# Electrical Level 2

## Grounding and Bonding 26209-14

# Objectives

## When trainees have completed this lesson, they should be able to do the following:

1. Explain the purpose of grounding and bonding and the scope of ***NEC Article 250***.
2. Distinguish between a short circuit and a ground fault.
3. Define the *National Electrical Code*® requirements related to bonding and grounding.
4. Distinguish between grounded systems and equipment grounding.
5. Use ***NEC Table 250.66*** to size the grounding electrode conductor for various AC systems.
6. Explain the function of the grounding electrode system and determine the grounding electrodes to be used.
7. Define electrodes and explain the resistance requirements for electrodes using ***NEC Section 250.56***.
8. Use ***NEC Table 250.122*** to size the equipment grounding conductor for raceways and equipment.
9. Explain the function of the main and system bonding jumpers in the grounding system and size the main and system bonding jumpers for various applications.
10. Size the main bonding jumper for a service utilizing multiple service disconnecting means.

# Objectives and Performance Tasks

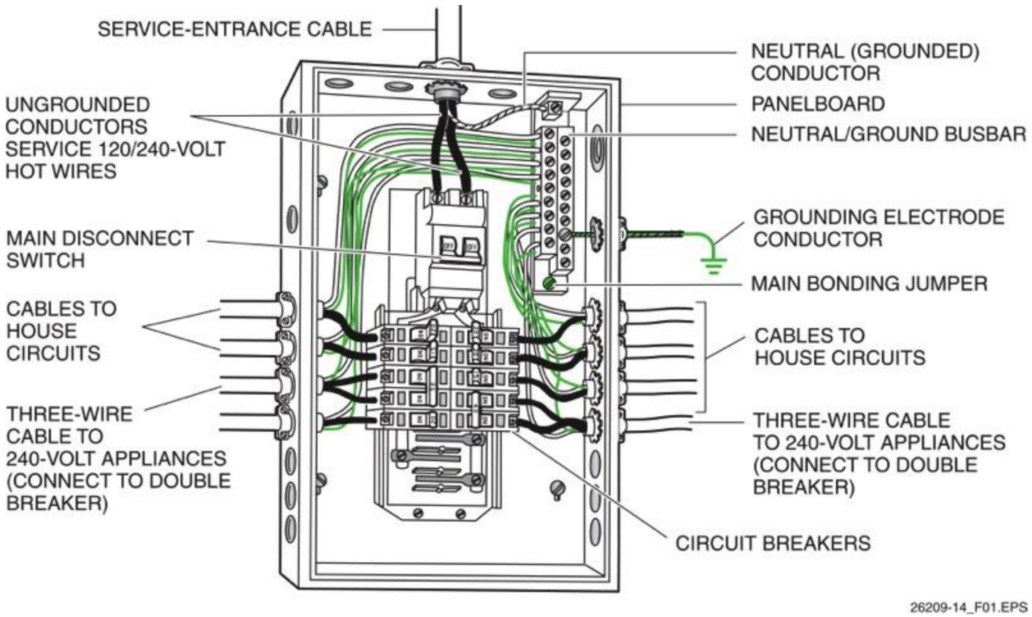
11. Explain the importance of bonding equipment in clearing ground faults in a system.
12. Explain the purposes of the grounded conductor (neutral) in the operation of overcurrent devices.

## Performance Tasks

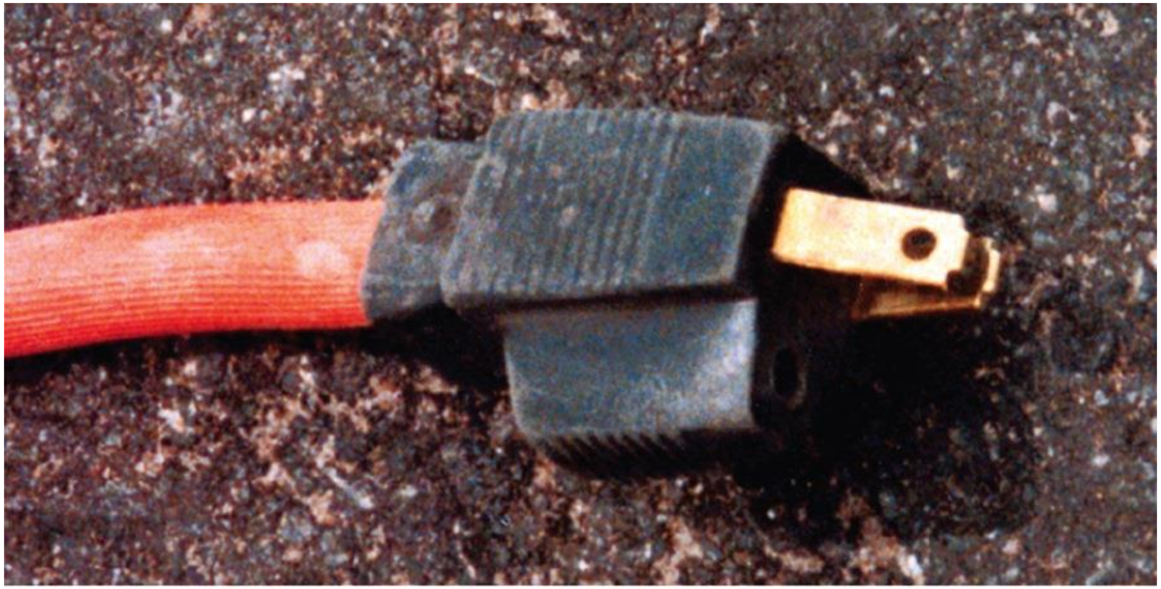
1. Using the proper fittings, connect one end of a No. 4 AWG bare copper grounding wire to a length of ¾" galvanized water pipe and the other end to the correct terminal in a main panelboard.
2. Install two lengths of Type NM cable in a switch box using Type NM cable clamps:
   - Strip the ends of the cable to conform with *National Electrical Code*® requirements.
   - Secure the cable in the switch box and tighten the cable clamps.
   - Connect and secure the equipment grounding conductors according to *NEC*® requirements, and secure to the switch box with either a ground clip or a grounding screw.
3. Size the minimum required grounding electrode conductor for a 200A service fed by 3/0 copper.
4. Size the minimum required equipment grounding conductor in each conduit for a 400A feeder gap using two parallel runs of 3/0 copper.
5. Size the minimum required bonding jumper for a copper water pipe near a separately derived system (transformer) where the secondary conductors are 500 kcmil copper.

# Introduction; Purpose of Grounding and Bonding; *NEC*® Requirements

- Circuits are grounded to limit the voltage on the circuit and ensure the stability and continuity of the electrical system.
- ***NEC Article 250*** covers the requirements for grounding.



## *What's wrong with this picture?*



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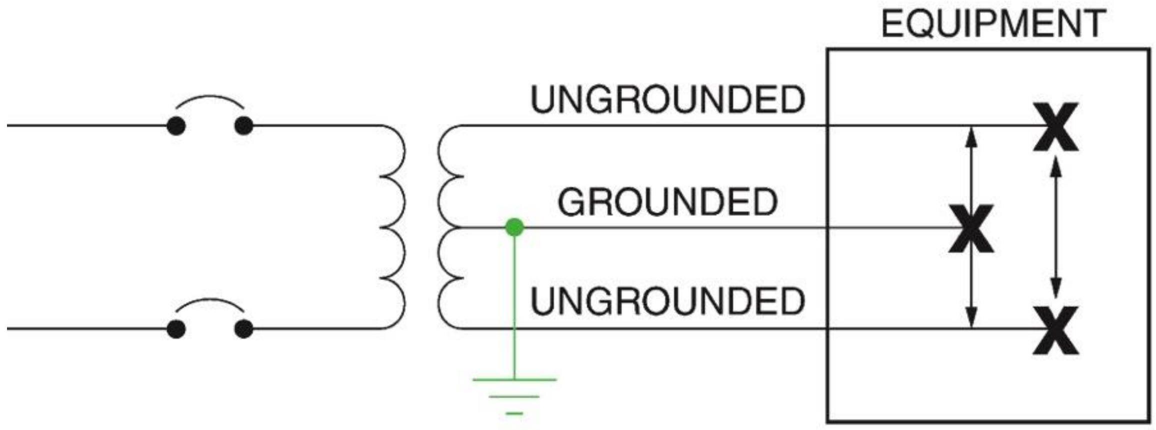
# Short Circuit Versus Ground Fault

- A short circuit is a conducting connection, whether intentional or accidental, between any of the conductors of an electrical system, whether it is from line-to-line or line-to-ground.
- The maximum value of fault current depends on the available capacity the system can deliver to the point of fault.

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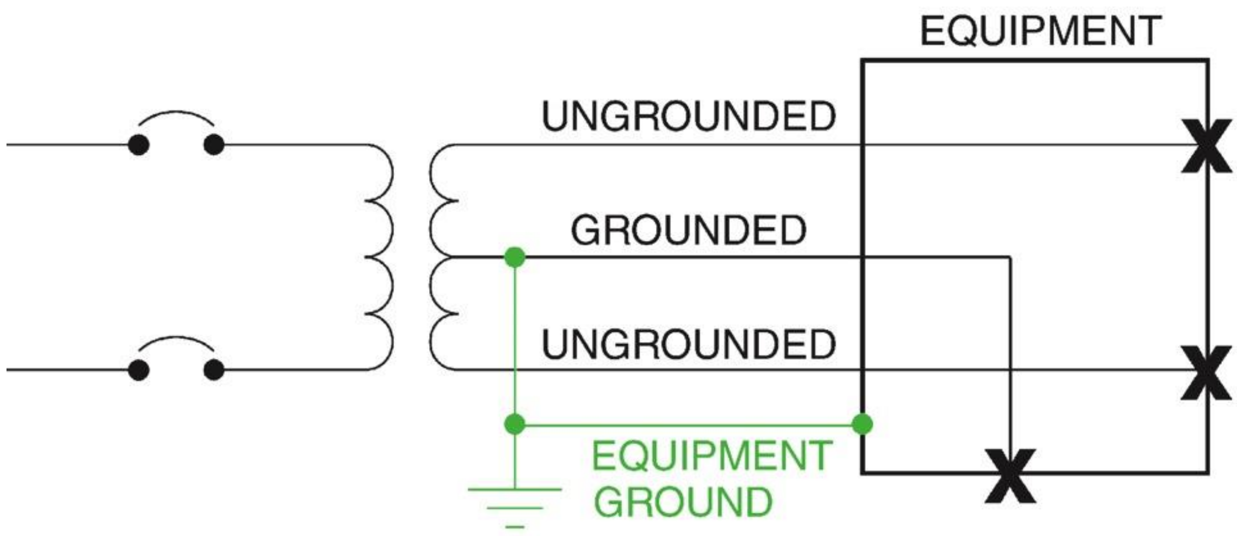
# Ground Fault

A ground fault is an unintentional, electrically conducting connection between an ungrounded conductor of an electrical circuit and the normally noncurrent-carrying conductors, metal enclosures, metallic raceways, metallic equipment, or the earth.

