

MEA 2017 NEC Grounding and Bonding Part 3

2-hour class presented by
Minnesota Electrical Association

This seminar will satisfy the 2-hour electrical code training for electricians required by the State of Minnesota.



Minnesota Electrical Association


1

Acknowledgements

Some material and illustrations presented are with permission of Cengage Learning from:
Electrical Grounding and Bonding 2014
by Phil Simmons


The National Electrical Code (NEC)[®] is:
Document 70 from the National Fire Protection Association (NFPA)






Objectives:

- The requirements for the grounding electrode system
- Grounding electrodes **required** and those **not permitted** to be used
- Installation requirements for the grounding electrode system
- Requirements for **supplementary grounding electrodes**
- Installation of **auxiliary grounding electrodes**




3



Objectives:

- Resistance requirements for rod, pipe and plate electrodes
- Requirements for the use of a common grounding electrode
- Installation requirements for grounding electrode conductors
- Minimum size of grounding electrode conductors
- Methods for connecting grounding and bonding conductors to grounding electrodes
- Using building structural metal members and water pipes as grounding electrode conductors



4

250.50 Grounding Electrode System

- All grounding electrodes described in **250.52(A)(1) through (A)(7)** that are present at each building or structure served are required to be bonded together to form the grounding electrode system.
- If **none of these grounding electrodes exist**, one or more of the grounding electrodes in **250.52(A)(4) through (8)** must be installed and used.



5

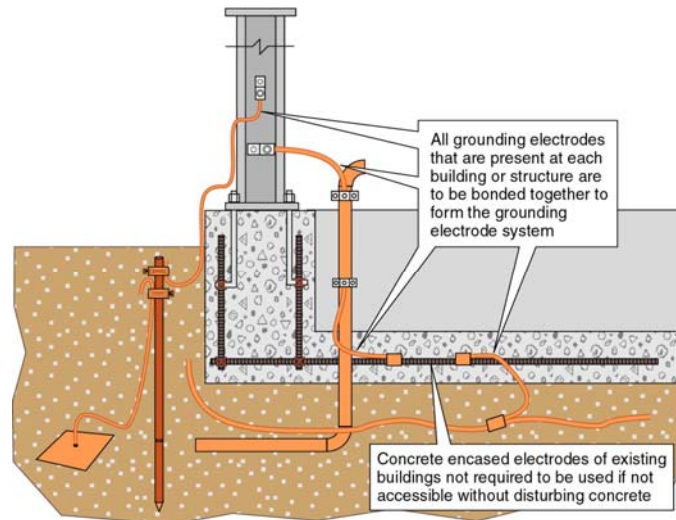
250.50 Grounding Electrode System

Exception: Concrete-encased electrodes of existing buildings or structures are not required to be part of the grounding electrode system **if the steel reinforcing bars or rods are not accessible for use without disturbing the concrete.** *Do not expose re-bar to soil conditions*



6

250.50 Grounding Electrode System



Copyright © Cengage Learning

7

250.52(A) Electrodes Permitted For Grounding

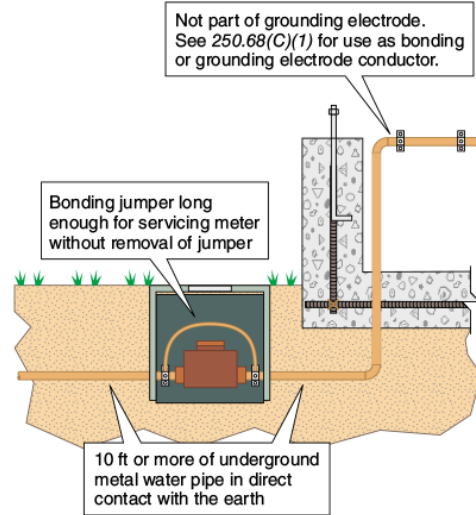
- Use of the grounding electrodes in this section becomes mandatory due to the requirement in 250.50
- Some electrodes are traditionally installed by other trades
- Electrodes in (A)(4) through (A)(8) are often installed by electricians
- Some installation requirements are contained in the description of the grounding electrodes



8

250.52(A)(I) Metal Underground Water Pipe

Required to be used if 10 ft. or more is in direct contact with the earth



Copyright © Cengage Learning

9

Ground clamp to water pipe



10

New 250.52(A)(2) Metal in ground support structures

- One or more metal in-ground support structures in direct contact with the earth for 10 ft. or more vertically, with or without concrete encasement.
- If more than one support structure is present, then permitted to bond to only one in the grounding electrode system

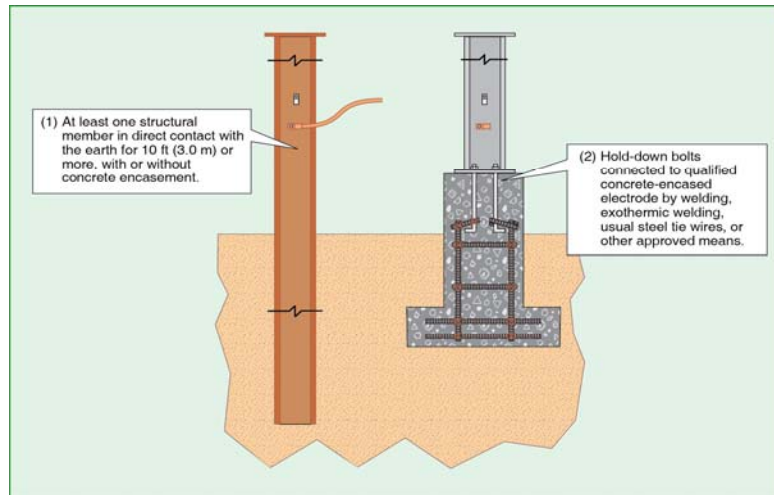


250.52(A)(2) Frame of the Building or Structure

- Methods of making an earth connection of the metal frame of the building or structure are described
- **Requires direct contact with the earth, concrete encasement or by connection to concrete encased grounding electrode**
- Once a recognized grounding electrode, it can be used to bond other electrodes



