



# ***Soares Book on Grounding and Bonding 2014 NEC***

## ***Connecting to Earth - The Grounding Electrode System***



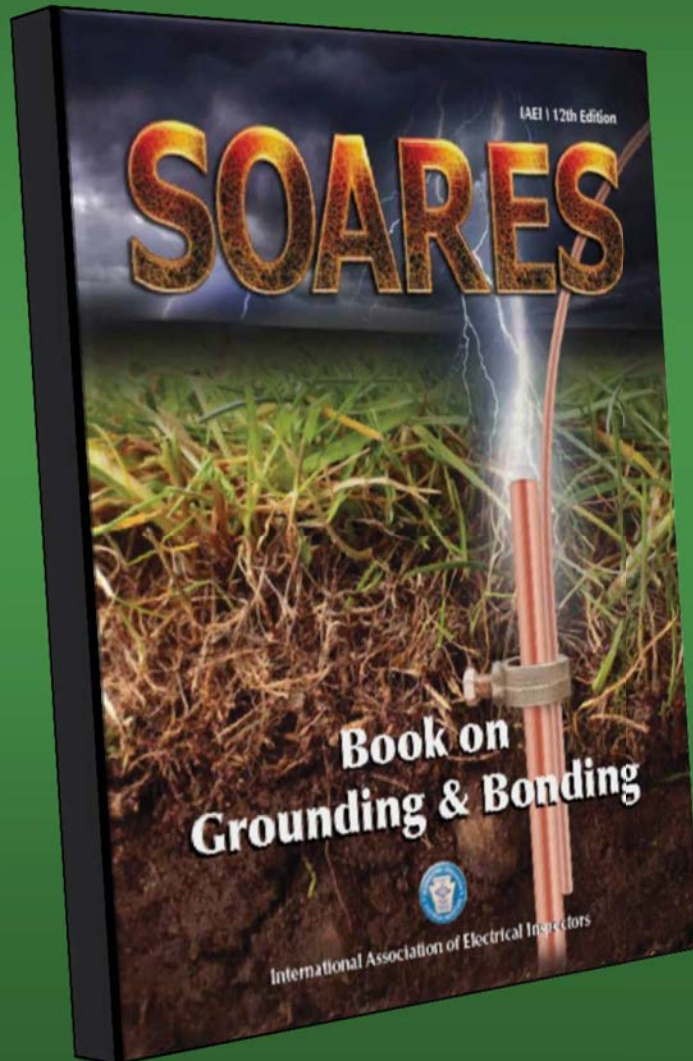
Presentation by:  
International Association of Electrical Inspectors



# Instructor: L. Keith Lofland

- IAEI – Director of Education, Codes & Standards
- Former Chief Electrical Inspector- Garland, TX
- Member: NEC CMP 9
- Member: UL Electrical Council
- Certified Electrical Inspector-  
IAEI, ICC, IAEI/NFPA
- Master and Journeyman Electrician
- Former Secretary/Treasurer-  
Texas Chapter IAEI
- International Instructor - IAEI

# Soares Book on Grounding and Bonding



- IAEI's *Soares Book on Grounding and Bonding*
- 12<sup>th</sup> Edition
- Based on the requirements of the 2014 *National Electrical Code*
- Dedicated to the memory of Eustace Soares

# The Planet Earth



Bringing *Grounding and Bonding* down to earth



# The Earth as a Conductor

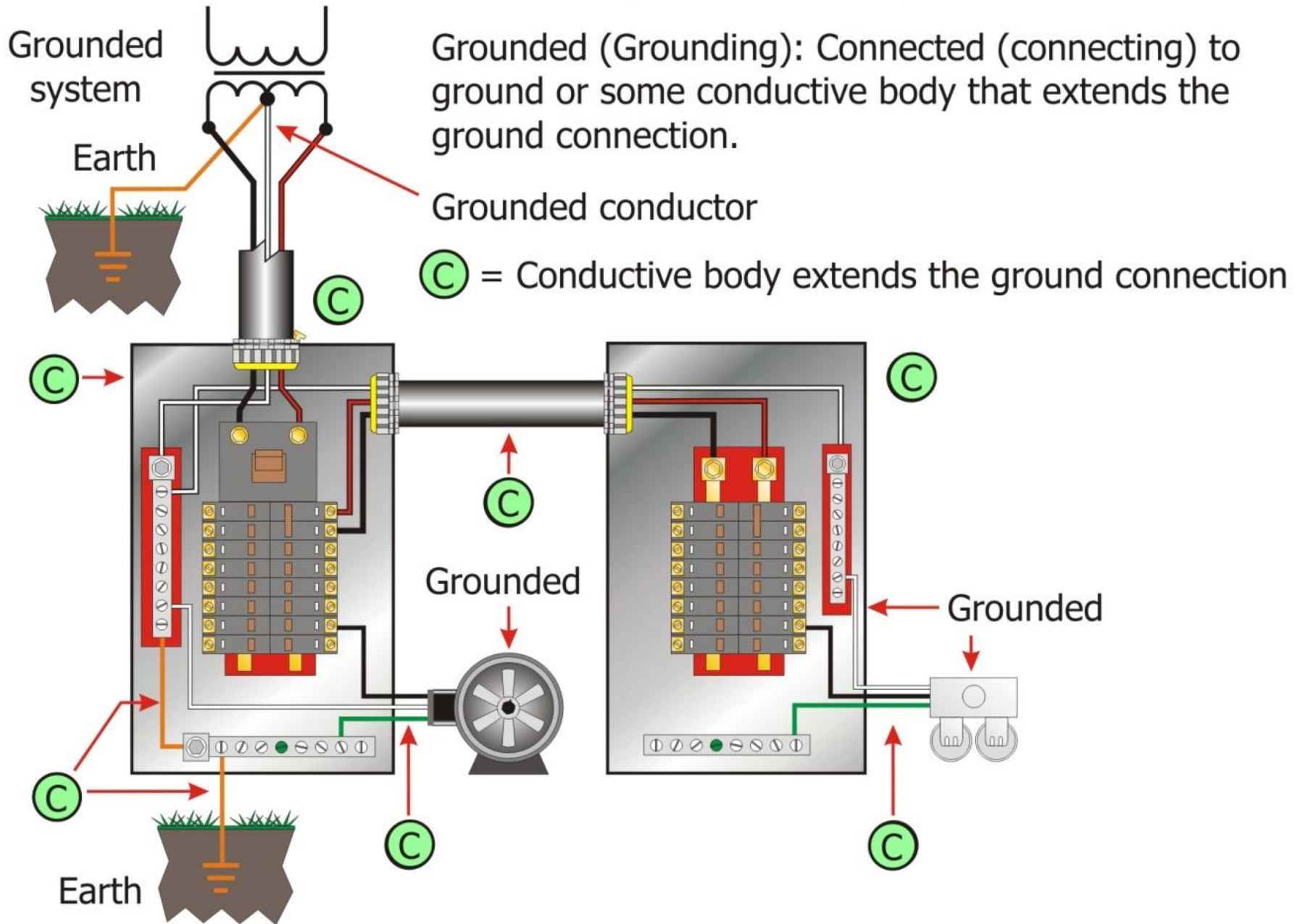


Grounded: "Connected (connecting) to ground or to a conductive body that extends the ground connection"



The earth as a conductor is assumed to have an electrical voltage potential of zero

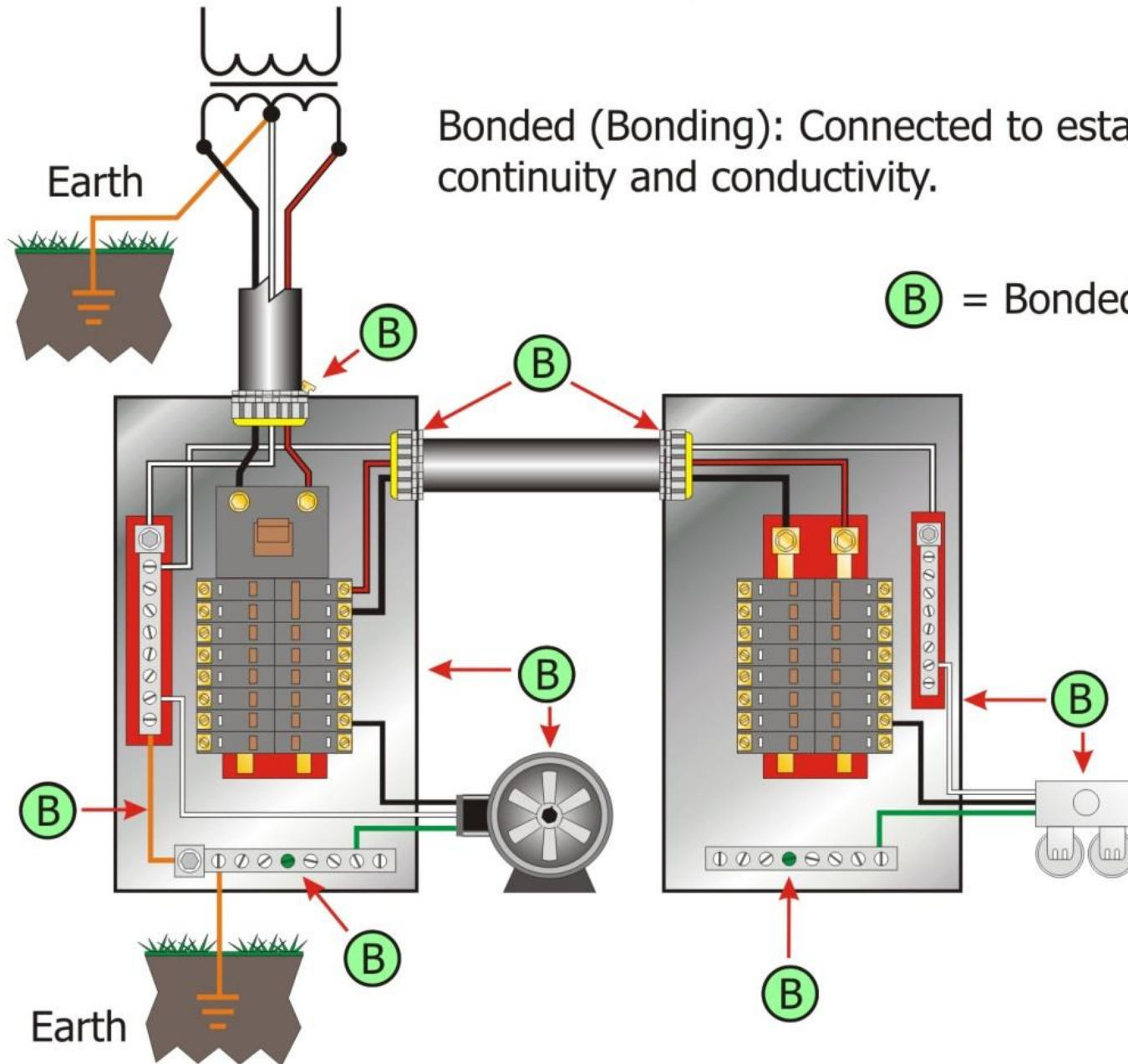
# Grounded (Grounding)



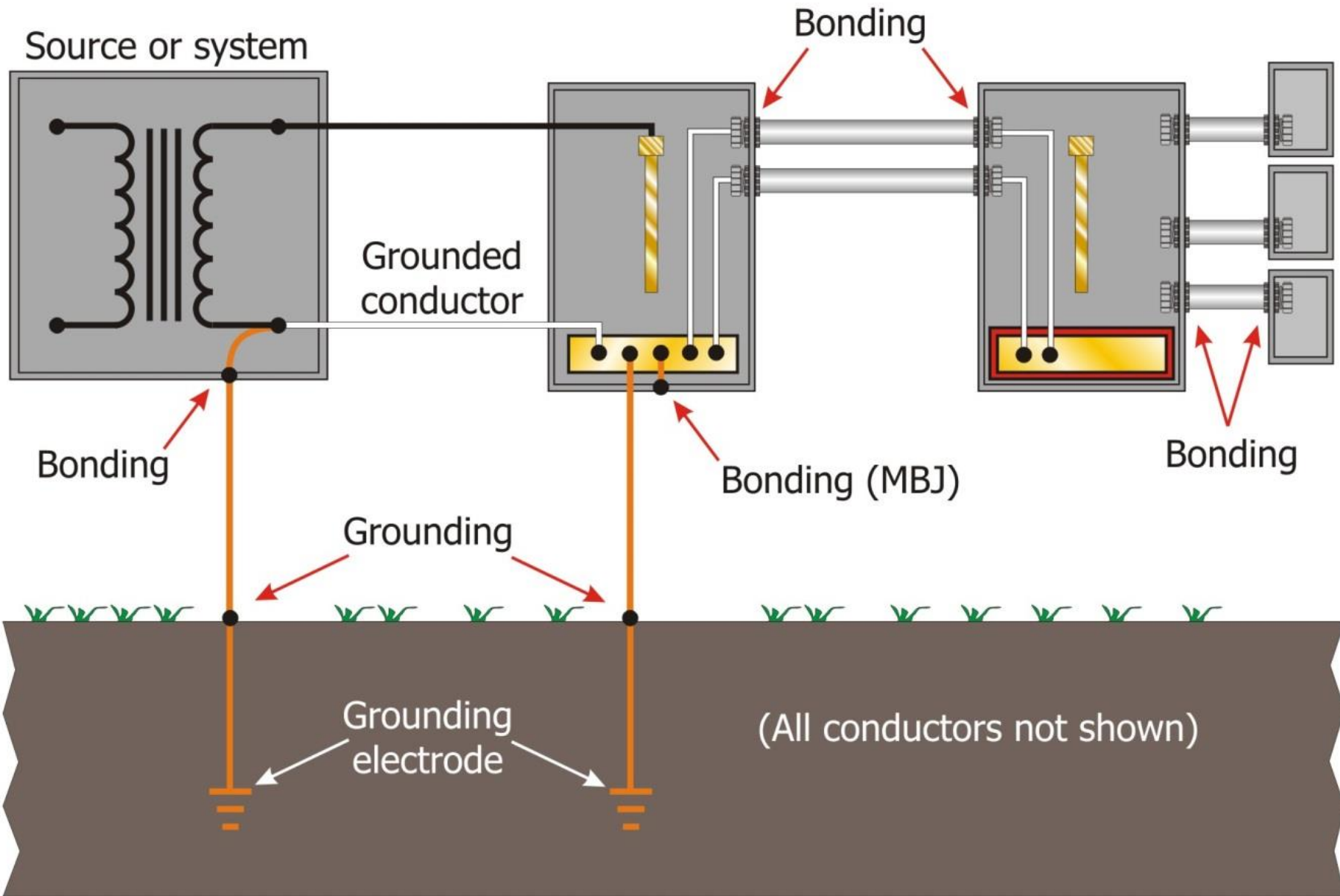
# Bonded (Bonding)

Bonded (Bonding): Connected to establish electrical continuity and conductivity.

