changing the connection of an electric circuit and is not normally designed to interrupt short circuit current, although some devices, such as molded case and oil-circuit breakers, may be used as short circuit protective devices and may also serve as switches. Examples of devices used as switches include drum controllers, motor controllers, knife switches, air break switches, snap switches, circuit breakers, limit switches, disconnect switches, foot switches, oil switches, float switches, pushbutton switches, proximity switches, reversing switches, and selector switches. Switches may be operated manually, or by electromagnets such as motor controllers, by motors such as oil-circuit breakers, or by solenoids.

Evaluation of switches must include the following:

1. Verify that switches are rated for the circuit voltage, current, and horsepower (if applicable). Ratings are normally specified on a plate attached to the switch.
2. Verify that switches safely perform their intended function.
3. Verify that switches are constructed with proper electrical and mechanical strength.
4. Verify that switches are installed where they are accessible for use and properly protected against mechanical damage.
5. Verify that switches are suitable for the environment in which they are located. Indoor switches should be installed in National Electrical Manufactures Association (NEMA) Type 1, NEMA Type 12, or equivalent enclosures to prevent accidental contact with the enclosed apparatus. Outdoor switches should be installed in NEMA Type 3R or equivalent rain-tight enclosures. NEMA Type 3R enclosures are also considered to be drip tight, splash proof, and moisture resistant. Switches in locations that are washed occasionally by hosing, such as preparation plants, should be installed in NEMA Type 4 or equivalent water-tight enclosures.

E. Lightning Arresters

The voltage rating of lightning arresters is based on the maximum circuit voltage and the degree of the system's neutral grounding. Consequently, the rating of lightning arresters used on power systems in which the neutral is ungrounded or grounded through impedance (including resistance-grounded power systems) should be based on the maximum phase-to-phase voltage of the system.

Lightning arresters designed for use on AC power systems are not generally suitable for service on DC systems, since the means employed to interrupt follow current is not effective where this current does not periodically pass through zero. Arresters, however, are available for DC service. Modern DC arresters are simply capacitors; they are connected from line to ground and limit the crest value of a voltage surge by absorbing the current as a charge on the capacitor.

F. Intermachine Arcing Test Procedures

In coal mines and some metal and nonmetal mines, measures must be taken to prevent incendive arcing between the frames of different units of electric face equipment that normally come in contact in the working places or in return air. 30 CFR 75.524 establishes the maximum acceptable level of electrical energy that can exist between the frames of any two such machines in coal mines. While there is no similar requirement for metal and nonmetal mines, electrical specialists may use the test parameters and procedures in this chapter to check for incendive intermachine arcing in these mines.

The following procedure shall be used by all electrical specialists when testing for incendive intermachine arcing:

1. Connect a 0.1 ohm 10 watt 1 percent tolerance resistor between the two machine frames by means of two 6-foot lengths of 14 AWG stranded insulated copper wire and two heavy-duty, battery type clips (See Figure 25). Low resistance connections are crucial for accurate test results.
2. Connect a permissible multimeter across the resistor. Set the multimeter on the appropriate AC or DC millivolt range.
3. Start each motor on the machine in its proper sequence.
4. If, at any time, the meter indicates more than 100 millivolts, more than one ampere is flowing through the resistor. However, because of the tolerances of

the meter and changes in resistance due to temperature variations, a violation shall not be cited until the meter reading exceeds 110 millivolts.

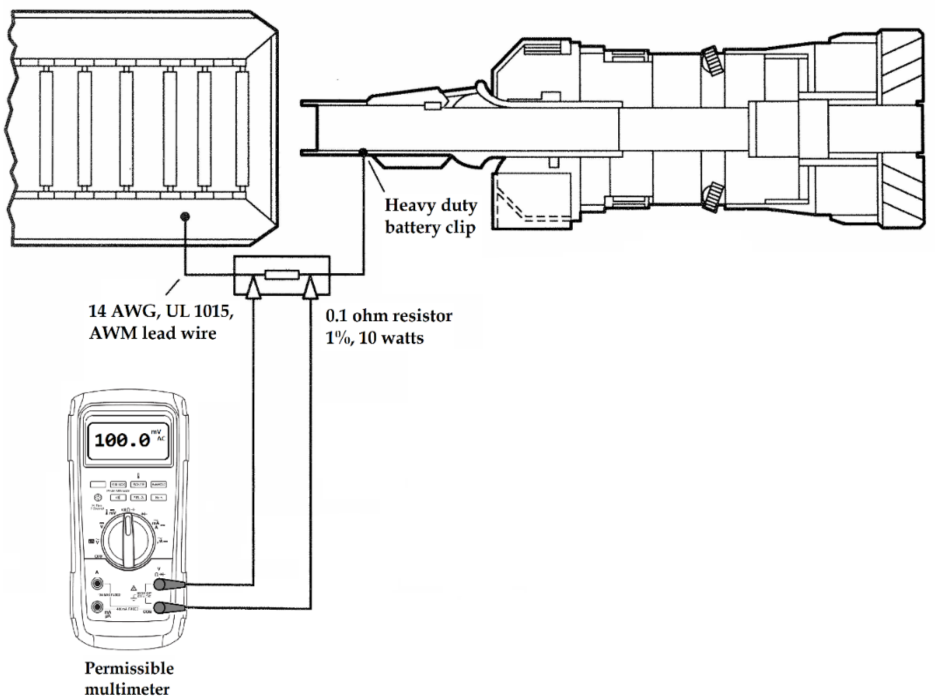


Figure 25 - Test device for measuring the electric current that exists between any two units of electric face equipment.

If a hazardous voltage is measured, an acceptable arc suppression device can be installed in the grounding circuit. When arc suppression devices are installed in power centers, the grounding connection from the grounding pin in the cable coupler to the metal shell of the cable coupler must be disconnected to prevent the arc suppressing device from being short circuited. In such cases, the metal shell of the cable coupler must be grounded to the frame of the power center through another pole in the coupler, or through a shunt or flexible wire connected between the power center frame and the metal shell of the cable coupler.

Any device inserted in a grounding conductor (including an arc suppression device and a parallel path suppression device) shall have a short circuit capacity that is not less than that of the grounding conductor in which it is installed. Electrical specialists should contact the MSHA Approval and Certification Center for guidance related to ground wire devices.

G. Evaluating Electric Equipment Maintenance Programs for Coal Mines

Inspectors should check the records of electrical equipment examinations during each regular inspection to determine if they are in order and to assure that the examinations are being made by qualified persons.

When inspectors observe several violations on a unit of electrical equipment, a citation should be issued for each violation under the appropriate 30 CFR section. The inspector should question the qualified person who made the last examination of that equipment. If there is evidence that thorough and complete examinations are not being made or that the required tests are not being conducted, a citation should also be issued under 30 CFR 75.512 or 77.502, indicating that the examinations and tests are not adequate to assure safe operating condition.

If each individual piece of electric equipment is not listed separately and identified by a unique description (such as serial number or company number) and location, and if all dangerous conditions and corrective actions are not recorded, the inspector shall consider the records of the examinations and tests of electric equipment to be in violation of 30 CFR 75.512 or 77.502. Since many electric-powered tools are not used during the normal production cycle, inspection personnel must make a special effort to ensure that they are examined, tested, and properly maintained as required by this section.

Additional guidance on the examination, testing, and maintenance of electrical equipment at coal mines is contained in PPM Volume V. Inspectors should consult this document when evaluating the mine operator's maintenance program.

H. Additional Procedures when using a Safety Circuit Tester

Safety circuit testers, such as those manufactured by Power Distribution Products (PDP) or SMC Electrical Products (SMC), or similar devices, are used to test grounded phase protection circuits and ground monitor dropout resistance. Safety circuit testers are designed to test protective devices associated with circuit breakers installed in resistance grounded systems only. Using the tester on any other type of system can be ineffective and potentially hazardous. In addition to the instructions provided by the manufacturer, electrical specialists shall follow the procedures below when using a safety circuit tester:

1. Use appropriate PPE including safety glasses, face shield, gloves and arc flash rated coveralls.
2. De-energize all circuits before connecting the safety circuit tester.

3. Remove all cable couplers and their ground bonding straps from the power center.
4. Prior to connecting the test leads to each phase, make certain no hazardous voltage is present even though the circuit breaker is open.
5. Prior to the circuit under test being energized, re-inspect all connections.

I. Electromagnetic Interference

Electromagnetic interference (EMI), including radio frequency interference (RFI), is an electromagnetic disturbance from an external source that affects the performance of an electrical circuit. RFI generated by portable radios operating in the very high frequency (VHF) and ultra-high frequency (UHF) bands has adversely affected the performance of remote control transmitters, atmospheric monitoring systems, machine-mounted methane monitors, proximity systems, and miners’ cap lamps.

Sources of EMI in underground mines include but are not limited to portable radios, electrical power systems, variable frequency drives, remote control transmitters, tracking tags and readers, and communication systems.

Inspectors should be aware of the potential problems posed by EMI and discuss this with mine operators during inspections. Inspectors should contact their immediate supervisor for guidance if they determine or suspect that EMI is adversely affecting the operation of any system or equipment. EMI issues involving approved devices or equipment should be reported to the Approval and Certification Center (A&CC).