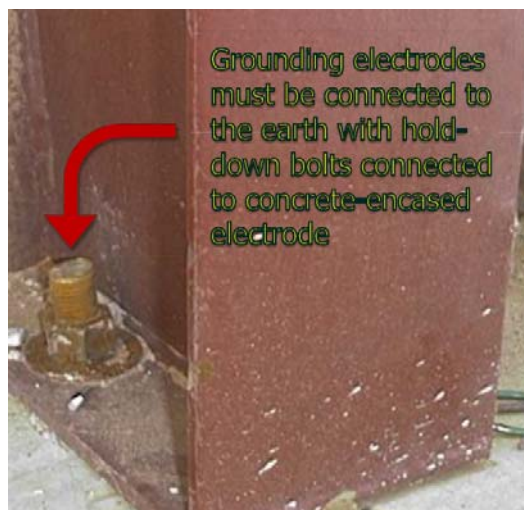
250.52(A)(2) Metal Frame of the Building or Structure



Copyright © Cengage Learning

13

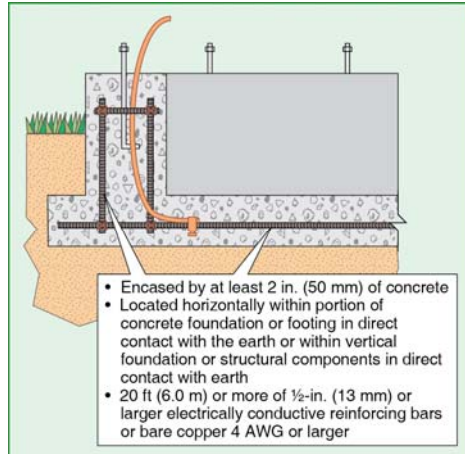
Hold down bolts for bldg. steel



14

250.52(A)(3) Concrete Encased Electrode

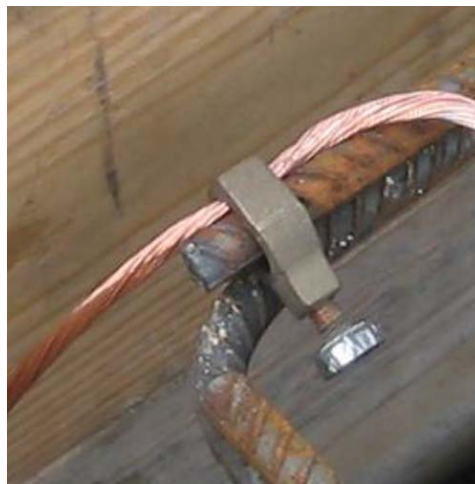
- Required to be used where present at the building or structure served
- Use of these electrodes pioneered in the early 1940s for the US Army in arid climates (Ufer)



Copyright © Cengage Learning

15

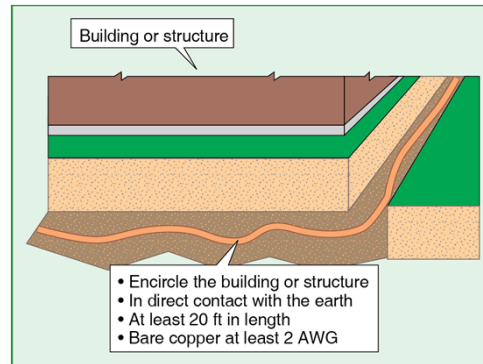
Re-bar clamp



16

250.52(A)(4) Ground Ring

- To encircle the building or structure
- Be in direct contact with the earth
- Consist of at least 20 ft of bare copper conductor not smaller than #2 AWG
- Burial depth is not less than 2½ ft [250.53(F)]

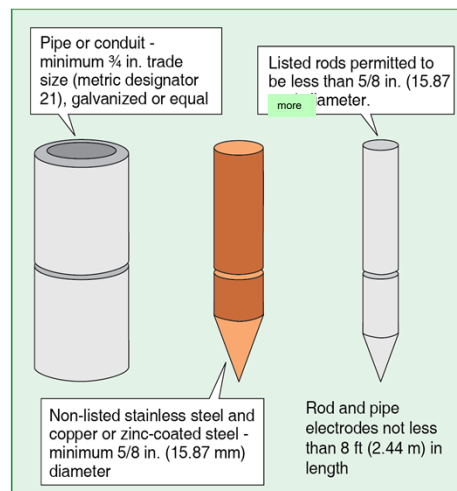


Copyright © Cengage Learning

17

250.52(A)(5) Rod and Pipe Electrodes

- Ideally, installed below permanent moisture level
- At least 8 ft in length
- Specifications may require thicker or longer electrodes and installation in specific configurations