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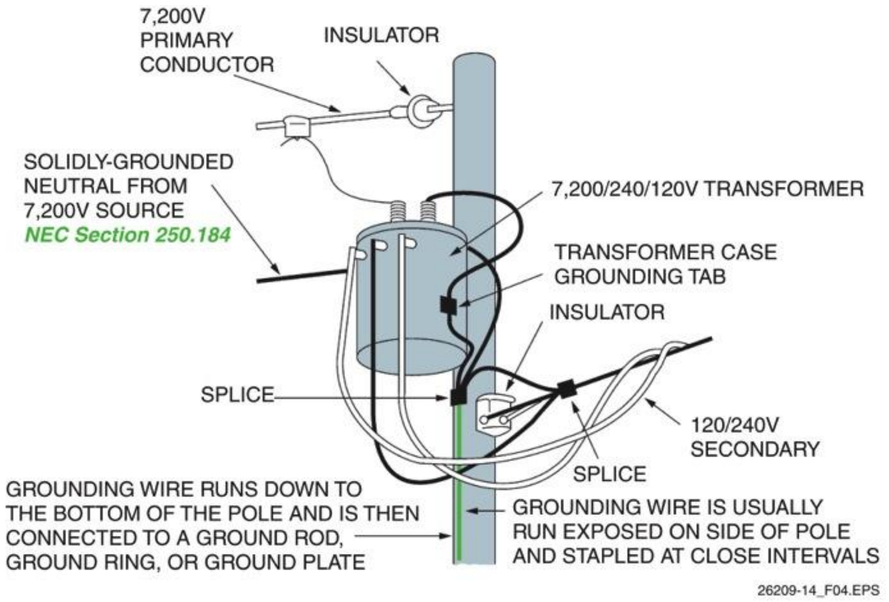
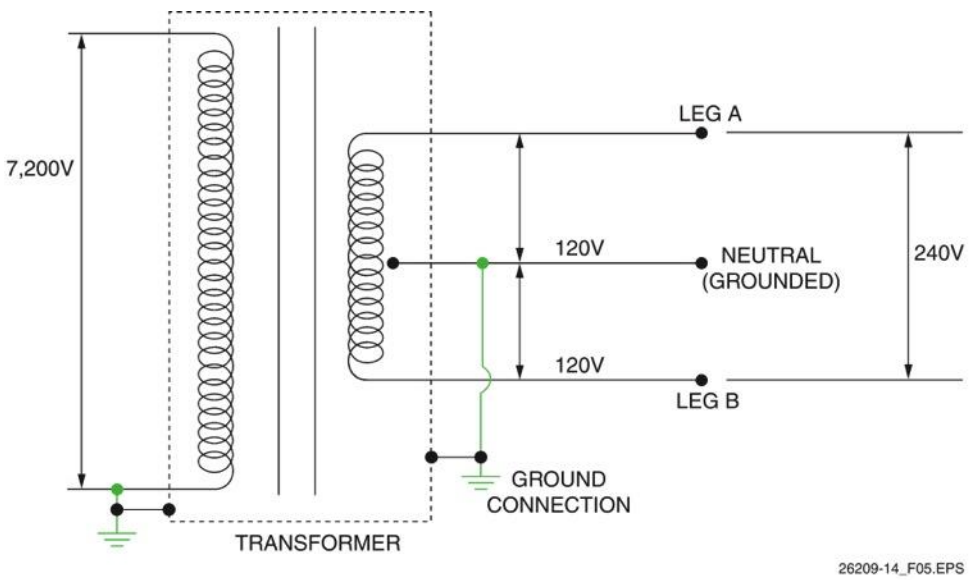
# Types of Grounding Systems

- There are two categories of grounding: system grounding and equipment grounding.
- System grounding relates to the service-entrance equipment and its bonded components.
- Equipment grounding conductors connect the noncurrent-carrying metal parts of equipment, conduit, boxes, or enclosures to the system grounded conductor, the grounding electrode conductor, or both.

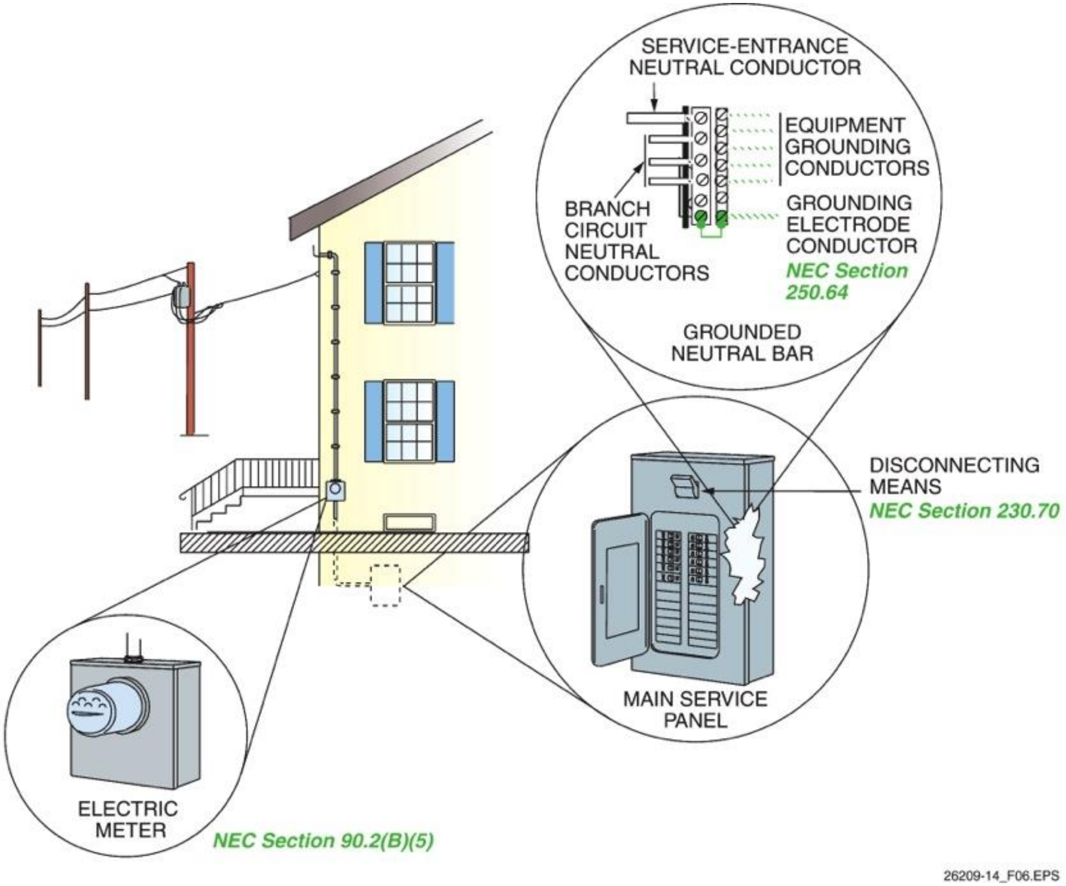


# Wiring Diagram of a 7,200V to 120/240V Single-Phase Transformer Connection

- This transformer steps down the power line voltage to 120/240V single-phase service suitable for residential use.
- Legs A and B are ungrounded conductors, while the neutral is the grounded conductor.

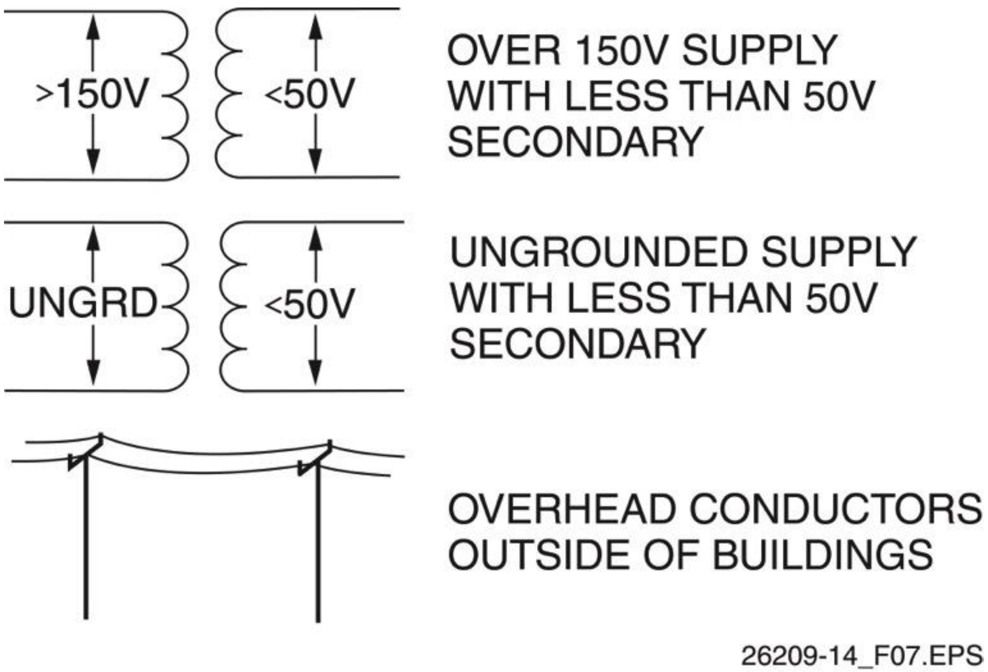


# Typical Service Entrance and Related Service Equipment



# Systems Less than 50V that Must be Grounded

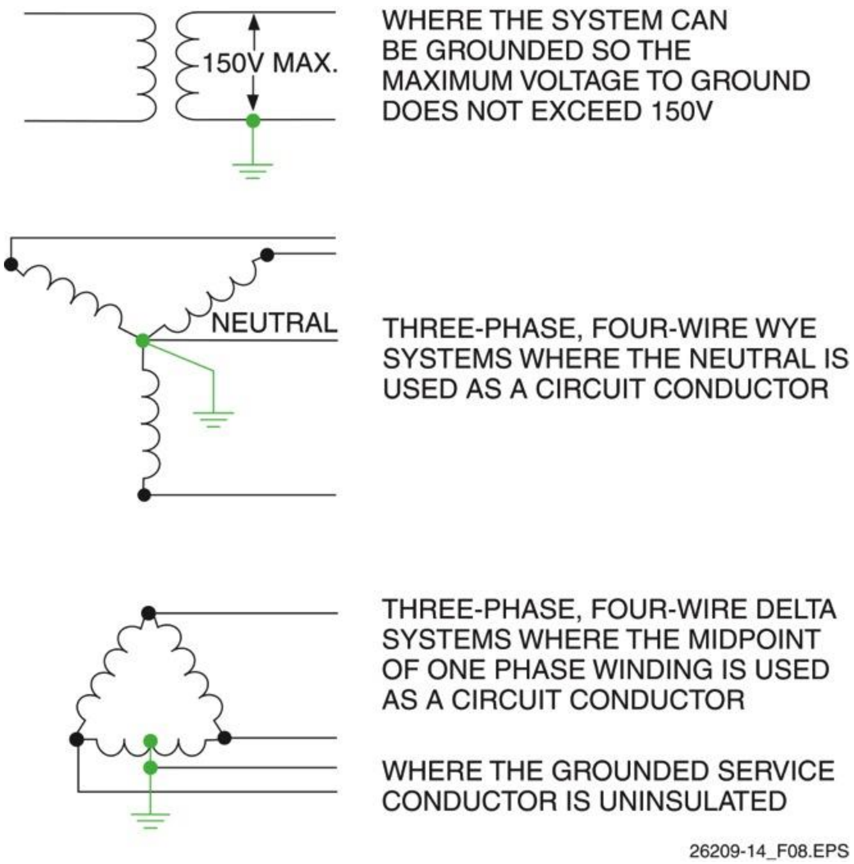
Certain systems operating at less than 50V require grounding, as shown here.



# 5.0.0 – 5.2.5

## Systems that Must be Grounded

- 50V to 1,000V systems require grounding under the conditions shown here.
- AC systems over 1,000V must be grounded if supplying mobile/portable equipment.
- Separately derived systems (including generators, transformers with no direct connection between the primary and secondary, and power derived from inverters or rectifiers) also require grounding.