J. Longwall Electrical Inspections

Longwall permissibility inspections involve complex, mine-specific, and high-voltage equipment. These inspections should be conducted by electrical specialists or inspectors who are qualified electricians, and coordinated with supervisors.

APPENDIX A – ICEA Ampacity Tables

Table A-1 – Ampacities for 90˚C portable power cables with copper conductors (40˚C ambient)

	Single Conductor					Three Conductor			
Power Conductor Size AWG or kcmil	2000 Volts or Less Non-shielded	2001 - 8000 Volts Shielded*	8001 - 15000 Volts Shielded*	150001 - 25000 Volts Shielded*	Two Conductor 2000 Volts or Less	5000 Volts or Less Non-shielded and Semi-Conductive Shielded	8000 Volts or Less Shielded	8001 - 15000 Volts Shielded	15001 - 25000 Volts Shielded
8	83	-	-	-	72	59	-	-	-
6	109	112	-	-	95	79	93	-	-
4	145	148	-	-	127	104	122	-	-
3	167	171	-	-	145	120	140	-	-
2	192	195	195	-	167	138	159	164	178
1	223	225	225	222	191	161	184	187	191
1/0	258	260	259	255	217	186	211	215	218
2/0	298	299	298	293	250	215	243	246	249
3/0	345	345	343	337	286	249	279	283	286
4/0	400	400	397	389	328	287	321	325	327
250	445	444	440	430	363	320	355	359	360
300	500	496	491	480	400	357	398	-	-
350	552	549	543	529	436	394	435	-	-
400	600	596	590	572	470	430	470	-	-
450	650	640	633	615	497	460	503	-	-
500	695	688	678	659	524	487	536	-	-
550	737	732	-	-	-	-	-	-	-
600	780	779	-	-	-	-	-	-	-
650	820	817	-	-	-	-	-	-	-
700	855	845	-	-	-	-	-	-	-
750	898	889	-	-	-	-	-	-	-
800	925	925	-	-	-	-	-	-	-
900	1,010	998	-	-	-	-	-	-	-
1,000	1,076	1,061	-	-	-	-	-	-	-

*These ampacities are based on single isolated cable in air operated with open-circuited shield.
Ampacities are based on insulation temperature ratings of 90˚C. To determine ampacities for other temperature ratings, see Table A-7.
Ampacities are based on an ambient temperature of 40˚C. Ampacities for ambient temperatures other than 40˚C can be obtained by applying the correction factors in Table A-8.
SOURCE: *American National Standard for Portable and Power Feeder Cables for Use in Mines and Similar Applications*, ANSI/NEMA WC 58-2017 / ICEA S-75-381-2017, Annex H, Table H-1

Table A-2 – Ampacities for 90˚C portable power cables with copper conductors (30˚C ambient)

Power Conductor Size AWG or kcmil	Single Conductor				Two Conductor 2000 Volts or Less	Three Conductor			
	2000 Volts or Less Non-shielded	2001 - 8000 Volts Shielded*	8001 - 15000 Volts Shielded*	150001 - 25000 Volts Shielded*		5000 Volts or Less Non-shielded and Semi-Conductive Shielded	8000 Volts or Less Shielded	8001 - 15000 Volts Shielded	15001 - 25000 Volts Shielded
8	91	-	-	-	79	65	-	-	-
6	120	123	-	-	105	87	102	-	-
4	160	163	-	-	140	114	134	-	-
3	184	188	-	-	160	132	154	-	-
2	211	215	215	-	184	152	175	180	196
1	245	248	248	244	210	177	202	206	210
1/0	284	286	285	281	239	205	232	237	240
2/0	328	329	328	322	275	237	267	271	274
3/0	380	380	377	371	315	274	307	311	315
4/0	440	440	437	428	361	316	353	358	360
250	490	488	484	473	399	352	391	395	396
300	550	546	540	528	440	393	438	-	-
350	607	604	597	582	480	433	479	-	-
400	660	656	649	629	517	473	517	-	-
450	715	704	696	677	547	506	553	-	-
500	765	757	746	725	576	536	590	-	-
550	811	805	-	-	-	-	-	-	-
600	858	857	-	-	-	-	-	-	-
650	902	899	-	-	-	-	-	-	-
700	941	930	-	-	-	-	-	-	-
750	988	978	-	-	-	-	-	-	-
800	1018	1018	-	-	-	-	-	-	-
900	1111	1098	-	-	-	-	-	-	-
1,000	1184	1167	-	-	-	-	-	-	-

*These ampacities are based on single isolated cable in air operated with open-circuited shield.
Ampacities are based on insulation temperature ratings of 90˚C. To determine ampacities for other temperature ratings, see Table A-7.
Ampacities for 30˚C ambient are derived by applying the correction factors in Table A-8 to the values in Table A-1.

APPENDIX A – ICEA Ampacity Tables

Table A-3 – Ampacities for 90˚C portable power cables with copper conductors (20˚C ambient)

Power Conductor Size AWG or kcmil	Single Conductor				Two Conductor 2000 Volts or Less	Three Conductor			
	2000 Volts or Less Non-shielded	2001 - 8000 Volts Shielded*	8001 - 15000 Volts Shielded*	150001 - 25000 Volts Shielded*		5000 Volts or Less Non-shielded and Semi-Conductive Shielded	8000 Volts or Less Shielded	8001 - 15000 Volts Shielded	15001 - 25000 Volts Shielded
8	98	-	-	-	85	70	-	-	-
6	129	132	-	-	112	93	110	-	-
4	171	175	-	-	150	123	144	-	-
3	197	202	-	-	171	142	165	-	-
2	227	230	230	-	197	163	188	194	210
1	263	266	266	262	225	190	217	221	225
1/0	304	307	306	301	256	219	249	254	257
2/0	352	353	352	346	295	254	287	290	294
3/0	407	407	405	398	337	294	329	334	337
4/0	472	472	468	459	387	339	379	384	386
250	525	524	519	507	428	378	419	424	425
300	590	585	579	566	472	421	470	-	-
350	651	648	641	624	514	465	513	-	-
400	708	703	696	675	555	507	555	-	-
450	767	755	747	726	586	543	594	-	-
500	820	812	800	778	618	575	632	-	-
550	870	864	-	-	-	-	-	-	-
600	920	919	-	-	-	-	-	-	-
650	968	964	-	-	-	-	-	-	-
700	1009	997	-	-	-	-	-	-	-
750	1060	1049	-	-	-	-	-	-	-
800	1092	1092	-	-	-	-	-	-	-
900	1192	1178	-	-	-	-	-	-	-
1,000	1270	1252	-	-	-	-	-	-	-

*These ampacities are based on single isolated cable in air operated with open-circuited shield.
Ampacities are based on insulation temperature ratings of 90˚C. To determine ampacities for other temperature ratings, see Table A-7.

Ampacities for 20˚C ambient are derived by applying the correction factors in Table A-8 to the values in Table A-1.

Table A-4 - Ampacities for 90˚C three-conductor mine power cables (40˚C ambient)

Conductor Size AWG or kcmil		Ampacities					
		2001-8000 Volts		8001-15000 Volts		15001-25000 Volts	
Copper	Aluminum	Copper	Aluminum	Copper	Aluminum	Copper	Aluminum
6	4	93	95	-	-	-	-
4	2	122	124	-	-	-	-
2	1/0	159	165	164	168	168	170
1	2/0	184	189	187	192	191	194
1/0	3/0	211	218	215	221	218	223
2/0	4/0	243	251	246	254	249	256
3/0	250	279	278	283	281	286	283
4/0	350	321	342	325	344	326	346
250	400	355	360	359	367	360	369
300	450	398	395	401	393	402	404
350	500	435	425	438	424	439	426
400	-	470	-	473	-	473	-
450	-	502	-	504	-	-	-
500	-	536	-	536	-	536	-

Ampacities are based on insulation temperature ratings of 90˚C. To determine ampacities for other temperature ratings, see Table A-7.

Ampacities are based on an ambient temperature of 40˚C. Ampacities for ambient temperatures other than 40˚C can be obtained by applying the correction factors in Table A-8.

SOURCE: *American National Standard for Portable and Power Feeder Cables for Use in Mines and Similar Applications*, ANSI/NEMA WC 58-2017 / ICEA S-75-381-2017, Annex I, Table I-1

Table A-5 - Ampacities for 90˚C three-conductor mine power cables (30˚C ambient)

Conductor Size AWG or kcmil		Ampacities					
		2001-8000 Volts		8001-15000 Volts		15001-25000 Volts	
Copper	Aluminum	Copper	Aluminum	Copper	Aluminum	Copper	Aluminum
6	4	102	105	-	-	-	-
4	2	134	136	-	-	-	-
2	1/0	175	182	180	185	185	187
1	2/0	202	208	206	211	210	213
1/0	3/0	232	240	237	243	240	245
2/0	4/0	267	276	271	279	274	282
3/0	250	307	306	311	309	315	311
4/0	350	353	376	358	378	359	381
250	400	391	396	395	404	396	406
300	450	438	435	441	432	442	444
350	500	479	468	482	466	483	469
400	-	517	-	520	-	520	-
450	-	552	-	554	-	-	-
500	-	590	-	590	-	590	-

Ampacities are based on insulation temperature ratings of 90˚C. To determine ampacities for other temperature ratings, see Table A-7.
Ampacities for 30˚C ambient are derived by applying the correction factors in Table A-8 to the values in Table A-4.

