

GROUNDING AND BONDING NATIONAL ELECTRICAL CODE ARTICLE 250

By Jim Biesterveld

**Some of the material is taken from
Mike Holt and Soars presentations**

NEC 250.1 Scope

- (1) Systems, circuits, and equipment require, permitted, or not permitted to be grounded
- (2) Circuits conductors to be grounded on grounded systems

(3) Location of grounding connections

(4) Type and size of grounding and bonding conductors and electrodes

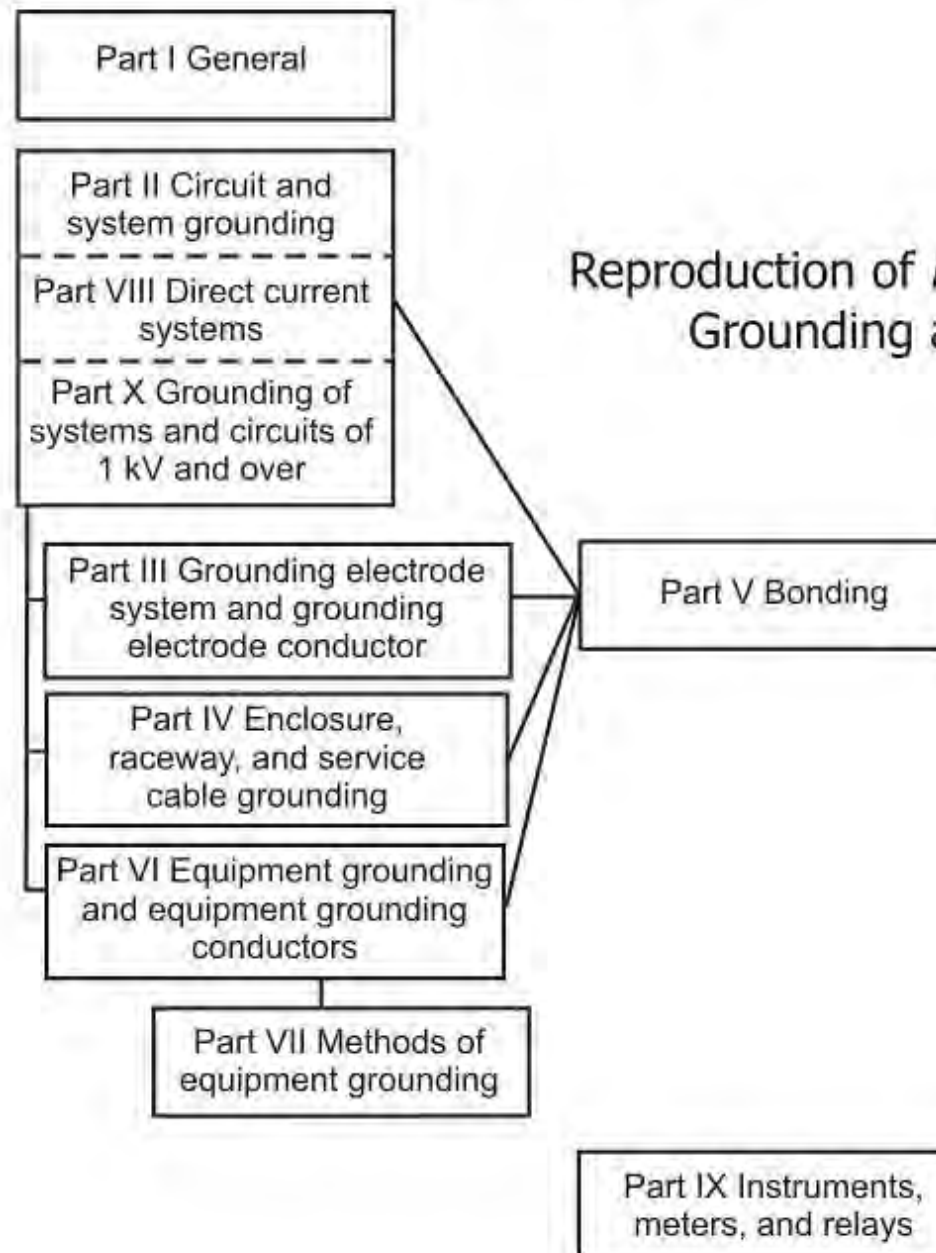
(5) Methods of grounding and bonding

(6) Conditions under which guards, isolation, or insulation maybe substituted for grounding

The code has it's definitions and these need to be understood to properly understand and interpret the code requirements of the NEC and Wisconsin Comm 16



Figure 250.1



Reproduction of *NEC* Figure 250.1
Grounding and Bonding

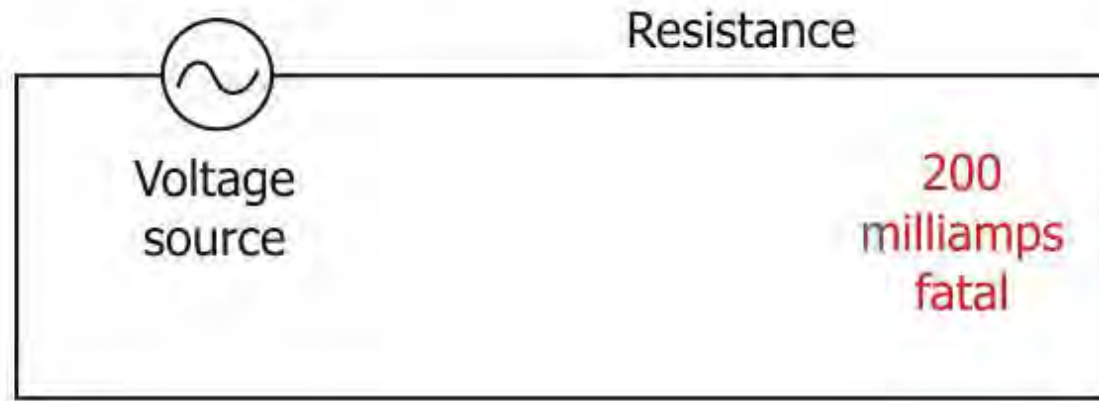


Severity of Electric Shock

The severity of electric shock is related to three elements.

If the combination of these three elements is just right, the shock can be severe or lead to electrocution.

1. Amount of current
2. Length of time current is present
3. Path of current through the body
4. Frequency of the current (Hz)



Amount of time current is allowed to pass through the body

Effects of Electricity on Humans



1000 milliamperes or 1 ampere



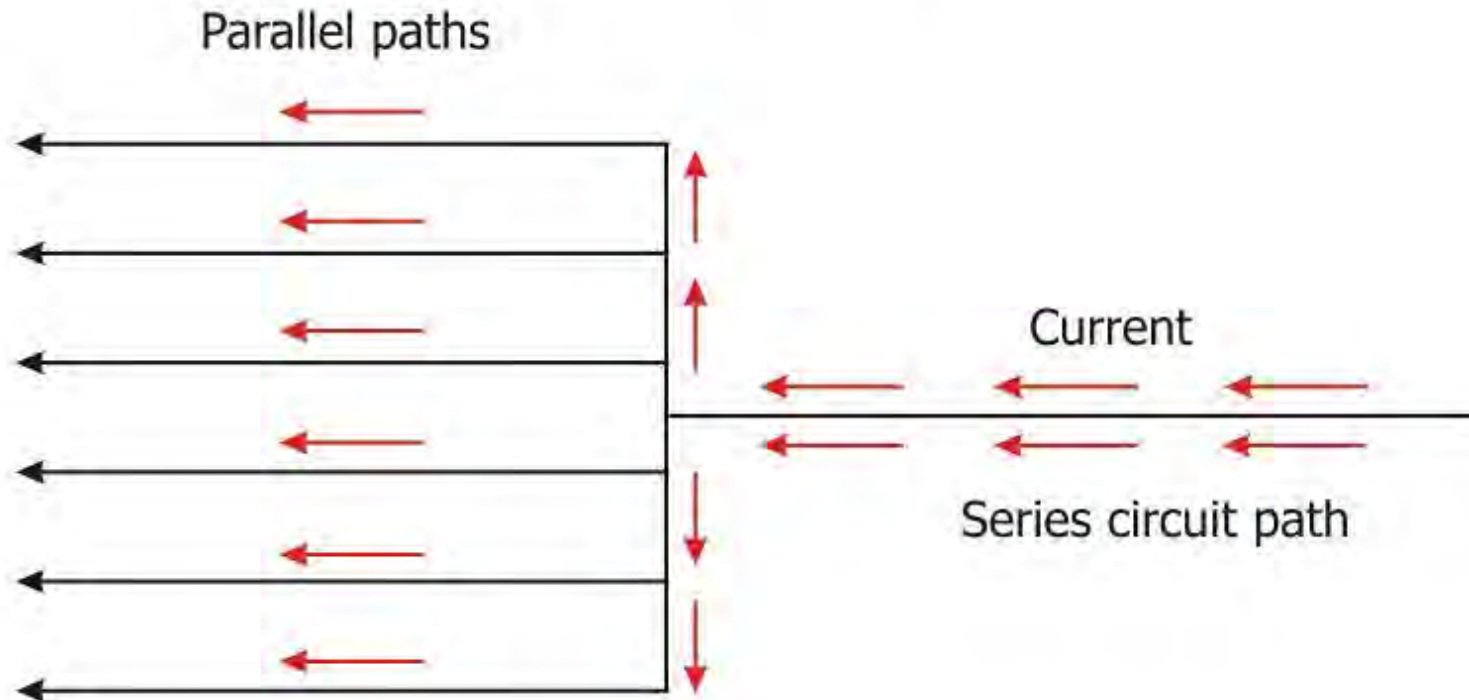
It doesn't take much current to cause injury or to cause death.

milliamperes

1000	Will light a 100-watt bulb
900	Severe burns
300	Breathing stops
200	
100	Heart stops beating
90	
60	
30	Suffocation possible
20	Muscle contraction
10	Cannot let go
5	GFCI will trip
2	Mild shock
1	Threshold of sensation



Series and Parallel Paths for Current



Current will always try to return to the source

Current will return in as many paths that are available to it

Amount of current on a particular path depends on the impedance of that path

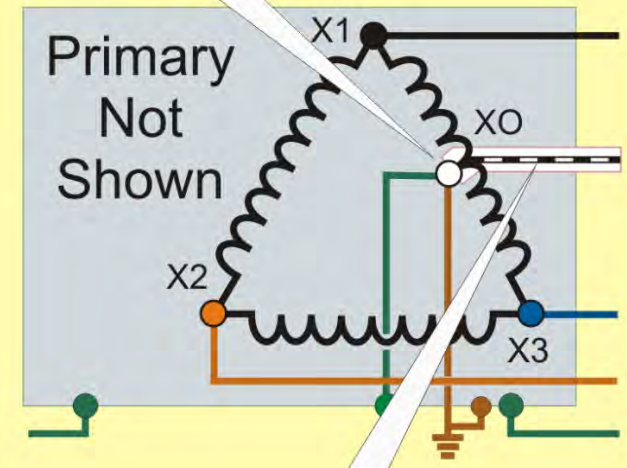
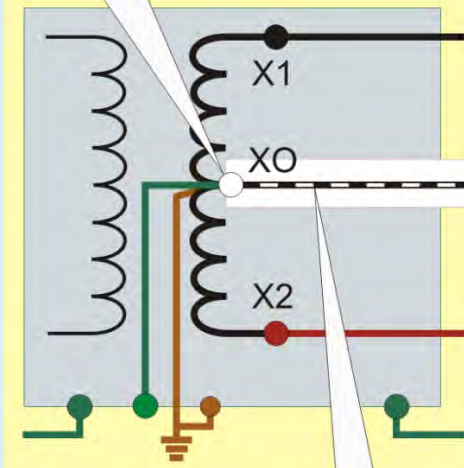
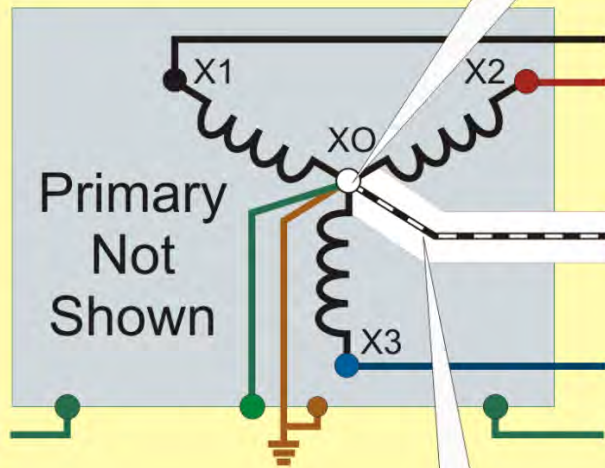
Grounded Conductor *Article 100 Definition*