# 5.0.0 – 5.2.5

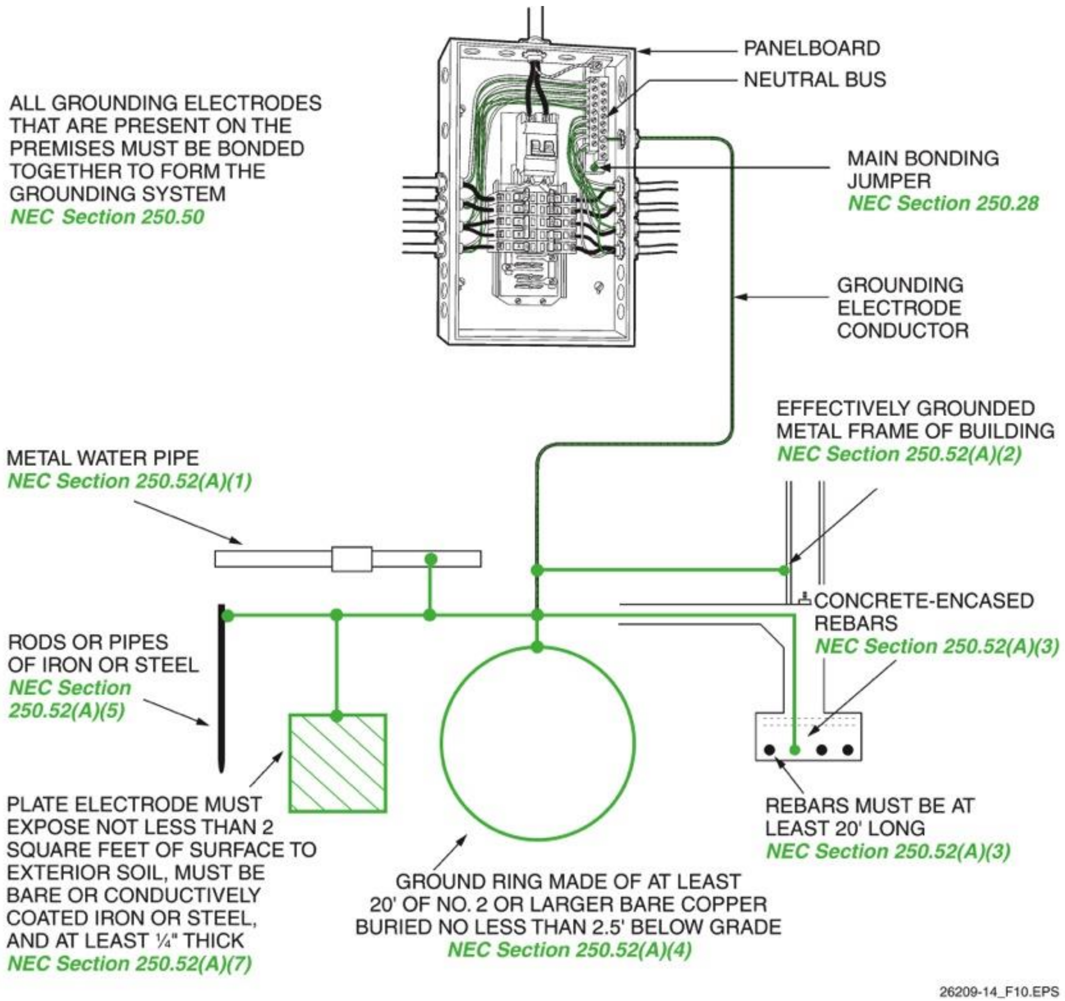
## Next Session…

## *NEC*® Requirements

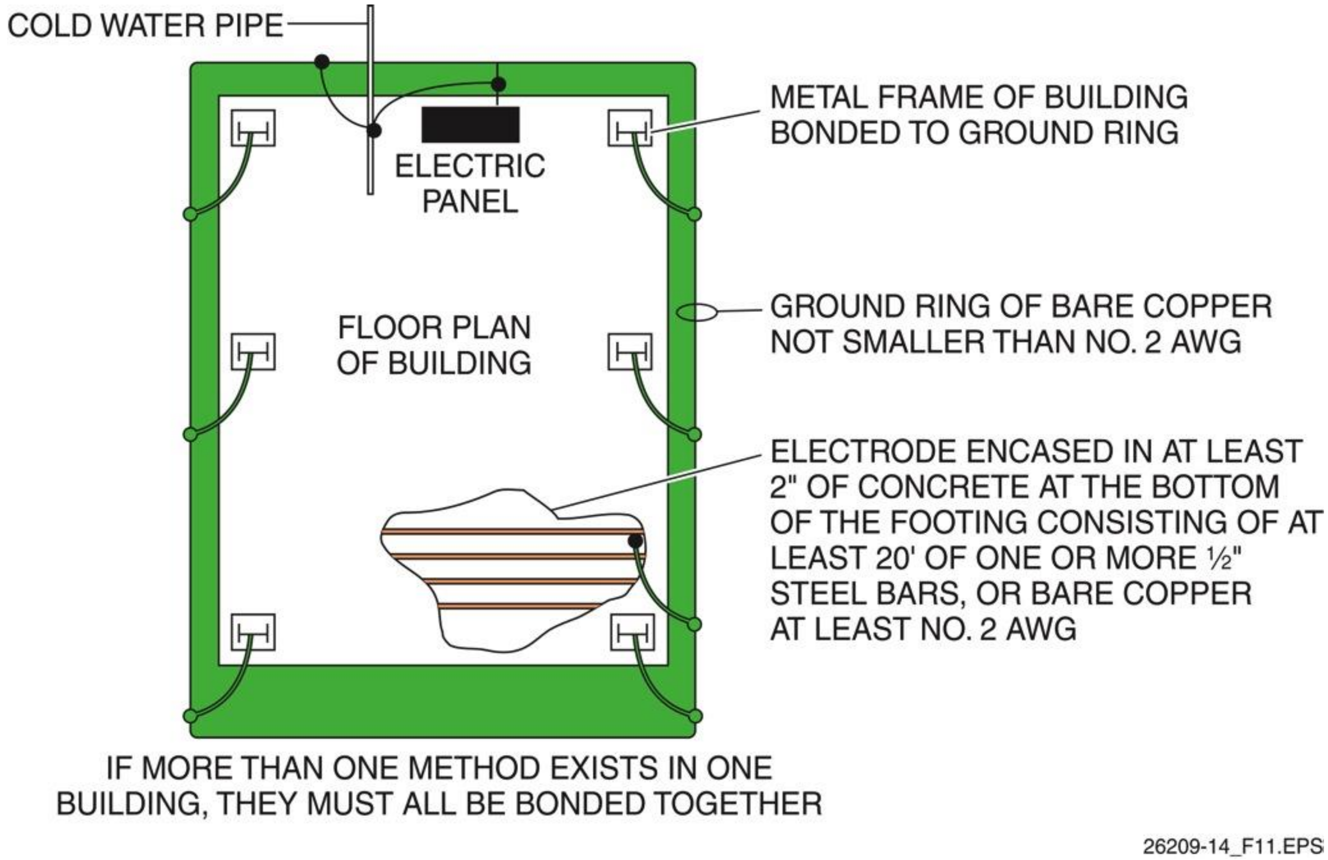
Circuits that are Not Permitted to be Grounded

Certain systems are not permitted to be grounded, as shown here.

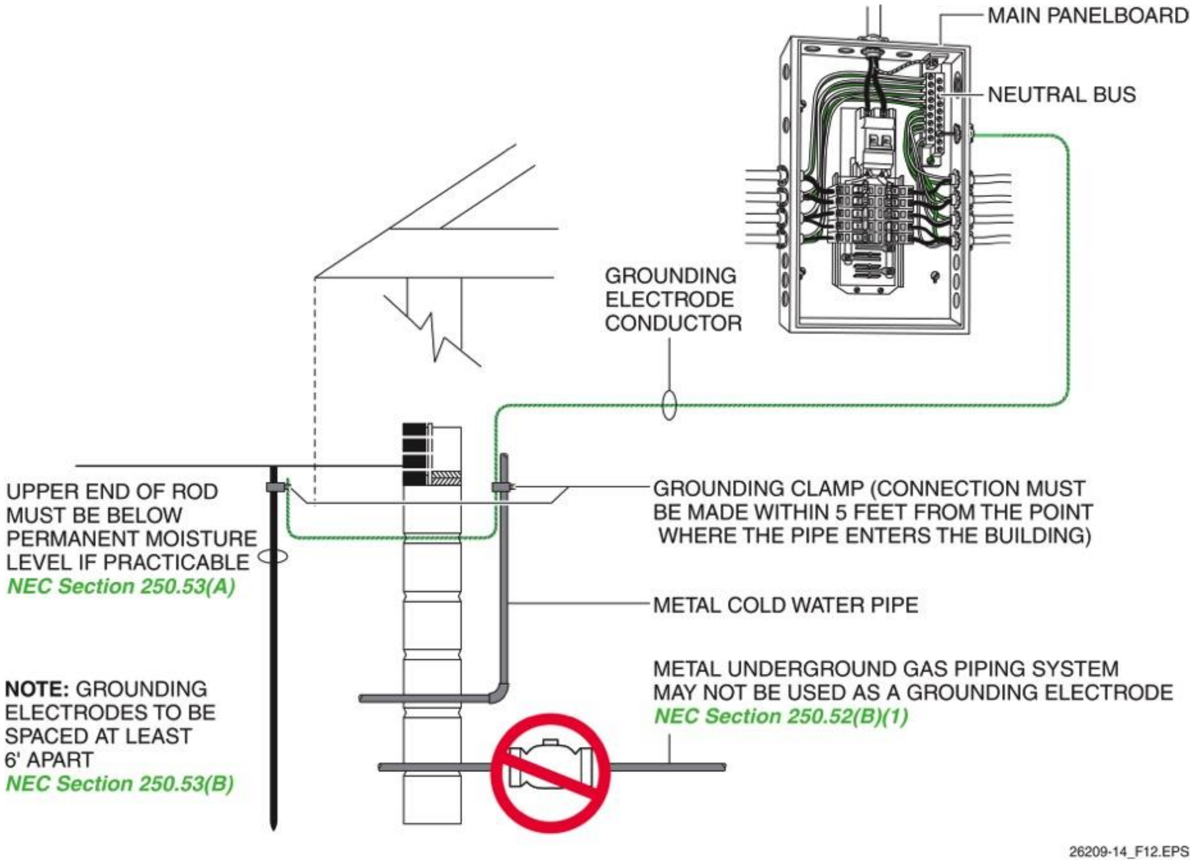
# *NEC*® Requirements



# Floor Plan of the Grounding System for an Industrial Building



# Grounding Requirements for Non-Industrial Buildings

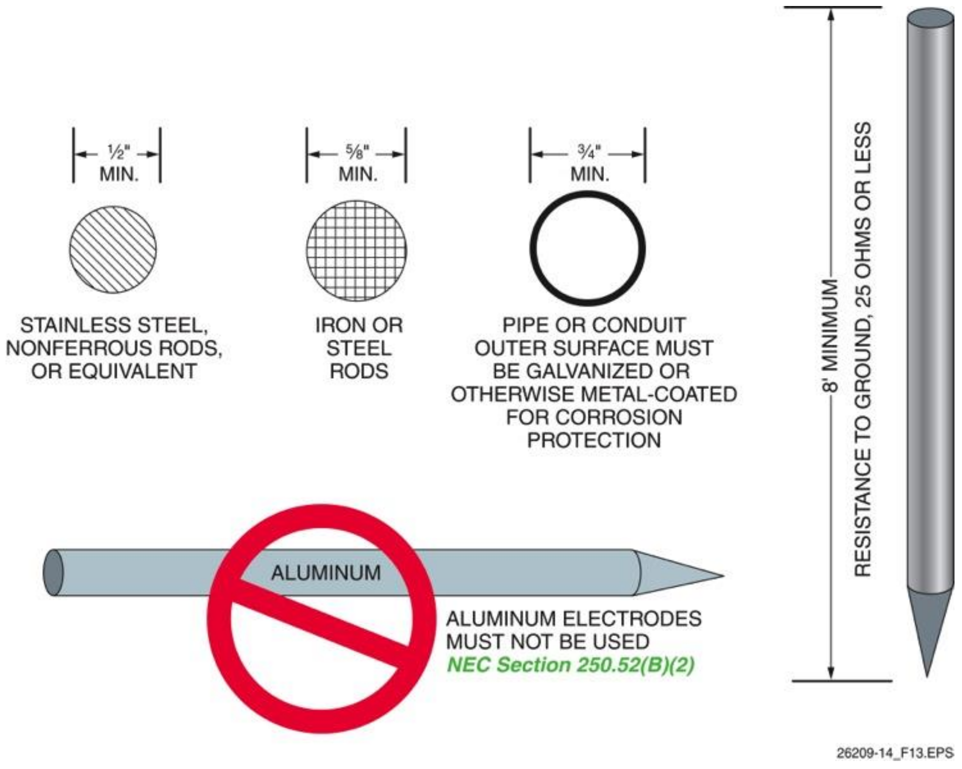


# 6.0.0 – 6.1.0

# Requirements for Ground Rods

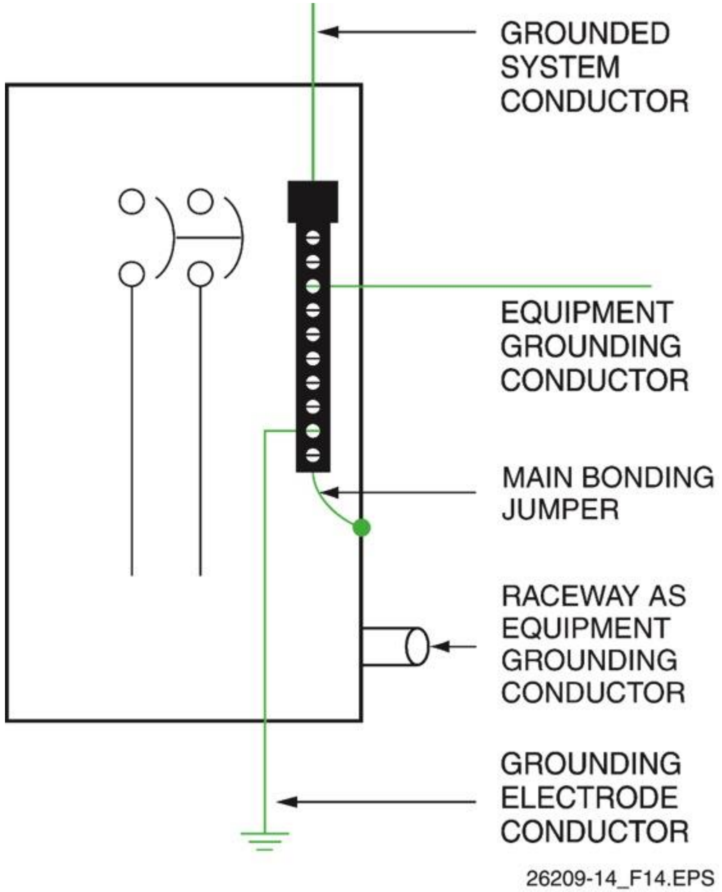
Supplemental grounding electrodes must meet the following requirements:

- Withstand and dissipate repeated surge currents
- Provide corrosion resistance to various soil chemistries
- Be rugged enough to drive into the soil with minimal effort and damage



# Grounding Electrode Conductor

- *NEC Section 250.64* lists the requirements for installing grounding electrode conductors.
- A common grounding electrode conductor is required to ground both the circuit grounded conductor and the equipment grounding conductor.