Table A-6 - Ampacities for 90˚C three-conductor mine power cables (20˚C ambient)

Conductor Size AWG or kcmil		Ampacities					
		2001-8000 Volts		8001-15000 Volts		15001-25000 Volts	
Copper	Aluminum	Copper	Aluminum	Copper	Aluminum	Copper	Aluminum
6	4	110	112	-	-	-	-
4	2	144	146	-	-	-	-
2	1/0	188	195	194	198	198	201
1	2/0	217	223	221	227	225	229
1/0	3/0	249	257	254	261	257	263
2/0	4/0	287	296	290	300	294	302
3/0	250	329	328	334	332	337	334
4/0	350	379	404	384	406	385	408
250	400	419	425	424	433	425	435
300	450	470	466	473	464	474	477
350	500	513	502	517	500	518	503
400	-	555	-	558	-	558	-
450	-	592	-	595	-	-	-
500	-	632	-	632	-	632	-

Ampacities are based on insulation temperature ratings of 90˚C. To determine ampacities for other temperature ratings, see Table A-7.

Ampacities for 20˚C ambient are derived by applying the correction factors in Table A-8 to the values in Table A-4.

Table A-7 – Correction factors for ICEA cable ampacities at operating temperatures other than 90˚C

Ambient Temperature Degrees C	Multiplying Correction Factors
10	1.26
20	1.18
30	1.10
40	1.00
50	0.90

SOURCE: *American National Standard for Portable and Power Feeder Cables for Use in Mines and Similar Applications*, ANSI/NEMA WC 58-2017 / ICEA S-75-381-2017, Annex H

Table A-8 – Correction factors for ICEA cable ampacities at ambient temperatures other than 40˚C

Ambient Temperature Degrees C	Multiplying Correction Factors
10	1.26
20	1.18
30	1.10
40	1.00
50	0.90

SOURCE: *American National Standard for Portable and Power Feeder Cables for Use in Mines and Similar Applications*, ANSI/NEMA WC 58-2017 / ICEA S-75-381-2017, Annex H

TABLE A-9 – Ampacities for 0-2000 volt portable cords with insulation temperature ratings of 75˚C, unshielded copper conductors

Conductor Size AWG or MCM	Ampacities*		
	Current-carrying conductors		
	1	2	3
**14		20	17
**12		28	22
**10		33	28

*Ampacities are based on an ambient temperature of 20˚C. To determine ampacities at other ambient temperatures, see Table A-11.

**Maximum voltage ratings are (1) 600 volts for S, SO, ST, and STO cables, and (2) 300 volts for SJ, SJO, SJT, and SJTO cables.

SOURCE: ***Rubber-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy***. Insulated Cable Engineers Association, Publication No. S-19-81, National Electrical Manufacturers Association Publication No. WC3-1980.

TABLE A-10 – Ampacities for 0-2000 volt portable cords with insulation temperature ratings of 90˚C, unshielded copper conductors

Conductor Size AWG or MCM	Ampacities*		
	Current-carrying conductors		
	1	2	3
**14		20	17
**12		28	22
**10		33	28

*Ampacities are based on an ambient temperature of 20˚C. To determine ampacities at other ambient temperatures, see Table A-11.

**Maximum voltage ratings are (1) 600 volts for S, SO, ST, and STO cables, and (2) 300 volts for SJ, SJO, SJT, and SJTO cables.

SOURCE: ***Ethylene-Propylene-Rubber-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy***. Insulated Cable Engineers Association, Publication No. S-68-516, National Electrical Manufacturers Association Publication No. WC8-1976.

TABLE A-11 – Correction for ICEA portable cord ampacities at ambient temperatures over 20˚C

Ambient Temperature	Correction Factors			
	70˚C	75˚C	85˚C	90˚C
20˚C	1.00	1.00	1.00	1.00
30˚C	0.89	0.90	0.92	0.93
40˚C	0.78	0.80	0.83	0.85

SOURCES: ***Rubber-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy.*** Insulated Cable Engineers Association, Publication No. S-19-81, National Electrical Manufacturers Association Publication No. WC3-1980.

Ethylene-Propylene-Rubber-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy. Insulated Cable Engineers Association, Publication No. S-68-516, National Electrical Manufacturers Association Publication No. WC8-1976.

APPENDIX B - 1968 National Electrical Code Ampacity Tables

TABLE B-1 – Ampacities for insulated copper conductors, not more than three conductors in a raceway or cable or direct burial (based on ambient temperature of 30˚C / 86˚F)

Conductor Size AWG or MCM	Temperature rating of conductor						
	60˚C 140˚F	75˚C 167˚F	85˚C 185˚F	90˚C 194˚F	110˚C 230˚F	125˚C 257˚F	200˚C 392˚F
	Types RUW 14-2, T, TW	Types RH,RHW, RUH 14-2, THW, THWN, XHHW	Types V, Ml	Types TA,TBS, SA, AVB , SIS, FEP, FEPB, RHH THHN XHHW	Types AVA,AVL	Types Al 14-8, ALA	Types A 14-8, AA, FEP, FEPB
14	15	15	25	25†	30	30	30
12	20	20	30	30†	35	40	40
10	30	30	40	40†	45	50	55
8	40	45	50	50	60	65	70
6	55	65	70	70	80	85	95
4	70	85	90	90	105	115	120
3	80	100	105	105	120	130	145
2	95	115	120	120	135	145	165
1	110	130	140	140	160	170	190
0	125	150	155	155	190	200	225
00	145	175	185	185	215	230	250
000	165	200	210	210	245	265	285
0000	195	230	235	235	275	310	340
250	215	255	270	275	315	335	-
300	240	285	300	300	345	380	-
350	260	310	325	325	390	420	-
400	280	335	360	360	420	450	-
500	320	380	405	405	470	500	-
630	355	420	455	455	525	545	-
700	385	460	490	490	560	600	-
750	400	475	500	500	580	620	-
800	410	490	515	515	600	640	-
900	435	520	555	555	-	-	-
1000	455	545	585	585	680	730	-
1250	495	590	645	645	-	-	-
1500	520	625	700	700	785	785	-
1750	545	650	735	735	-	-	-
2000	560	665	775	775	840	-	-

†The ampacities for Types FEP, FEPB, RHH, THHN, and XHHW conductors for sizes AWG 14, 12 and 10 shall be the same as designated for 75˚C conductors in this Table.

SOURCE: ***National Electrical Code, 1968 Edition (NFPA 70-1968), National Fire Protection Association***

APPENDIX B - 1968 National Electrical Code Ampacity Tables

TABLE B-2 – Ampacities for insulated copper conductor, single conductor in free air (based on ambient temperature of 30˚C / 86˚F)

Conductor Size AWG or MCM	Temperature rating of conductor							Bare and covered conductors
	60˚C 140˚F	75˚C 167˚F	85˚C 185˚F	90˚C 194˚F	110˚C 230˚F	125˚C 257˚F	200˚C 392˚F	
	Types RUW 14-2, T, TW	Types RH,RHW, RUH 14-2, THW, THWN, XHHW	Types V, Ml	Types TA,TBS, SA, AVB , SIS, FEP, FEPB, RHH THHN XHHW	Types AVA,AVL	Types Al 14-8, ALA	Types A 14-8, AA, FEP, FEPB	
14	20	20	30	30†	40	40	45	30
12	25	25	40	40†	50	50	55	40
10	40	40	55	55†	65	70	75	55
8	55	65	70	70	85	90	100	70
6	80	95	100	100	120	125	135	100
4	105	125	135	135	160	170	180	130
3	120	145	155	155	180	195	210	150
2	140	170	180	180	210	225	240	175
1	165	195	210	210	245	265	280	205
0	195	230	245	245	285	305	325	235
00	225	265	285	285	330	355	370	275
000	260	310	330	330	385	410	430	320
0000	300	360	385	385	445	475	510	370
250	340	405	425	425	495	530	-	410
300	375	445	480	480	555	590	-	460
350	420	505	530	530	610	655	-	510
400	455	545	575	575	665	710	-	555
500	515	620	660	660	765	815	-	630
630	575	690	740	740	855	910	-	710
700	630	755	815	815	940	1005	-	780
750	655	785	845	845	985	1045	-	810
800	680	815	880	880	1020	1085	-	845
900	730	870	940	940	-		-	905
1000	780	935	1000	1000	1165	1240	-	965
1250	890	1065	1130	1130	-	-	-	-
1500	980	1175	1260	1260	1450	-	-	1215
1750	1070	1280	1370	1370	-	-	-	-
2000	1155	1385	1470	1470	1715	-	-	1405

†The ampacities for Types FEP, FEPB, RHH, THHN, and XHHW conductors for sizes AWG 14, 12 and 10 shall be the same as designated for 75˚C conductors in this Table.