Wye 3-phase,
4-wire System

1-phase, 3-wire
System

Delta 3-phase,
4-wire System

Neutral Point

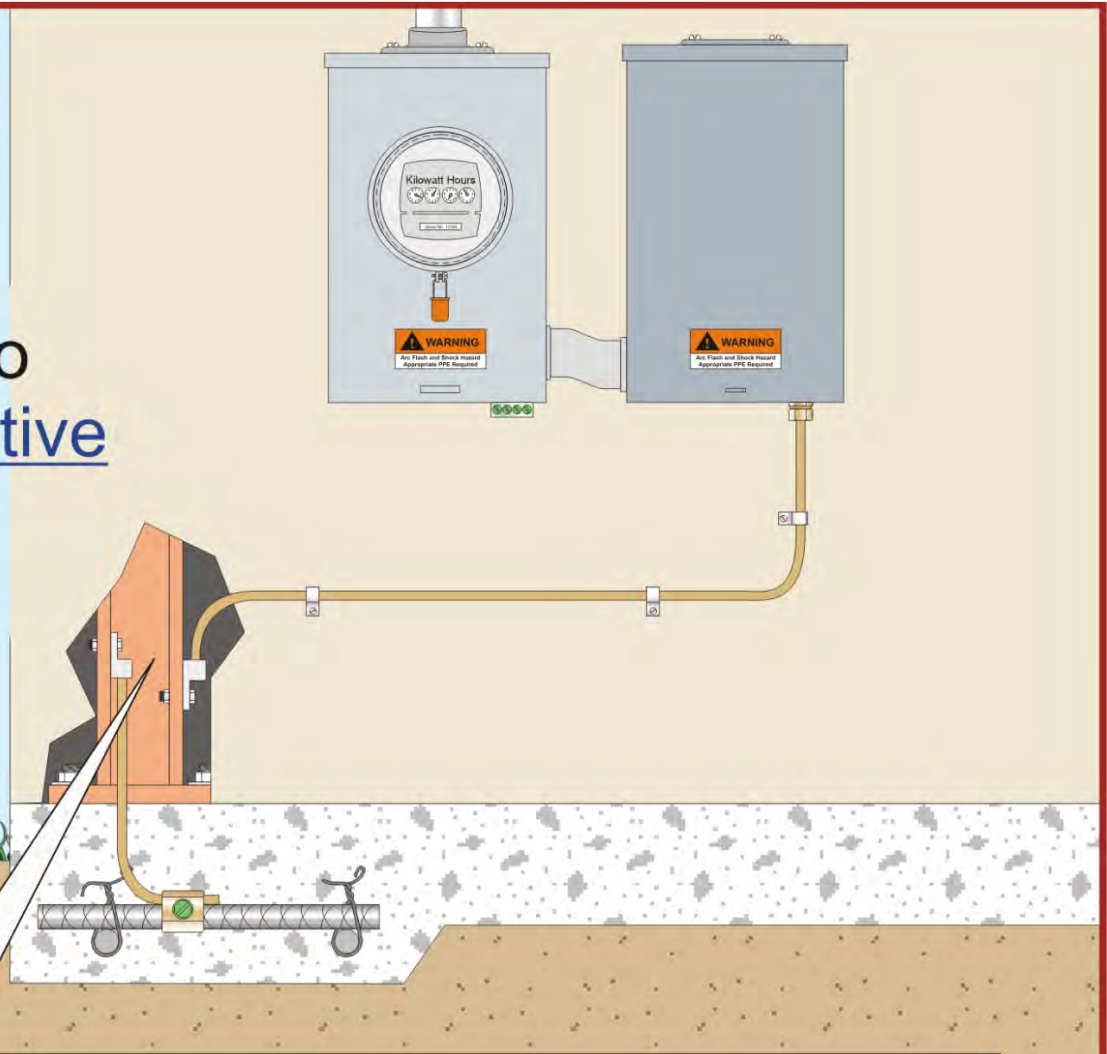


Grounded Conductor: A system or circuit conductor that is intentionally grounded. For these systems, it is also the neutral conductor.

Grounded (Grounding) *Article 100 Definition*

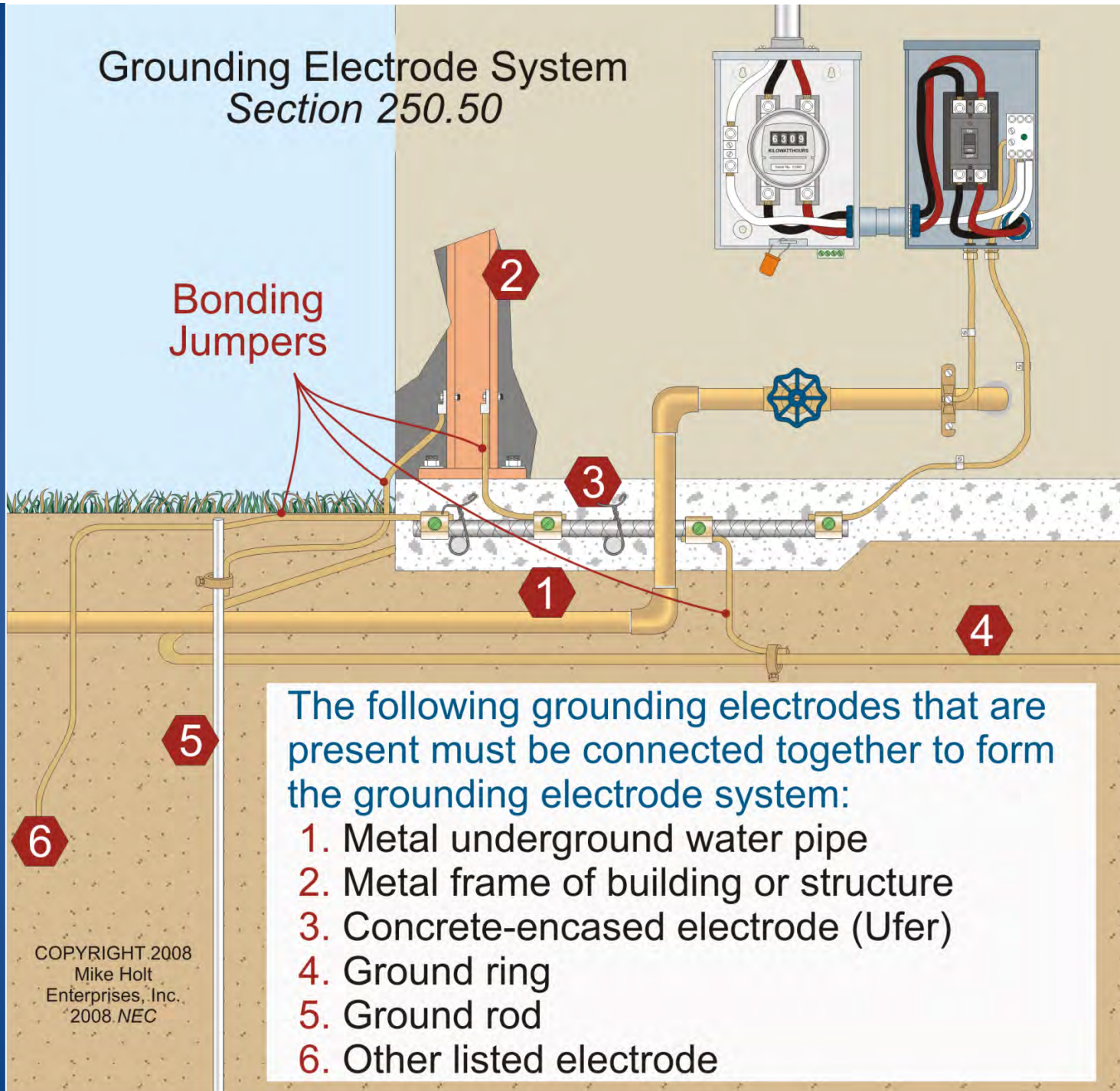
Grounded: Connected to ground or some conductive body that extends the ground connection.

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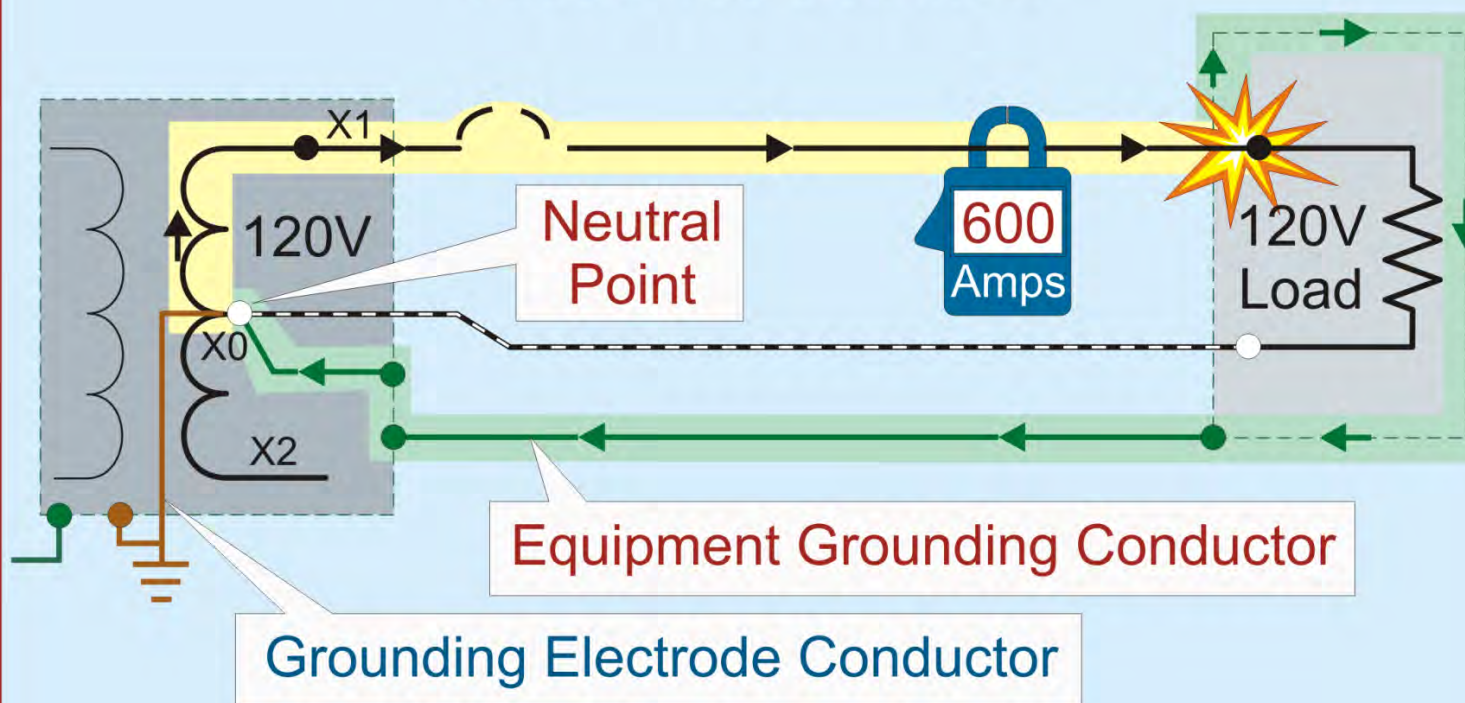
Structural steel that is connected to the grounding electrode system is an example of a conductive body that extends the ground connection.