ⓑ = Bonded (Bonding)

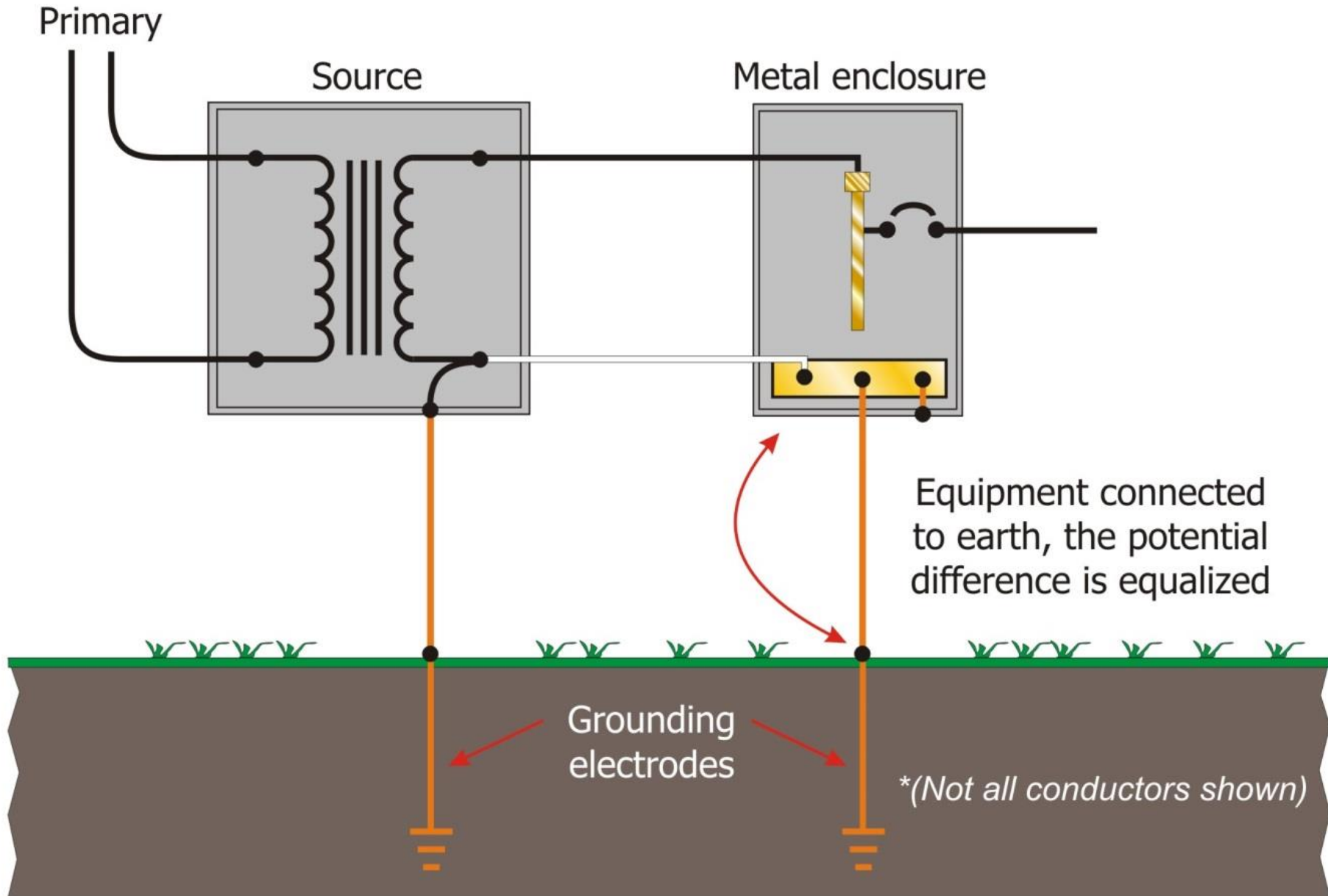


# Grounding Compared to Bonding



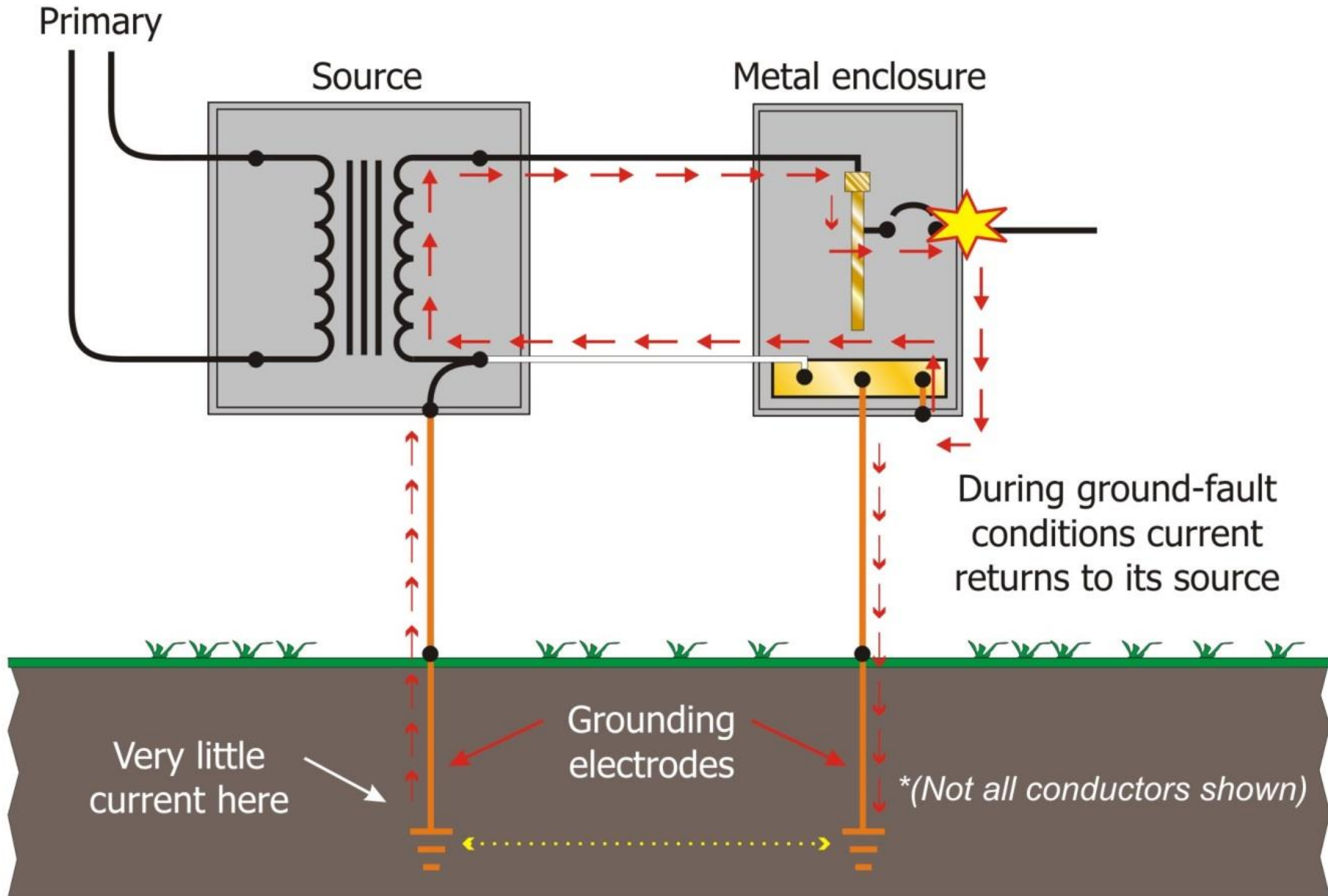


# Grounding Fundamentals

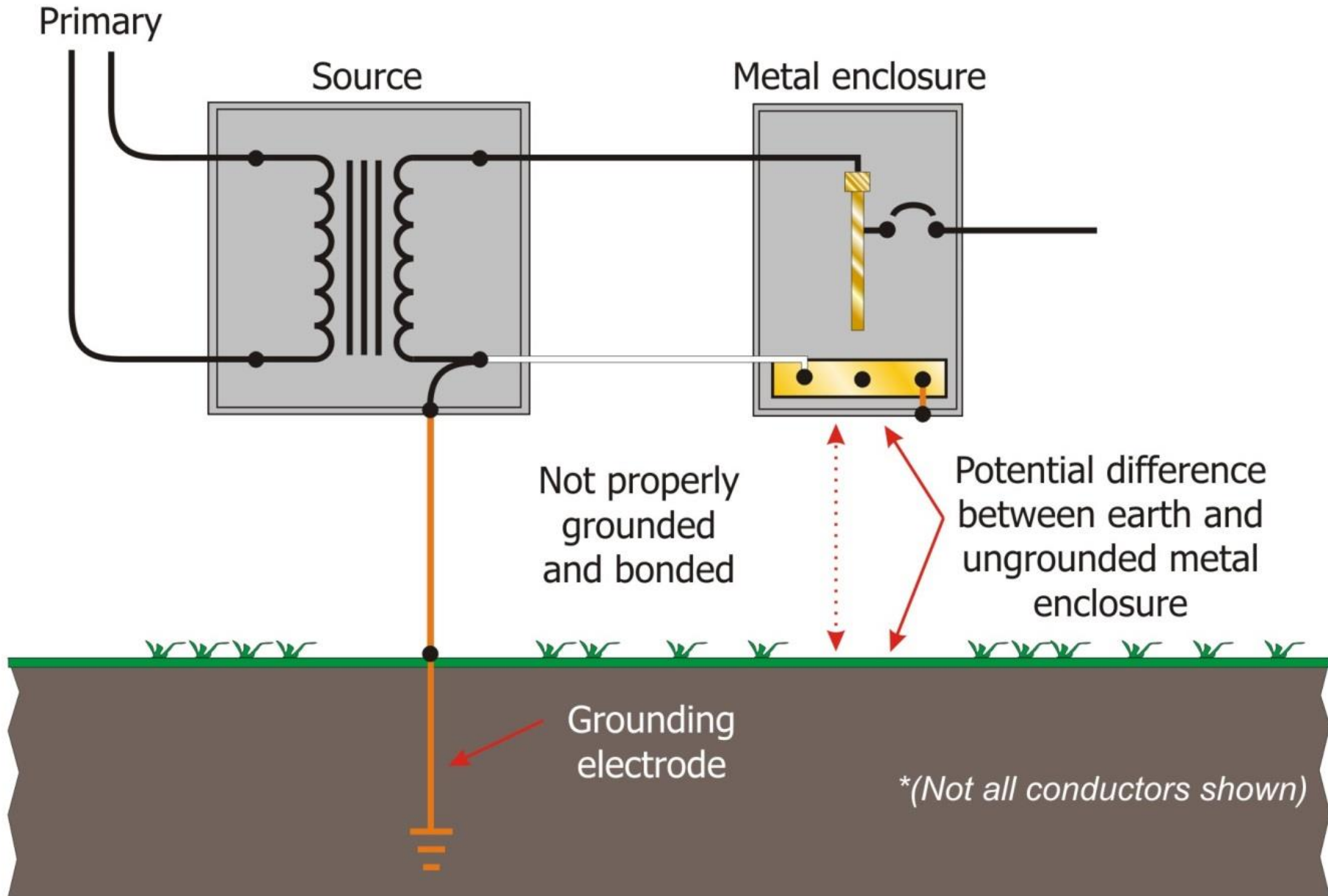




# Grounding Fundamentals



# Voltage Potential Difference (Hazard)





# **Chapter Six:**

## **The Grounding Electrode System**

- **Definitions and general requirements for grounding electrodes**
- **Grounding electrode system to be used**
- **Sizing interconnecting bonding jumpers for the grounding electrode system**
- **Description and installation of grounding electrodes**
- **Common grounding electrode**
- **Objectionable current and resistance of grounding electrodes**



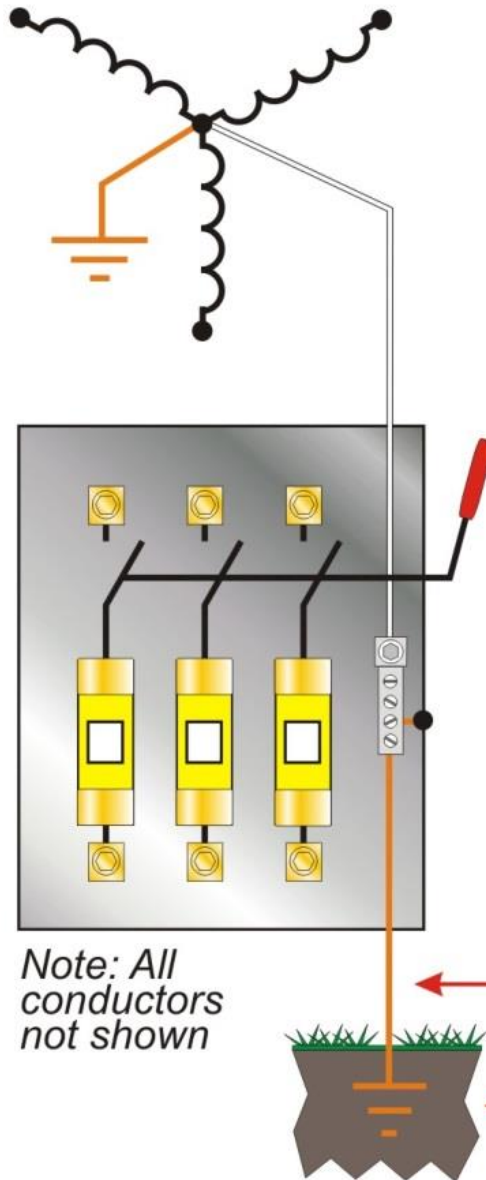


# Definition

- *Grounding Electrode:* A conducting object through which a direct connection to earth is established.
- See Article 100
- The details and descriptions of the various grounding electrodes acceptable for grounding are contained in 250.52(A)
- The definition of *grounding electrode* is intended to work cooperatively with the list of electrodes identified in 250.52(A)