Copyright © Cengage Learning

18

Other Listed Electrodes


Other listed grounding electrodes are permitted

Copyright © Cengage Learning

Other Listed electrodes By Superior Grounding Systems

CHEMICAL GROUNDING SYSTEM

Electrolytic Ground Electrode

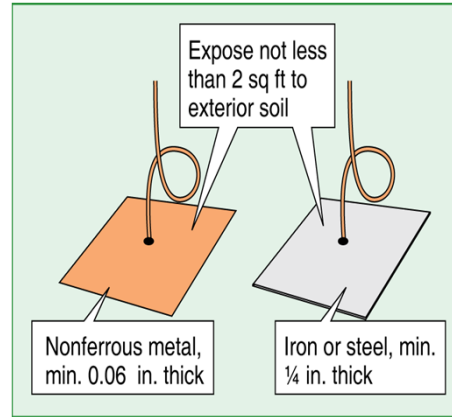


The SUPERIOR GROUNDING SYSTEM™ is chemically charged with metallic minerals. Condensation allows the mineral inside the tube to extract moisture from the air through the air holes at the top of the rod. Moisture accumulates and trickles down along the sides of the tube (passing through the minerals) to the bottom of the rod. As the moisture mixes with the minerals, an electrolytic solution is formed. Within a short period of time, the solution builds up past the drain holes and leaches out into the surrounding earth. This process creates electrolytic roots which conditions the soil and provides a reduction in resistance between the electrode and the earth.

20

250.52(A)(7) Plate Electrodes

- Each plate electrode required to expose not less than 2 sq ft to exterior soil
- Some interpret rule as permitting a 12 in. square plate (verify 2 sided ??)
- Installation rules are at 250.53(A), (B), (E), (H)



Copyright © Cengage Learning

21

Buried ground plate electrode



250.52(A)(8) Other Grounding Electrodes

Included in “if none of the electrodes in 1-4, then one of the 4-8 electrodes must be installed” - are local metal underground systems or structures such as:

- Piping systems
- Underground tanks
- Underground metal well casings that are not effectively bonded to a metal water pipe



23

250.52(B) Electrodes **Not Permitted** for Grounding

1. Metal underground gas piping systems
 - [Interior piping systems **are** required to be bonded by 250.104(B)]
2. Aluminum structures
3. **(NEW)** The structural reinforcing steel under a pool



24

250.53 Grounding Electrode System Installation

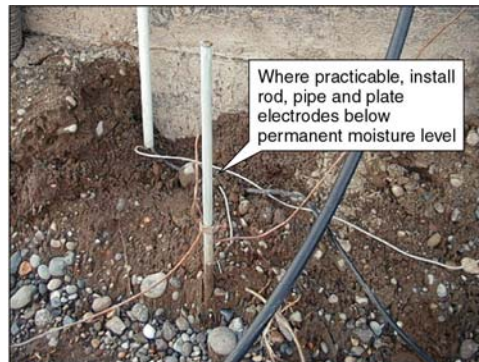
- Rod, pipe and plate grounding electrodes are required to meet the requirements of (A)(1) through (A)(3) **Following**
- See 547.9 and 547.10 for special grounding and bonding requirements for agricultural buildings



25

250.53(A)(1) Rod, Pipe, and Plate Electrodes

- Where practicable, these electrodes are to be embedded below permanent moisture level
- Must be free from nonconductive coatings



Copyright © Cengage Learning

26

Exposed or Buried



250.53(A)(2) Supplemental Electrode Required

Where only a **Single rod, pipe, or plate electrode** is used it shall be supplemented by an additional electrode of a type specified in 250.52(A)(2) through (A)(8).

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

1. Rod, pipe, or plate electrode
2. Grounding electrode conductor
3. Grounded service-entrance conductor
4. Nonflexible grounded service raceway
5. Any grounded service enclosure

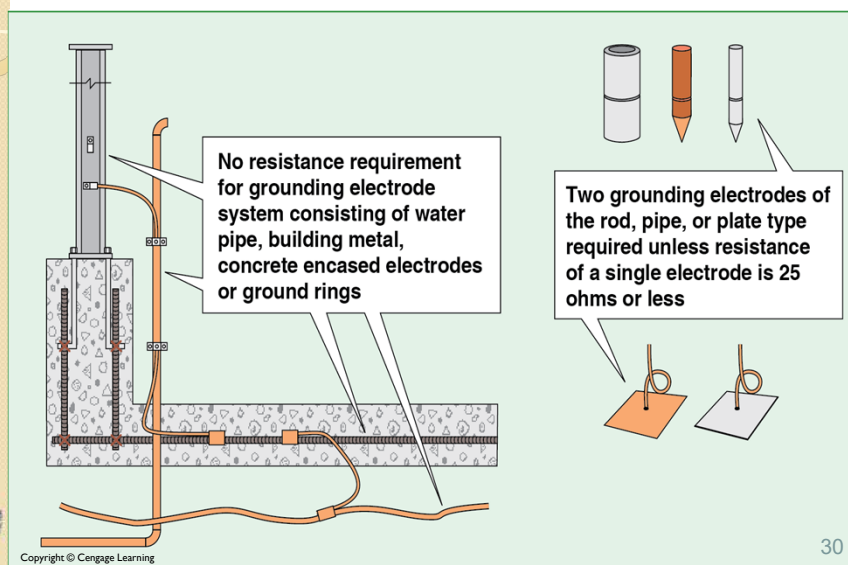


Exception to 250.53(A)(2)