Grounding Electrode System Section 250.50



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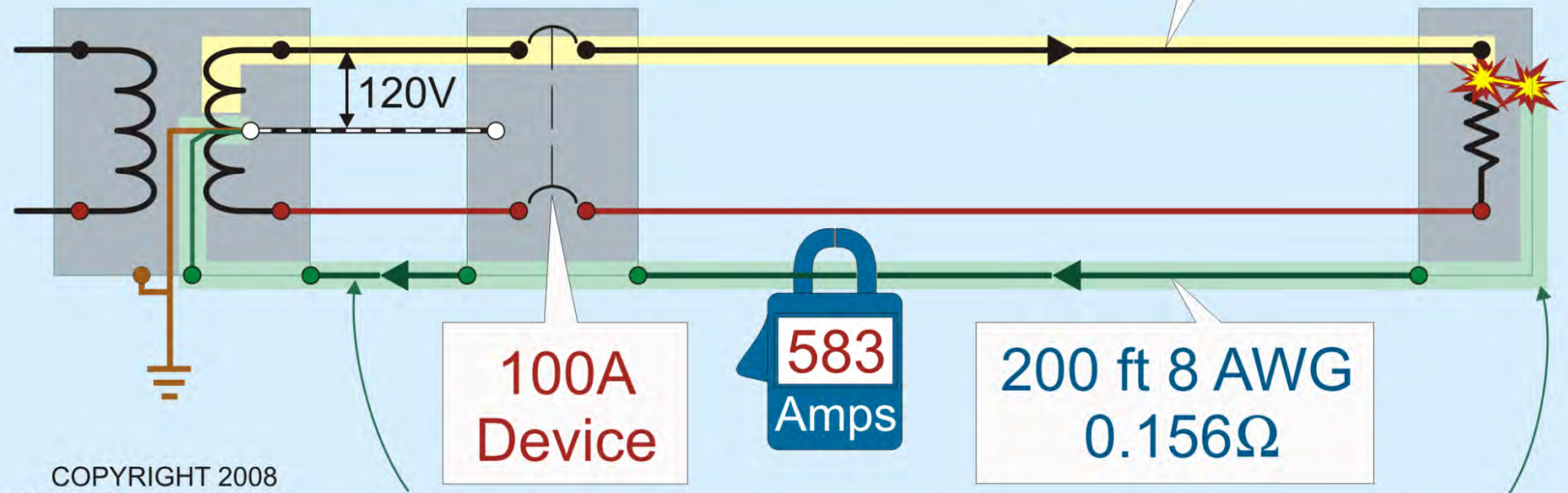
Grounding Conductor, Equipment *Article 100 Definition*



The conductive path installed to connect normally noncurrent-carrying metal parts of equipment together and to the system neutral conductor or to the grounding electrode conductor, or both.

The equipment grounding conductor also performs bonding [FPN No. 1].

Effective Ground-Fault Current Path To Open Overcurrent Device *Section 250.118 FPN*



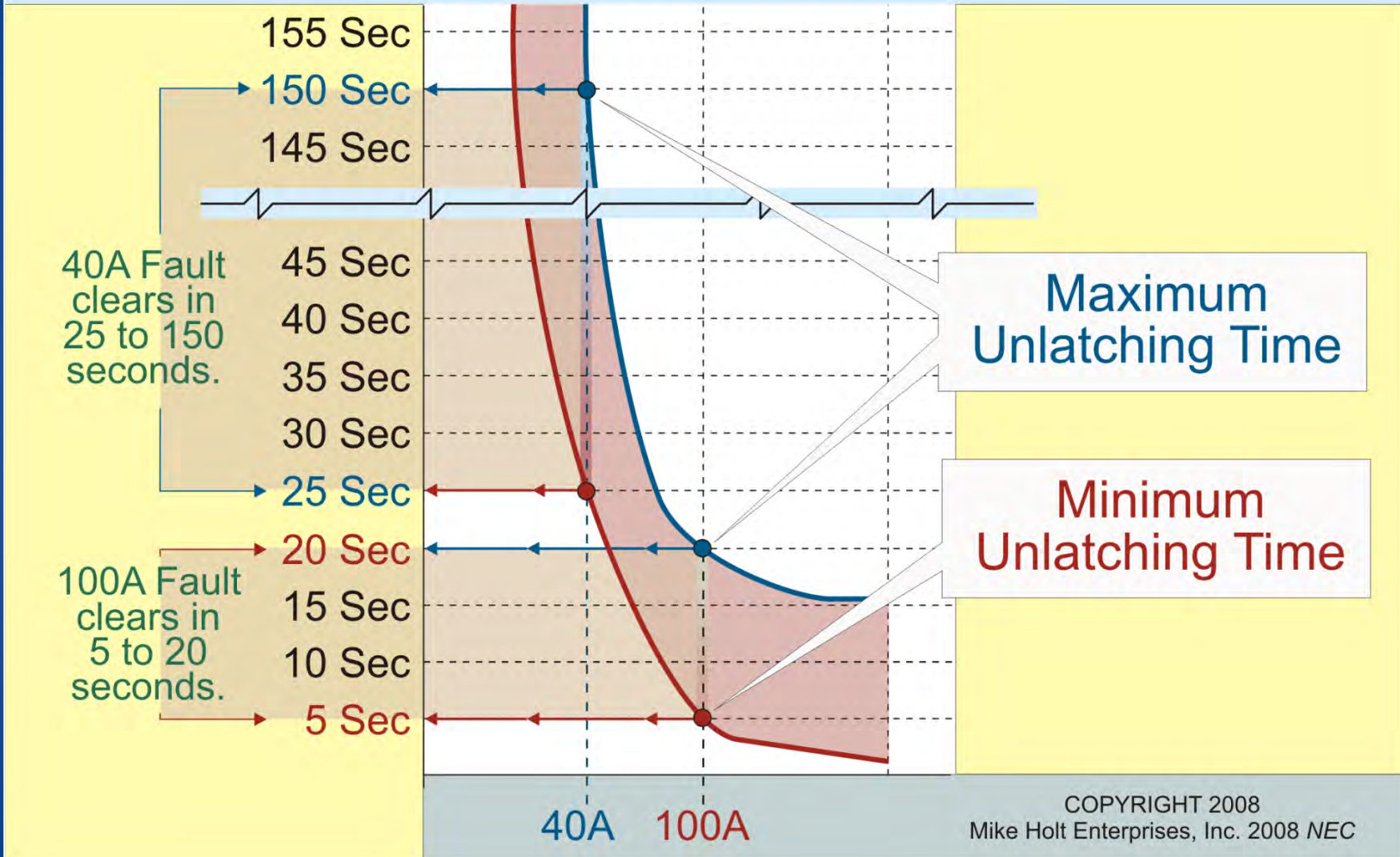
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Effective Ground-Fault Current Path [250.2]

$$\text{Fault-Current Amps} = \frac{E}{Z} = \frac{120V}{0.206\Omega} = 583A$$

The 100A overcurrent device quickly opens and removes dangerous voltage from metal parts.

Time-Current Curve 20A Inverse Time Breaker



The higher the current, the faster the fault clears.



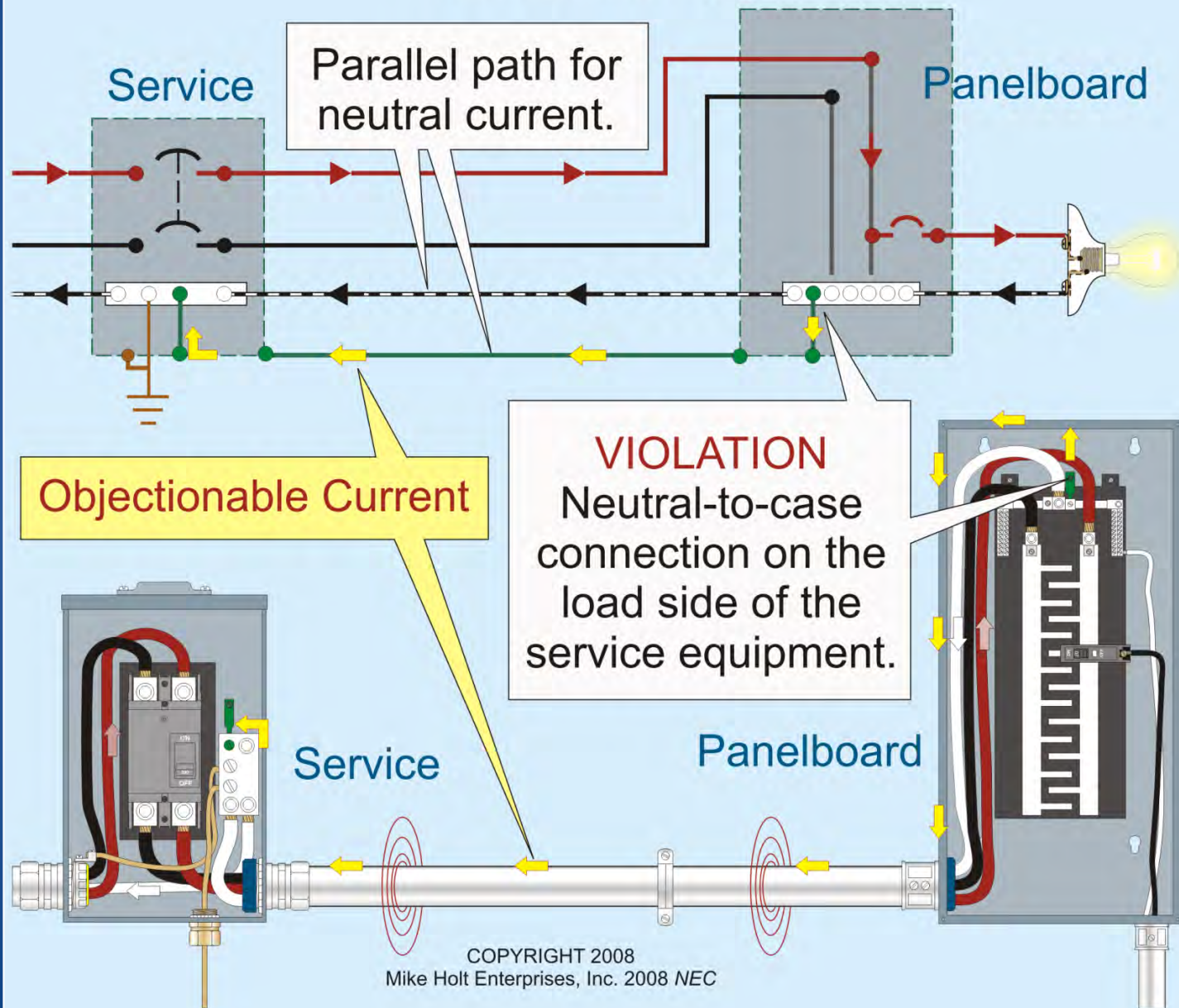
250.4 General Requirements for Grounding and Bonding

- EARTH IS NOT AN EFFECTIVE GROUND-FAULT
CURRENT PATH

250.4 General Requirements for Grounding and Bonding

- BONDING CONDUCTIVE MATERIALS
- To quickly remove ground-fault voltage by the opening of the circuit protection device, metal parts of the building structure must be connected to the source via the equipment grounding conductor.