# Functions of Grounding Electrode



**Grounding Electrode** - A conducting object through which a direct connection to earth is established.

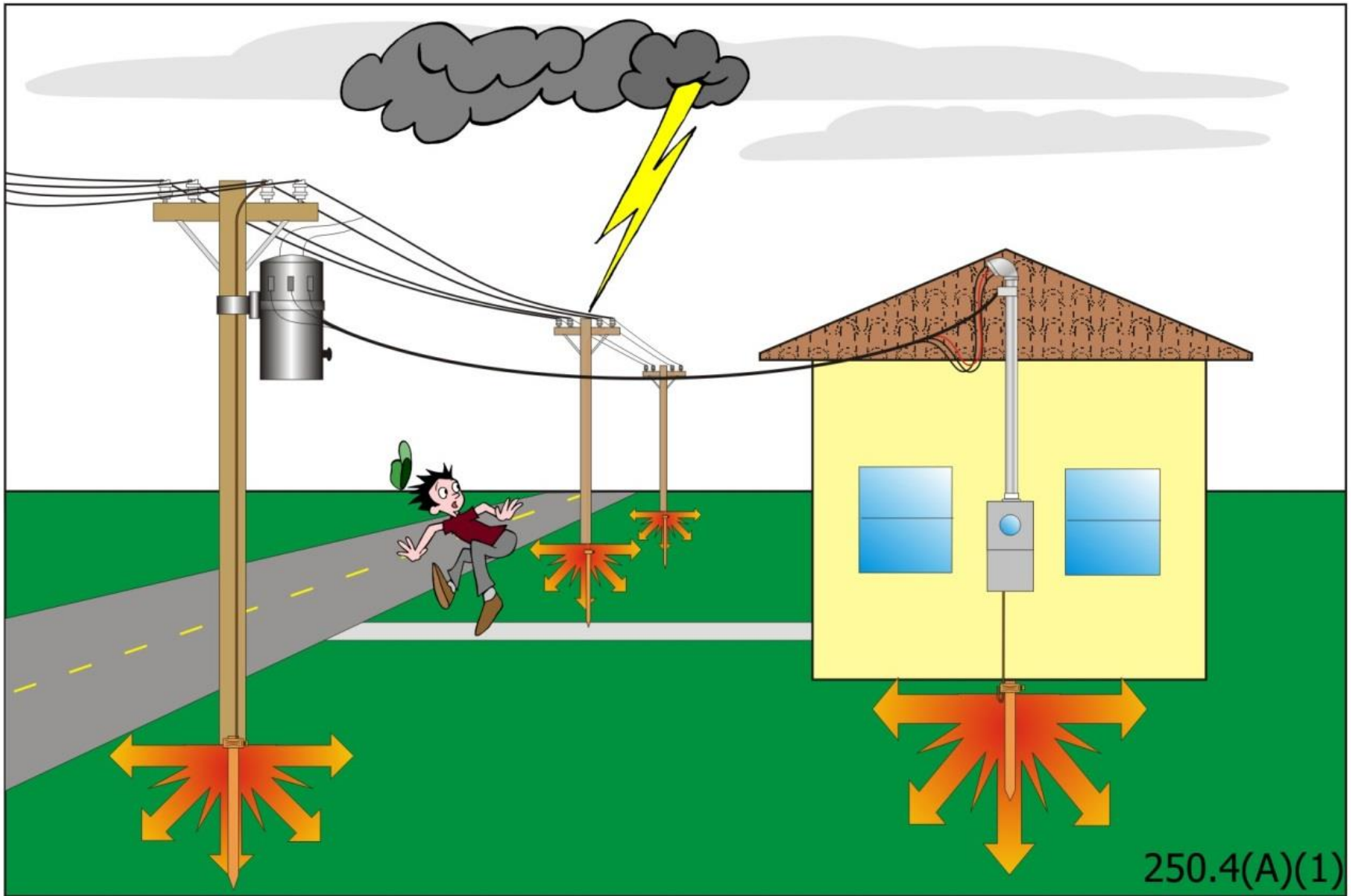
1. Connects the electrical system to earth
2. Connects electrical equipment to earth
3. Attempts to maintain equipment at the earth voltage potential

**Little effect in clearing ground faults**  
*(not its function)*

← Grounding electrode conductor

← Grounding electrode system

# Dissipation of Over-Voltages

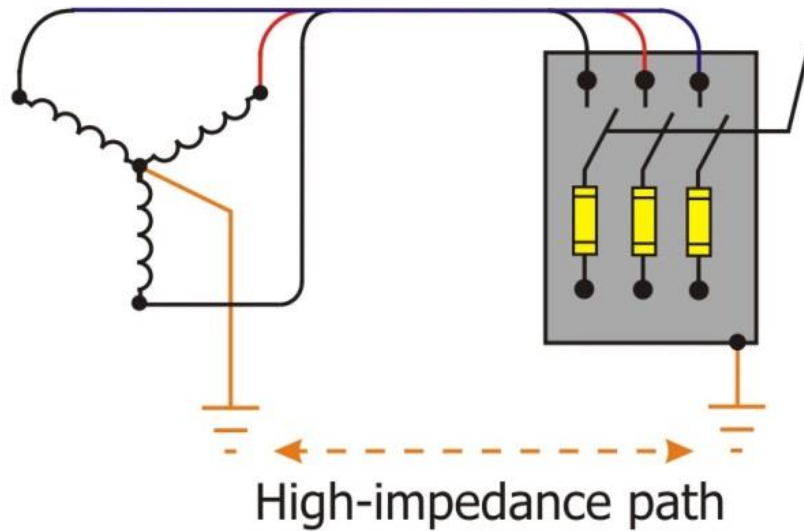


250.4(A)(1)

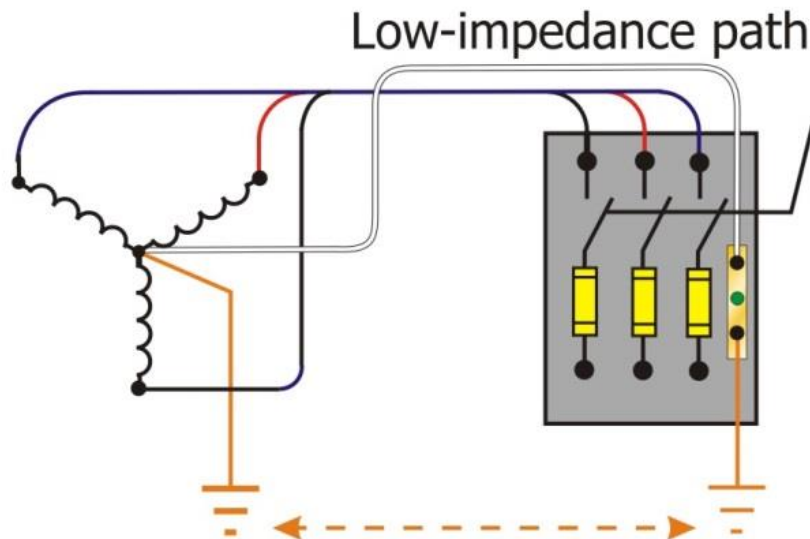
# Earth Prohibited as Return Path

- In discussing grounding electrodes, notice that no mention is made for providing a low-resistance, low-impedance common grounding electrode path for clearing ground faults
- The high impedance of the earth makes it an ineffective path for the levels of current common to power systems
- The earth should never be used as a ground fault current path, as it is a very poor conductor
- See 250.4(A)(5)

# 250.4(A)(5) Earth Return Prohibited



Ground fault at service attempts to return to source (*transformer*) through the **high-impedance path** through the earth (*ineffective and not permitted*)



A **low-impedance path** for clearing ground faults is provided through the grounded service conductor

# Grounding Electrodes for Grounding

- Section 250.52(A) includes the details and descriptions of grounding electrodes that are required to be used for the grounding electrical systems (*when present*)
- Section 250.52(B) includes items that are not permitted to be used as grounding electrodes for electrical systems and equipment
- Installation provisions for the electrodes described in 250.52(A) are provided in 250.53 titled “Grounding Electrode System Installation”



# Grounding Electrodes for Grounding

- Section 250.52(A) includes the details and descriptions of grounding electrodes that are required to be used for the grounding electrical systems (*where present*):
  - (A)(1) Metal underground water pipe
  - (A)(2) Metal frame of a building or structure
  - (A)(3) Concrete-encased electrode
  - (A)(4) Ground ring
  - (A)(5) Rod and pipe electrode
  - (A)(6) Other listed electrodes
  - (A)(7) Plate electrodes
  - (A)(8) Other local metal underground systems or structures

# Grounding Electrode Required

- Where the grounding electrodes described in 250.52(A) are not present, a grounding electrode must be installed
- Where none of these grounding electrodes exist, one or more of the grounding electrodes specified in 250.52(A)(4) through (A)(8) shall be installed and used
- These “made” electrodes can consist of rod, pipe, and plate electrodes, or other listed electrodes, or local metal underground systems or structures
- See 250.50 and 250.52(A)(4) through (A)(8)

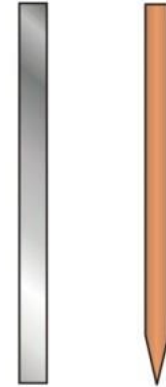
# 250.52(A) Installed Grounding Electrodes



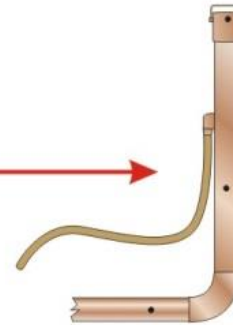
(A)(4) Ground ring  
2 AWG copper minimum



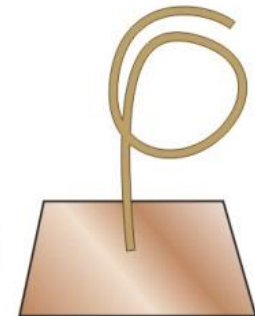
(A)(5) Rod and pipe electrodes



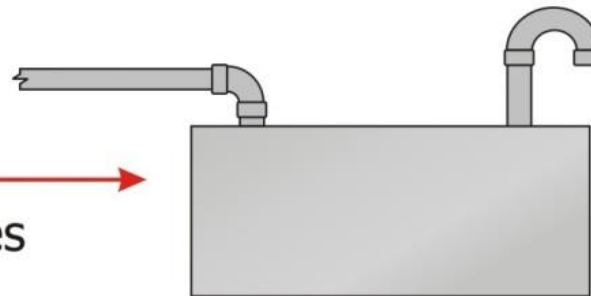
(A)(6) Other listed electrodes



(A)(7) Plate electrodes



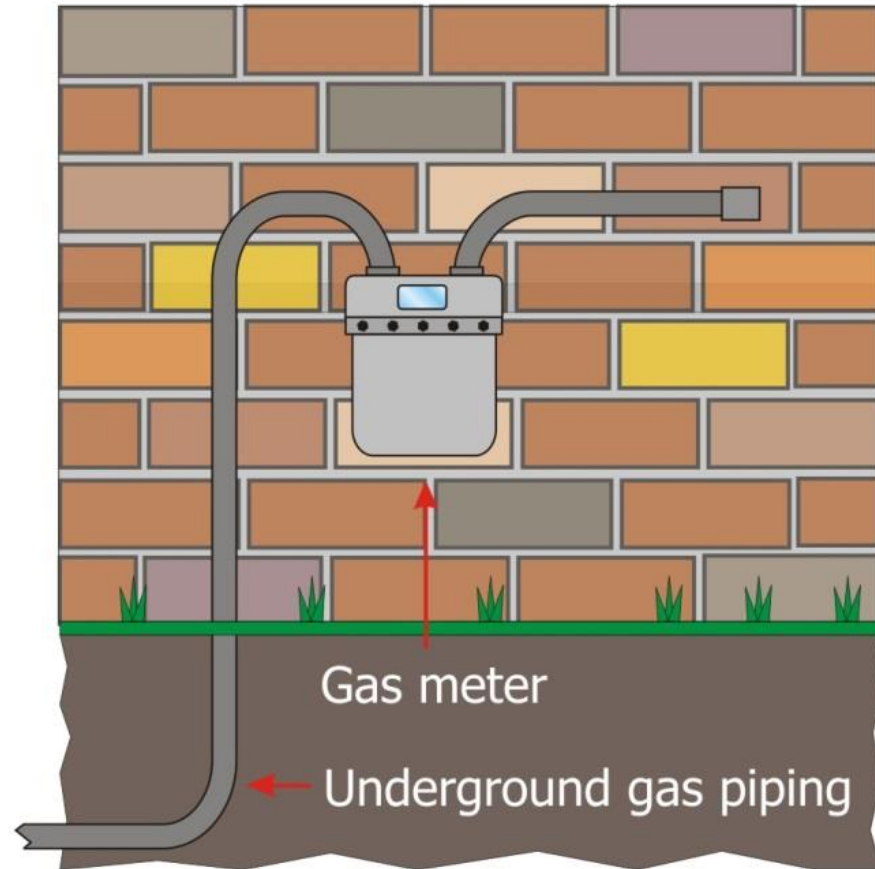
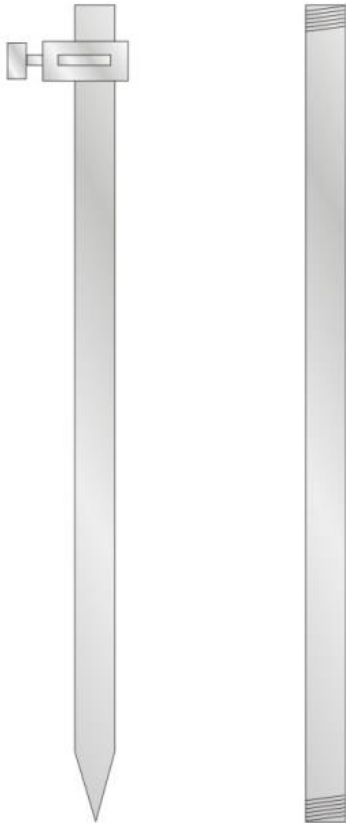
(A)(8) Local underground  
systems or structures