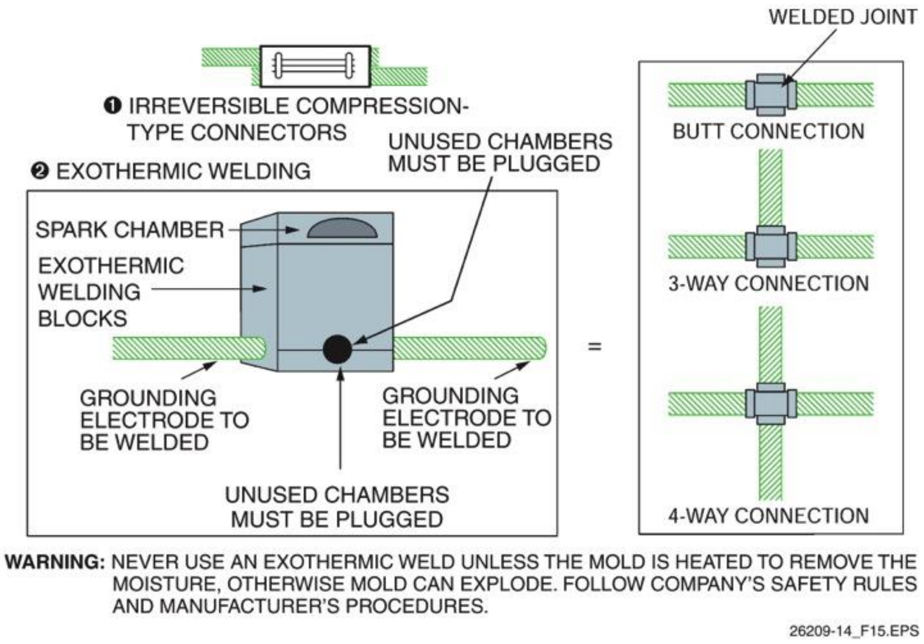



**Performance Task**

Trainees practice sizing grounding electrode conductors.

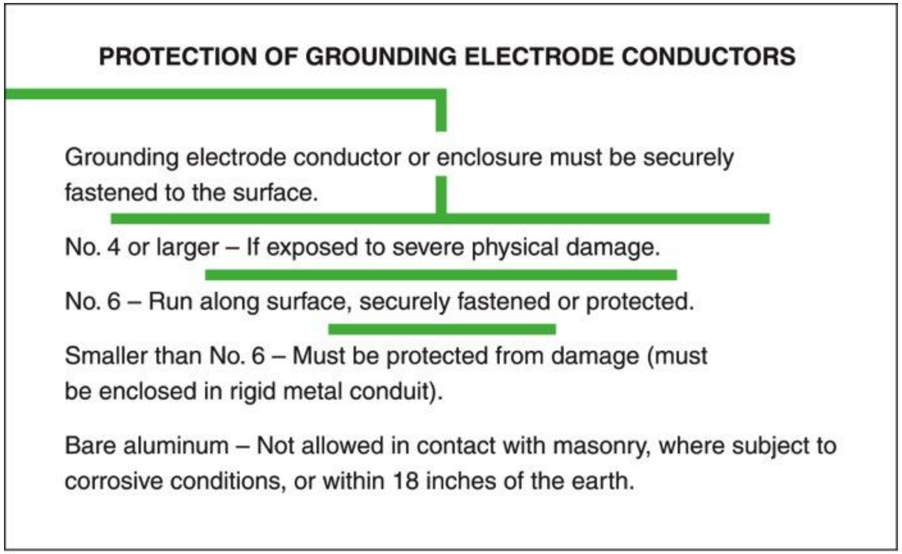
# Methods of Splicing Grounding Conductors

- Wire-type grounding electrode conductors may be spliced at any location by means of irreversible compression fittings or exothermic welding.
- Exothermic welding may only be performed by qualified individuals.



# Protection of Grounding Electrode Conductors

- The size of the grounding electrode conductors depends on the size of the service entrance.
- ***NEC Table 250.66*** lists the proper sizes of grounding electrode conductors for various service sizes.

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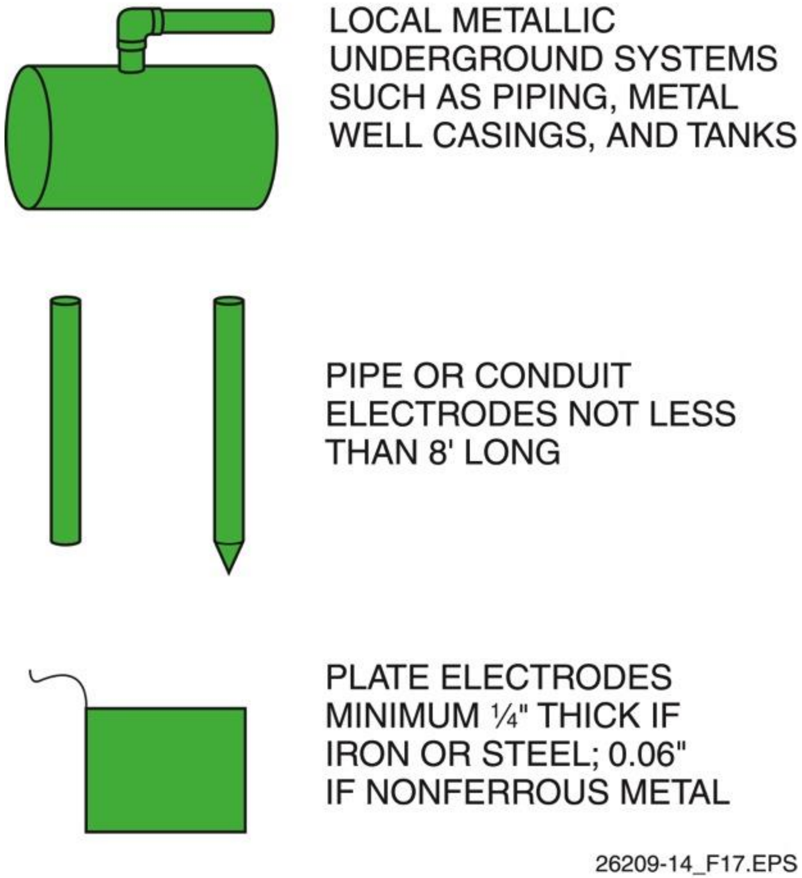
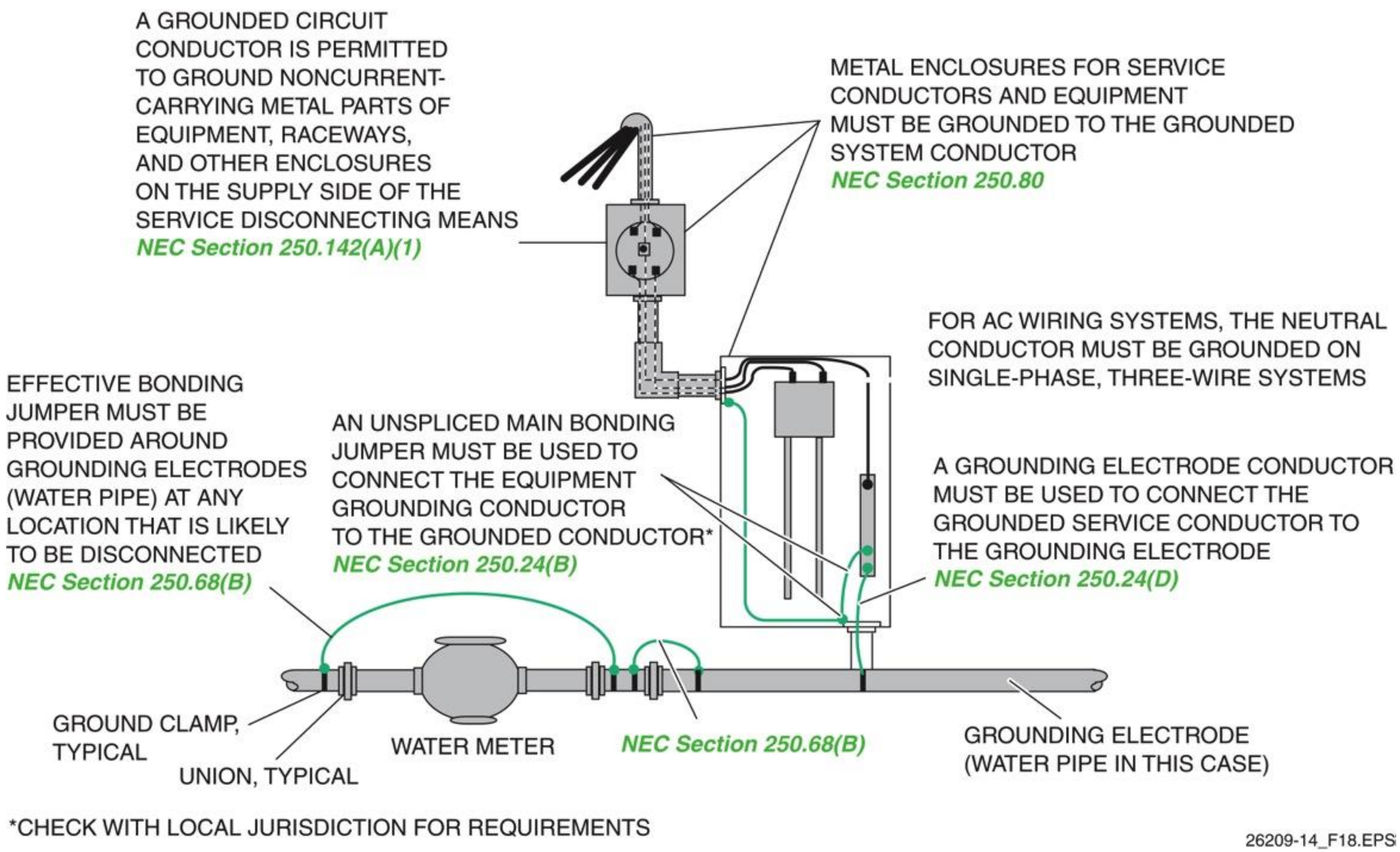
# Other Electrodes

- Other types of electrodes include rod and pipe, plate electrodes, and other local metal underground systems such as water piping.
- *NEC Section 250.52* lists the requirements for these electrodes.