Objectionable Current Improper Neutral Connection Section 250.6(A)



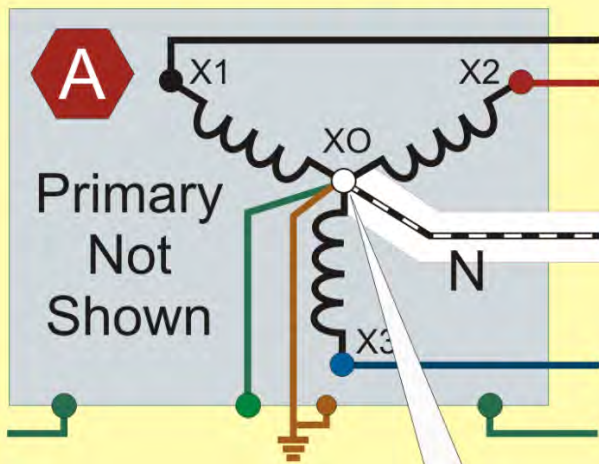
250.24 Service Equipment

- Service equipment supplied from a grounded system must have the neutral conductor grounded.

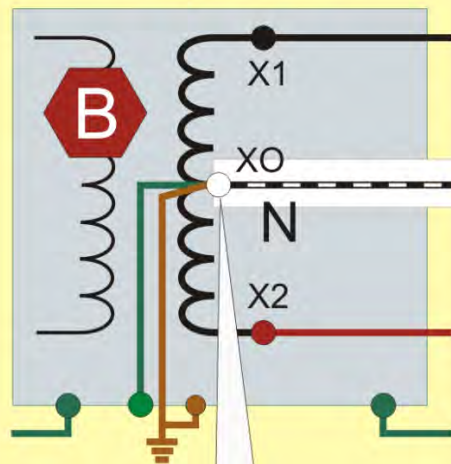
Neutral Point

Article 100 Definition

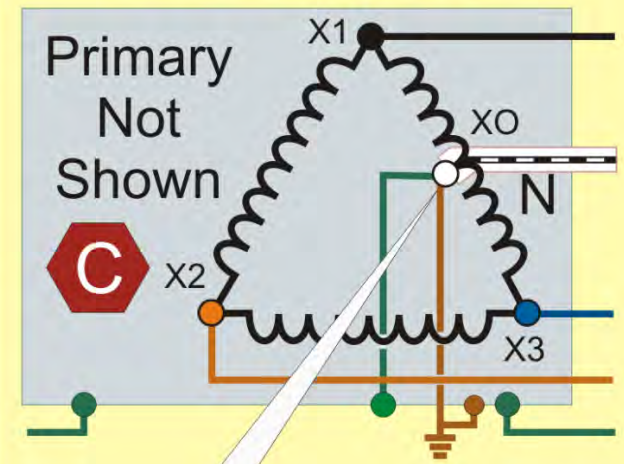
Wye 3-phase, 4-wire System



1-phase, 3-wire System



Delta 3-phase, 4-wire System



Neutral Point: A neutral point is the:

A - Common point of a wye 3-ph, 4-wire system

B - Midpoint of a 1-ph, 3-wire system

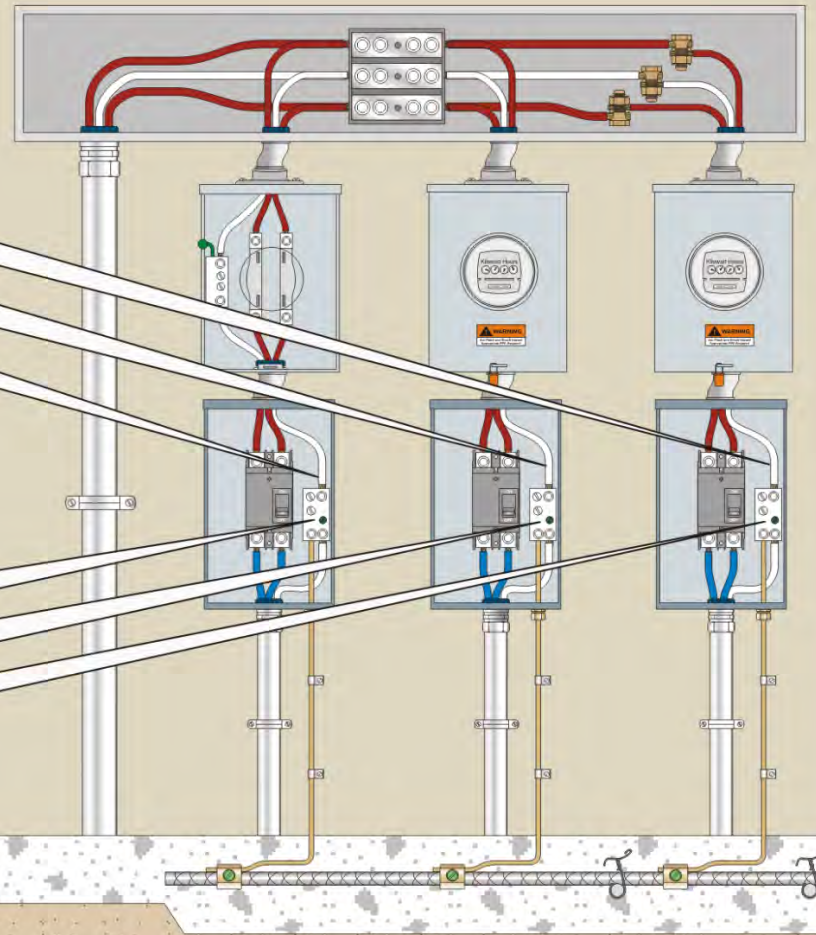
C - Midpoint of one phase of a delta 3-ph, 4-wire system

Service Equipment - Multiple Disconnect Neutral Conductor Required *Section 250.24(C)*

Service neutral
conductor at each
service disconnect.

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Neutral-to-case
connection required
in each disconnect.



The neutral conductor must be run to, and connected to, each service disconnect via a main bonding jumper.

Service Grounding Connections Section 250.24(A)(1)

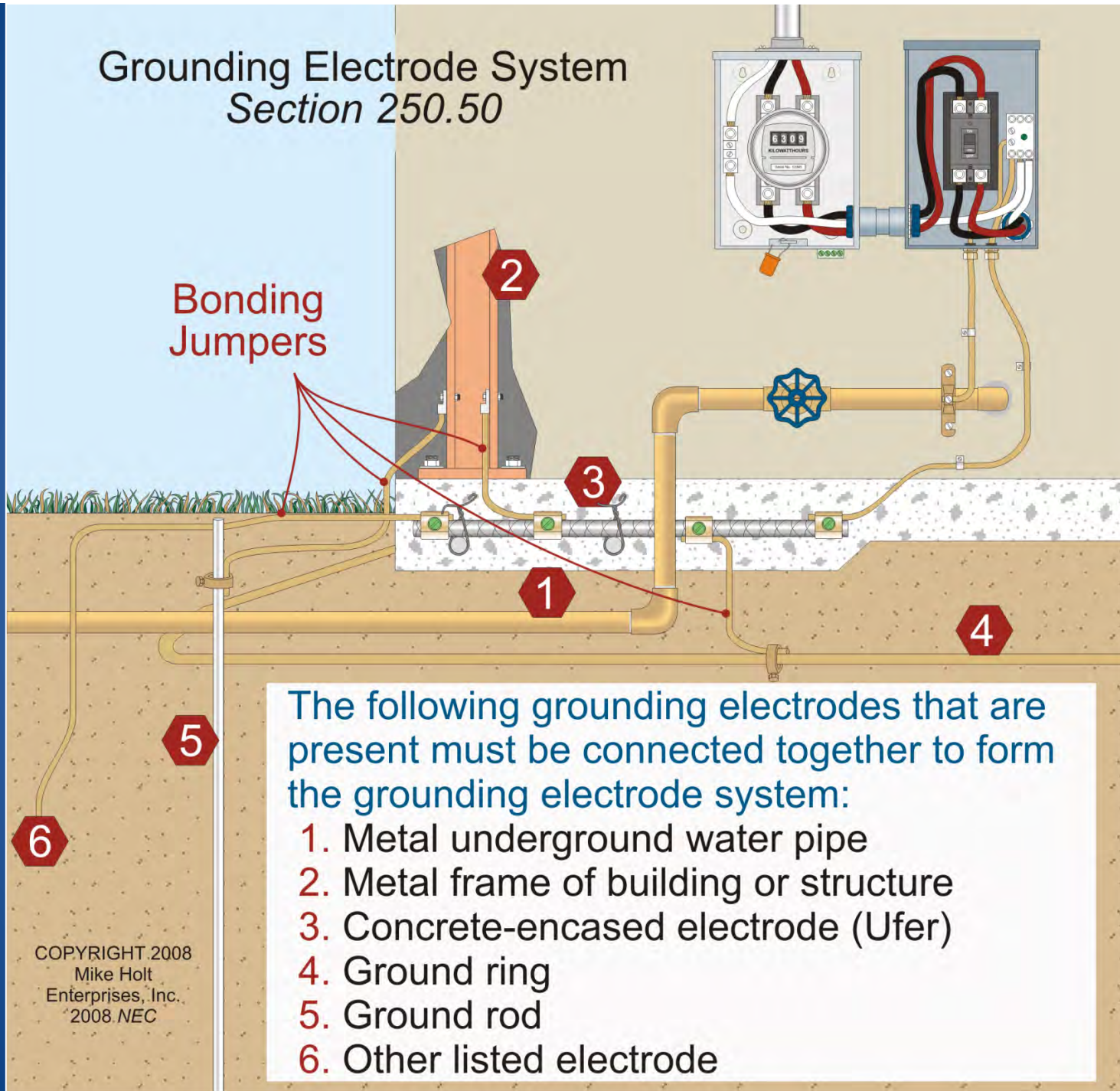


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A grounding electrode conductor must connect the neutral conductor to a grounding electrode at the:

1. Service drop,
2. Meter enclosure, or
3. Service disconnect

Grounding Electrode System Section 250.50



Bonding
Jumpers

The following grounding electrodes that are present must be connected together to form the grounding electrode system:

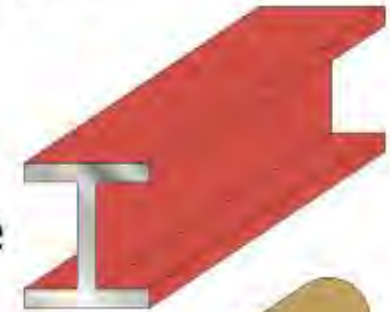
1. Metal underground water pipe
2. Metal frame of building or structure
3. Concrete-encased electrode (Ufer)
4. Ground ring
5. Ground rod
6. Other listed electrode