# 250.52(B) Not Permitted as Grounding Electrodes

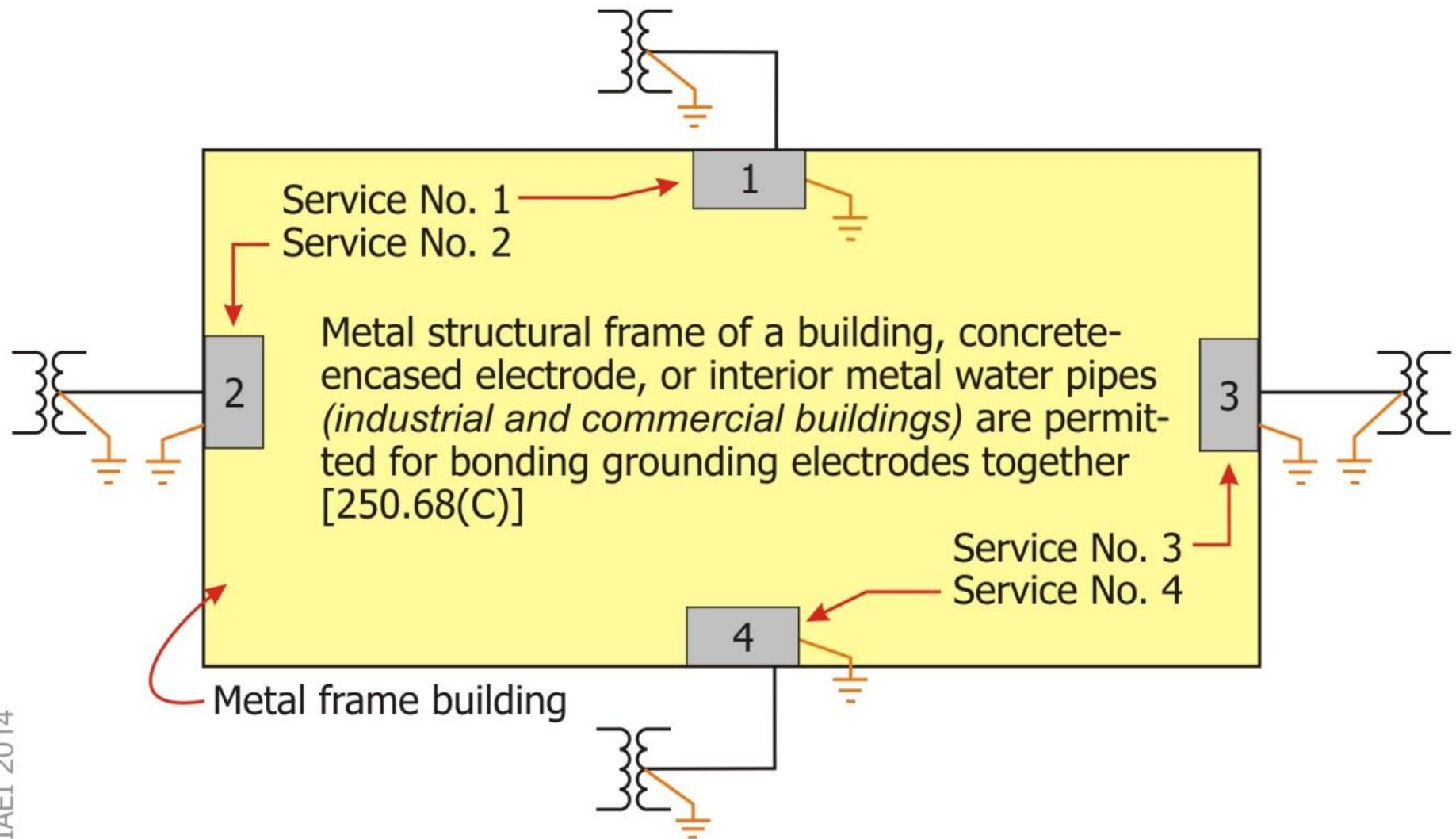


Aluminum electrodes are **not permitted** as a grounding electrode



Underground gas piping is **not permitted** as a grounding electrode

# 250.58 Common Grounding Electrode



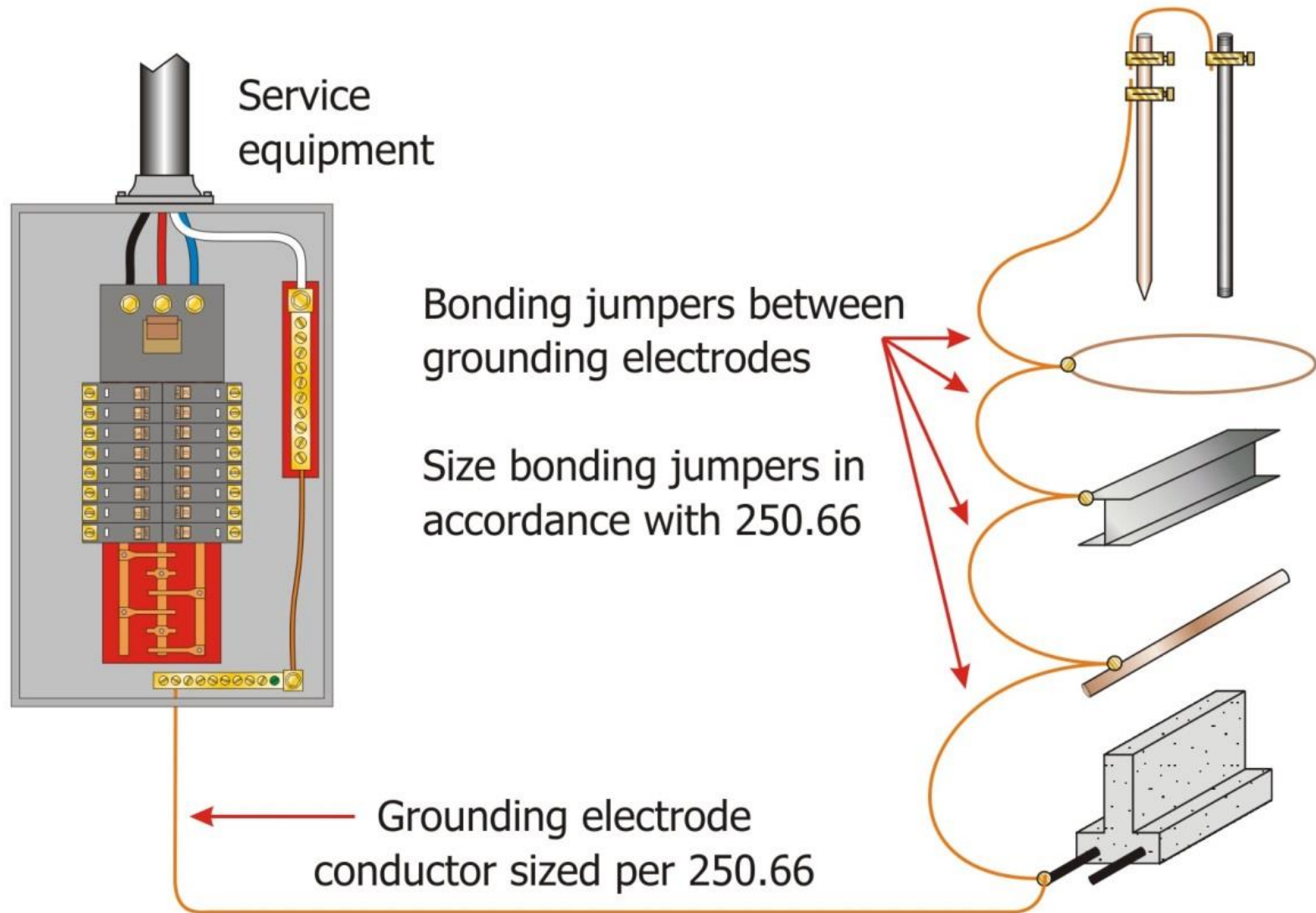
The same grounding electrode(s) must be used for all services, feeders, and branch circuits. Two or more electrodes bonded together are considered one grounding electrode system [250.58]



# Bonding Jumper(s) for Grounding Electrode System

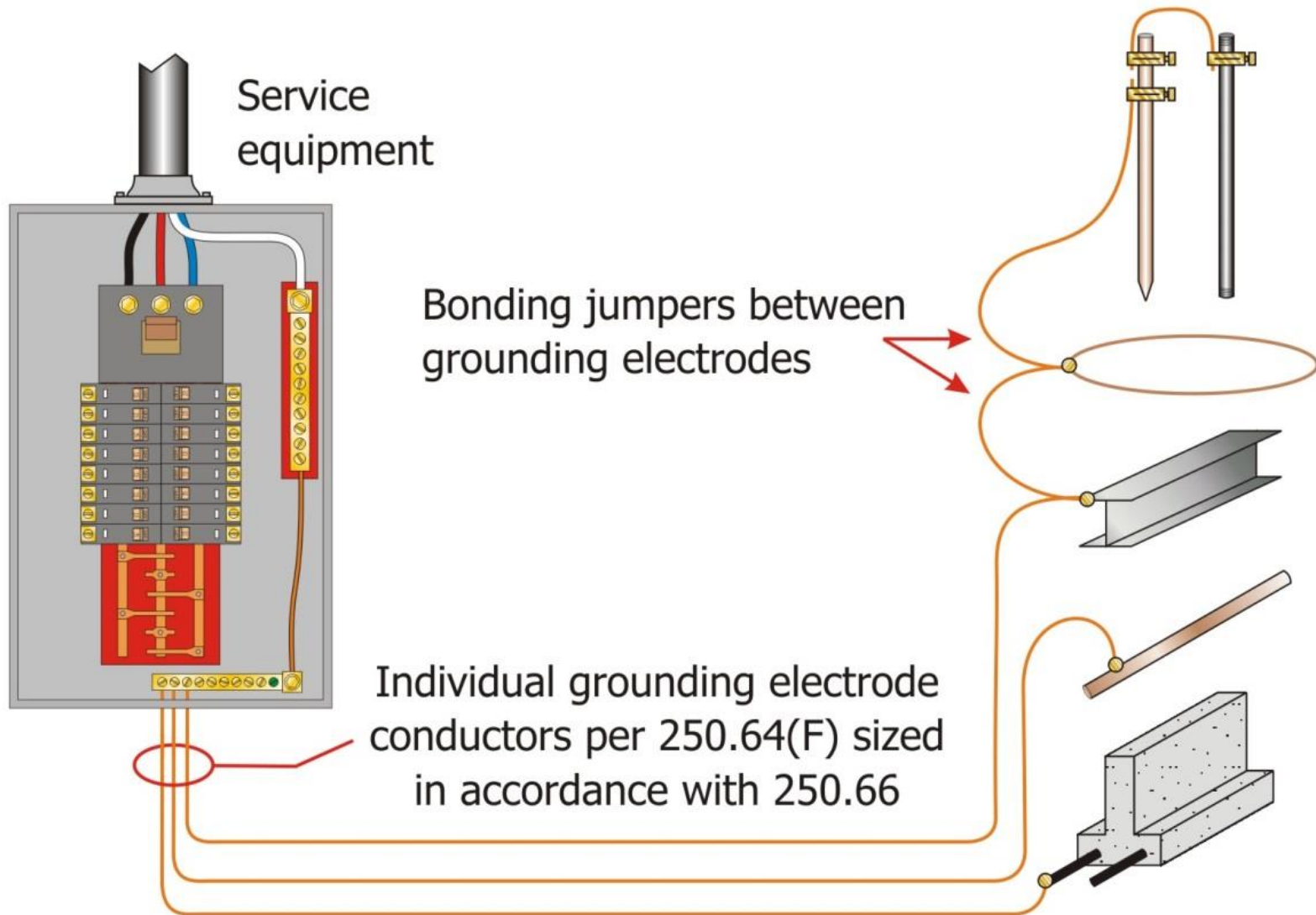


Grounding electrodes connected together with bonding jumpers that are installed in accordance with 250.64(A), (B), and (E)



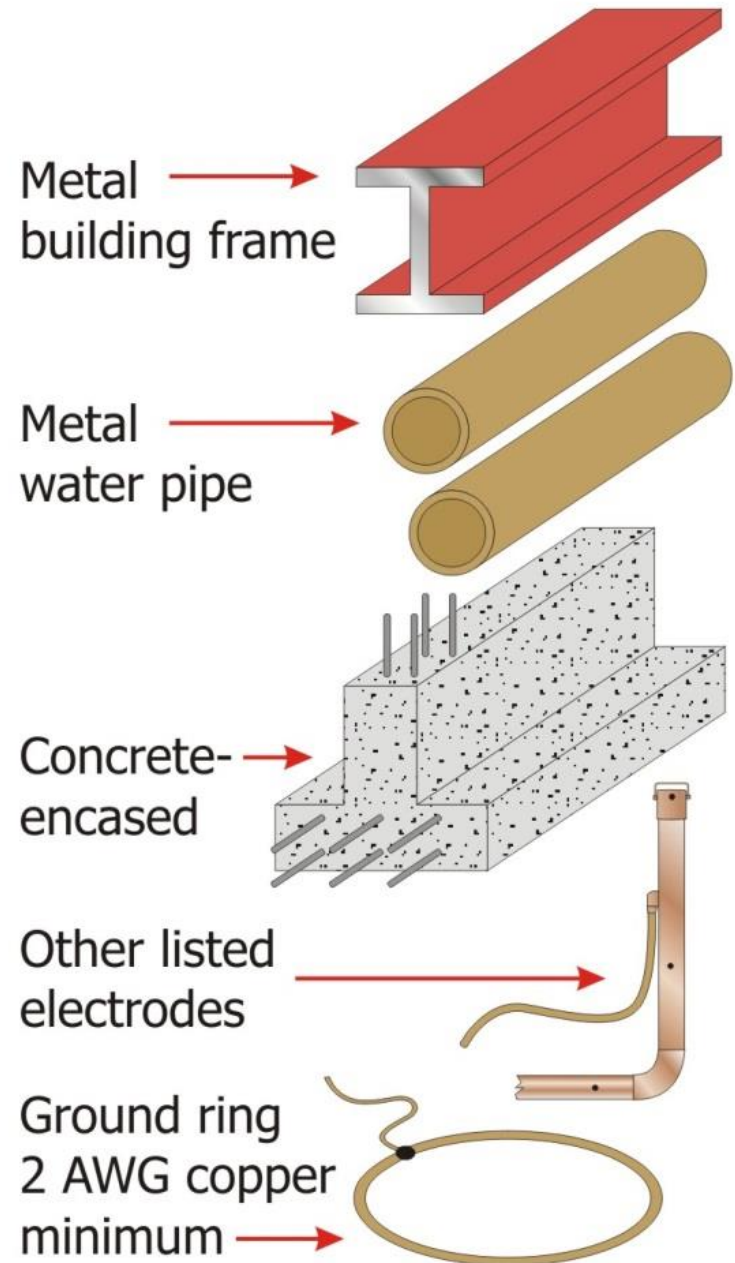
# Individual Grounding Electrode

Individual grounding electrode conductor(s) are permitted to be run to any convenient grounding electrode in the grounding electrode system

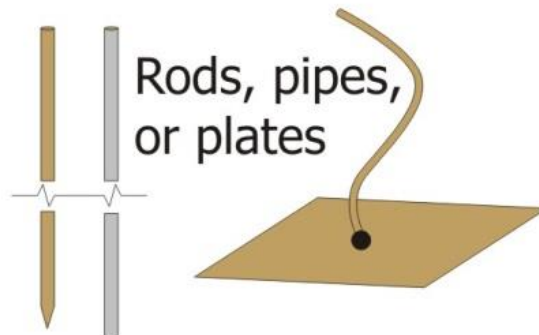


# 250.50 Grounding Electrode System

- Where present, grounding electrodes required to be used to form the grounding electrode system
- Includes electrodes that are an inherent component of the building construction (*metal structure, etc.*)
- By exception, existing concrete-encased electrodes not required to be used where doing so involves disturbing concrete footings of existing structures or buildings



Other metal structures













# Metal Underground Water Piping Systems

- Section 250.52(A)(1) requires metal underground water piping systems to be used for the grounding electrical systems (*where present*)
- Must be in direct contact with the earth for 3.0 m (10 ft) or more and electrically continuous
- Includes any metal well casing bonded to the pipe
- Can be made electrically continuous by bonding around insulating joints or insulating pipe