If resistance of **single rod, pipe or plate** is **25 ohms or less**, a supplemental grounding electrode is not required



250.53(A)(2) Resistance of Rod, Pipe and Plate Electrodes



Earth Resistance Tester

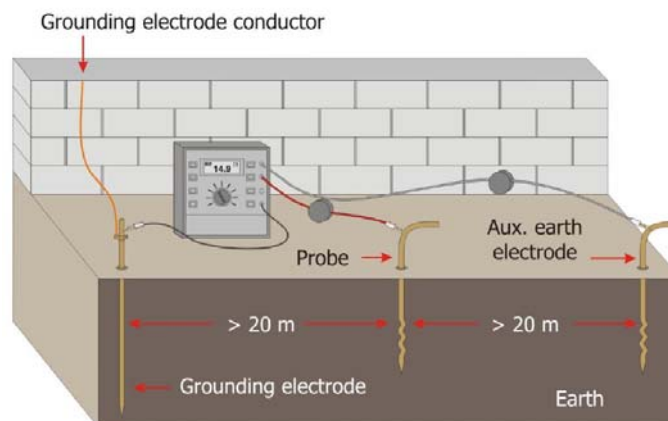
- Test with proper equipment not common volt-meter, ohmmeter or ammeter
- Follow manufacturer's instructions



Copyright © Cengage Learning

31

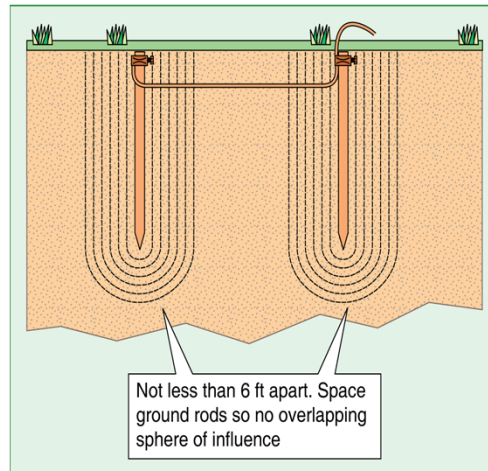
Three point test for fall of potential



32

250.53(A)(3) Multiple Rods, Pipes or Plates

- If supplemental rod, pipe or plate electrodes are required, then space not less than 6 ft apart
- Avoid overlapping “sphere of influence”
- Installation of additional electrodes not required to obtain 25 ohms resistance



33



IN – Note, Spacing of Rods

- The paralleling efficiency of ground rods is increased by spacing them twice the length of the longest rod.
- This spacing may be required in manufacturer’s installation requirements and is so stated, must be followed to comply with 110.3(B).

34



Table 3-2 Current Through Rods

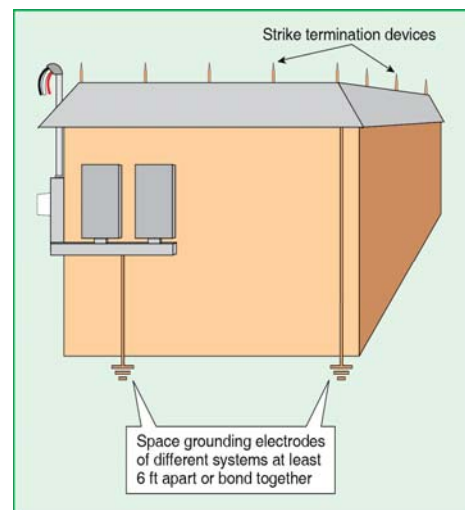
System Voltage	Rod Resistance	Amperes
120	25	4.8
240	25	9.6
277	25	11.08
480	25	19.2
2400	25	96
4160	25	166.4
7200	25	288
12,470	25	508.8
100,000	25	4,000

35



250.53(B) Electrode Spacing

If more than one of the rod, pipe, or plate, electrodes are used, (A5–A7), space electrodes of one grounding system not less than 6 ft. from the other system (strike terminations)



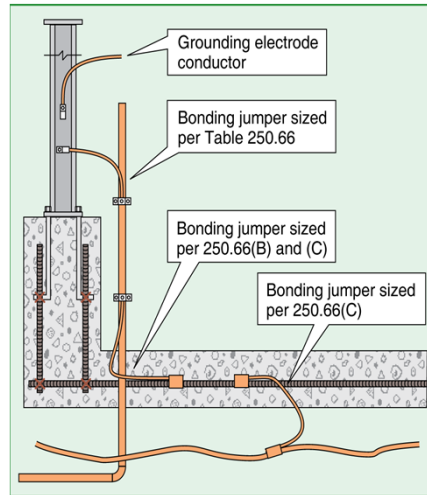
36



Copyright © Cengage Learning

250.53(C) Bonding Jumper

- Bonding jumper is used to connect grounding electrodes together
- Install per 250.64(A), (B) and (E)
- Size per 250.66
- Connect per 250.70



37



Table 3-1 (Based on 2-500 kcmil SEC)

Grounding Electrode	Minimum Size Bonding Jumper	NEC Section or Table
Water pipe to building steel	2/0 AWG Copper	Table 250.66
Building steel to concrete encased	2 AWG copper*	250.66(B) and (C)
Concrete encased to ground ring	2 AWG copper**	250.66(C)
Ground ring to rod or plate	6 AWG copper	250.66(A)