250.50 Grounding Electrode System



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

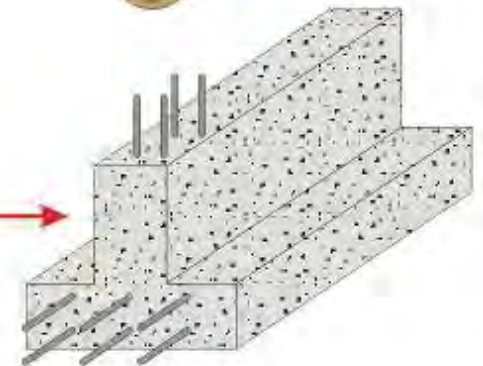
Metal building frame



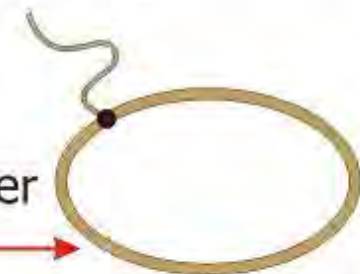
Metal water pipe



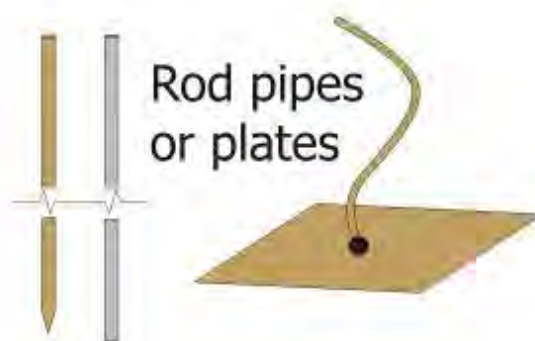
Concrete encased



Ground ring
2 AWG copper
minimum

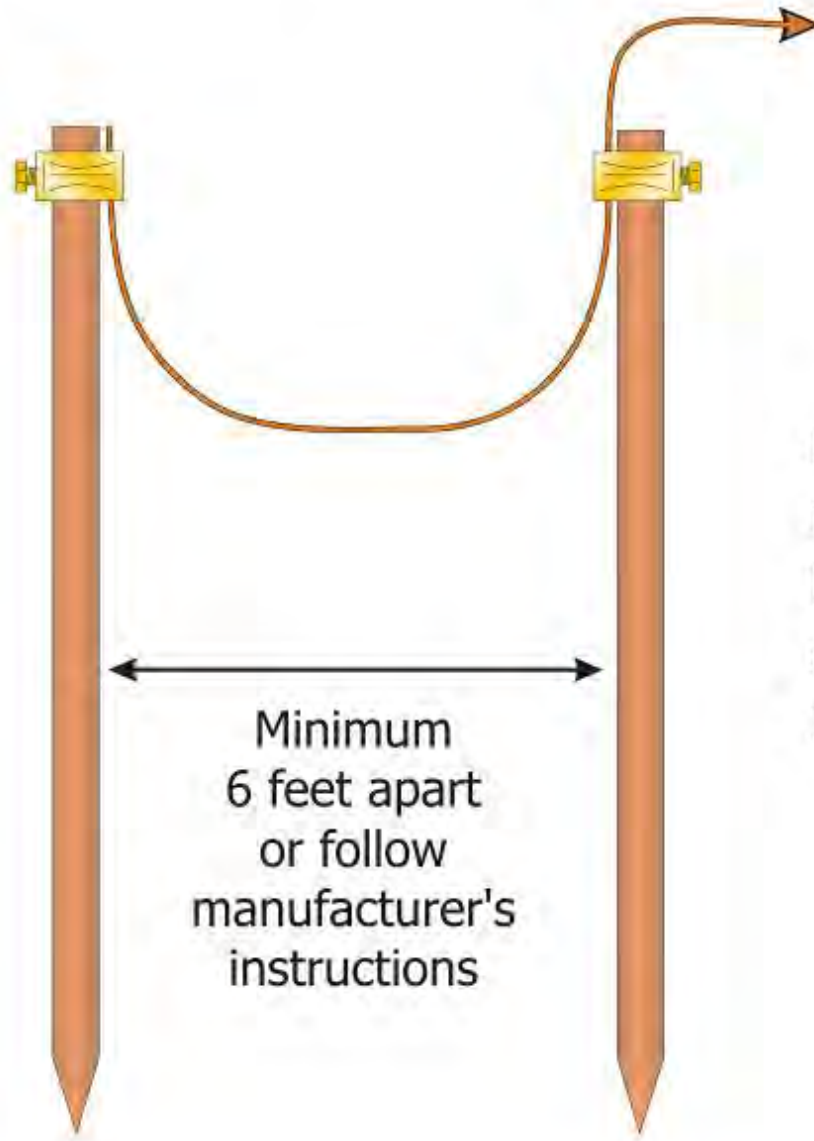


Other metal structures



Rod pipes
or plates

Resistance of Rod, Pipe, and Plate Electrodes

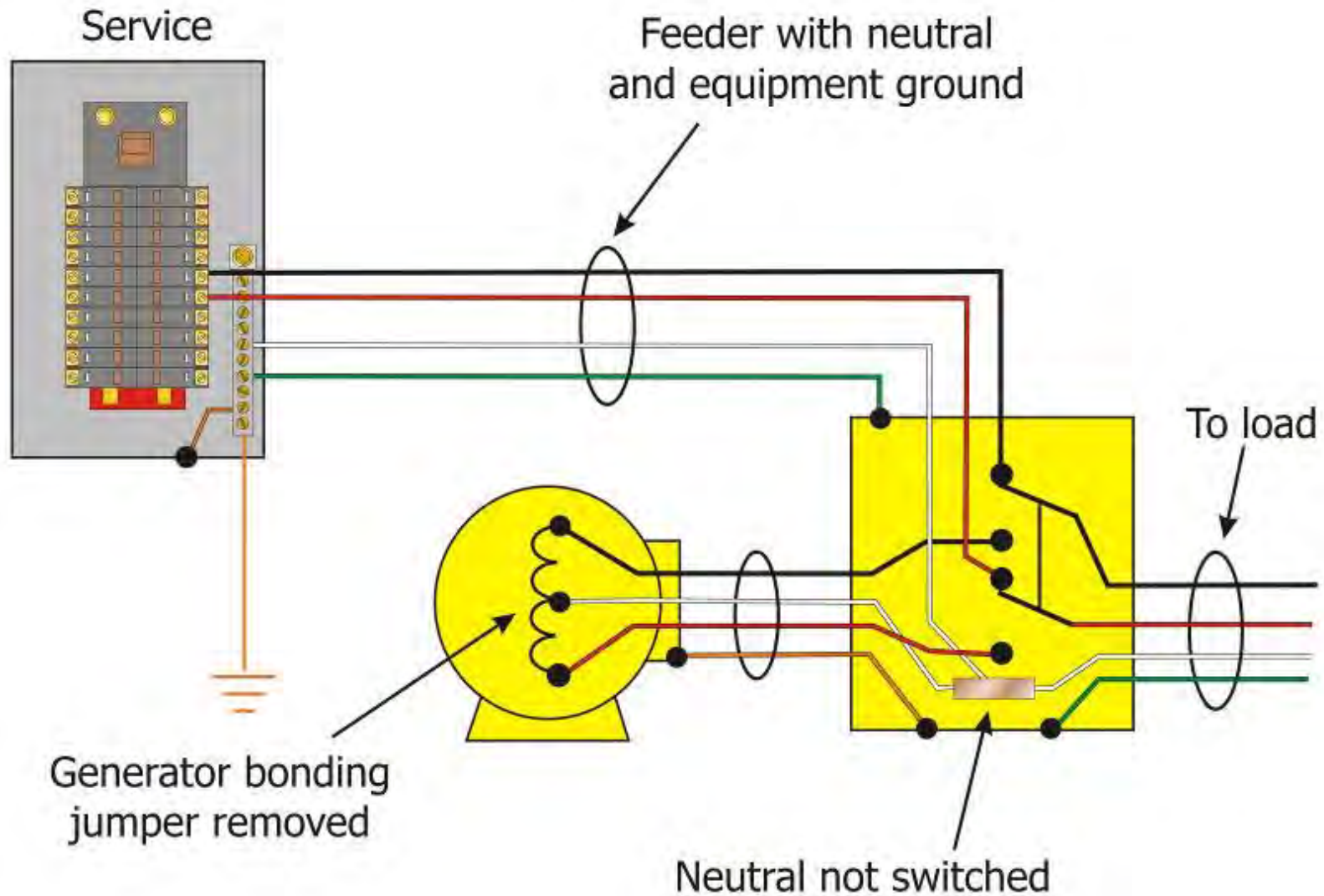


Rod, pipe, or plate electrode that exceeds 25 ohms must be augmented by an additional electrode of a type specified in 250.52(A)(4) through (A)(8)

COMM 16 2-rods



Generator - Not Separately Derived System

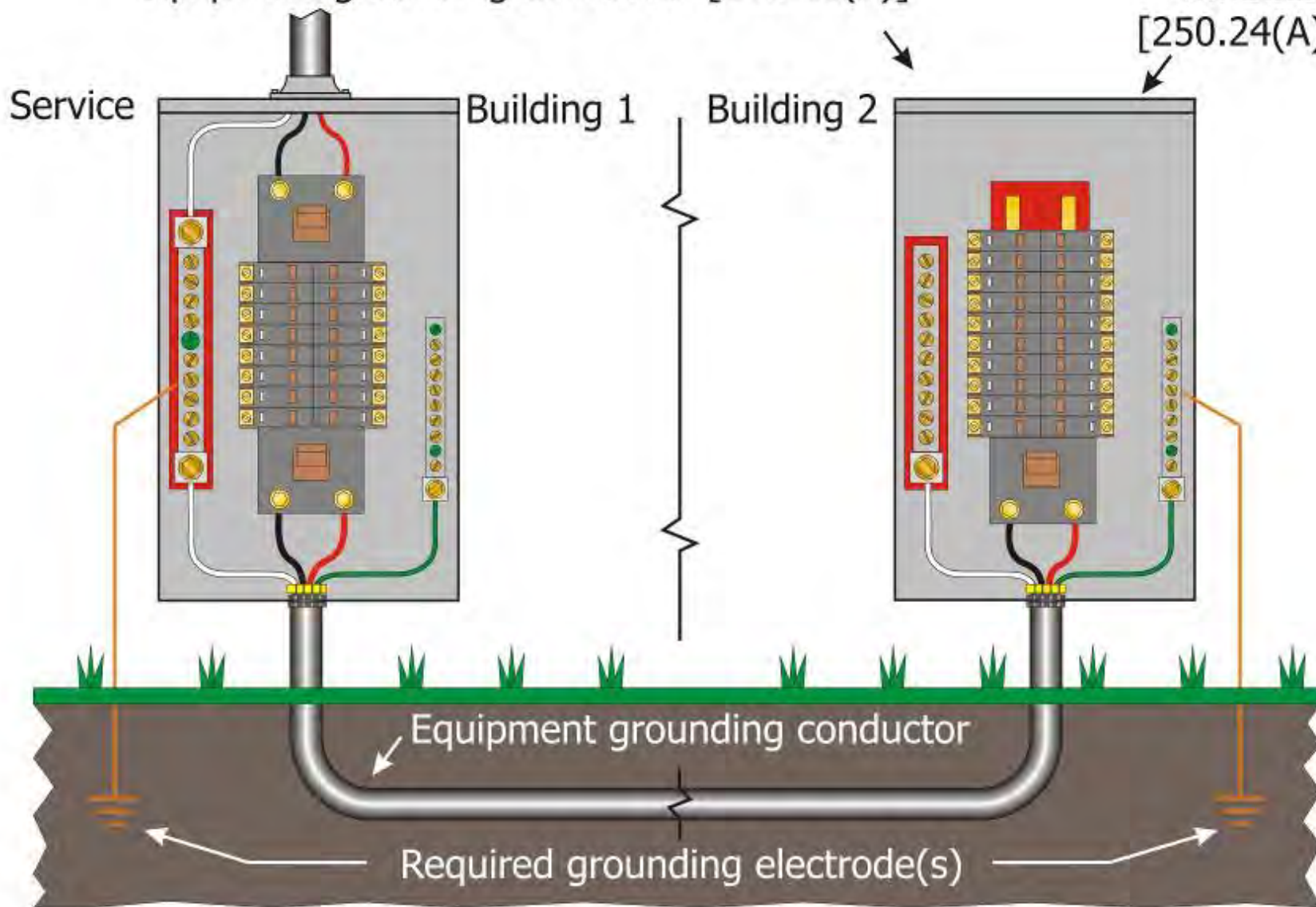




Grounding Method 1 [250.32(B)]