## 250.52(A)(1) Metal Underground Water Pipe





# 250.53(D)(2) Supplemental Electrode Connection

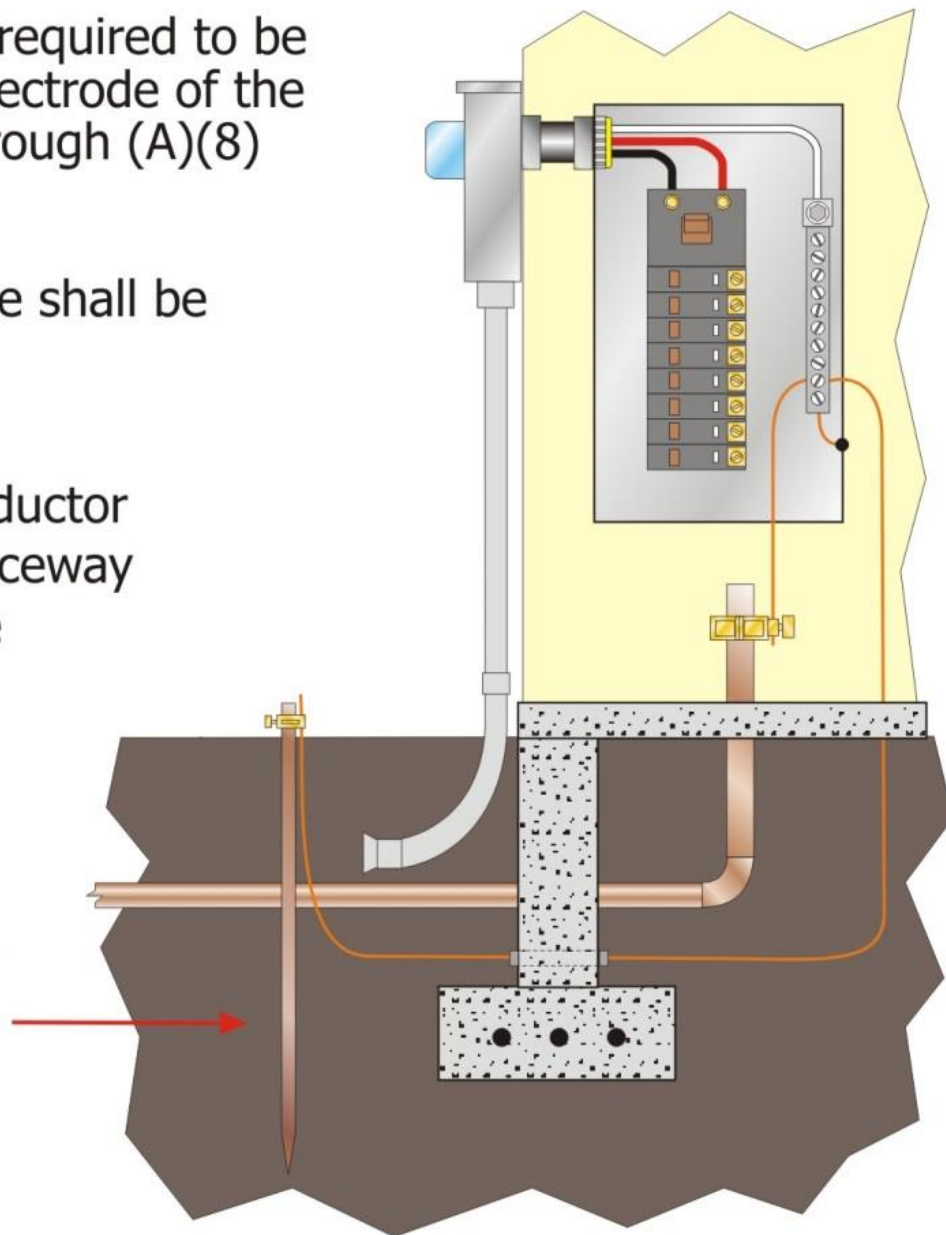


**Metal underground water pipe** is required to be supplemented by an additional electrode of the type specified in 250.52(A)(2) through (A)(8)

Supplemental grounding electrode shall be bonded to one of the following:

- Grounding electrode conductor
- Grounded service-entrance conductor
- Nonflexible grounded service raceway
- Any grounded service enclosure
- As provided by 250.32(B)

If the supplemental grounding electrode is a single rod, pipe, or plate, must be supplemented as well or must meet 25-ohm rule [250.53(A)(2) and Exception]





# Metal Frame of a Building or Structure

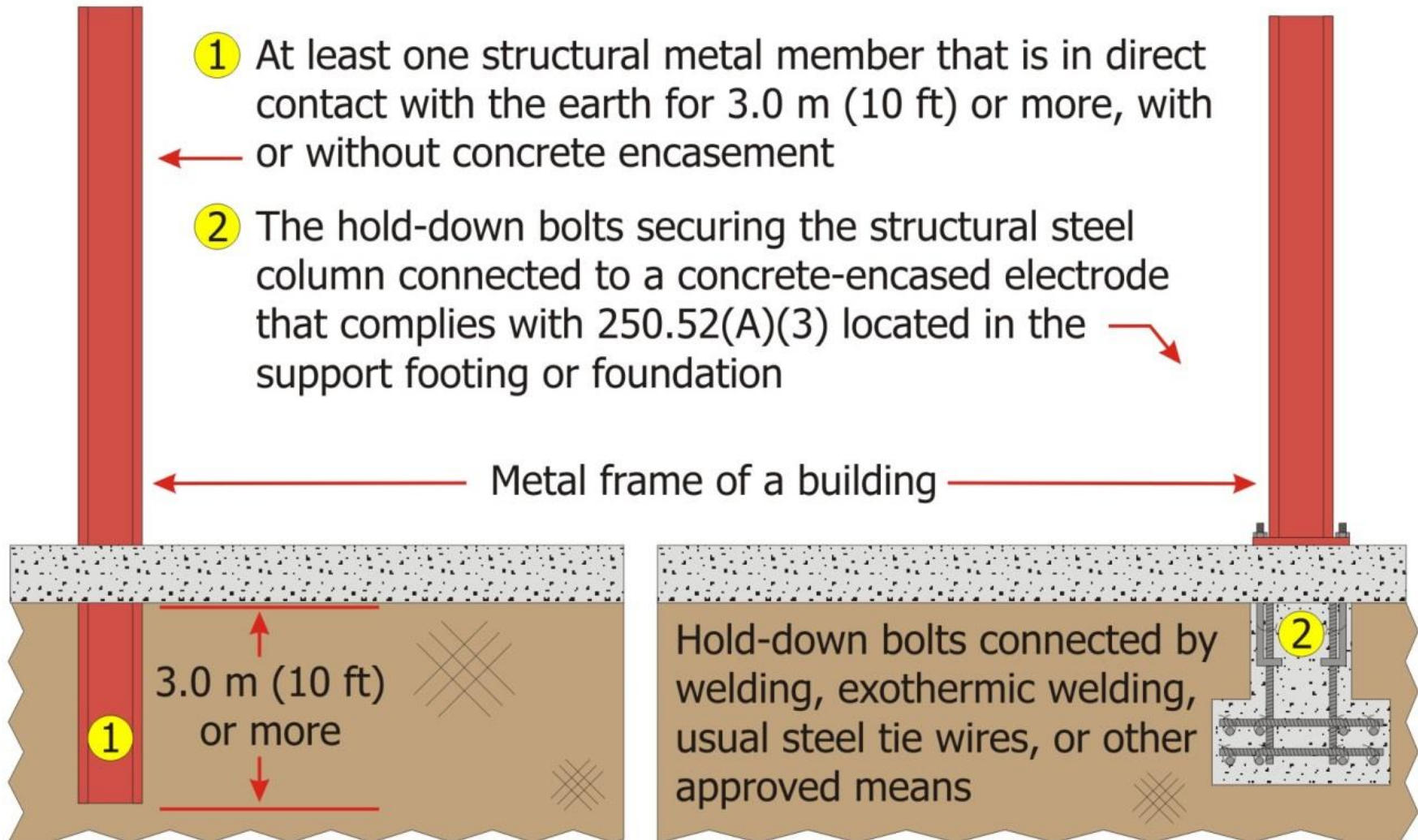
- Section 250.52(A)(2) requires the metal frame of a building or structure to be used for the grounding electrical systems *(where present and qualifies)*
- Must be connected to the earth by one or more of the following methods:
  - At least one structural metal member that is in direct contact with the earth for 3.0 m (10 ft) or more *(with or without concrete encasement)*
  - Hold-down bolts securing the structural steel column that are connected to a concrete-encased electrode that complies with 250.52(A)(3) *(located in the support footing or foundation)*

# 250.52(A)(2) Metal Frame of Building or Structure



The metal frame of the building permitted as grounding electrode where connected to the earth by **one or more** of the following methods:

- ① At least one structural metal member that is in direct contact with the earth for 3.0 m (10 ft) or more, with or without concrete encasement
- ② The hold-down bolts securing the structural steel column connected to a concrete-encased electrode that complies with 250.52(A)(3) located in the support footing or foundation









Grounding electrodes must be connected to the earth with hold-down bolts connected to concrete-encased electrode

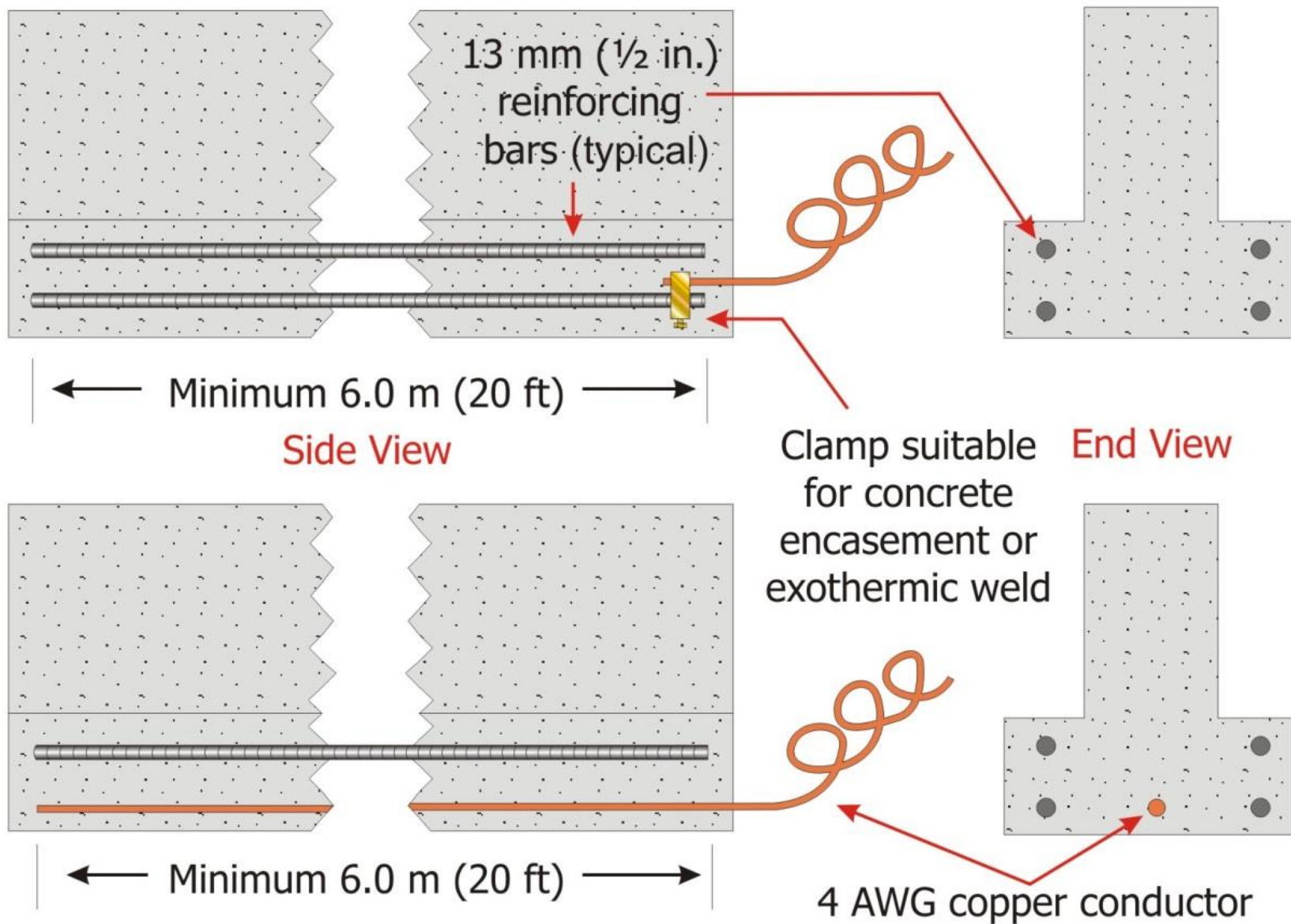




# Concrete-Encased Electrode

- Section 250.52(A)(3) requires concrete-encased electrode is to consist of:
  - At least 6.0 m (20 ft) of bare copper conductor not smaller than 4 AWG or one or more bare or electrically conductive coated steel reinforcing bars or rods of not less than 13 mm (½ in.) in diameter
  - Installed in one continuous 6.0 m (20 ft) length, or multiple pieces connected together by the usual steel tie wires, exothermic welding, welding, etc. to create a 6.0 m (20 ft) or greater length
  - Metallic components to be encased by at least 50 mm (2 in.) of concrete
  - Located horizontally within that portion of a concrete foundation or footing in direct contact with the earth or within vertical structural components in direct contact with the earth

# 250.52(A)(3) Concrete-Encased Electrode





# Concrete-Encased Electrode

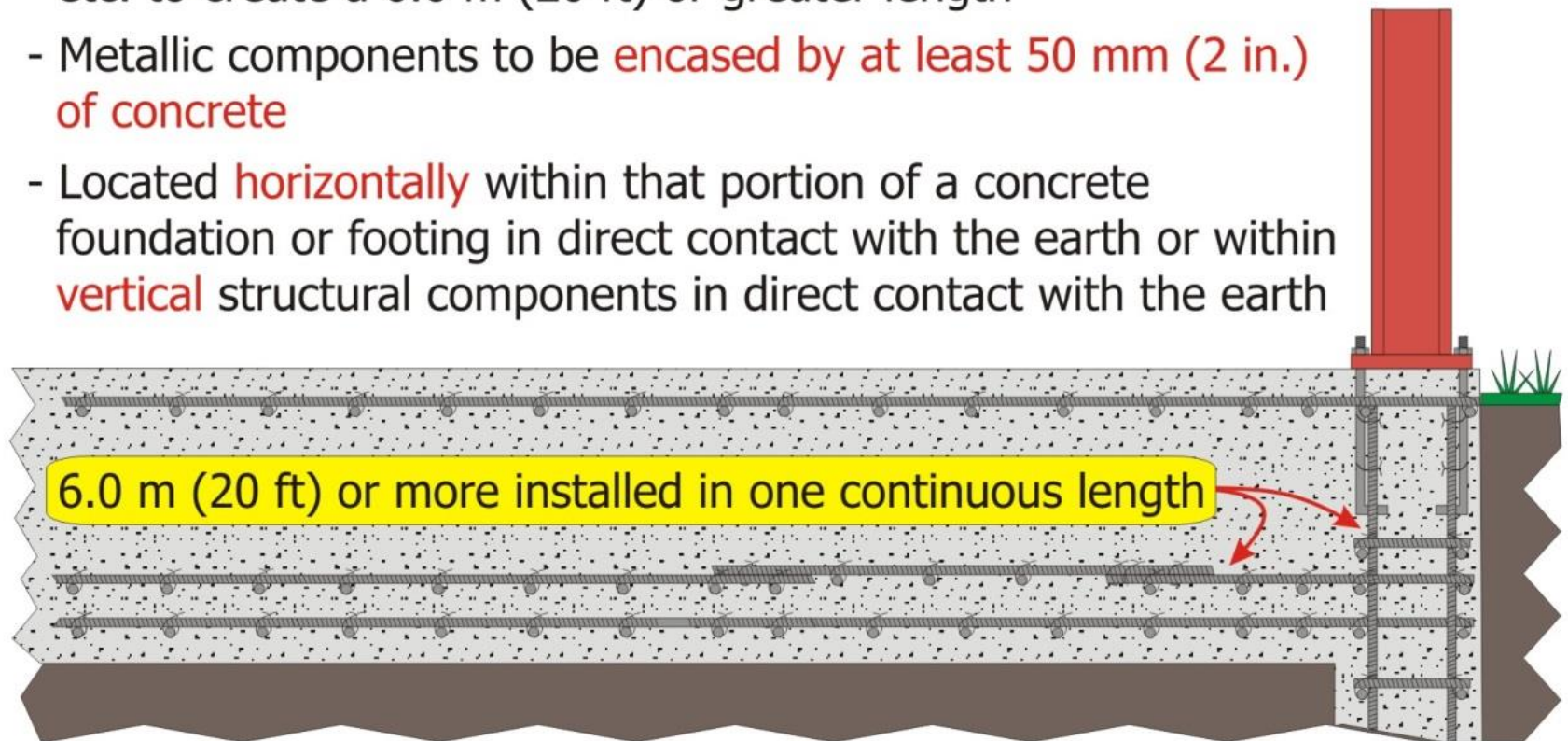




# 250.52(A)(3) Concrete-Encased Electrode

Concrete-encased electrode to consist of:

- At least 6.0 m (20 ft) of **bare copper conductor not smaller than 4 AWG** or one or more bare or electrically conductive coated steel reinforcing bars or rods, not less than 13 mm (½ in.) in diameter,
- Installed in **one continuous 6.0 m (20 ft) length**, or multiple pieces connected together by the usual steel tie wires, exothermic welding, etc. to create a 6.0 m (20 ft) or greater length
- Metallic components to be **encased by at least 50 mm (2 in.) of concrete**
- Located **horizontally** within that portion of a concrete foundation or footing in direct contact with the earth or within **vertical** structural components in direct contact with the earth













































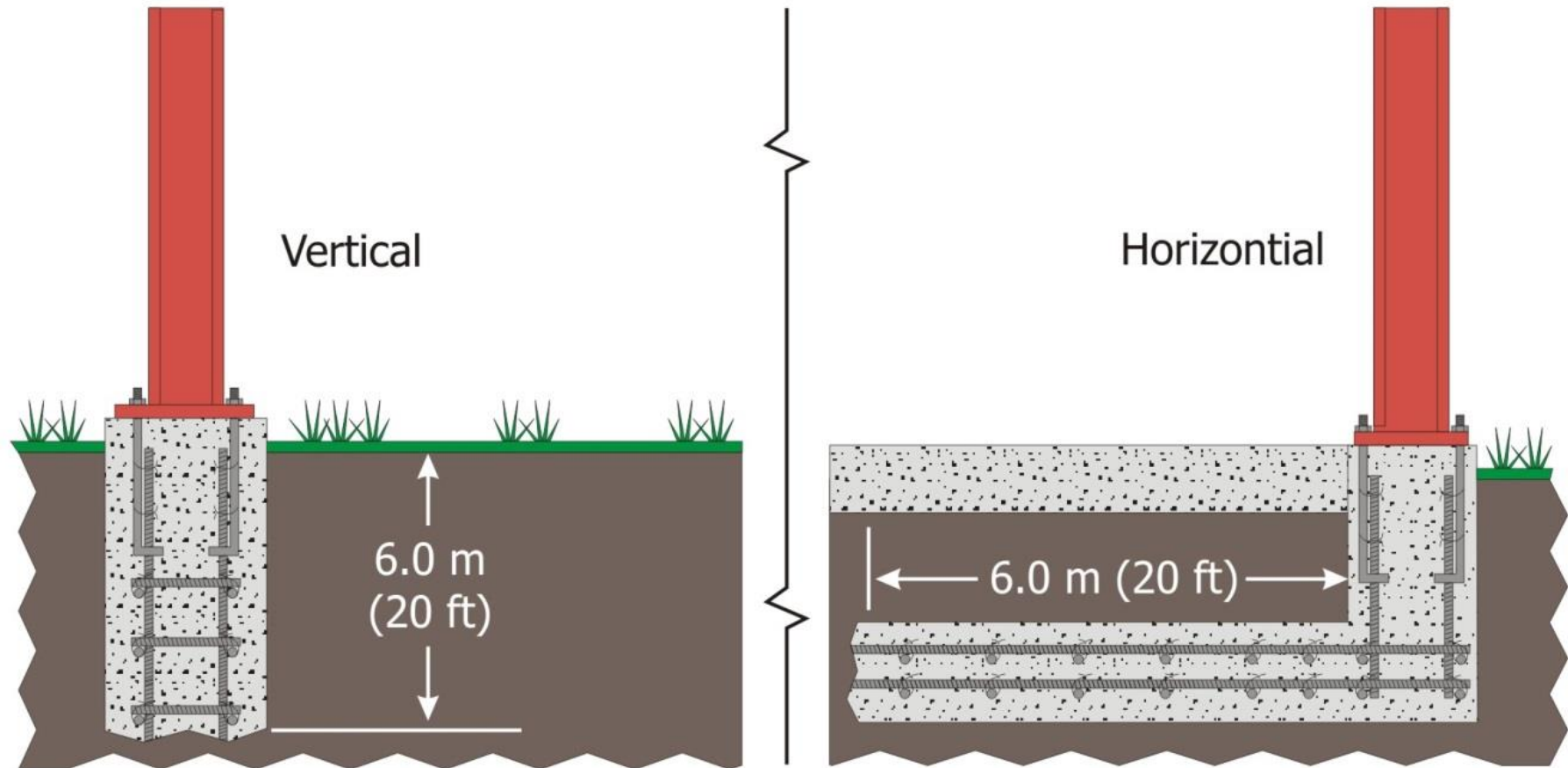


# 250.52(A)(3) Concrete-Encased Electrode



Encased by at least 50 mm (2 in.) of concrete, located **horizontally** within that portion of a foundation or footing in direct contact with the earth or **vertically** foundations or structural components that are in direct contact with the earth

Where multiple concrete-encased electrodes are present, it is permissible to bond only one into the grounding electrode system













# Ground Ring Electrodes

- Section 250.52(A)(4) describes a ground ring encircling the building or structure, in direct contact with the earth, consisting of at least **6.0 m (20 ft)** of bare copper conductor not smaller than **2 AWG**



250.52(A)(4)  
Installation of a Ground Ring Electrode



*( Photo courtesy of East Coast  
Lightning Equipment of Winsted, CT)*





# Rod and Pipe Electrodes

- Section 250.52(A)(5) requires rod and pipe electrodes to be not less than **2.44 m (8 ft)** in length and shall consist of the following materials:
  - Grounding electrodes of **pipe or conduit** shall not be smaller than **metric designator 21 (trade size 3/4)** and, where of steel, shall have the outer surface galvanized or otherwise metal-coated for corrosion protection
  - **Rod-type** grounding electrodes of stainless steel and copper or zinc coated steel shall be at least **15.87 mm (5/8 in.) in diameter**, unless listed

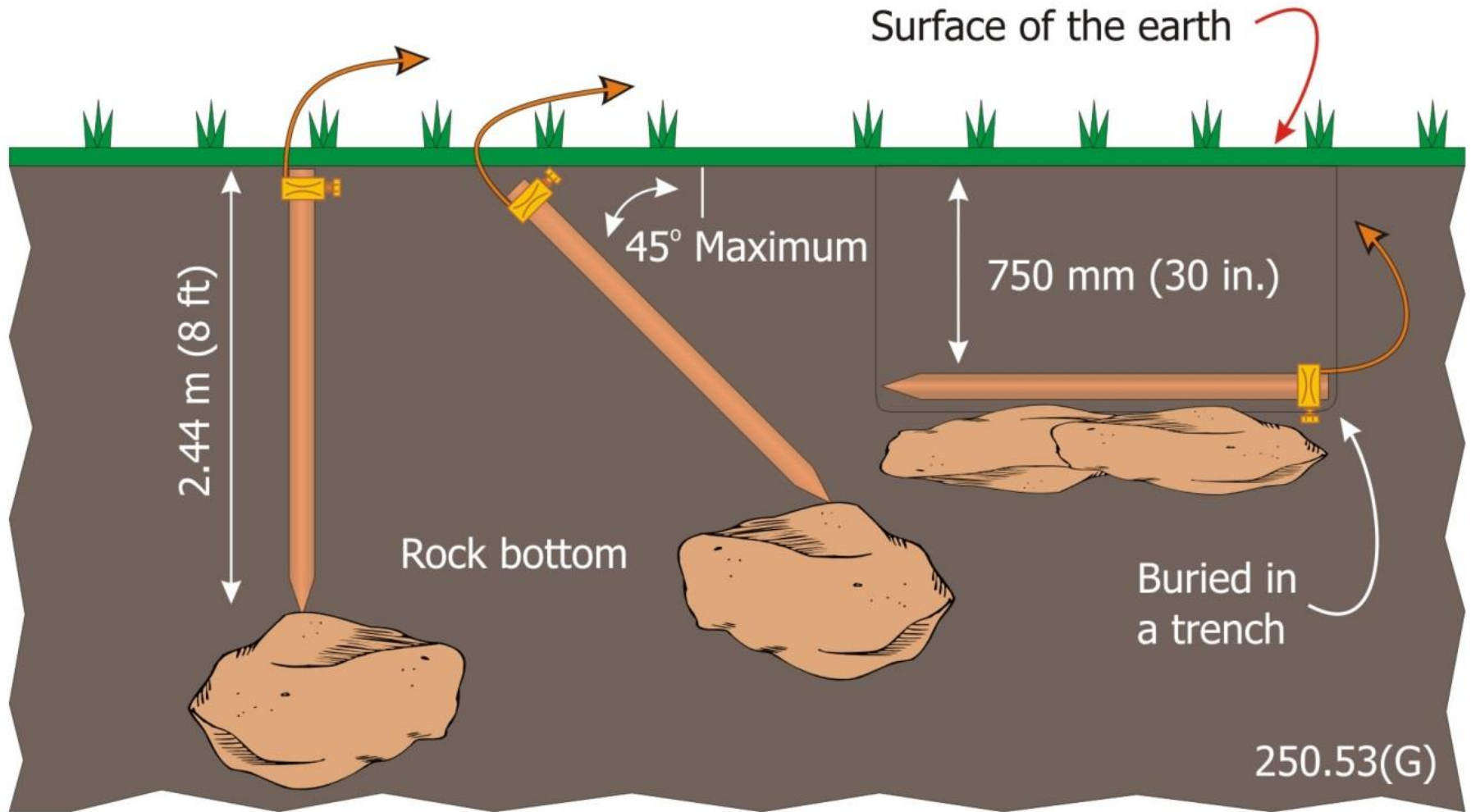


## 250.52(A)(5) Rod and Pipe Electrodes





# Installation of Rod or Pipe Electrodes



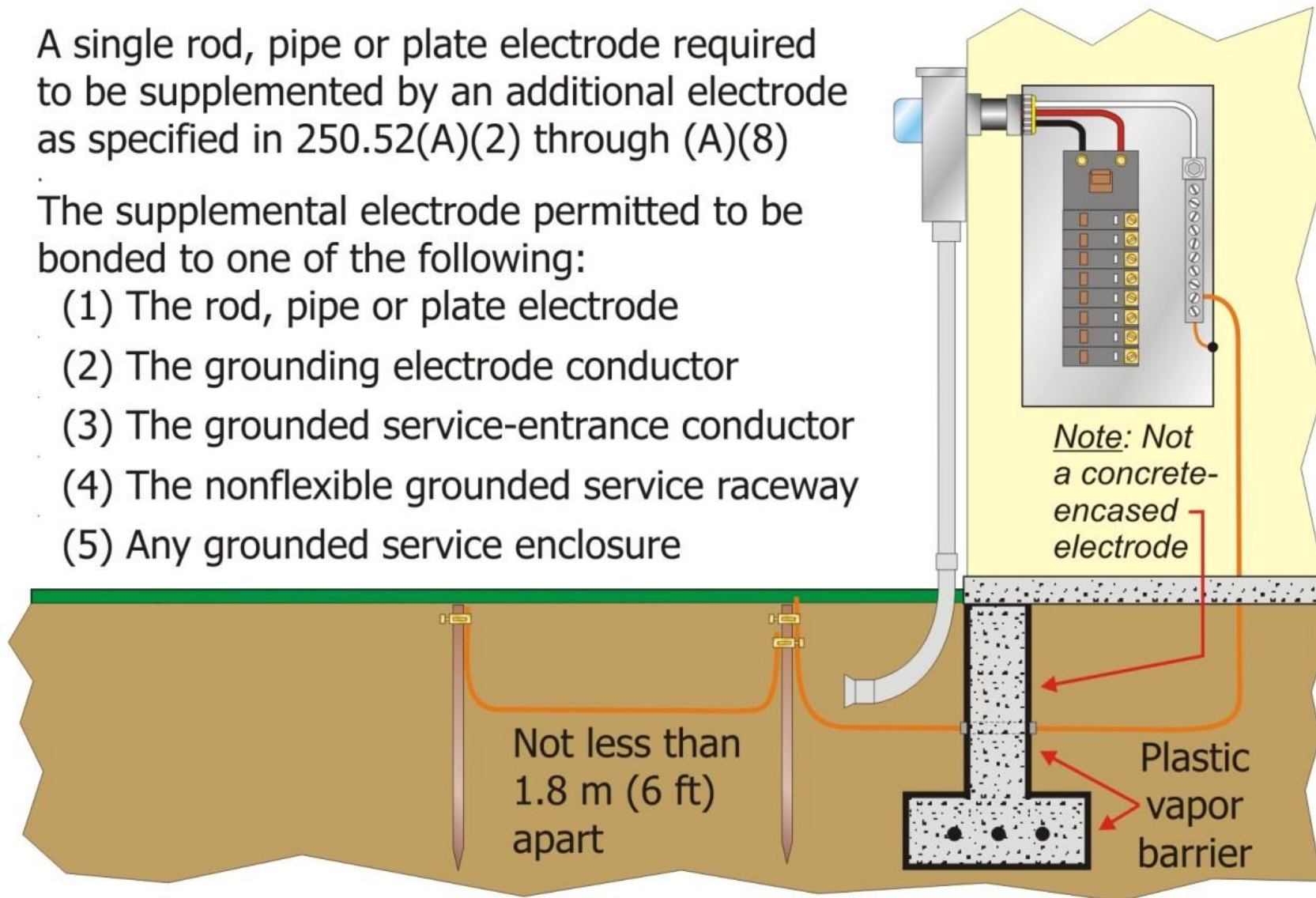
# 250.53(A) Rod, Pipe, and Plate Electrodes



A single rod, pipe or plate electrode required to be supplemented by an additional electrode as specified in 250.52(A)(2) through (A)(8)

The supplemental electrode permitted to be bonded to one of the following:

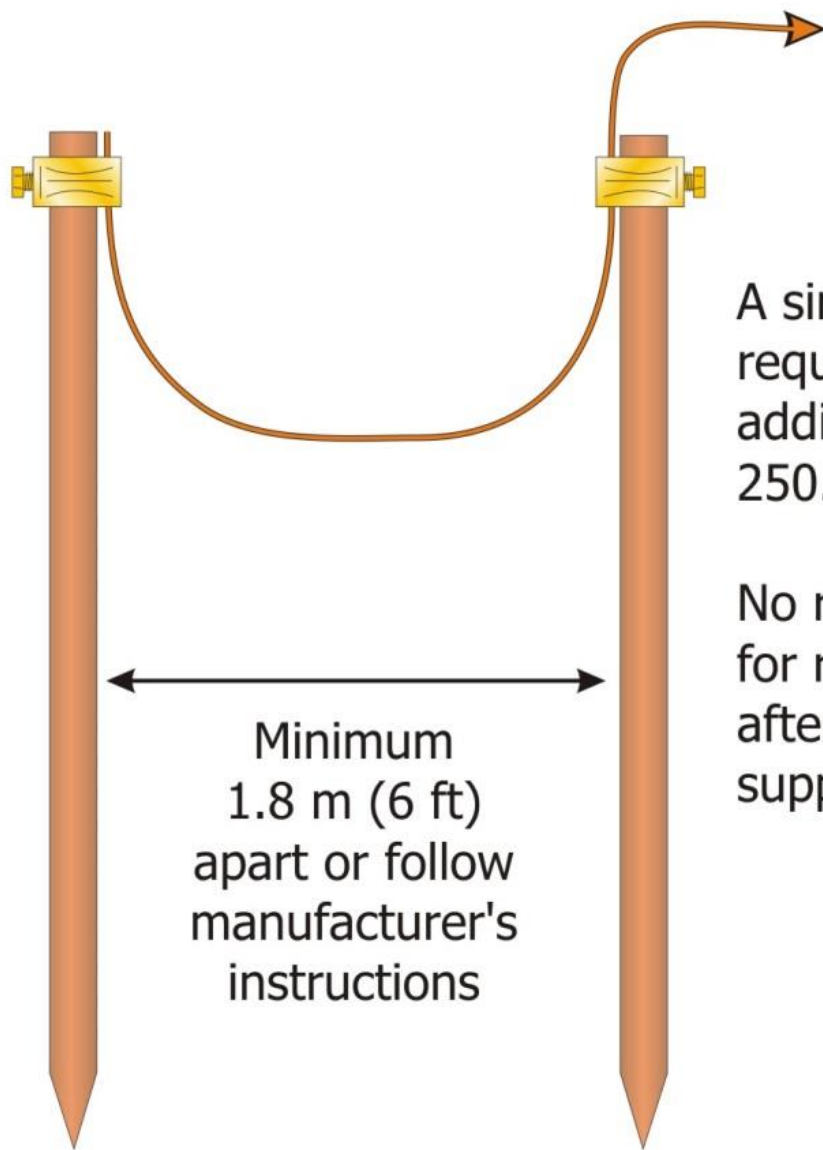
- (1) The rod, pipe or plate electrode
- (2) The grounding electrode conductor
- (3) The grounded service-entrance conductor
- (4) The nonflexible grounded service raceway
- (5) Any grounded service enclosure



**Exception:** If a single rod, pipe, or plate grounding electrode has a resistance to earth of **25 ohms or less**, the supplemental electrode shall not be required



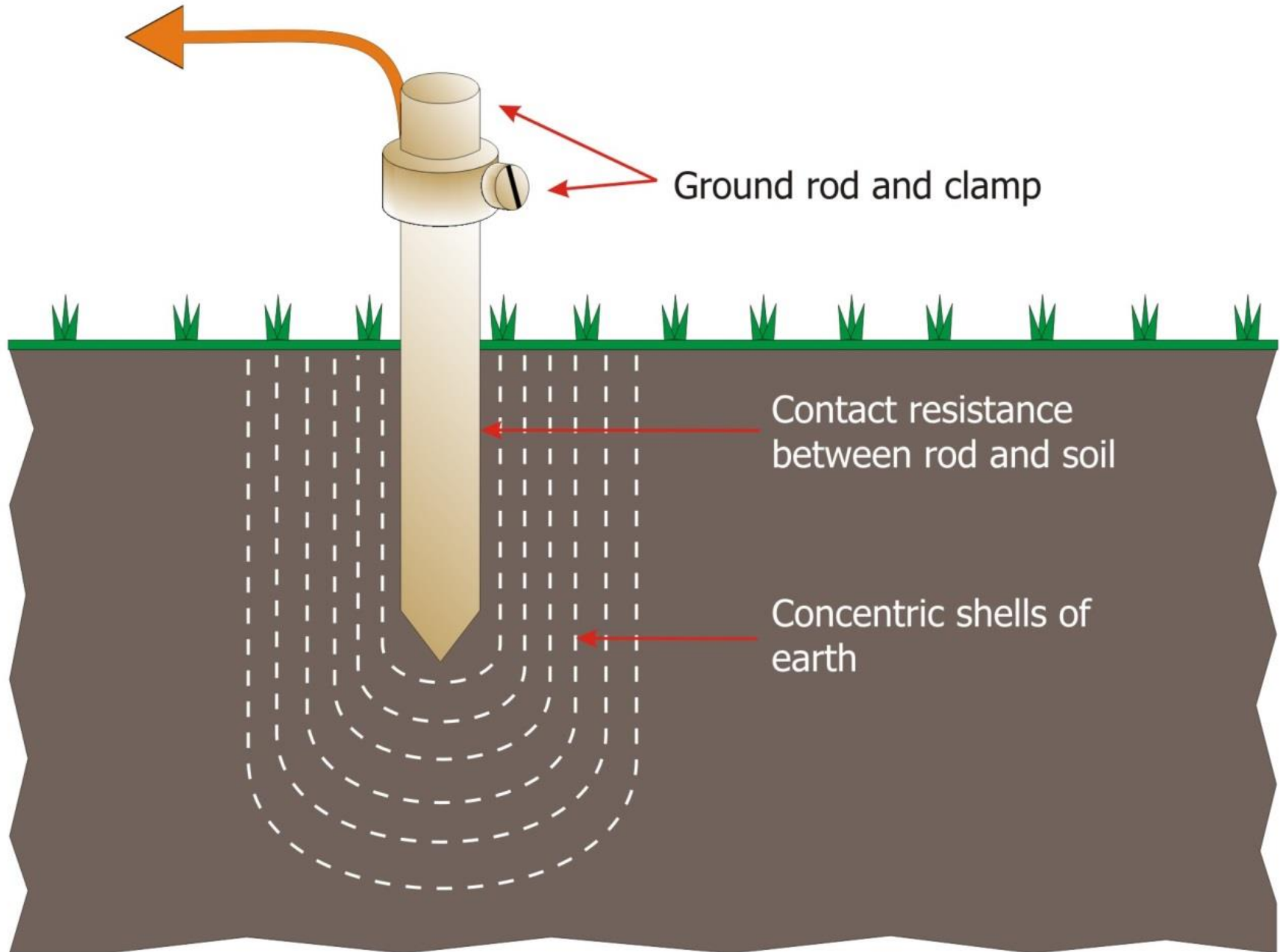
# Resistance of Rod, Pipe, and Plate Electrodes



A single rod, pipe or plate electrode required to be supplemented by an additional electrode as specified in 250.52(A)(2) through (A)(8)

No resistance measurement required for rod, pipe, and plate electrodes after these electrodes have been supplemented

# Ground Rod Resistance







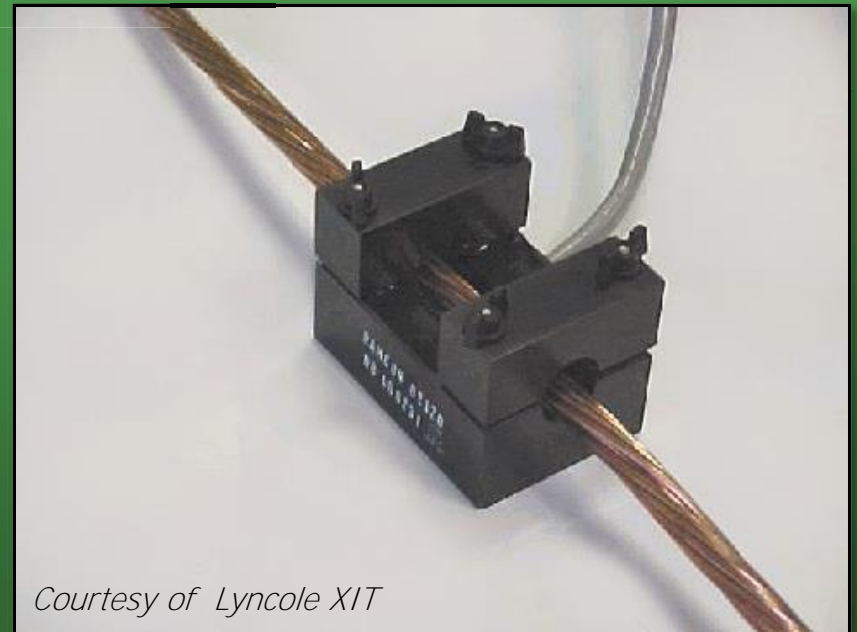
Concept courtesy of Lyncole XIT

# Grounding Resistance Monitoring System



Monitor

Sensor



*Courtesy of Lyncole XIT*



# Nature of Earth Electrode

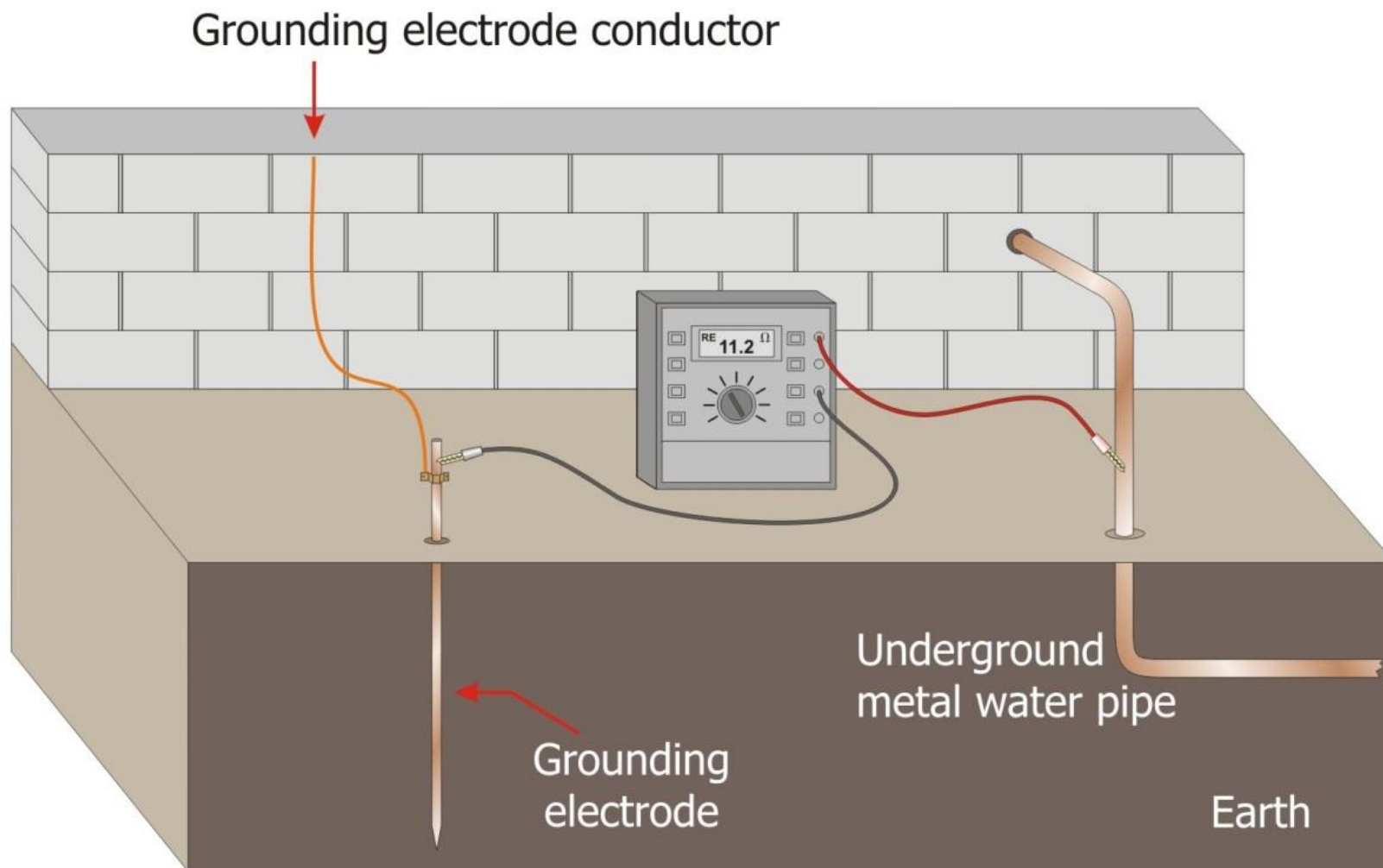
- Grounding electrodes are usually made of very conductive material with adequate cross sections so overall resistance is negligible
- NIST (*National Institute of Standards and Technology*) has demonstrated that resistance between the surrounding earth and the electrode is negligible if electrode is free of paint, grease or other coating, and the earth is firmly packed
- The electrode can be thought of as being surrounded by concentric shells of earth or soil, all of the same thickness
- The closer the shell to the electrode the smaller its surface; hence, the greater its resistance

# Maximum Resistance of Grounding Electrodes

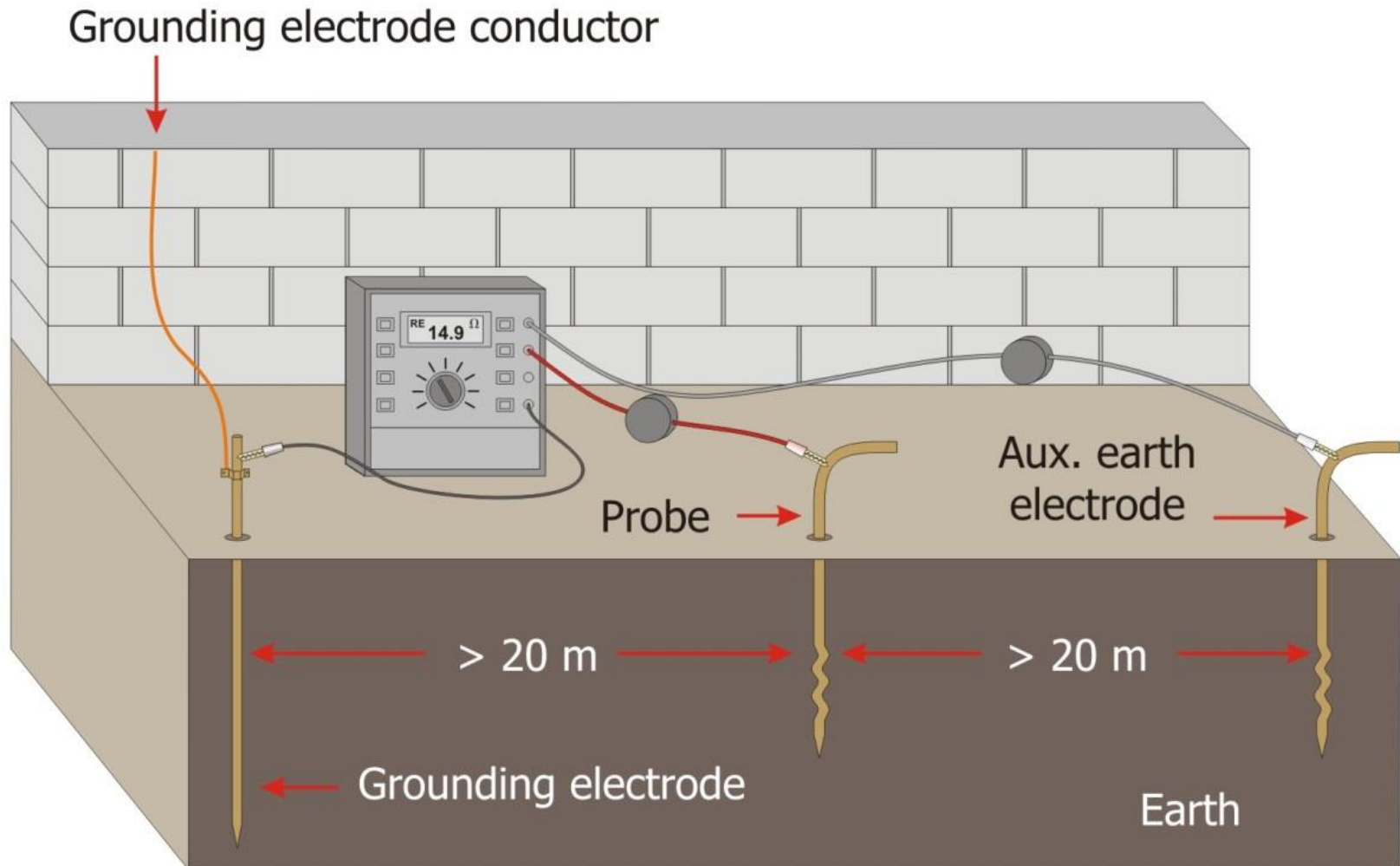
- No maximum resistance for a grounding electrode system
- Maximum 25 ohms for single electrodes of the rod, pipe, or plate types when not supplemented *[250.53(A)(2), Ex.]*
- Rod, pipe, or plate electrode are required to be supplemented by an additional electrode
- When supplemented, no maximum earth resistance for the rod, pipe, or plate electrode(s) applies (*no 25 ohms rule*)