SOURCE: ***National Electrical Code, 1968 Edition (NFPA 70-1968), National Fire Protection Association***

TABLE B-3 – Ampacities for insulated aluminum conductors, not more than three conductors in a raceway or cable or direct burial (based on ambient temperature of 30°C / 86°F)

Conductor Size AWG or MCM	Temperature rating of conductor						
	60°C 140°F	75°C 167°F	85°C 185°F	90°C 194°F	110°C 230°F	125°C 257°F	200°C 392°F
	Types RUW 14-2, T, TW	Types RH,RHW, RUH 12-2, THW, THWN, XHHW	Types V, MI	Types TA,TBS, SA, AVB , SIS, RUH, THHN, XHHW	Types AVA,AVL	Types AI 12-8, AIA	Types A 12-8, AAA
12	15	15	25	25[†]	25	30	30
10	25	25	30	30[†]	30	40	45
8	30	40	40	40	45	50	55
6	40	50	55	55	60	65	75
4	55	65	70	70	80	90	95
3	65	75	80	80	95	100	115
2	75	90	95	95	105	115	130
1	85	100	110	110	125	135	150
0	100	120	125	125	150	160	180
00	110	135	145	145	170	180	200
000	130	155	165	165	195	210	225
0000	155	180	185	185	215	245	270
250	170	205	215	215	250	270	
300	190	230	240	240	275	305	
350	210	250	260	260	310	335	
400	225	270	290	290	335	360	
500	260	310	330	330	380	405	
600	285	340	370	370	425	440	
700	310	375	395	395	455	485	
750	320	385	405	405	470	500	
800	330	395	415	415	485	520	
900	355	425	455	455			
1000	375	445	480	480	560	600	
1250	405	485	530	530			
1500	435	520	580	580	650		
1750	455	545	615	615			
2000	470	560	650	650	705		

[†] The ampacities for Types RHH, THHN, and XHHW conductors for sizes AWG 12 and 10 shall be the same as designated for 75°C conductors in this Table.

SOURCE: ***National Electrical Code, 1968 Edition (NFPA 70-1968), National Fire Protection Association***

TABLE B-4 – Ampacities for insulated aluminum conductor, single conductor in free air (based on ambient temperature of 30°C / 86°F)

Conductor Size AWG or MCM	Temperature rating of conductor							Bare and covered conductors
	60°C 140°F	75°C 167°F	85°C 185°F	90°C 194°F	110°C 230°F	125°C 257°F	200°C 392°F	
	Types RUW 14-2, T, TW	Types RH,RHW, RUH 12-2, THW, THWN, XHHW	Types V, MI	Types TA,TBS, SA, AVB , SIS, RHH THHN XHHW	Types AVA,AVL	Types AI 12-8, AIA	Types A 12-8, AA	
12	20	20	30	30[†]	40	40	45	30
10	30	30	45	45[†]	50	55	60	45
8	45	55	55	55	65	70	80	55
6	60	75	80	80	95	100	105	80
4	80	100	105	105	125	135	140	100
3	95	115	120	120	140	150	165	115
2	110	135	140	140	165	175	185	135
1	130	155	165	165	190	205	220	160
0	150	180	190	190	220	240	255	185
00	175	210	220	220	255	275	290	215
000	200	240	255	255	300	320	335	250
0000	230	280	300	300	345	370	400	290
250	265	315	330	330	385	415	-	320
300	290	350	375	375	435	460	-	360
350	330	395	415	415	475	510	-	400
400	355	425	450	450	520	555	-	435
500	405	485	515	515	595	635	-	490
600	455	545	585	585	675	720	-	560
700	500	595	645	645	745	795	-	615
750	515	620	670	670	775	825	-	640
800	535	645	695	695	805	855	-	670
900	580	700	750	750	-	-	-	725
1000	625	750	800	800	930	990	-	770
1250	710	855	905	905	-	-	-	-
1500	795	950	1020	1020	1175	-	-	985
1750	875	1050	1125	1125	-	-	-	-
2000	960	1150	1220	1220	1420	-	-	1165

†The ampacities for Types RHH, THHN, and XHHW conductors for sizes AWG 12 and 10 shall be the same as designated for 75°C conductors in this Table.

SOURCE: ***National Electrical Code, 1968 Edition (NFPA 70-1968), National Fire Protection Association***

Table B-5 – Correction factors for National Electrical Code, 1968, ampacities at ambient temperatures over 30˚C / 86˚F

˚C	˚F	60˚C 140˚F	75˚C 167˚F	85˚C 185˚F	90˚C 194˚F	110˚C 230˚F	125˚C 257˚F	200˚C 392˚F
40	104	0.82	0.88	0.9	0.9	0.94	0.95	-
45	113	0.71	0.82	0.85	0.85	0.9	0.92	-
50	122	0.58	0.75	0.8	0.8	0.87	0.89	-
55	131	0.67	0.67	0.74	0.74	0.83	0.86	-
60	140	-	0.58	0.67	0.67	0.79	0.83	0.91
70	158	-	0.35	0.52	0.52	0.71	0.76	0.87
75	167	-	-	0.43	0.43	0.66	0.72	0.86
80	176	-	-	0.3	0.3	0.61	0.69	0.84
90	194	-	-	-	-	0.5	0.61	0.8
100	212	-	-	-	-	-	0.51	0.77
120	248	-	-	-	-	-	-	0.69
140	284	-	-	-	-	-	-	0.59

SOURCE: ***National Electrical Code, 1968 Edition (NFPA 70-1968), National Fire Protection Association***

APPENDIX C - Motor Full-Load Current

Table C-1 – Full-load current in amperes, direct current motors*

HP	120V	240V
1/4	2.9	1.5
1/3	3.6	1.8
1/2	5.2	2.6
3/4	7.4	3.7
1	9.4	4.7
1 ½	13.2	6.6
2	17.0	8.5
3	25.0	12.2
5	40.0	20.0
7 ½	58.0	29.0
10	76.0	38.0
15		55.0
20		72.0
25		89.0
30		100.0
40		140.0
50		173.0
60		206.0
75		255.0
100		341.0
125		425.0
150		506.0
200		675.0

*The full-load currents listed are for motors running at base speed.

SOURCE: ***National Electrical Code, 1968 Edition (NFPA 70-1968), National Fire Protection Association***

Table C-2 – Full-load current in amperes, single-phase alternating current motors*

HP	120V	240V
1/4	2.9	1.5
1/3	3.6	1.8
1/2	5.2	2.6
3/4	7.4	3.7
1	9.4	4.7
1 ½	13.2	6.6
2	17.0	8.5
3	25.0	12.2
5	40.0	20.0
7 ½	58.0	29.0
10	76.0	38.0
15		55.0
20		72.0
25		89.0
30		100.0
40		140.0
50		173.0
60		206.0
75		255.0
100		341.0
125		425.0
150		506.0
200		675.0

*The full-load currents listed are for motors running at usual speeds and motors with normal torque characteristics. Motors built for especially low speeds or high torques may have higher full-load currents. Multispeed motors will have full load currents varying with speed, in which case the name plate current rating shall be used.

SOURCE: ***National Electrical Code, 1968 Edition (NFPA 70-1968), National Fire Protection Association***

APPENDIX C - Motor Full-Load Current

TABLE C-3 – Full load current in amperes, three-phase alternating current motors*

Induction type squirrel-cage and wound rotor motors					Synchronous type unity power factor				
HP	115V	230V	460V	575V	2300V	220V	440V	550V	2300V
1/2	4	2	1	0.8					
3/4	5.6	2	1.4	1.1					
1.0	7.2	3.6	1.8	1.4					
1-1/2	10.4	5.2	2.6	2.1					
2.0	13.6	6.8	3.4	2.7					
3.0		9.6	4.8	3.9					
5.0		15	7.6	6.1					
7-1/2		22	11	9					
10.0		28	14	11					
15.0		42	21	17					
20.0		54	27	22					
25.0		68	34	27		54	27	22	
30.0		80	40	32		65	33	26	
40.0		104	52	41		86	43	35	
50.0		130	65	52		108	54	44	
60.0		154	77	62	16	128	64	51	12
75.0		192	96	77	20	161	81	65	15
100.0		248	124	99	26	211	106	85	20
125.0		312	156	125	31	264	132	106	25
150.0		360	180	144	37		158	127	30
200.0		480	240	192	49		210	168	40

*For full-load currents of 208-and 200-volt motors, increase the corresponding 230-volt motor full-load current by 10 and 15 percent, respectively.

*These values of full-load current are for motors running at speeds usual for belted motors and motors with normal torque characteristics. Motors built for especially low speeds or high torques may require more running current, and multispeed motors will have full-load current varying with speed, in which case the nameplate current rating shall be used.

*For 90 and 80 percent P.F., the above figures shall be multiplied by 1.1 and 1.25 respectively.
The voltages listed are rated motor voltages. Corresponding nominal system voltages are 110 to 120, 220 to 240 440 to 480 and 550 to 600 volts.

SOURCE: ***National Electrical Code, 1968 Edition (NFPA 70-1968), National Fire Protection Association***

APPENDIX D - Minimum Requirements for Motor Short Circuit and Overload Protection

Table D-1 – Motor and circuit protection, 110 to 120 volt single-phase motors

HP	Full-load current of motor	Minimum size of power conductor (AWG) [1]	Minimum size of ground conductor (AWG) [2]	Instantaneous branch circuit protection in amperes, 700% of motor full load current [3]	Maximum thermal motor running protection in amperes
1/4	5.8	14	14	41.0	8.0
1/3	7.2	14	14	51.0	9.0
1/2	9.8	14	14	69.0	13.0
3/4	13.8	12	12	97.0	18.0
1.0	16.0	12	12	112.0	20.0
1 ½	20.0	10	10	140.0	25.0
2.0	24.0	10	10	168.0	30.0
3.0	34.0	8	8	238.0	43.0
5.0	56.0	4	6	392.0	70.0
7 ½	80.0	3	6	560.0	100.0
10.0	100.0	1	3	700.0	125.0

Notes:

[1] Minimum conductor size is based on ampacities taken from Table B-1 (75˚C insulation, 30˚C ambient temperature).