* Would be 4 AWG if concrete-encased electrode were connected after the ground ring

** Same size as for ground ring, up to 3/0 per 250.66(C)



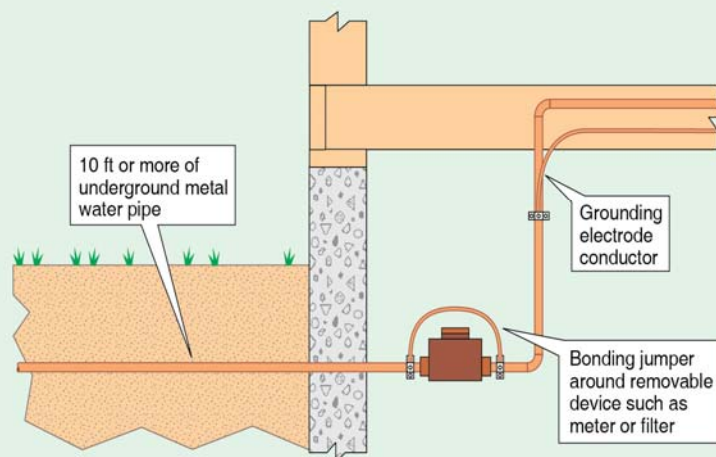
250.53(D)(I) Continuity

- Continuity of the grounding path or the bonding connection to interior piping **shall not rely on water meters or filtering devices** and similar equipment. **Use jumper**
- Bond around any such equipment to assure continuity.



39

Metal Underground Water Pipe Grounding Electrode



Copyright © Cengage Learning

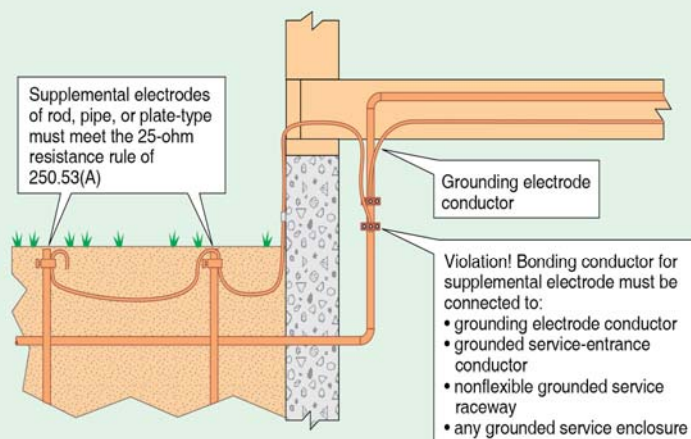
250.53(D)(2) Supplemental Electrode Required

- **Metal underground water pipe is required to be supplemented by another electrode** specified in 250.52(A)(2) through (A)(8).
- If a rod, pipe or plate is used, must comply with the 25-ohm rule of 250.53(A)(2)
- Bond to grounding electrode conductor, grounded service conductor, nonflexible service raceway or grounded service enclosure



41

Supplemental Grounding Electrode for Water Pipe Electrode



Copyright © Cengage Learning

250.53(D)(2) Exception

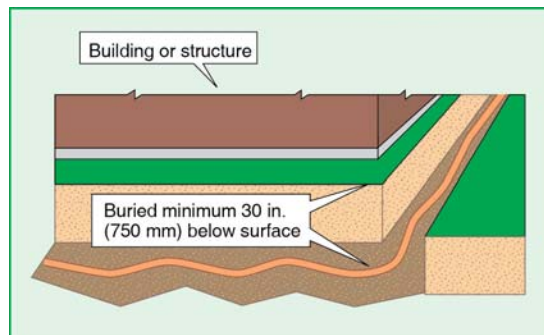
- The supplemental grounding electrode is permitted to be connected at any convenient point as covered in 250.68(C)(1) Exception
- Industrial occupancy- interior metal water pipe can be used throughout if visible and no intervening non conductive sections



43

250.53(F) Ground Ring

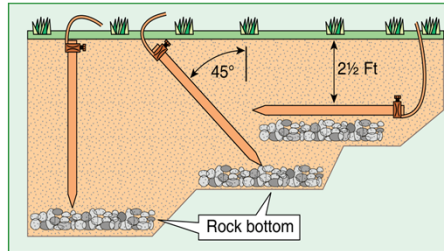
Must be buried not less than 30" below the earth's surface



44

250.53(G) Rod and Pipe Electrodes

- At least 8 ft in contact with the soil
- If rock bottom is encountered, install at maximum 45° angle
- If rock bottom is then encountered, burial in trench 2½ ft deep is permitted

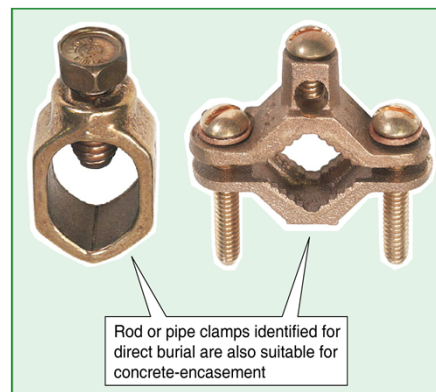


45



Rod and Pipe Clamps

- Listed clamps required
- Must be suitable for the conductor and the rod or pipe
- Listed for direct soil burial or concrete encasement
- Marked "DB", also suitable for concrete encasement