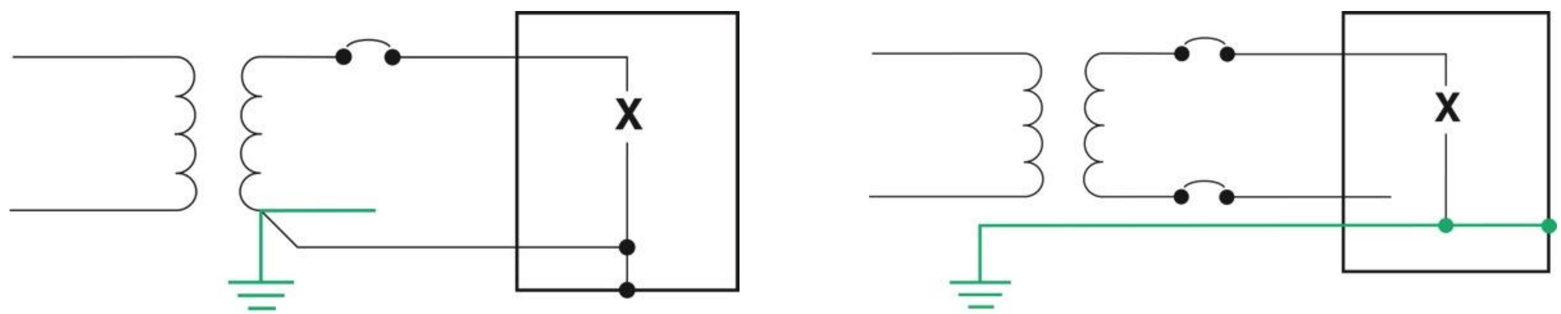
# Equipment Grounding



# 7.1.0 – 7.1.2

## Equipment Grounding Conductor

The equipment grounding conductor (EGC) is the conductor used to interconnect and bond the noncurrent-carrying metal parts of equipment, raceways, and other enclosures to the system grounded conductor and/or the grounding electrode conductor at the service equipment or the source of a separately derived system.




GROUND FAULT IN GROUNDED SYSTEM

GROUND FAULT IN UNGROUNDED SYSTEM

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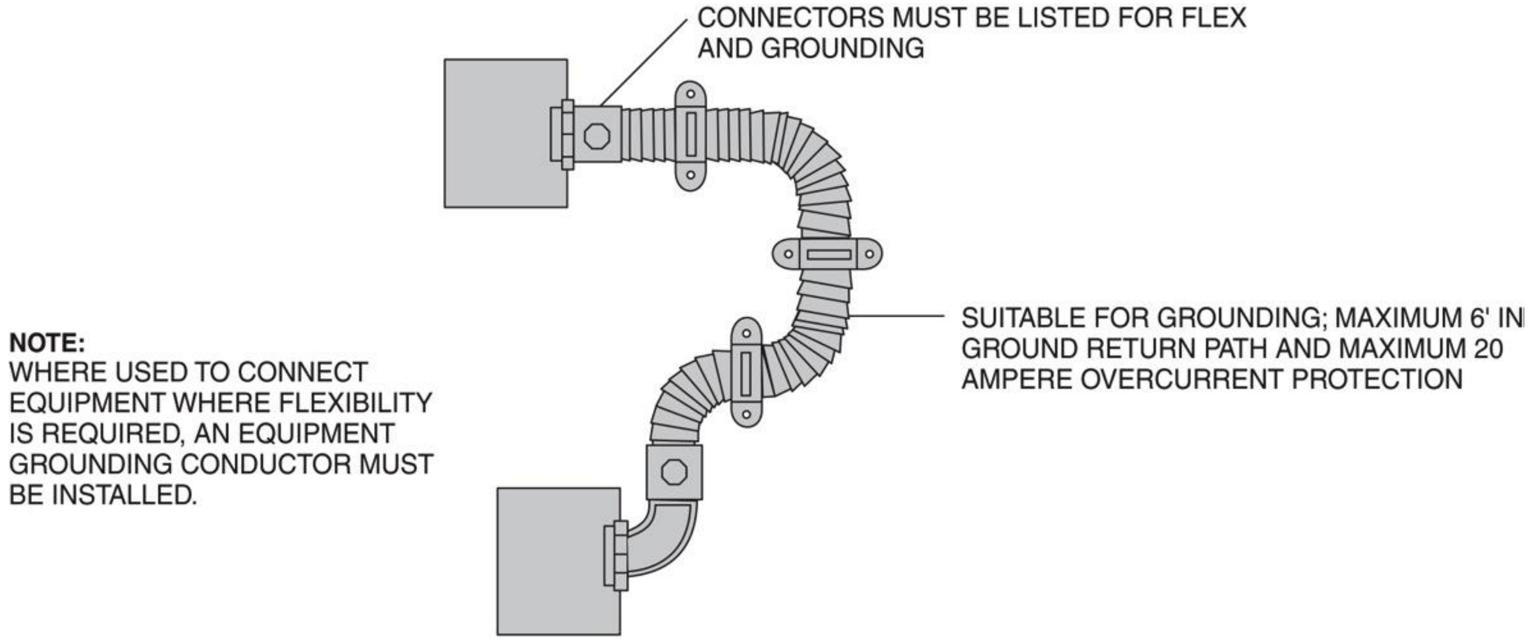
7.1.0 – 7.1.2

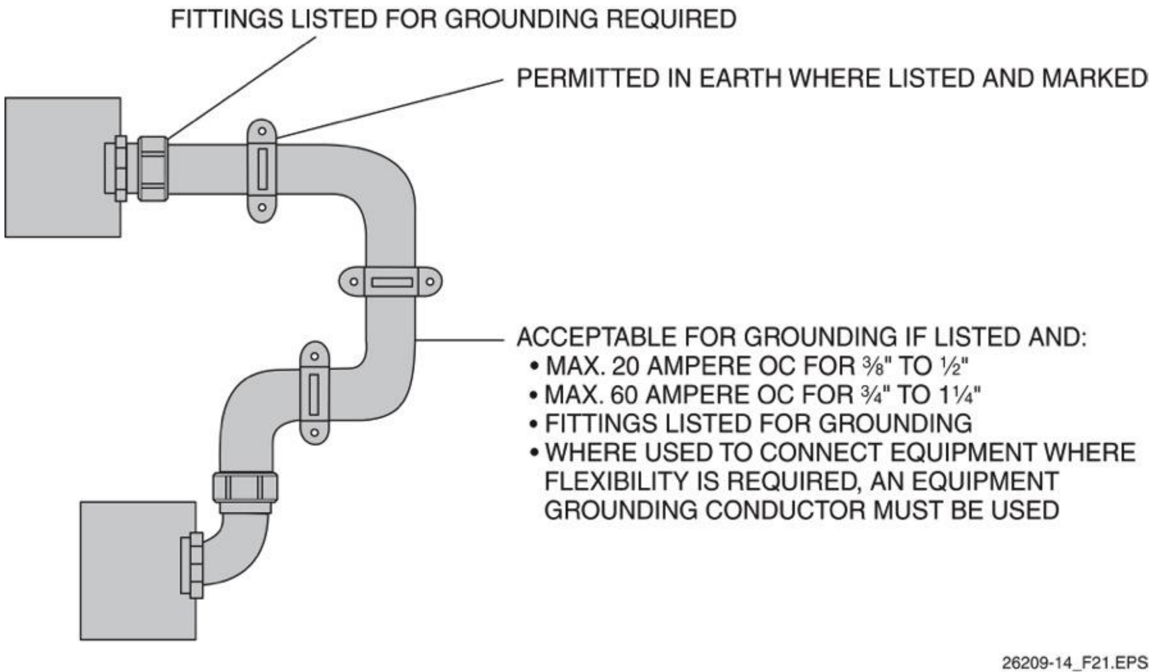
# Installation Requirements for Flexible Metal Conduit

Flexible metal conduit can be used as an equipment ground if it meets the *NEC*® installation requirements.



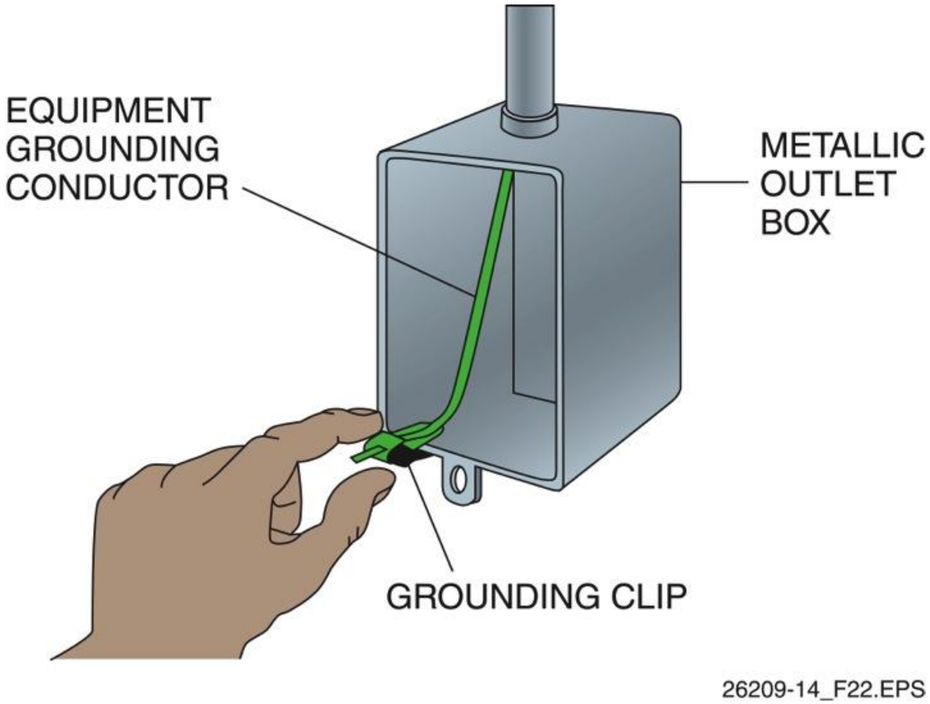
# Installation Requirements for Liquidtight Flexible Metal Conduit

Liquidtight flexible metal conduit can also be used as an equipment ground if it meets the *NEC*® installation requirements.

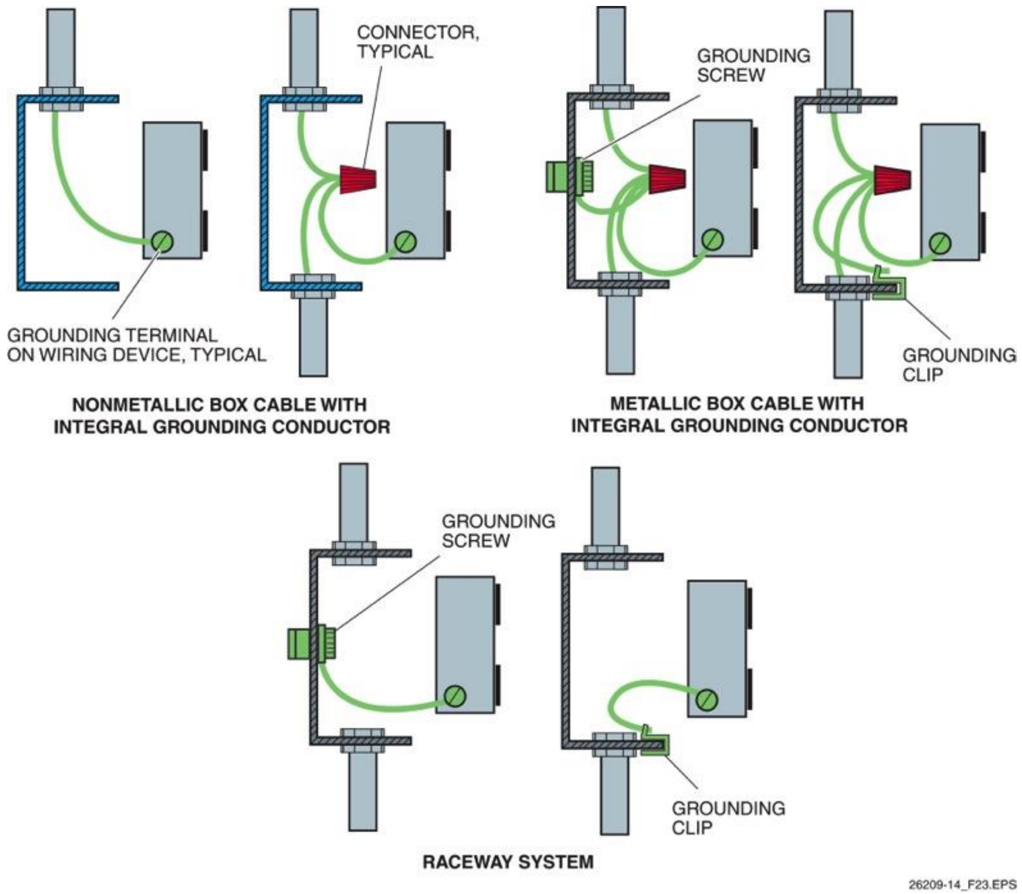


# Grounding Enclosures

- A grounding clip or other device is used to secure the equipment grounding conductor to each receptacle to ensure continuity of the grounding system.
- ***NEC Section 250.8*** lists the requirements for connecting these grounding conductors to enclosures.