[2] Minimum ground conductor size is based on the requirements of 30 CFR 75.701-4 and 77.701-3. Article 250 of the 1968 National Electrical Code specifies equipment grounding conductor size based on the rating or setting of the overcurrent device (see Table 250-95).

[3] The setting of an instantaneous trip circuit breaker may be increased above these values to allow proper starting of the motor but shall in no case exceed 1300 percent of the motor full-load current.

Table D-2 – Motor and circuit protection, 220 to 240 volt single-phase motors

HP	Full-load current of motor	Minimum size of power conductor (AWG) [1]	Minimum size of ground conductor (AWG) [2]	Instantaneous branch circuit protection in amperes, 700% of motor full load current [3]	Maximum thermal motor running protection in amperes
1/4	2.9	14	14	21.0	4.0
1/3	3.6	14	14	26.0	5.0
1/2	4.9	14	14	35.0	7.0
3/4	6.9	14	14	4.9	9.0
1.0	8.0	14	14	56.0	10.0
1 ½	10.0	14	14	70.0	13.0
2.0	12.0	14	14	84.0	15.0
3.0	17.0	10	10	119.0	22.0
5.0	28.0	8	8	196.0	35.0
7 ½	40.0	6	8	280.0	50.0
10.0	50.0	6	8	350.0	63.0

Notes:

[1] Minimum conductor size is based on ampacities taken from Table B-1 (75˚C insulation, 30˚C ambient temperature).

[2] Minimum ground conductor size is based on the requirements of 30 CFR 75.701-4 and 77.701-3. Article 250 of the 1968 National Electrical Code specifies equipment grounding conductor size based on the rating or setting of the overcurrent device (see Table 250-95).

[3] The setting of an instantaneous trip circuit breaker may be increased above these values to allow proper starting of the motor but shall in no case exceed 1300 percent of the motor full-load current.

Table D-3 – Motor and circuit protection, 440 to 480 volt three-phase motors

HP	Full-load current of motor	Minimum size of portable cord [1]	Minimum 75˚C cable size [2]	Minimum 90˚C cable size [3]	Instantaneous branch circuit protection in amperes, 700% of motor full load current [4]	Inverse time circuit breaker rating [5]
1.0	1.8	18	-	-	13.0	-
1½	2.6	18	-	-	19.0	-
2.0	3.4	18	-	-	24.0	
3.0	4.8	18	-	-	34.0	15.0
5.0	7.6	16	-	-	54.0	20.0
7½	11.0	14	-	-	77.0	30.0
10.0	14.0	12	-	-	98.0	35.0
15.0	21.0	8	-	-	147.0	60.0
20.0	27.0	8	-	-	189.0	70.0
25.0	34.0	6	-	-	238.0	90.0
30.0	40.0	4	8	8	280.0	100.0
40.0	52.0	2	6	8	364.0	150.0
50.0	65.0	-	6	6	455.0	175.0
60.0	77.0	-	4	4	539.0	200.0
75.0	96.0	-	3	4	672.0	250.0
100.0	124.0	-	1	2	868.0	350.0
125.0	156.0	-	2/0	1/0	1092.0	400.0
150.0	180.0	-	3/0	2/0	1260.0	450.0
200.0	240.0	-	250 MCM	4/0	1680.0	600.0

Notes:

[1] Minimum conductor size is based on ampacities taken from the 1968 National Electrical Code, Table 400-9(b).

[2] Minimum conductor size is based on ampacities taken from Table A-1 in Appendix A.

[3] Minimum conductor size is based on ampacities taken from Table A-2 in Appendix A.

[4] The setting of an instantaneous trip circuit breaker may be increased above these values to allow proper starting of the motor but shall in no case exceed 1300 percent of the motor full-load current.

[5] The setting of an inverse time circuit breaker may be increased above these values to allow proper starting of the motor but shall in no case exceed 400 percent of the motor full-load current.

Table D-4 – Motor and circuit protection, 550 to 600 volt three-phase motors

HP	Full-load current of motor	Minimum size of portable cord [1]	Minimum 75˚C cable size [2]	Minimum 90˚C cable size [3]	Instantaneous branch circuit protection in amperes, 700% of motor full load current [4]	Inverse time circuit breaker rating [5]
1.0	1.4	18	-	-	10.0	-
1½	2.1	18	-	-	15.0	-
2.0	2.7	18	-	-	19.0	-
3.0	3.9	18	-	-	28.0	15.0
5.0	6.1	16	-	-	43.0	20.0
7½	9.0	14	-	-	63.0	25.0
10.0	11.0	14	-	-	77.0	30.0
15.0	17.0	10	-	-	119.0	50.0
20.0	22.0	10	-	-	154.0	60.0
25.0	27.0	8	-	-	189.0	70.0
30.0	32.0	6	-	-	224.0	80.0
40.0	41.0	4	8	-	287.0	110.0
50.0	52.0	2	6	8	364.0	150.0
60.0	62.0	2	6	6	434.0	175.0
75.0	77.0	-	4	4	539.0	200.0
100.0	99.0	-	3	3	693.0	250.0
125.0	125.0	-	1	2	875.0	350.0
150.0	144.0	-	1	1	1008.0	400.0
200.0	192.0	-	3/0	2/0	1344.0	500.0

Notes:

[1] Minimum conductor size is based on ampacities taken from the 1968 National Electrical Code, Table 400-9(b).

[2] Minimum conductor size is based on ampacities taken from Table A-1 in Appendix A.

[3] Minimum conductor size is based on ampacities taken from Table A-2 in Appendix A.

[4] The setting of an instantaneous trip circuit breaker may be increased above these values to allow proper starting of the motor but shall in no case exceed 1300 percent of the motor full-load current.

[5] The setting of an inverse time circuit breaker may be increased above these values to allow proper starting of the motor but shall in no case exceed 400 percent of the motor full-load current.

APPENDIX E - Ratings and Magnetic Trip Range Adjustments for Common Molded Case Circuit Breakers

Table E-1 – Continuous ampere ratings and magnetic trip ranges / adjustment positions for Westinghouse standard front-adjustable magnetic-only circuit breakers

FB	3	7	8	8.5	9	10	11	12	13	15	16	18	19	20	22
FB	5	15	17	18	20	22	24	26	28	30	33	36	39	42	45
FB	10	35	40	45	50	55	60	65	70	80	85	90	100	105	110
FB	25	32	35	39	43	47	50	54	58	62	65	69	73	76	80
FB	25	66	75	80	85	90	100	110	120	130	140	150	165	175	190
FB	30	50	56	65	72	80	90	96	105	110	120	125	135	140	150
FB	30	90	100	110	115	125	140	155	170	185	200	215	230	250	270
FB	50	66	75	80	85	90	100	110	120	130	140	150	165	175	190
FB	50	160	180	195	210	230	250	285	320	350	380	405	430	455	480
FB	70	100	110	125	140	150	165	175	190	205	215	230	245	255	270
FB	100	150	170	190	205	225	250	285	320	350	380	405	430	455	480
FB	100	450	500	540	580	625	670	750	825	900	1000	1125	1250	1400	1550
FB	150	575	650	700	750	825	900	1050	1200	1300	1400	1500	1600	1700	1800
JB-KB	250	350	400	440	480	525	560	610	660	-	-	-	-	-	-
JB-KB	250	625	700	780	860	940	1020	1050	1170	-	-	-	-	-	-
JB-KB	250	750	850	930	1030	1125	1210	1300	1400	-	-	-	-	-	-
JB-KB	250	875	980	1100	1200	1300	1400	1500	1640	-	-	-	-	-	-
JB-KB	250	1125	1290	1425	1560	1700	1840	1980	2115	-	-	-	-	-	-
JK-KB	250	1250	1400	1560	1720	1880	2040	2100	2340	-	-	-	-	-	-
LBB-LB	400	350	400	440	480	525	560	610	660	-	-	-	-	-	-
LBB-LB	400	625	700	780	860	940	1020	1050	1170	-	-	-	-	-	-
LBB-LB	400	750	850	930	1030	1125	1210	1300	1400	-	-	-	-	-	-
LBB-LB	400	875	980	1100	1200	1300	1400	1500	1640	-	-	-	-	-	-
LBB-LB	400	1125	1290	1425	1560	1700	1840	1980	2115	-	-	-	-	-	-
LBB-LB	400	1500	1690	1875	2065	2250	2440	2630	2815	-	-	-	-	-	-
LBB-LB	400	2000	2250	2500	2750	3000	3250	3500	3750	-	-	-	-	-	-
LA	600	1125	1265	1405	1555	1690	1830	1970	2110	-	-	-	-	-	-
LA	600	1500	1685	1875	2060	2250	2435	2625	2810	-	-	-	-	-	-
LA	600	2000	2250	2500	2750	3000	3250	3500	3750	-	-	-	-	-	-
LA	600	2500	2815	3125	3440	3750	4065	4375	4690	-	-	-	-	-	-
LA	600	3000	3375	3750	4125	4500	4875	5250	5625	-	-	-	-	-	-