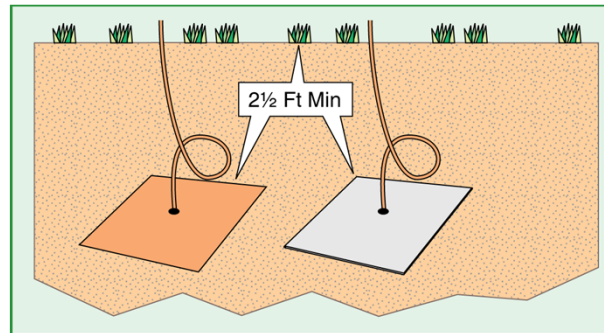


46



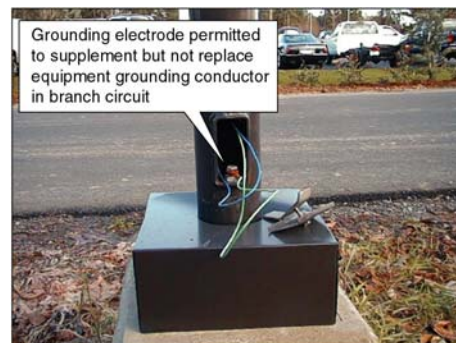
250.53(H) Plate Electrode

To be installed not less than 30 in. below the surface of the earth



250.54 Auxiliary Grounding Electrodes

- Permitted to connect to equipment grounding conductor
- Not required to comply with 250.50, 250.53(C) or the resistance requirements of 250.53(A)(2)
Exception



- Not permitted as effective ground-fault current return path



Effect of Soil Moisture on Ground Rods

The resistivity of the soil varies significantly based on the moisture content

TABLE 3-3

Effect of Moisture Content on Earth Resistivity¹

Moisture Content % By Weight	Resistivity, ohm-cm	
	Top Soil	Sandy Loam
0	1000×10^4	1000×10^6
2.5	250,000	150,000
5	165,000	43,000
10	53,000	18,500
15	17,000	10,500
20	12,000	6,300
30	6,400	4,200

¹Military Handbook, *Grounding, Bonding, and Shielding for Electronic Equipments and Facilities*, Volume II of two volumes, Applications.



Effect of Soil Moisture on Ground Rods

The resistivity of the soil varies significantly based on the temperature

TABLE 3-4

Effect of Temperature on Earth Resistivity²

Temperature		Resistivity ohm-cm
°F	°C	
68	20	7,200
50	10	9,900
32 (water)	0	13,800
32 (ice)	0	30,000
23	-5	79,000
5	-15	330,000

For sandy loam, 15.2% moisture.

²Military Handbook, *Grounding, Bonding, and Shielding for Electronic Equipments and Facilities*, Volume II of two volumes, Applications.



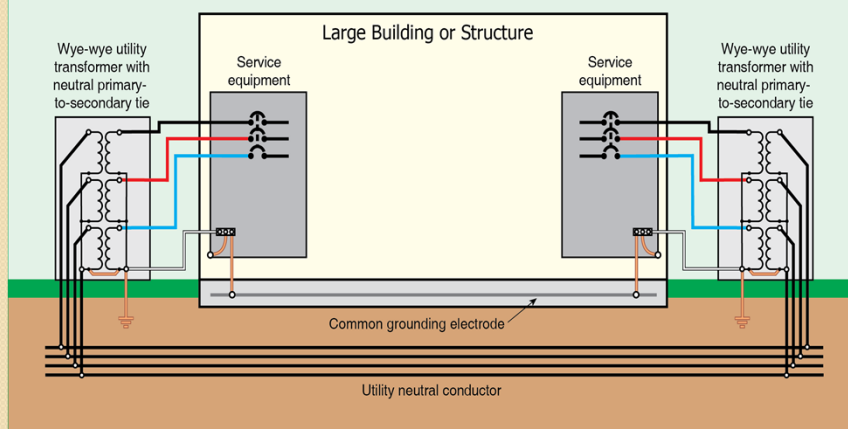
250.58 Common Grounding Electrode

- The same grounding electrode (system) is required to be used to ground the electrical system as well as any equipment
- Where separate services, feeders or branch circuits supply a building or structure, the same grounding electrode must be used
- Two or more grounding electrodes that are bonded together are considered a single grounding electrode



51

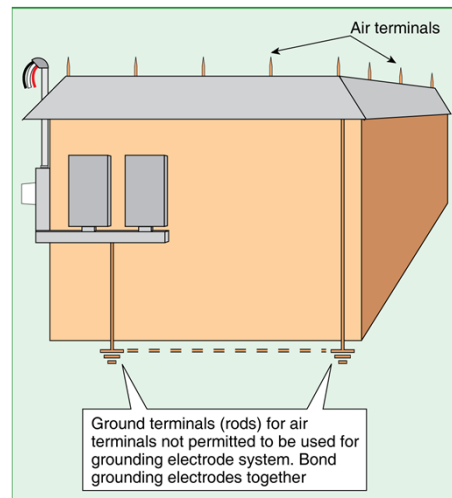
Common Grounding Electrode



Copyright © Cengage Learning

250.60 Use of Strike (Lightning) Termination Devices

- Earth electrodes for strike termination devices **not permitted to be used in lieu of grounding electrode system for electrical supply**
- Rule does not prohibit bonding grounding electrodes together. See 250.106.
- Shall be bonded together



Copyright © Cengage Learning

53

250.62 Grounding Electrode Material

- Grounding electrode material shall be of copper, aluminum or copper clad aluminum.
- Conductors may be solid or stranded, and can be insulated covered or bare.