# Grounding Receptacles With Different Wiring Methods



7.3.0

# Next Session…

# Bonding Service Equipment

## Main Bonding Jumper

- The main bonding jumper must be rated for the size of the service conductors.
- ***NEC Table 250.102(C)(1)*** is used to size the main bonding jumper.


**Performance Task**

This session concludes with trainees practicing installing NM cable in a switch box and sizing equipment grounding conductors.

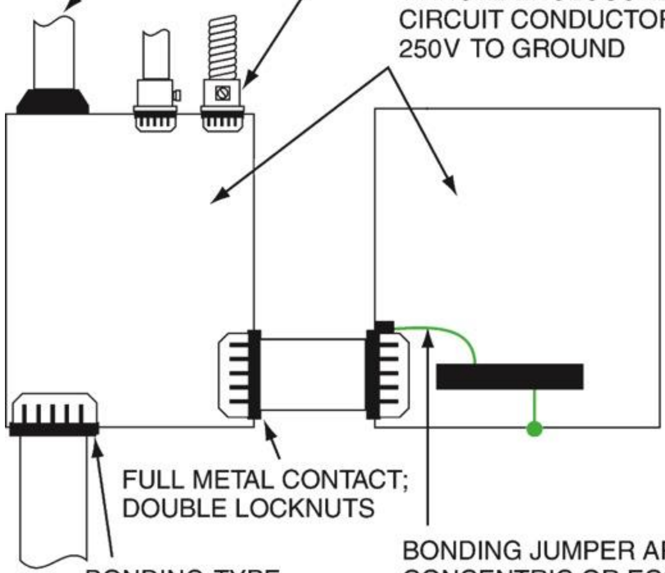
# Bonding Service Equipment

- The bonding of multiple service disconnects is covered in ***NEC Article 230***.
- This table shows various sizes of bonding jumpers based on the size of the service-entrance conductor.

| **Service-Entrance Conductor** | **Bonding Jumper (Copper)** |
|---|---|
| 500 kcmil in service mast | 1/0 |
| 1,000 kcmil in wireway | 2/0 |
| 300 kcmil | No. 2 |
| 3/0 | No. 4 |
| No. 2 | No. 8 |

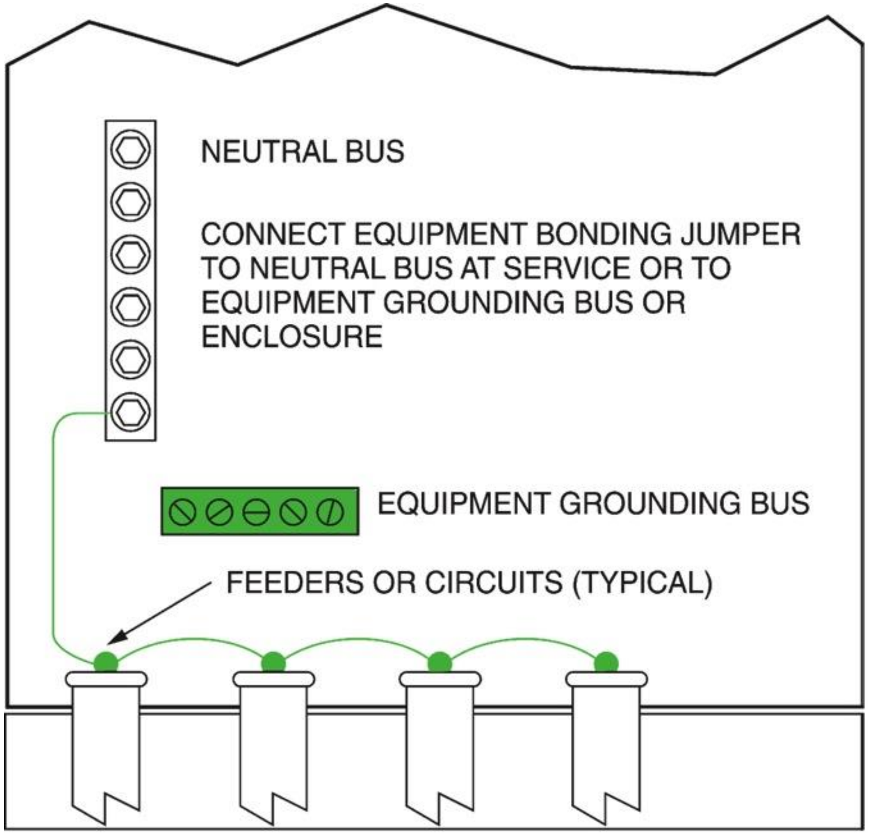
# Bonding of Enclosures and Equipment

Circuits over 250V must meet the bonding requirements shown here.



# Bonding Multiple Raceways

***NEC Table 250.102(D)*** allows the use of a single conductor to bond two or more raceways or cables when the bonding jumper is sized in accordance with ***NEC Table 250.122*** for the largest overcurrent device supplying the associated circuits.

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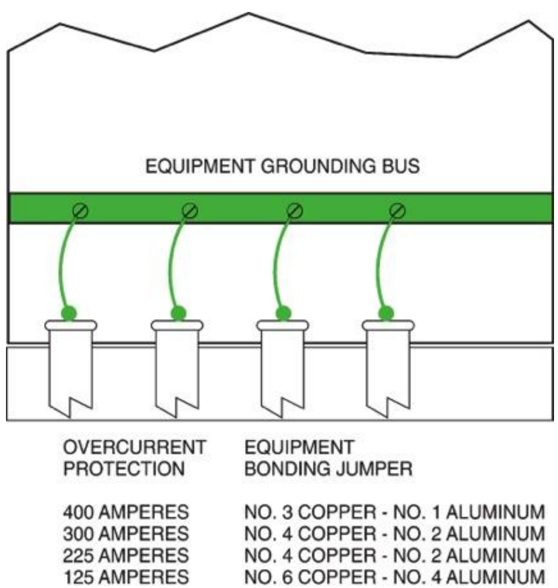
# 8.2.0 – 8.2.3

## Individual Bonding Jumpers

- Individual bonding jumpers may be installed from each raceway to equipment grounding terminals on a main grounding bus.
- Each bonding conductor is sized in accordance with ***NEC Table 250.122***.




(A)

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(B)

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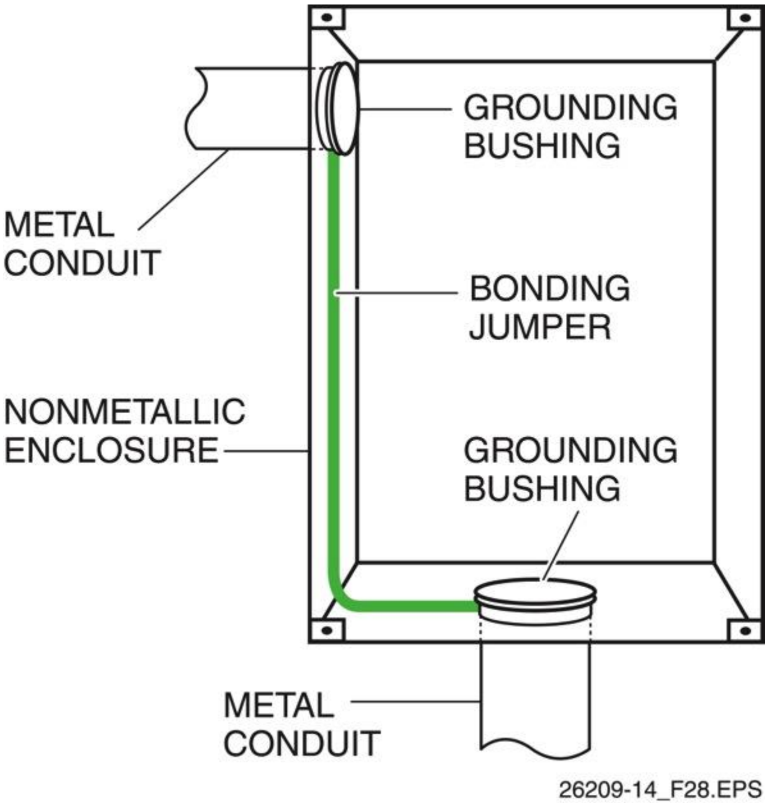
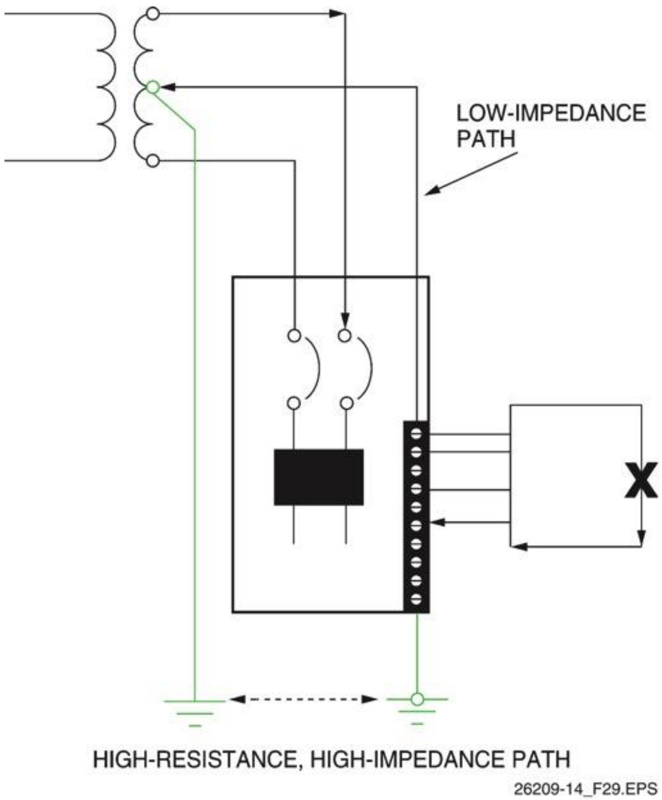
# Bonding Jumper

- An equipment bonding jumper may be installed either inside or outside of a raceway or enclosure. Jumpers installed outside of the raceway may be no longer than six feet and must follow the routing of the raceway.
- Equipment bonding jumpers must be sized for the overcurrent device.



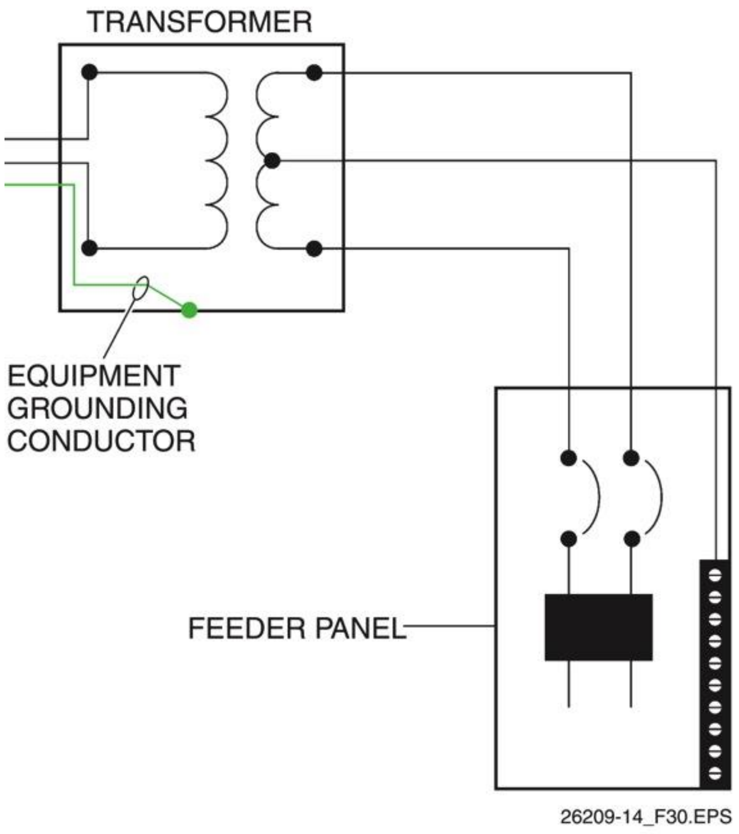
# Effective Grounding Path; Grounding Conductor

- An effective ground fault path provides a permanent, continuous path to safely conduct fault current, and has low enough impedance to limit the voltage to ground and facilitate the operation of circuit protective devices.
- The grounded conductor or neutral permits utilization of power at line-to-neutral voltage and provides a low-impedance return path for the flow of fault current.