SOURCE: ***Application Data 29-160***, Westinghouse Electric Corporation, Low Voltage Breaker Division, Beaver, Pennsylvania 15009

APPENDIX E - Ratings and Magnetic Trip Range Adjustments for Common Molded Case Circuit Breakers

Table E-2 - Continuous ampere ratings and magnetic trip ranges for Westinghouse Seltronic front-adjustable magnetic-only circuit breakers

Breaker type / Continuous rating		Continuously adjustable magnetic trip range Low / High	
LC	600	375	750
LC	600	450	900
LC	600	500	1000
LC	600	625	1250
LC	600	750	1500
LC	600	875	1750
LC	600	1000	2000
LC	600	1250	2500
LC	600	1375	2750
LC	600	1500	3000
LC	600	1750	3500
LC	600	2000	4000
LC	600	2250	4500
LC	600	2500	5000
LC	600	3000	6000
MC	800	2000	4000
MC	800	2500	5000
MC	800	3000	6000
MC	800	3500	7000
MC	800	4000	8000
NC	1200	2400	4800
NC	1200	2800	5000
NC	1200	3200	6000
NC	1200	3600	7000
NC	1200	4000	8000
NC	1200	4800	9600
PC	2000	3000	6000
PC	2000	3600	7200
PC	2000	4200	8400
PC	2000	4800	9600
PC	2000	5400	10800
PC	2000	6000	12500
PC	2500	3500	7000
PC	2500	4000	8000
PC	2500	4500	9000
PC	2500	5000	10000
PC	2500	6250	12500
PC	3000	3200	6400
PC	3000	3600	7200
PC	3000	4000	8000
PC	3000	5000	10000
PC	3000	6000	12000

SOURCE: ***Application Data 29-160***, Westinghouse Electric Corporation, Low Voltage Breaker Division, Beaver, Pennsylvania 15009

APPENDIX E - Ratings and Magnetic Trip Range Adjustments for Common Molded Case Circuit Breakers

Table E-3 - Continuous ampere ratings and magnetic trip ranges/adjustment positions for General Electric standard duty front-adjustable magnetic-only circuit breakers

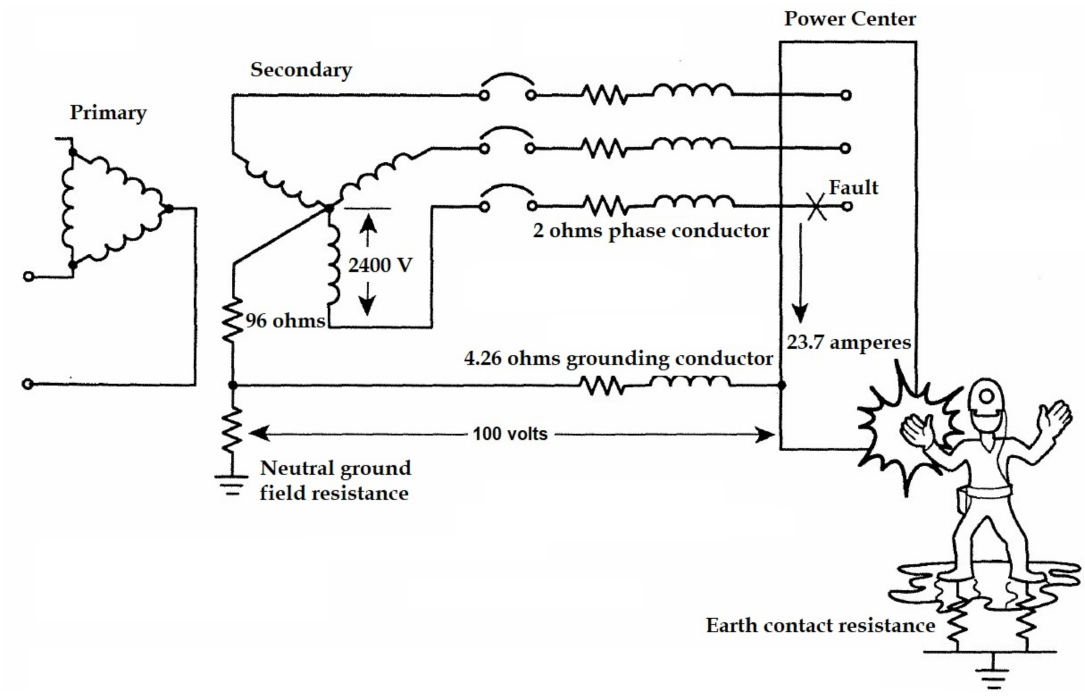
Catalog No. 3-pole	Continuous ampere rating	Trip setting positions						
		Low	2	4	6	8	10	High
TEC36003	3	8	13	18	23	28	33	38
TEC36007	7	18	30	42	54	65	78	90
TEC36015	15	42	68	94	120	146	172	198
TEC36030	30	90	140	190	240	290	340	390
TEC36050	50	180	260	340	420	500	580	660
TEC36100	100	300	468	636	804	972	1140	1308
TEC36150	150	600	950	1300	1650	2000	2350	2700

Catalog No. 3-pole	Continuous ampere rating	Trip setting positions						
		Low	2	3	4			High
TFC36225A	225	1000	1325	1650	1950	-	-	2250
TJC36400B	400	1200	1400	1880	2500	-	-	4000
TJC36600A	600	1800	2400	3300	4500	-	-	6000
TKC36800A	800	2400	3200	4400	6000	-	-	8000
TKC361200A	1200	2400	3200	4400	6000	-	-	8000

Catalog No. 2-pole	Continuous ampere rating	Trip setting positions						
		Low	2	4	6	8	10	High
TEC26007	7	18	30	42	54	66	78	90
TEC26015	15	42	68	94	120	146	172	198
TEC26030	30	90	140	190	240	290	340	390
TEC26050	50	180	260	340	420	500	580	660
TEC26100	100	300	468	635	804	972	1140	1308
TEC26150	150	600	950	1300	1650	2000	2350	2700

SOURCE: General Electric Company

APPENDIX F - Calculations for Resistance Grounded Circuit



Sample calculation for maximum allowable resistance in grounding conductor R_{GC}:

Voltage external to the grounding resistor (V_{EG}) $= 100$ volts

Line to neutral voltage (V_{LN}) $= 2400$ volts

Phase Conductor Resistance ($R_{\emptyset}$) $= 2$ ohms

Grounding Resistor Resistance (R_G) $= 96$ ohms

Total Resistance(R_T) $= R_{\emptyset} + R_{GC} + R_G$

$$V = IR \text{ and } I = \frac{V}{R}$$

$$V_{EG} = R_{GC}\frac{V_{LN}}{R_T}$$

$$100 = R_{GC}\left(\frac{2400}{R_{\emptyset} + R_G + R_{GC}}\right)$$

$$100 = R_{GC}\left(\frac{2400}{2 + 96 + R_{GC}}\right)$$

$$100 = R_{GC}\left(\frac{2400}{98 + R_{GC}}\right)$$

$$100 = \frac{2400R_{GC}}{98 + R_{GC}}$$

$$100(98 + R_{GC}) = 2400R_{GC}$$

$$9800 + 100R_{GC} = 2400R_{GC}$$

$$9800 = 2300R_{GC}$$

$$R_{GC} = \frac{9800}{2300}; \qquad \mathbf{R_{GC} = 4.26\ ohms}$$

Sample calculation for ground fault current:

$$I_F = \frac{V_{LN}}{R_T}$$

$$I_F = \frac{2400}{2 + 96 + 4.26}$$

$$I_F = \frac{2400}{102.26}$$

$$\mathbf{I_F = 23.47\ amps}$$

Check the voltage drop across R_{GC}:

$$V_{EG} = I_F R_{GC}$$

$$V_{EG} = 23.47 \text{ X } 4.26$$

$$\mathbf{V_{EG} = 100\ vol}$$

VOLUME II

CHAPTER 1 INTRODUCTION

The following Electrical Inspection Procedures Handbook is intended for MSHA general inspectors who encounter mine electrical systems and electric-powered equipment during the course of their inspections. Inspectors who do not have specialist training or knowledge of electrical systems and equipment should limit their inspection of such systems to visual observation only without entering, touching or manipulating secured/locked areas, boxes, or components, regardless of system or equipment power and voltage.

Not all procedures and requirements are applicable for all mine types. Any deviation from the procedures outlined in this handbook should be based on the inspector's professional judgement, and discussion with the inspector's supervisor. If an inspector has any questions or is not comfortable regarding the procedures outlined below, the inspector should immediately contact their Supervisor.

CHAPTER 2 GROUNDING

Review records to determine whether the required tests were performed, including continuity and resistance testing, on all equipment grounding systems (such as grounding conductors, grounding electrode conductors, and grounding electrodes) and results of the tests recorded. Note that branch circuit grounds must be isolated to effectively evaluate continuity.