250.64(A) Aluminum or Copper-Clad Aluminum Conductors

- Bare Al. conductors not permitted in contact with masonry or the earth or where subject to corrosive conditions
- Where used outside, **not permitted to be terminated within 18 in.** of the earth



55

250.64(B) Securing and Protection Against Physical Damage

- **If exposed**, grounding electrode conductor or enclosure **must be securely fastened**
- Permitted to **be installed on or through framing members**
- #6 AWG or larger that is free from exposure to physical damage is permitted to be run along surface of building if securely fastened.
- If exposed to physical damage, protect with raceway



56

250.64(B) Securing and Protection Against Physical Damage

3. Grounding electrode conductors smaller than 6 AWG **must** be protected by:

- Rigid metal conduit
- Intermediate metal conduit
- Rigid nonmetallic conduit
- Cable armor



57

250.64(B) Securing and Protection Against Physical Damage

- ### 4. In contact with the earth are not required to be buried as per 300.5 (**burial depths**) but shall be buried to protect from physical damage.



250.64(C)(1) Continuous

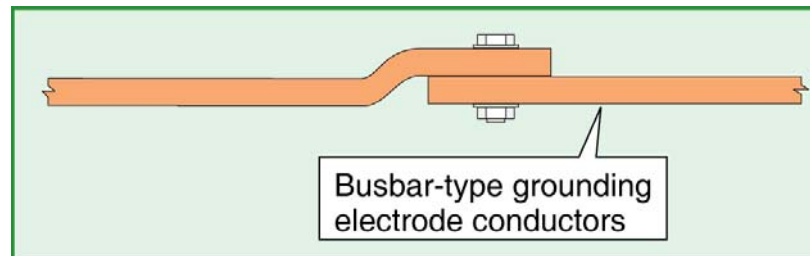
Grounding electrode conductors to be in **one continuous length** unless spliced by irreversible compression connectors listed as grounding and bonding equipment or the exothermic welding process



59

250.64(C)(2) Continuous

- Sections of busbars are permitted to be connected together to form a grounding electrode conductor



60

250.64(C)(3) Continuous

- 3. Bolted, riveted, or welded connections of structural metal frames of buildings are permitted



61

250.64(C) Continuous

- 4. Threaded, welded, brazed, soldered, or bolted-flange connections of water piping are permitted



62

250.64(D) Building or Structure with Multiple Disconnecting Means in Separate Enclosures

Permitted where the service consists of more than a single enclosure

Three methods permitted **as following**

- (D)(1) Grounding Electrode Conductor Taps
- (D)(2) Individual Grounding Electrode Conductors
- (D)(3) Connections at a Common Location



63

250.64(D)(1) Grounding Electrode Conductor taps

- A common grounding electrode conductor is run from the grounding electrode or grounding electrode system to the vicinity of the service equipment (no specific proximity specified in rule)
- Common grounding electrode conductor shall be sized in accordance with 250.66, based on the sum of the circular mil area of the largest ungrounded conductor(s) of each set of conductors that supplies the disconnecting means.
- If service-entrance conductors connect directly to overhead service conductors, service drop, underground service conductors, or service lateral, common grounding electrode conductor shall be sized based on Table 250.66, note 1.



64

Grounding Electrode Taps

Common grounding electrode conductor sized for circular mil area of largest set of service-entrance conductors

Tap conductor sized for service-entrance conductors that serve individual enclosure

Common grounding electrode per 250.66

65

Copyright © Cengage Learning

Sizing Grounding Electrode Conductors

Service Disconnect	Service-Entrance Conductor		Grounding Electrode Conductor
	Size	Area	
200 A	3/0 AWG	167,800 cm	4 AWG Tap
400 A	500 kcmil	500,000 cm	1/0 AWG Tap
Total Area		667,800 cm	2/0 AWG Common

66

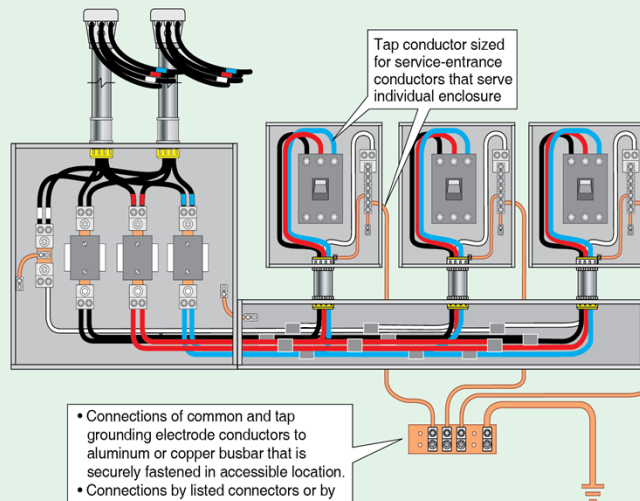
250.64(D)(1) Grounding Electrode Conductor taps