# Separately Derived Systems

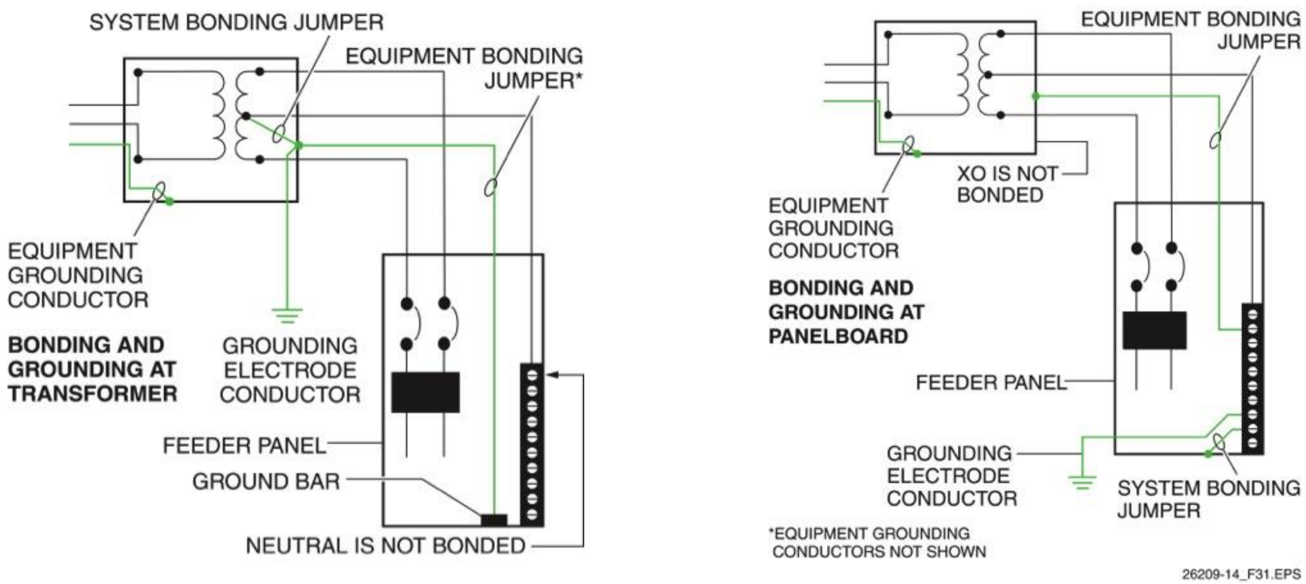
- A transformer-type separately derived system has no direct electrical connection to the premises' power source.
- Grounding of separately derived systems is covered in ***NEC Section 250.30***.



# Separately Derived System Grounding and Bonding Locations

The grounding electrode for separately derived systems must be:

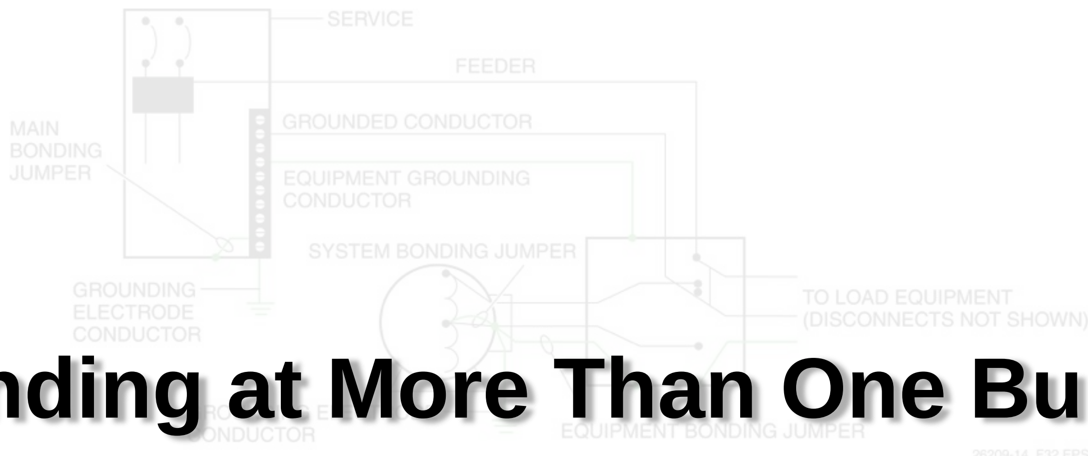
- As near as practical to the system
- The nearest available grounded structural metal member or water pipe
- Other electrodes per ***NEC Sections 250.50 and 250.52***



# Next Session…

## Grounding at More Than One Building; Systems Over 1kV

Generator-Type Separately Derived System




- To determine if a generator is a separately derived system, examine the transfer switch. If the neutral and all phase conductors are switched, the transformer is separately derived.
- The system bonding jumper may be installed at the generator or any point in between.

**Performance Task**

This session concludes with trainees practicing sizing bonding jumpers.

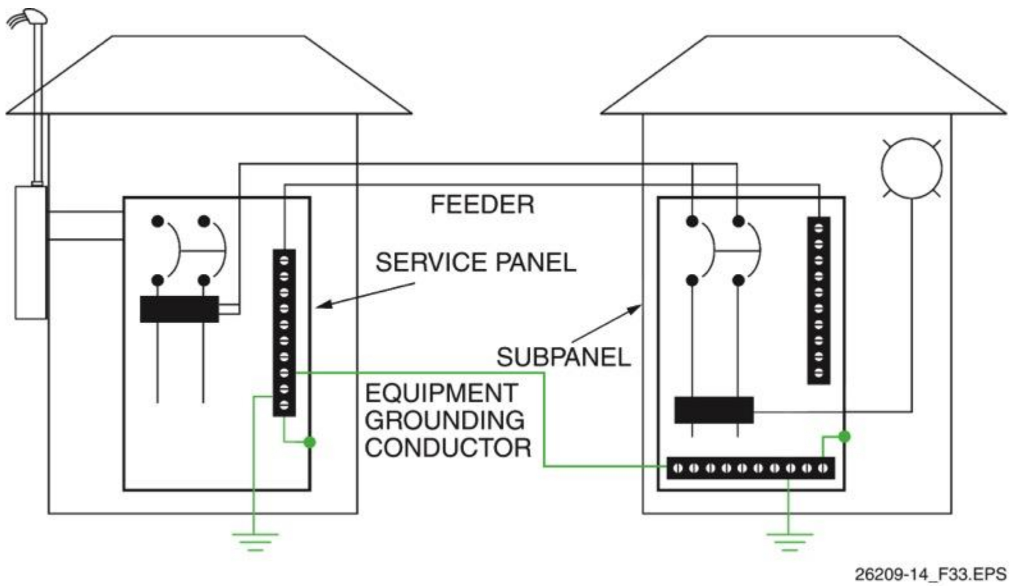
# Grounding at More Than One Building; Systems Over 1kV

- When installing grounding at more than one building, the grounding circuit conductor and equipment grounding conductor must both be extended to the second building.
- The number and type of conductors that must be taken from the first structure to the second structure are shown here.

| System | Ungrounded | Grounded | Equipment Ground |
|---|---|---|---|
| 120V | 1 | 1 | 1 |
| 120/240V | 2 | 1 | 1 |
| 208/120V | 3 | 1 | 1 |
| 480/277V | 3 | 1 | 1 |

# Grounding Neutral at Second Building

- When no grounding electrodes are available at the second structure, they must be installed per ***NEC Section 250.52***.
- ***NEC Article 250, Part X*** lists grounding requirements for systems over 1,000V.



# Testing for Effective Grounds

- An earth ground resistance tester is used to measure soil resistivity and the resistance of the installed grounding electrode system.
- Ground testers may only be used by qualified personnel.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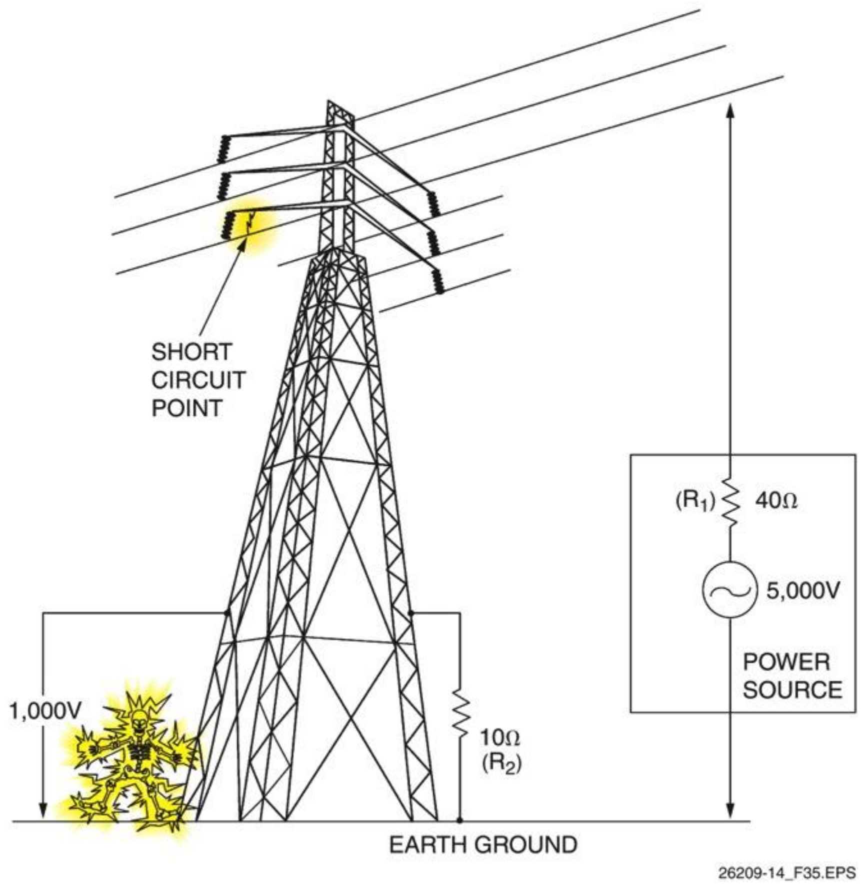
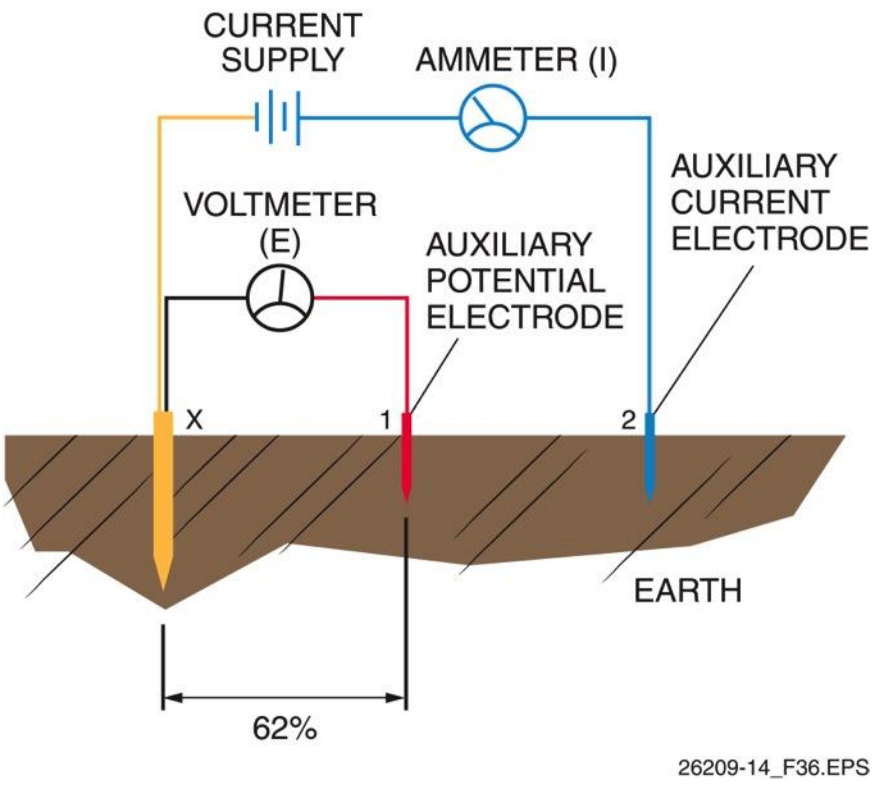
# Measuring Earth Resistance

- Connections to the earth are made with grounding electrodes, ground grids, and ground mats.
- A poorly grounded system can result in serious injury or death due to hazardous step and touch voltages.