# Two-Point Resistance Measurement Method



# Three-Point Fall-of-Potential Test Method





# Ground Resistance Clamp-on Tester



- Digital earth test clamp
- Courtesy of Megger



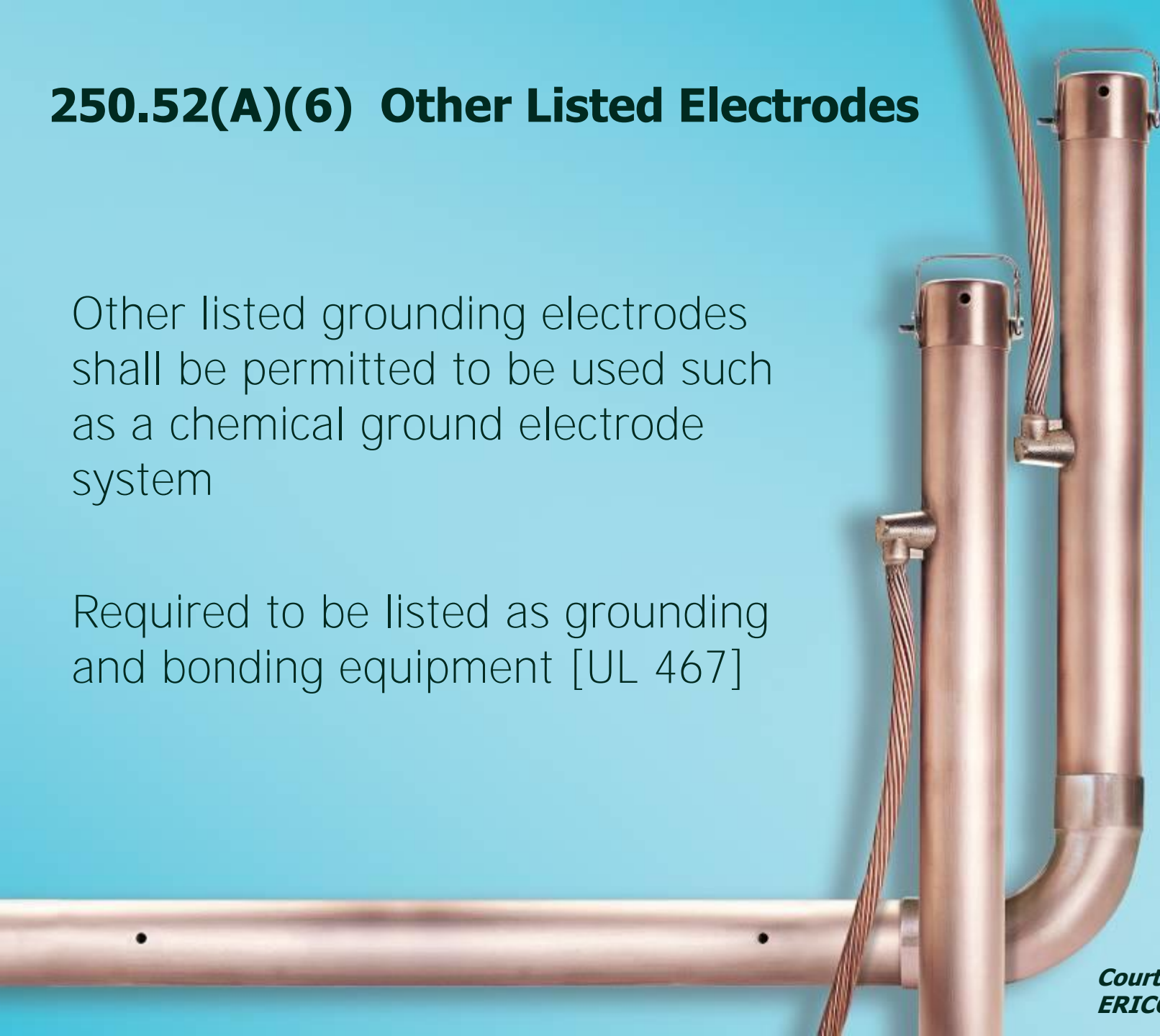




## 250.52(A)(6) Other Listed Electrodes

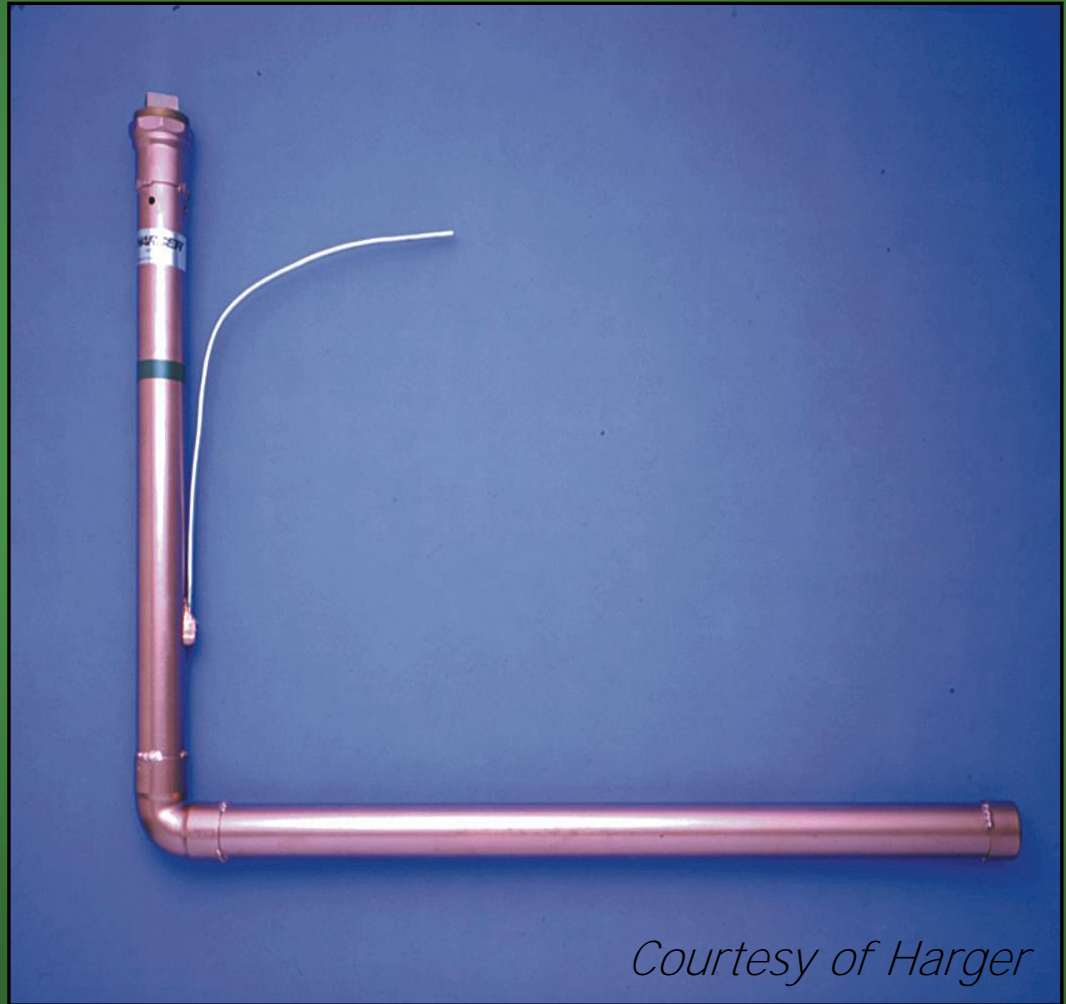
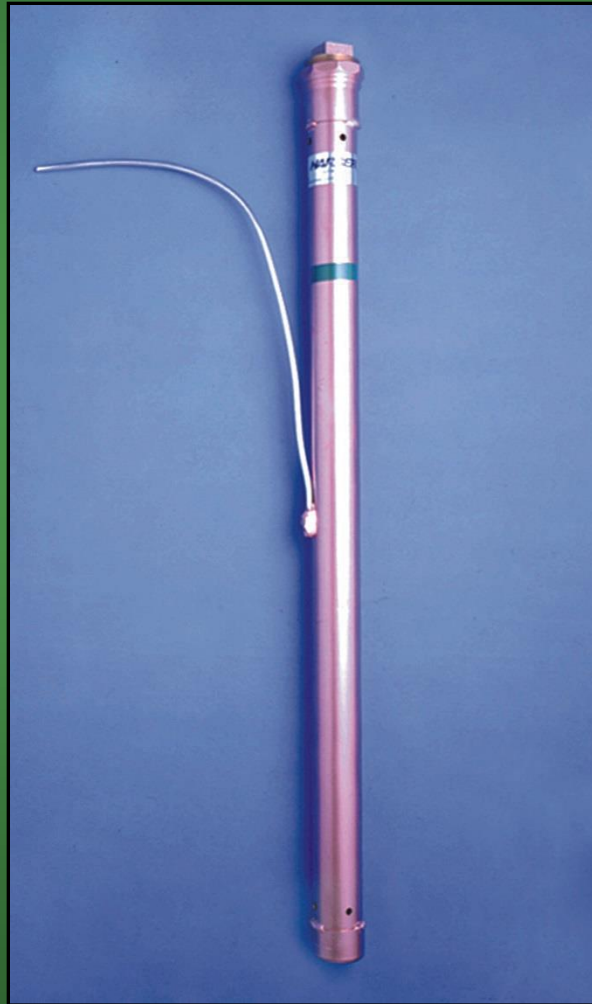
Other listed grounding electrodes shall be permitted to be used such as a chemical ground electrode system

Required to be listed as grounding and bonding equipment [UL 467]



*Courtesy of  
ERICO International*

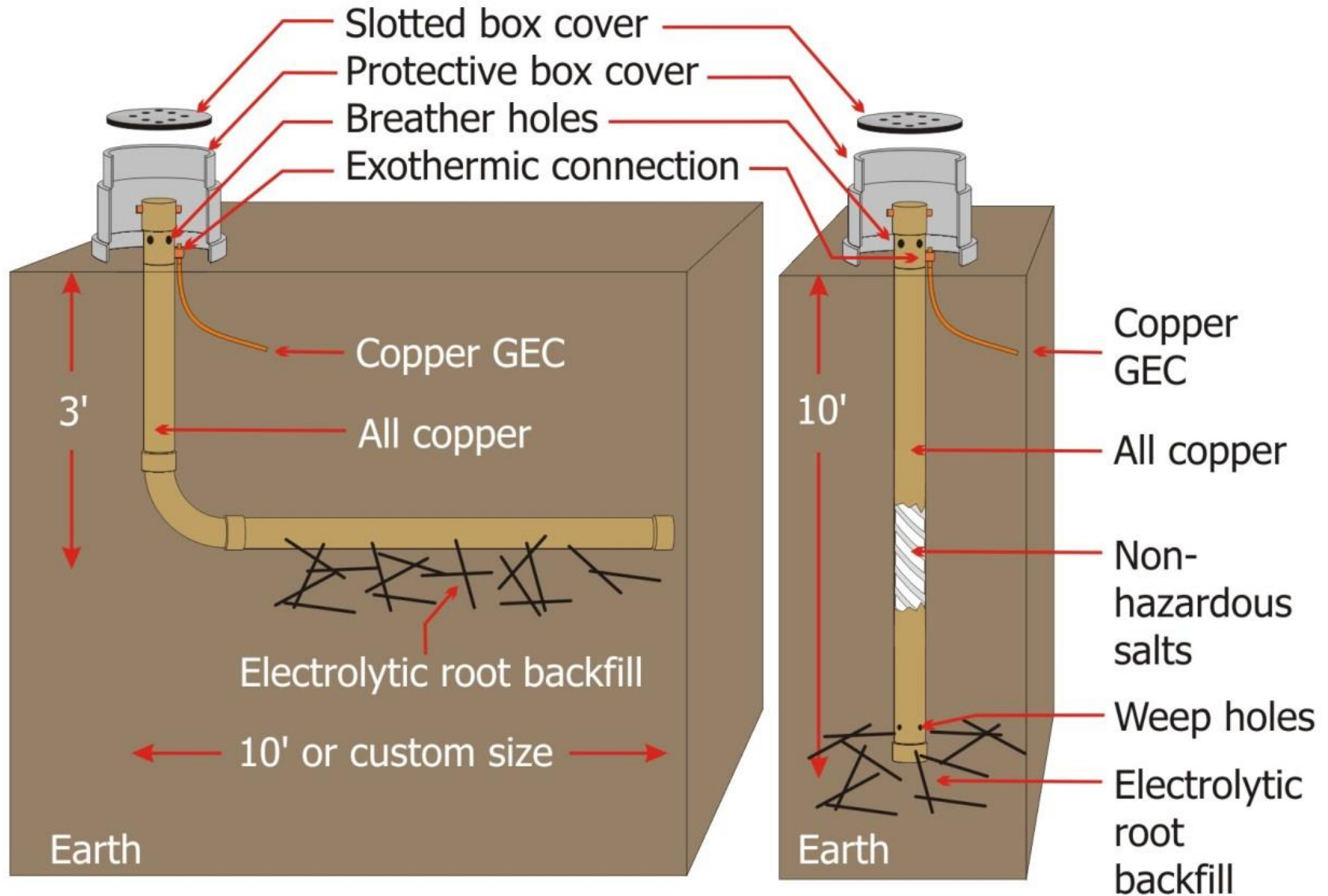
# Enhanced Grounding Electrodes



*Courtesy of Harger*



# Enhanced Grounding Electrode - Anatomy



Concept courtesy of Lyncole XIT



## 250.52(A)(7) Plate Electrodes



*( Photo courtesy of Bonded Lightning  
Protection of Argyle, TX)*





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**End of Part 1**



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