During the inspection, visually determine whether all equipment grounds are installed and secured, including loose ground connections. Visually confirm whether enclosures, structures, and mobile equipment are properly grounded as required by 30 CFR §§ 56/57.12025, 56/57.12026, 56/57.12027, and 75/77.701.

Grounding system integrity should be evaluated by reviewing examination and testing records for evidence of:

- The date of the most recent examination and continuity and resistance tests;
- The qualifications of the examiner who conducted the examination and whether the examiner had the proper tools;
- Hazards identified and corrected as a result of the examination.

A visual examination of grounding system integrity should include a determination whether:

- any conductors are loose, missing, or damaged;
- grounding rods are at least 6 feet apart, when multiple grounding rods are installed;
- generators are properly anchored and aligned;
- physical damage to the generators is apparent.

The lowest resistance ground value should be the lowest value practical that will provide a safe and compliant electrical system. If further evaluation of the effectiveness and safety of a grounding system, including resistance testing, is needed, contact your Supervisor or electrical specialists for support as needed.

CHAPTER 3 CABLE INSULATION, PROTECTION, AND SPLICING

Inspectors should visually inspect power cables and wires and assess whether they meet the following requirements:

- Power cables and wires are protected from damage, are a sufficient size and capacity, and have sufficient or proper insulation;
- Cables and wires enter into metal frames of motors, splice boxes, and electrical compartments only through proper fittings and insulated bushings;
- Trailing cables and power cable connections are not made or broken under load;
- Have MSHA approval or acceptance as flame resistant, where applicable;
- Have MSHA approval or acceptance for use in permissible areas, where applicable, including legible and permanent MSHA-assigned approval markings, and number and size of conductors, cable type, and voltage rating;
- Have appropriate rating for the application; e.g., outdoor designated as weather and water resistant "W," suitable for wet locations and sunlight resistant, and "SUN, RES" or "SR" for sunlight resistant only;
- Do not show signs of damage, including excessive heat, smoldering, smoking, etc.;
- Adequate clearance is provided for panel and equipment access;
- Labels are provided for switches, receptacle, disconnect switches and circuit breakers; and
- Proper hangers or supports are being used where applicable.

A. Cable Splices

- Visually examine splices and repairs to ensure mechanical strength, electrical efficiency, moisture exclusion, and equality to or improvement over the original levels of insulation and damage protection, including a good bond with the outer jacket.
- Inspect for MSHA-assigned approval markings, which must be legible and permanently marked for approved splices according to 30 CFR § 7.409. The marking shall appear at least once on the assembled splice.
- When indications of a poor splice connection are apparent, the mine operator must de-energize, lock out and tag out the circuit prior to hand-over-hand examination by the inspector. These indications may include excessive heat or other damage to the cable and the inspector should evaluate whether the splice should be removed from service and repaired. Electrical specialists or supervisors should be contacted for assistance, as needed.

B. High Potential/High Voltage Cables (MNM: >650 VAC; Coal: >1,000 VAC)

High potential or high voltage equipment is extremely dangerous and inspectors must take the utmost caution during inspection. When inspectors encounter problems, have questions, or are uncertain of how to safely inspect this equipment, they should contact their supervisor or an electrical specialist for assistance.

Through visual inspection only, and without touching, determine whether:

- All high voltage circuits extending underground supplying power to portable, mobile, or stationary equipment are on a resistance grounded system, and whether the neutral grounding resistor is properly connected and in good condition;
- The high voltage power cables going underground are shielded. An "SHD" marking indicates a shielded cable. Otherwise, the operator may have additional information on the specific type and shielding;
- High voltage cables routed underground are all installed in regularly traveled air-ways;
- All couplers for high voltage circuits are latched, secured and free of physical damage. If damage is observed, the operator shall remove power from the cable and repair/replace before re-energizing;
- There is damage to the outer jacket of high voltage cables;
- Appropriately sized fittings are provided, and the cable is secured and adequately restrained;

- The high voltage cables are routed and placed to prevent damage;
- Guarding is provided when high voltage cables are hung less than 6½ feet above the mine floor or rail and routed where miners work or travel; and
- On longwall power systems, guarding is provided on cables where miners pass over or under, and where the cable leaves cable handling or support systems.

C. Low/Medium Voltage Cables (MNM: ≤650 VAC, Coal: ≤1000 volts)

Through visual inspection, determine whether:

- The low/medium voltage cable is sized appropriately for the equipment that it supplies, by reviewing the equipment ratings and cable specifications;
- All power cables are installed on insulated hangers;
- All cables and wires enter or exit metal frames of motors, splice boxes, and electrical compartments only through proper fittings and insulated bushings; and
- All cables are protected where they pass through doors and stoppings.

CHAPTER 4 HIGH VOLTAGE SUBSTATIONS AND DISTRIBUTION

High potential or high voltage equipment is extremely dangerous and the utmost caution must be taken during inspection. When inspectors encounter problems or have questions about how to safely inspect this equipment, they should contact their supervisor or an electrical specialist for assistance.

Identify the location where the utility power system ends and the mine operator (company) power system begins. The mine operator should be able to point out the location where the mine power system begins. The mine operator is responsible for all electric equipment and circuits on mine property, and all such equipment and circuits must be provided with switches/ controls designed and installed to safely remove power to conduct necessary examinations, maintenance, and repairs.

Walk around the outside perimeter of the installation and visually examine the following conditions to determine whether:

- The mine substation is completely surrounded by a secure metal fence, or housed completely in a metal enclosure, both the fence and the gate are grounded, that all access gates or doors are locked and secured, access is limited to authorized personnel only, and that the keys are secured;

- Proper training has been provided for those mine personnel with access, including those with access to any applicable electrical installations;
- Warning signs are posted on all approaches to the substation fence, e.g., "Authorized Person," Danger – High Voltage," Do Not Enter," "Lock-Out/Tag-Out Required";
- Fire extinguishers are charged and have been examined regularly, as required;
- Combustible materials are stored or allowed to accumulate within a 25-foot perimeter of the substation, including grass, weeds, or other organic materials;
- A disconnecting switch or other control is provided on the line (input) side of the substation high voltage transformer;
- An insulating mat or dry wooden platform is in place at all switchboards and power control switches, including any overhead high voltage disconnect switches or controls;
- Any Gang Operated Air Break (GOAB) is installed with a steel/metal, grounded grate or platform installed to the same potential where the GOAB is operated (when hot sticks and lineman gloves are used, no grounded platform is required);
- Each circuit incorporates an electrical protective device such as a circuit breaker or fuse;
- Each branch circuit incorporates a disconnect switch that allows visual confirmation of de-energization when the circuit is open;
- At coal mines, all circuits feeding underground and all mobile equipment on the surface are on a resistance grounded system;
- The frames of all equipment in the substation are connected to the substation ground by means of a securely attached ground wire;
- Each outgoing circuit is labeled to identify the circuit it feeds;
- The electrical components of the substation show evidence of any heat or fire damage, indicating the potential presence of an electrical fault;
- Lightning arrestors are installed, as required; and
- There are any damaged or missing insulators, including on the overhead structures, transformers, or other high voltage equipment.

A. Overhead Distribution Lines

- Visually determine whether overhead high voltage lines are installed at least 15 feet above driveways, haulage-ways and railroad tracks.

- If equipment with booms or masts are used on the mine property, evaluate whether there is at least 10 feet of clearance between booms/masts and overhead high voltage lines.
- Where guy wires are used on poles that support overhead power lines, determine whether insulators are installed on the guy wires at a point below any power connection points, to prevent electrical connection/conduction with the power lines should the guy wire become loose. If insulators are not provided, determine whether the guy wires are grounded.
- Evaluate whether high potential/ high voltage conductors/cables (MNM: >650 VAC; Coal: >1,000 VAC) are placed to prevent contact with low voltage power cables or communication circuits (MNM: ≤650 VAC; Coal: ≤1,000 VAC).
- Determine whether all power conductors and telephone/communication wires are equipped with lightning arrestors and where telephone/communication wires enter a building, that the lightning arrestor is installed at the point where the wire enters the structure.

B. Surface Electrical Distribution Circuits

Visually determine whether:

- Power wires and cables are adequately insulated where they pass into or out of electrical compartments, motors, and splice boxes, and whether they enter or exit those electrical compartments through proper fittings or appropriate insulated bushings;
- An electrical protective device (circuit breaker or fuse of the correct type and capacity) is provided to protect all electrical equipment;
- All electrical equipment is provided with a switch or control to allow it to be safely deenergized and whether that switch or control can be locked out as needed;
- For distribution boxes, a disconnection device is provided and labeled, allowing for visual observation that the circuit is deenergized;
- Transformers located on the surface of a mine are totally enclosed (inside a metal enclosure with no exposed electrical connection points), located at least 8 feet above the ground, or surrounded by fence at least 6 feet high and at least 3 feet from any energized components;
- All inspection covers on electrical devices are present and secured;
- Dry wooden platforms or insulating mats are in place at switchboards and power control switches where shock hazards exist, including if >40VAC component is exposed or other shock hazard is identified;

- Switches and devices are labeled to appropriately identify circuits; and
- All exposed power cables and wires are free of damage.