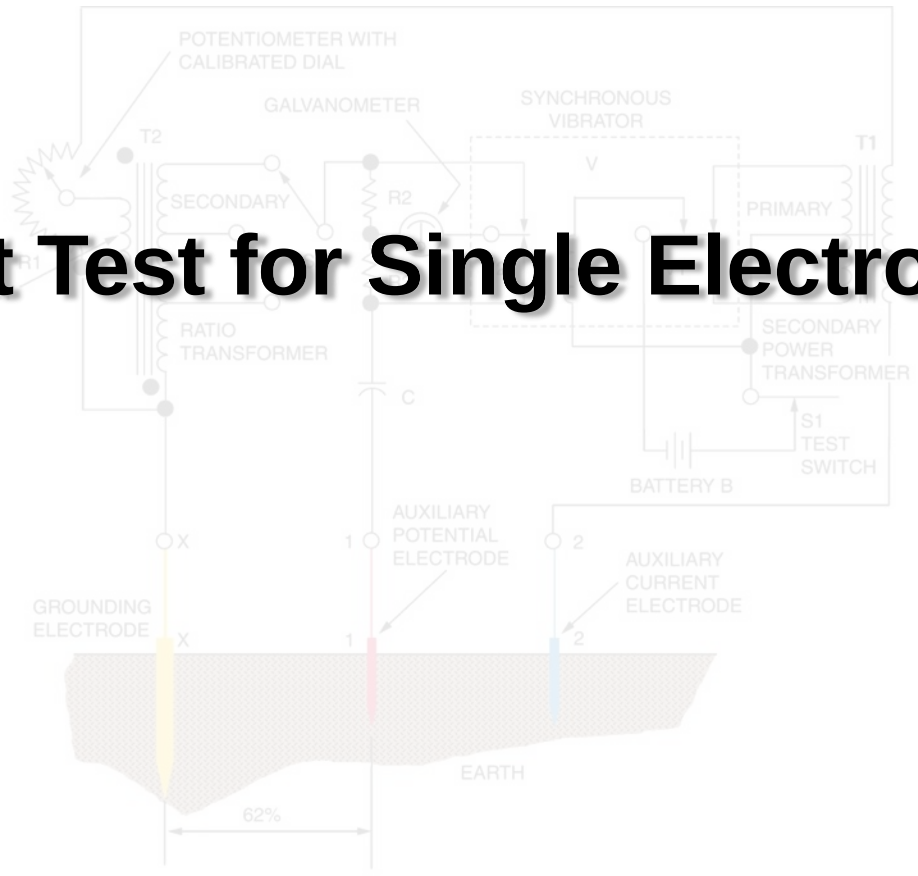
# Fall-of-Potential Method of Testing

- The fall-of-potential method measures the voltage drop between the grounding electrode and an auxiliary potential electrode.
- Incorrect readings may be obtained where there are natural soil currents caused by electrolytic action, or induced currents in the soil, instrument, or electrical leads.



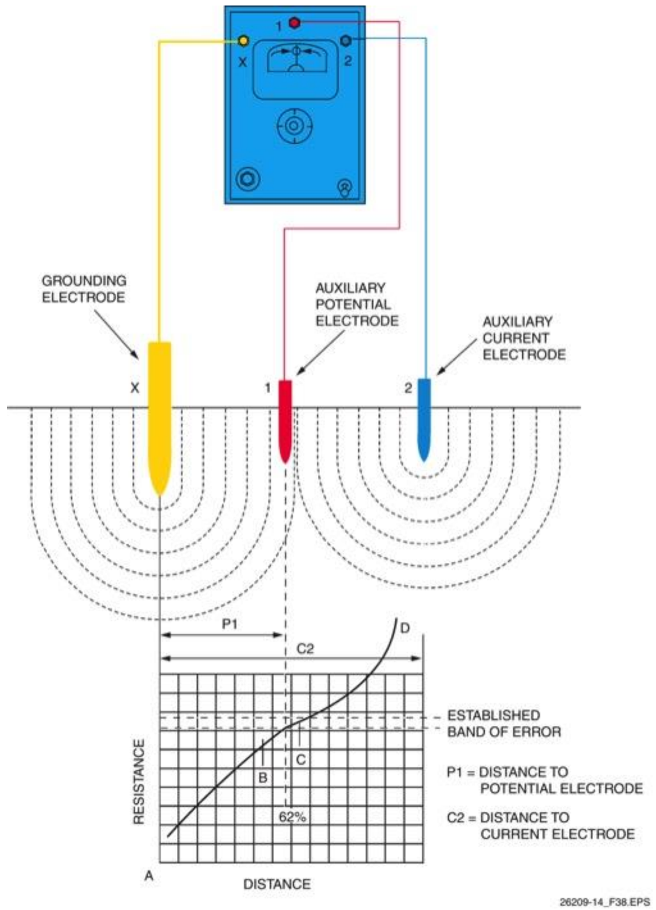
# Next Session…

Three-Point Testing
Using a Ground Tester

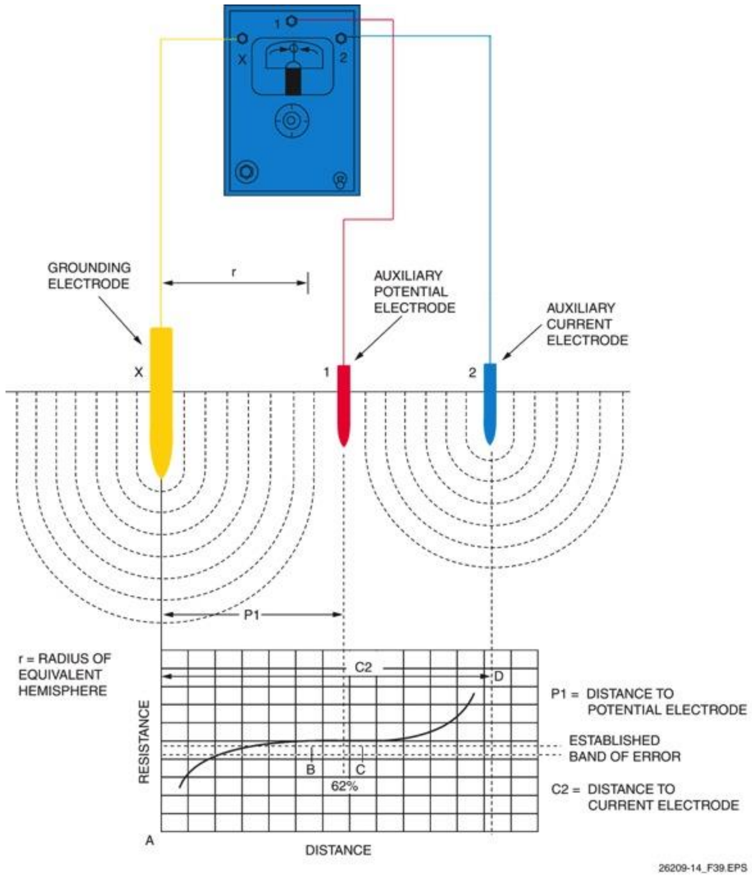



# Three-Point Test for Single Electrode/Triad

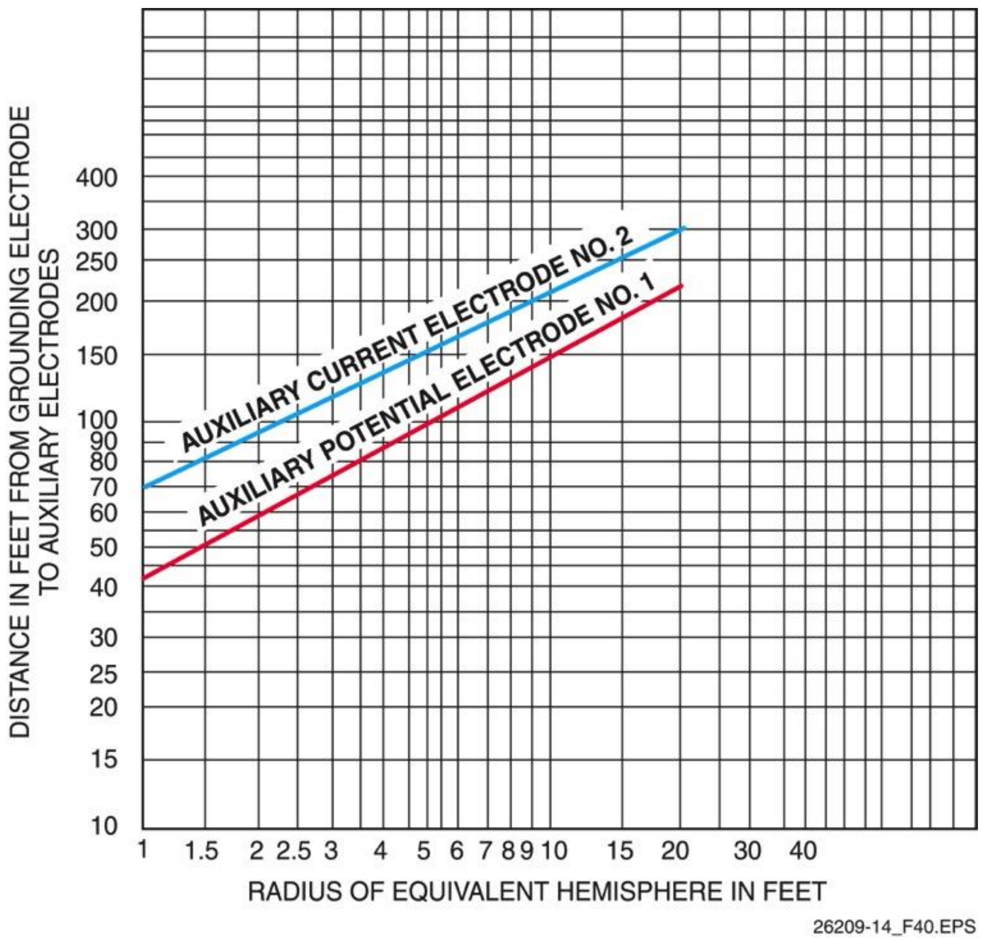
# Three-Point Test for Single Electrode/Triad



# Plotted Curve Showing Adequate Electrode Spacing



# Auxiliary Electrode Distance/Radii Chart

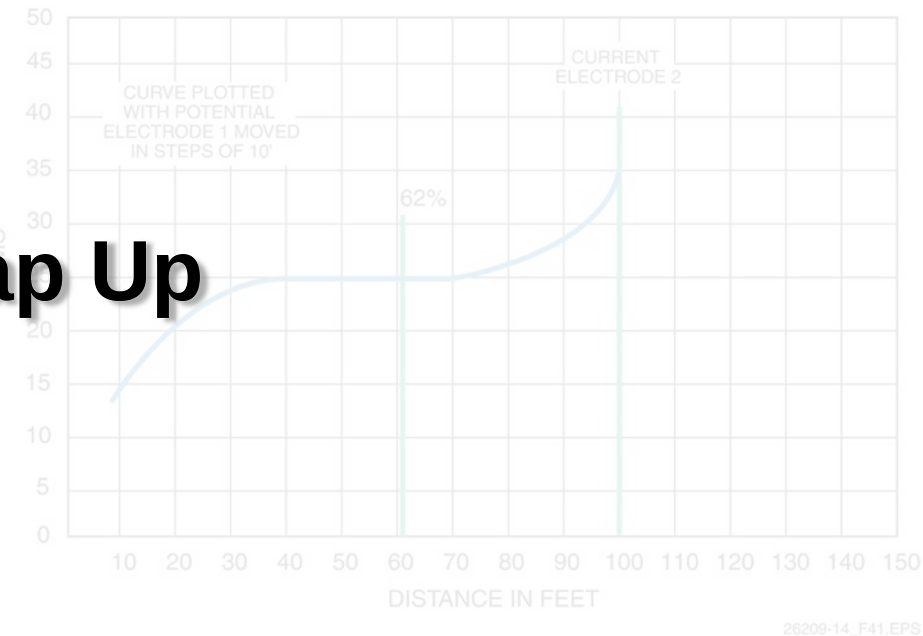


# 16.0.0

# Next Session…

Typical Grounding Resistance Curve to be Recorded and Retained

- A complete resistance curve should be plotted for each season of the year.
- Subsequent measurements need only be made at the 62% point and 10' on each side as long as there is no erratic deviation from the curve.




# Wrap Up

# Wrap Up

## 3-2-1

3 – Write 3 important things learned during class

2 – Write 2 questions you have about the material

1 – Write 1 thought you had about the material

# Next Session…

**MODULE EXAM**

Review the complete module to prepare for the module exam. Complete the Module Review as a study aid.