Grounding at separate building or structure using equipment grounding conductor [250.32(B)]

Isolate grounded conductor [250.24(A)(5)]

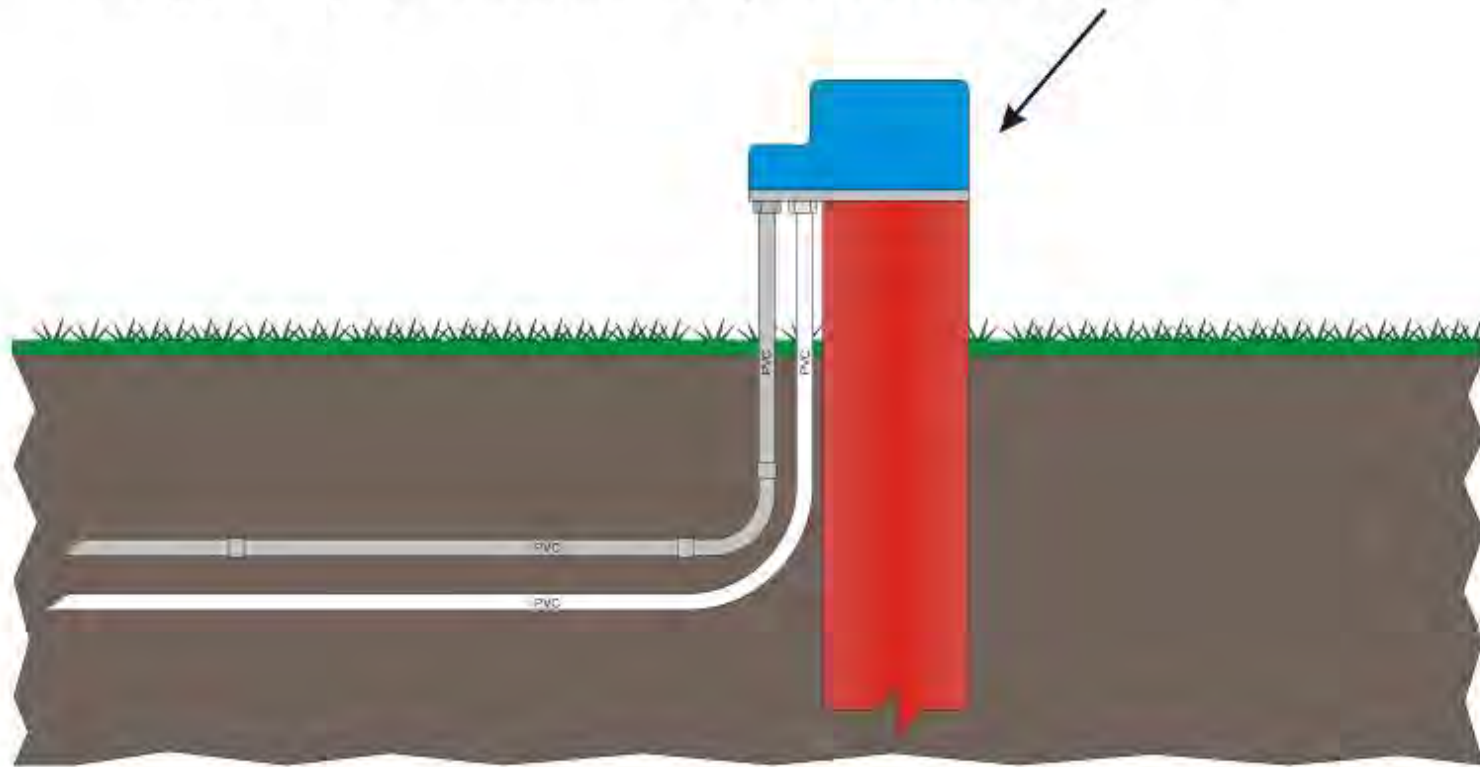




Grounding Metal Well Casings

Generally required to comply with the requirements of Article 250

A copper equipment grounding conductor is required

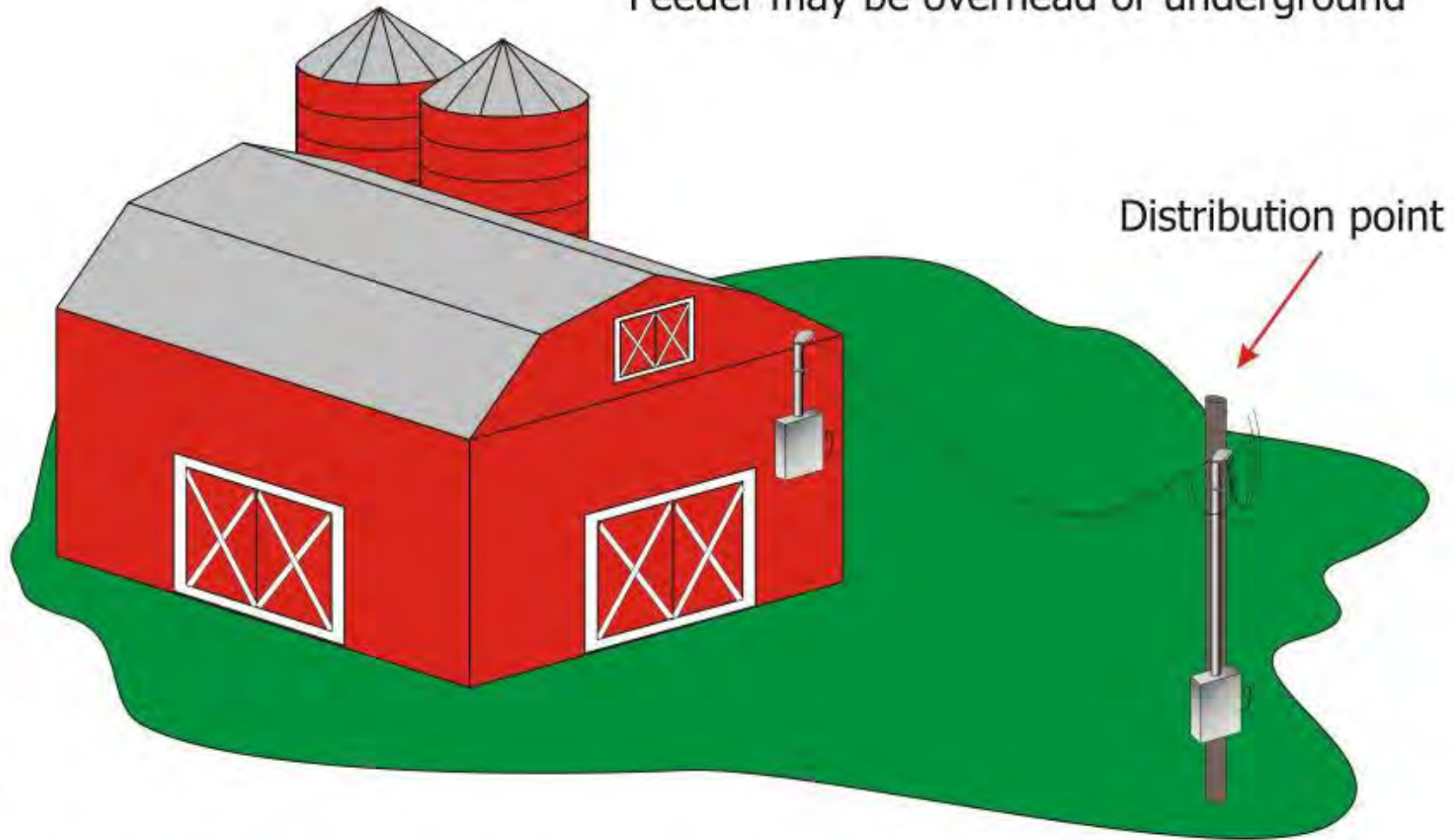


Metal well casing required to be bonded to the equipment grounding conductor supplying the pump circuit

Equipment Grounding Conductor Insulated



Feeder may be overhead or underground



Equipment grounding conductor required to be insulated or covered copper if installed underground

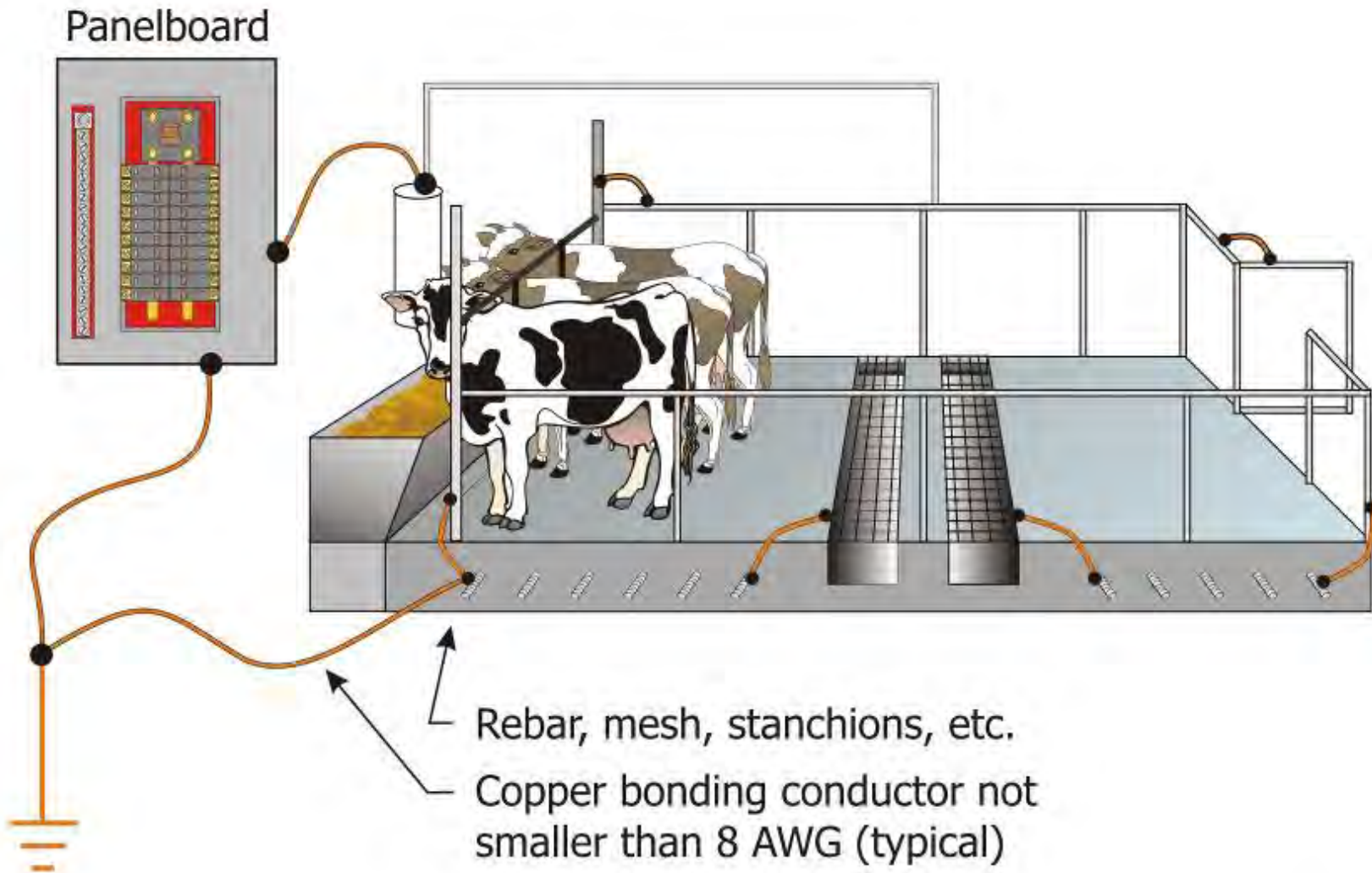
547.10 Equipotential Planes and Bonding of Equipotential Planes

- An equipotential plane must be installed at indoor and outdoor concrete confinement areas where metallic equipment is located that may become energized and is accessible to livestock.