C. Underground Electrical Distribution Circuits

Visually inspect underground electrical distribution circuits to determine whether:

- Each power conductor and each telephone/communication wire leading underground is equipped with a lightning arrestor within 100 feet of the point the circuit enters the mine;
- All high voltage power circuits are provided with a disconnecting switch installed underground within 500 feet of shaft bottoms and boreholes;
- All low and medium voltage circuits are provided with a disconnect control or switch within 500 feet of (on the surface) where power cables enter the underground area of the mine;
- A disconnect control or switch is provided at the beginning of all high voltage circuits (branches) and that the disconnect device is designed to allow visual confirmation that the circuit is de-energized when the circuit is open;
- All disconnects and circuits are labeled to identify the circuit it controls;
- All non-shielded power conductors as applicable are installed on insulated hangers and are not in contact with combustible material, roof, or ribs;
- All communication wires are installed on insulated hangers and provided with additional insulation where they pass over power conductors;
- Circuit breakers or fuses are installed to protect all electrical equipment (NOTE: electrical specialists or supervisors should be contacted for assistance if evaluation of conductor ampacity is needed);
- All electric equipment and circuits are provided with switches or other controls that are approved, or safely designed and constructed and are properly installed, as required; and
- Electrical equipment is free of physical or heat related damage.

CHAPTER 5 PERMISSIBILITY

Inspections of MSHA approved equipment require training and experience for special evaluations. When inspectors encounter problems or have questions about safely inspecting for permissibility, they should contact their supervisor or an electrical specialist for assistance. Permissible equipment is required in gassy mines including coal and some metal/nonmetal mines and mills, and needs to be regularly examined and properly maintained.

A step-by-step approach for a permissibility inspection is provided in Appendix A.

CHAPTER 6 ELECTRICAL EQUIPMENT AND OTHER INSPECTION ELEMENTS

Electrical inspections can vary greatly depending on the type of mine or facility. The following guidance illustrates common enforcement elements of an electrical inspection, but will not address all situations. Electrical specialists or supervisors should be contacted for assistance, as needed.

A. Double Insulated Equipment

Many hand tools are made from metal or other conductive materials that conduct electricity, and hazards may potentially exist when they come in contact with energized conductors. Double insulation provides an extra layer of safety otherwise provided by a ground wire and ground prong on the power cord.

Determine if a tool is double insulated by locating the manufacturer's data plate or sticker affixed to the tool, with the words "Double Insulated" or the international symbol, a "square-within-a-square" symbol (See Diagram 1).

Double insulation does not prevent all electrocution hazards; determine the integrity of the tools and equipment by inspecting for cracks, damage, loose, missing, or defective parts, fasteners, or other components, as well as insufficient repair work, e.g., wrapping the tool casing or housing with electrical tape is not acceptable. If such conditions are found, the tool or equipment should be removed from service immediately.

B. Electrical Equipment Components

Electrical equipment and components is a broad category—the following list is provided as a general guide of common safety elements inspectors should evaluate. Equipment should:

- Be suitable for its use, and installed and maintained in a neat and workmanlike manner;
- Have sufficient mechanical strength and durability, and adequate electrical insulation. Equipment should be free of damage, including any parts broken, bent, cut, or deteriorated by overuse, corrosion, chemical reaction, or overheating;

- Be installed and used to prevent overheating and hazardous arcing effects under all conditions of use. Where arc flash protection is required, determine if adequate training has been provided and appropriate equipment is used.
- Have safe access protections installed, including fencing, limited personnel access (authorized persons only), locking cabinets, covers or enclosures, or other safeguards, as appropriate (e.g., effective closures to protect any unused openings in boxes, raceways, auxiliary gutters, cabinets, equipment cases, or housings);
- Be firmly secured to its mounting surface;
- Not have conductors of dissimilar metals mixed in a terminal or splicing connector, e.g., copper and aluminum, copper and copper-clad aluminum, or aluminum and copper-clad aluminum, unless the device is identified for the purpose and conditions of use; and
- Use devices intended for splicing joining conductors. All splices and joints and the free ends of conductors should be covered with an insulation equivalent to that of the conductors or with an insulating device identified for the purpose.

C. Work Practices

Evaluate whether all persons who perform electrical work on mine property are competent, authorized and qualified to perform the duties to which they are assigned. Identify individuals who are assigned as a "Competent person" and "Authorized person," as defined by 30 CFR § 56/57.2 and "Qualified person" as defined by 30 CFR § 75/77.2. Determine whether any person assigned a duty or permitted access to specific locations, including access to major electrical installations, are qualified for that duty or level of access.

Lock Out and Tag Out Procedures: Inspectors evaluate activities performed by miners in light of the distinction between "electrical work" and "troubleshooting" when determining appropriate enforcement actions.

- During troubleshooting, circuits may remain energized if safety precautions are taken. Troubleshooting is identifying the source of the fault or problem by using data and analytical instruments to identify or isolate items that are outside acceptable ranges or defective. Troubleshooting shall be conducted by an adequately trained person who is "Qualified" or "Competent," and must include proper use of analytical instruments and appropriate PPE to prevent contacting energized components.
- In contrast, electrical circuits shall be deenergized, locked-out, tagged-out, high voltage circuits grounded, and verified before electrical work is performed. The rare exception, involving repairs to high-voltage lines, is found under 30 CFR

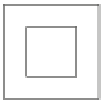
77.704-2 – 704-10, e.g., specialized high-voltage work performed by highly trained lineman. Troubleshooting and electrical work may be done in succession or alternate back and forth, but the safety requirements are distinct and should be followed accordingly.

Electrical work includes installing, maintaining, replacing, loosening or tightening electrical components or equipment.

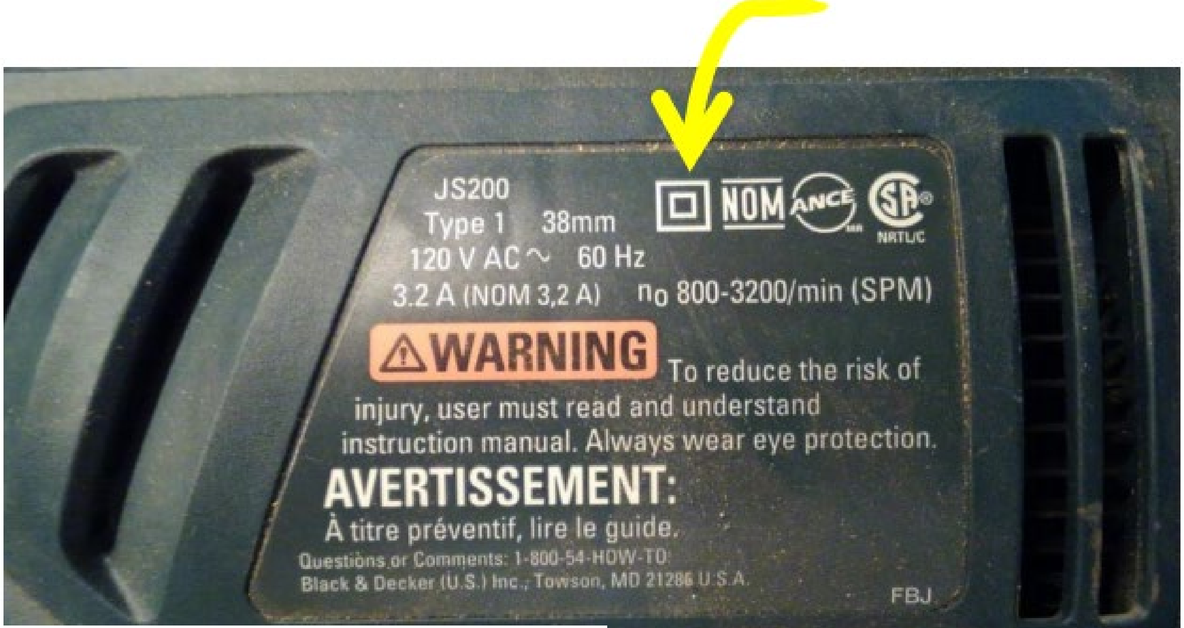
DIAGRAM 1

Polarized plug for a double insulated tool

Plug with ground pin for a grounded tool

Class II equipment symbol: 

Symbol for "Double Insulated" tool (square inside a square)



Class II Insulation Level (IEC 60364-4-41)

APPENDIX A – PERMISSIBILITY

A machine should not be examined for permissibility until the trailing cable supplying power to the machine has been deenergized. The inspector should confirm that the trailing cable supplying power to the machine is disconnected, locked out and suitably tagged, and verified, and if the equipment is powered with high voltage, the circuit is grounded, before the inspector examines the machine for permissibility.

Discuss the machine performance and any known machine hazards with the machine operator. Prior to the equipment inspection examine the area around the equipment to evaluate roof, rib, combustible material or tripping hazards.

Visually inspect the machine then examine and test all the safeties (panic switches, fire suppression, lights, methane monitors, parking brakes, etc.). The machine should be powered up prior to checking panic switches and emergency stop devices. The machine power should deenergize the power immediately upon activation of the panic switch. Where multiple panic bars are present, re-set the power to check each switch. Inspect machines equipped with an emergency stop or emergency stop override for full functionality.

The checklist provided in Chapter VI, Volume I of this document should be followed when evaluating equipment for permissibility. Any concerns or questions about examination of any of the checklist elements should be directed to an electrical specialist or supervisor.