Bonding & Grounding at Agricultural Buildings

- Specific requirements regarding grounding and bonding
- Two major concerns:
 - Integrity of grounding path due to corrosive conditions that exist in these locations
 - Neutral to earth stray voltages, if excessive, can cause behavior responses and can lead to loss of production and health problems in livestock
- Equipment grounding conductor run underground to these locations must be insulated or covered copper
- See Article 547 for specific *Code* sections.

Equipotential Bonding Planes

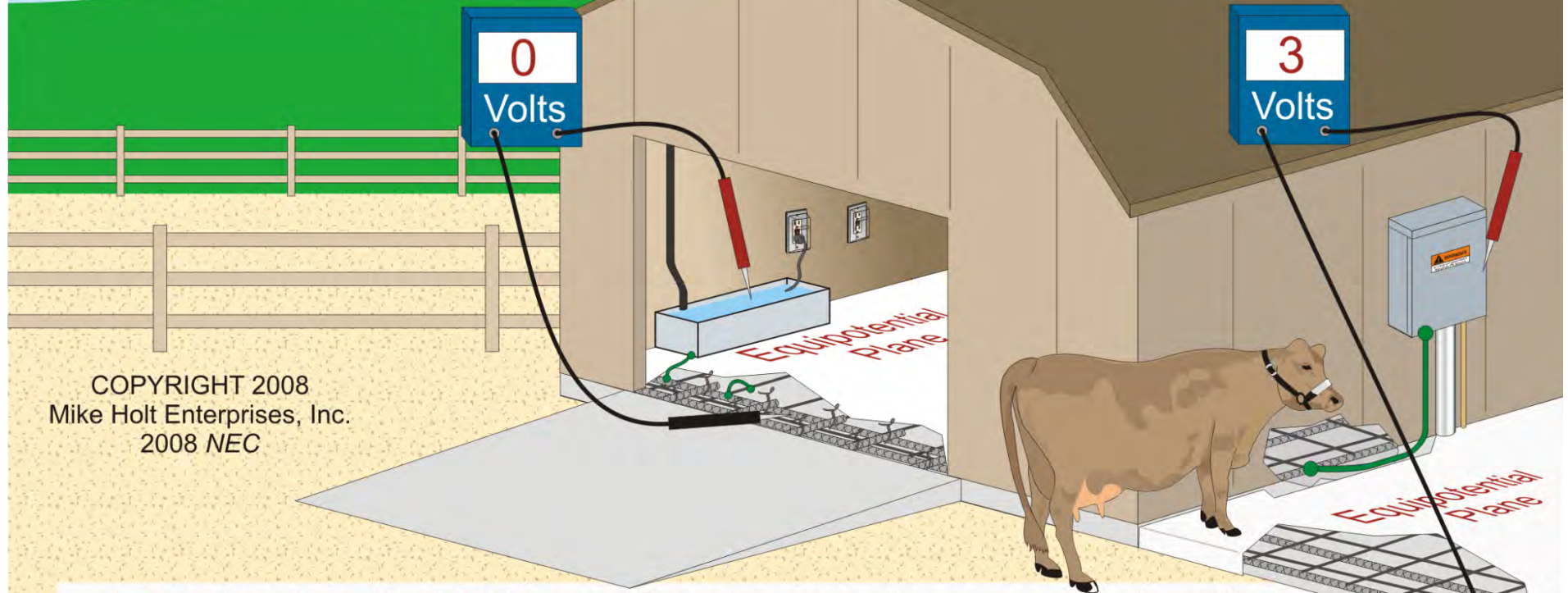


Equipotential Bonding in Animal Confinement Areas



Equipotential bonding plane is required in animal confinement areas with concrete floors or slabs in indoor and outdoor locations

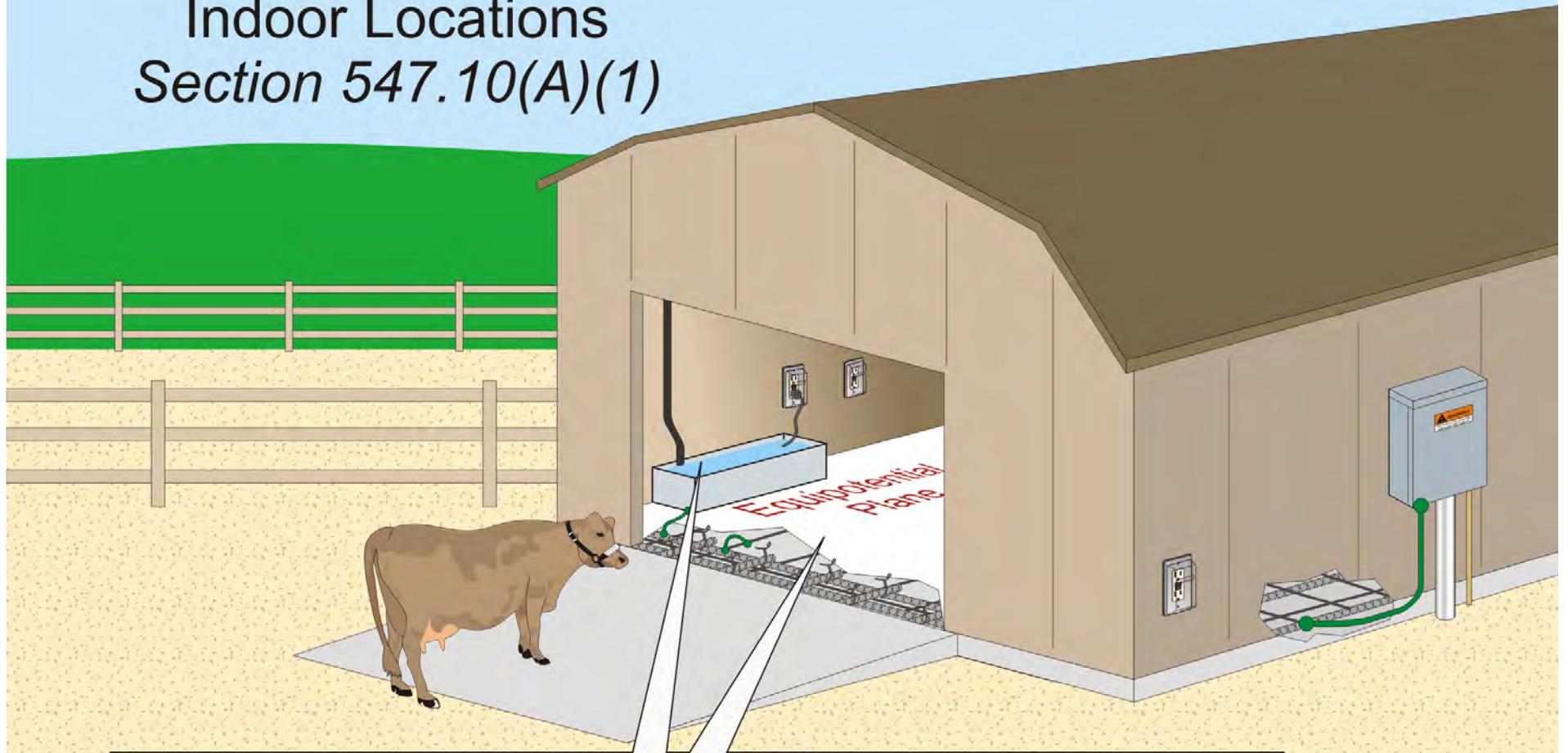
Agricultural Buildings Equipotential Plane *Section 547.2 Definition*



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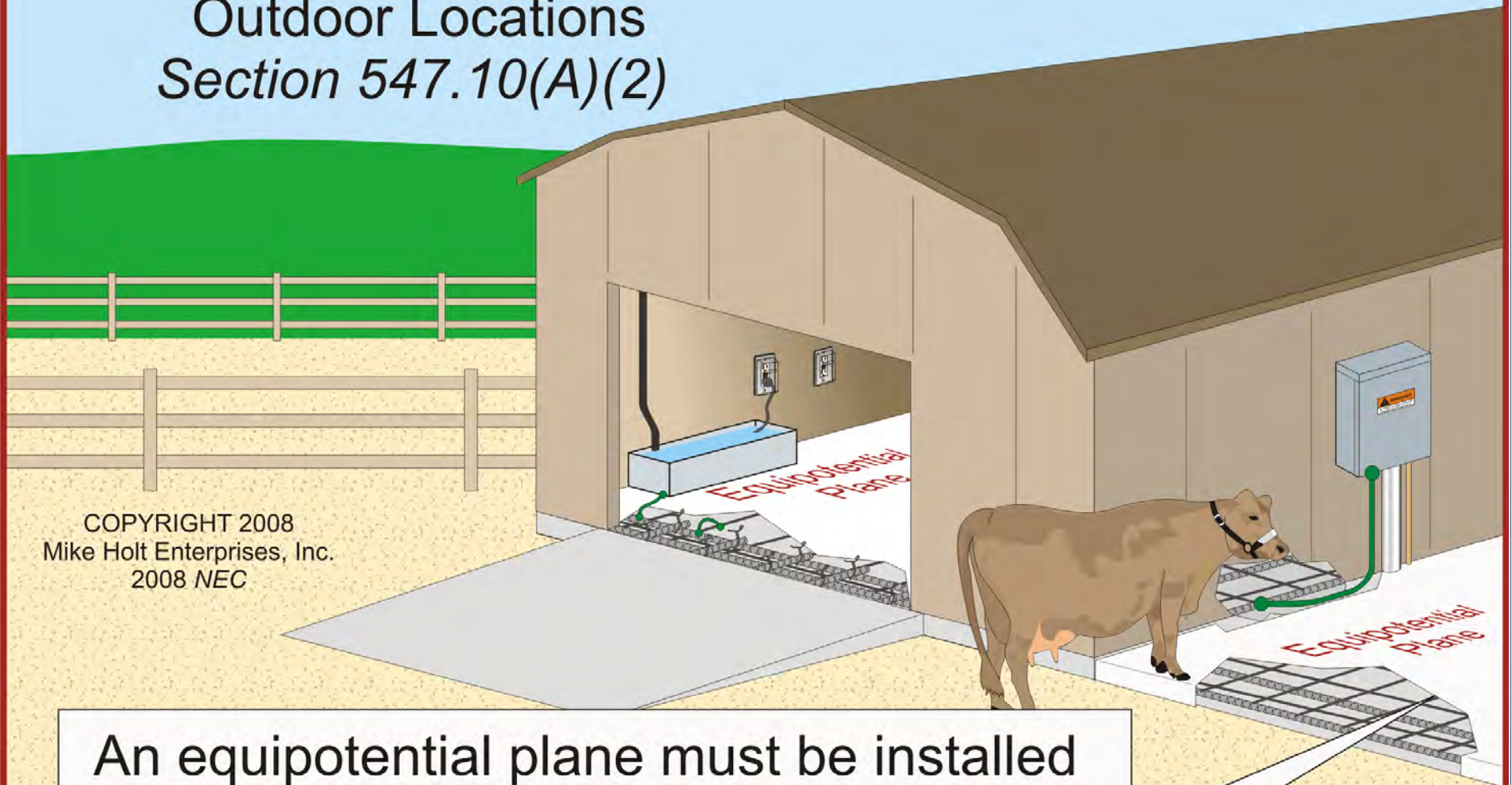
Equipotential Plane: An area where conductive elements in or under concrete are bonded to metal structures, fixed nonelectrical equipment, and the electrical grounding system to prevent a voltage difference from developing within the plane.

Equipotential Planes Indoor Locations *Section 547.10(A)(1)*



An equipotential plane must be installed in concrete floor confinement areas containing metallic equipment accessible to livestock.

Equipotential Planes Outdoor Locations Section 547.10(A)(2)



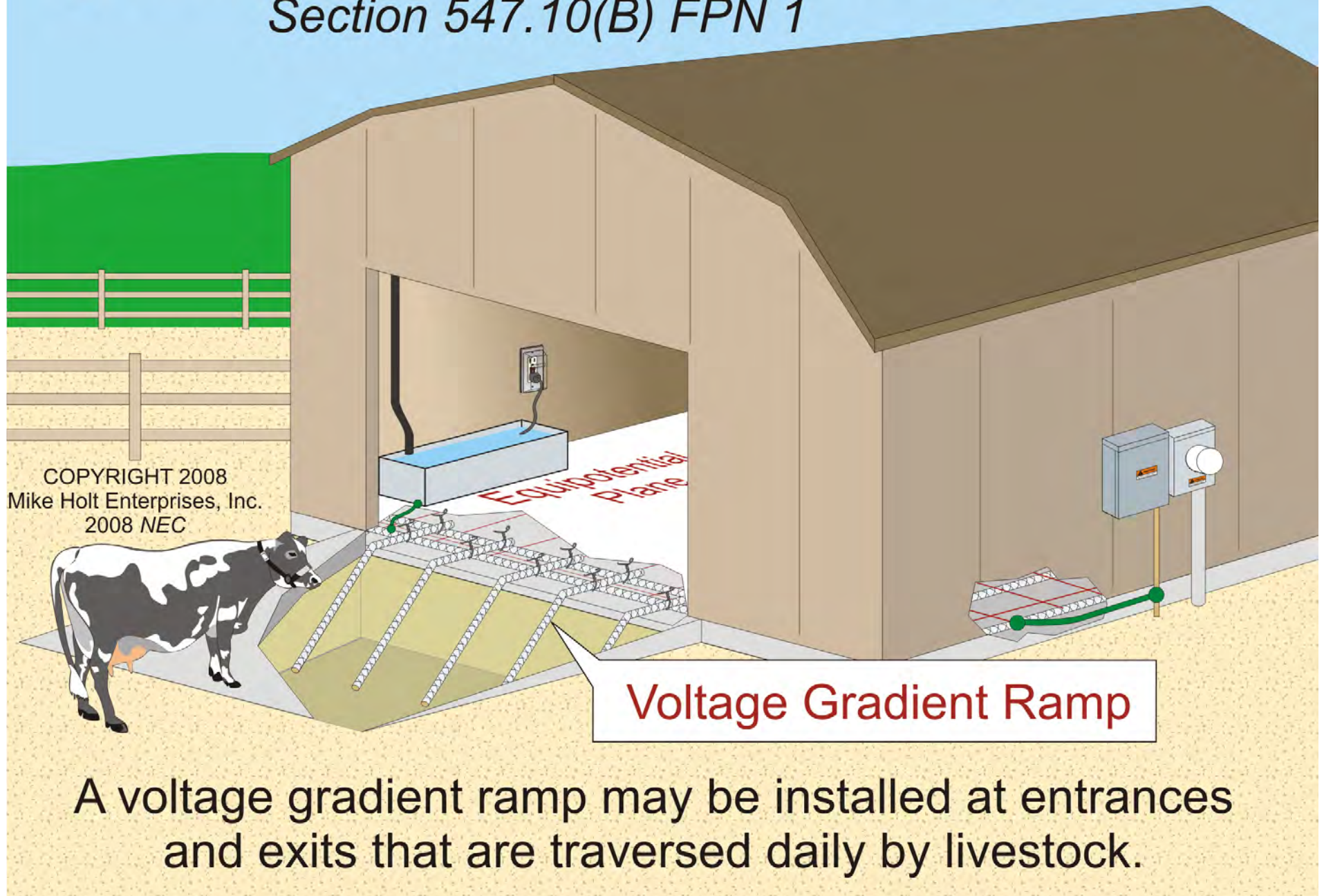
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An equipotential plane must be installed in outdoor concrete confinement areas containing metallic equipment accessible to livestock.

547.10 Equipotential Planes and Bonding of Equipotential Planes

- The equipotential plane must be connected to the building or structure's electrical grounding system with a copper conductor not smaller than 8 AWG.

Agricultural Building – Voltage Gradient Ramp *Section 547.10(B) FPN 1*



Agricultural Building – Voltage Gradient Ramp *Section 547.10(B) FPN 1*

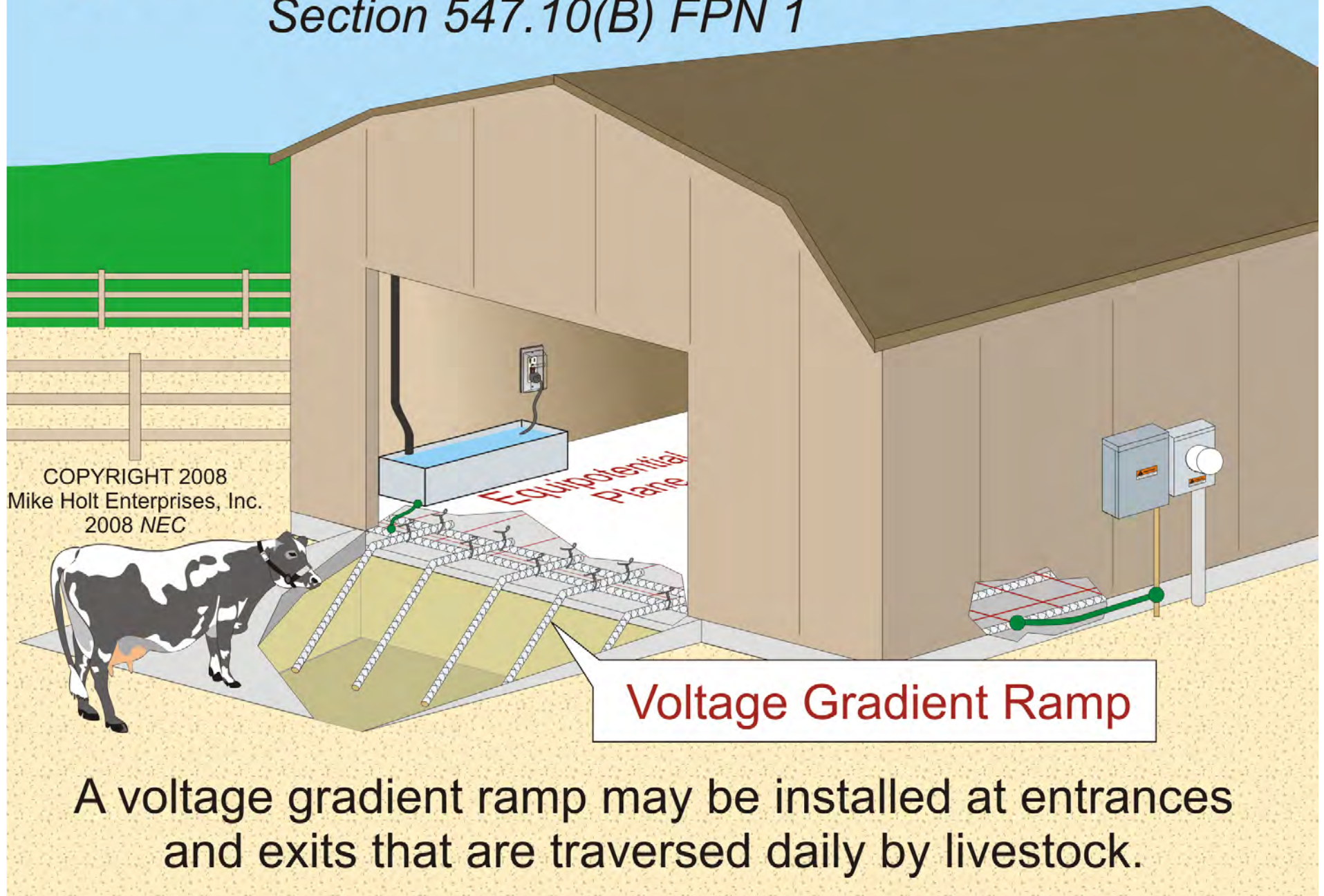


Table 250.122 Minimum Size Equipment Grounding Conductors for Grounding Raceway and Equipment

Rating or Setting of Automatic Overcurrent Device in Circuit Ahead of Equipment, Conduit, etc., Not Exceeding (Amperes)	Size (AWG or kcmil)	
	Copper	Aluminum or Copper-Clad Aluminum*
15	14	12
20	12	10
30	10	8
40	10	8
60	10	8
100	8	6
200	6	4
300	4	2
400	3	1
500	2	1/0
600	1	2/0
800	1/0	3/0
1000	2/0	4/0
1200	3/0	250
1600	4/0	350
2000	250	400
2500	350	600
3000	400	600
4000	500	800
5000	700	1200
6000	800	1200

*For aluminum or copper-clad aluminum conductors, the minimum size shall be 1/0 AWG for 250 kV (1/0) and 2/0 AWG for 350 kV (2/0).

Table 250.66 Grounding Electrode Conductor for Alternating-Current Systems

Size of Largest Ungrounded Service-Entrance Conductor or Equivalent Area for Parallel Conductors ^a (AWG/kcmil)		Size of Grounding Electrode Conductor (AWG/kcmil)	
Copper	Aluminum or Copper-Clad Aluminum	Copper	Aluminum or Copper-Clad Aluminum ^b
2 or smaller	1/0 or smaller	8	6
1 or 1/0	2/0 or 3/0	6	4
2/0 or 3/0	4/0 or 250	4	2
Over 3/0 through 350	Over 250 through 500	2	1/0
Over 350 through 600	Over 500 through 900	1/0	3/0
Over 600 through 1100	Over 900 through 1750	2/0	4/0
Over 1100	Over 1750	3/0	250