- Next figure shows overhead service with 3 service disconnecting means enclosures (6 permitted)
- Common grounding electrode conductor is run from grounding electrode to vicinity of service equipment (no specific proximity specified in rule)
- **Common grounding electrode** conductor is sized from Table 250.66 based upon the circular mil area of **ungrounded service-entrance conductors**
- **Tap grounding electrode conductors** are sized from Table 250.66 based upon size of **ungrounded service-entrance conductor to individual enclosures**

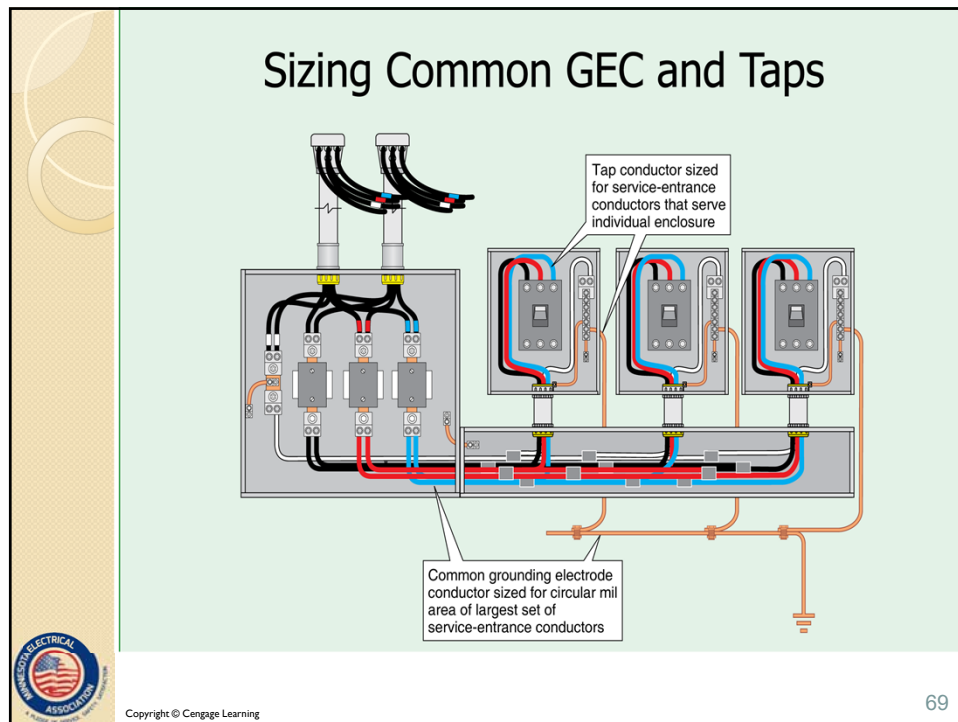


67

Grounding Electrode Taps



Copyright © Cengage Learning



250.64(F)(3) Installation to electrode

- **Copper or aluminum busbar** not smaller than $\frac{1}{4}$ thick \times 2 in. wide and of sufficient length to accommodate the number of terminations necessary for the installation is permitted for making connections of common grounding electrode conductor and grounding electrode conductor taps.
- If aluminum busbar is used, comply with 250.64(A)

250.64(D)(I) Grounding Electrode Conductor taps

- Next figure represents an overhead service with 6 service disconnecting means enclosures
- Common grounding electrode conductor is run from grounding electrode to vicinity of service equipment (no specific proximity specified in rule)
- Common grounding electrode conductor is sized from Table 250.66 based upon the circular mil area of ungrounded service-entrance conductors
- Tap grounding electrode conductors are sized from Table 250.66 based upon size of ungrounded service-entrance conductor to individual enclosures



71

Common conductor size		
Service Disconnect	Service-Entrance Conductor	Circular Mil Area
One	2 AWG	66,360
Two	3/0 AWG	167,800
Three	250 kcmil	250,000
Four	500 kcmil	500,000
Five	1/0 AWG	105,600
Six	2/0 AWG	133,100
3/0 Common GEC for Total SEC area		12.5% X 1,222,860

Tap size		
Service Disconnect	Service-Entrance Conductor	GEC Tap Size
One	2 AWG	8 AWG
Two	3/0 AWG	4 AWG
Three	250 kcmil	2 AWG
Four	500 kcmil	1/0 AWG
Five	1/0 AWG	6 AWG
Six	2/0 AWG	4 AWG

Common grounding electrode conductor sized for total circular mil area of all ungrounded service-entrance conductors

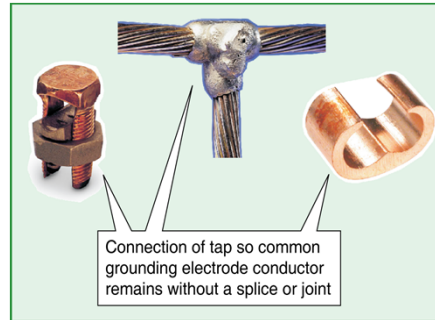
Tap conductor sized for service-entrance conductors that serve individual enclosure

Copyright © Cengage Learning

72

250.64(D)(1) - (3) Connection of Tap Conductors

- Tap conductors are required to be connected **to the common grounding electrode... with connectors listed for bonding and grounding**
- **Common Grounding Electrode Conductor remains without a splice or joint**



Copyright © Cengage Learning

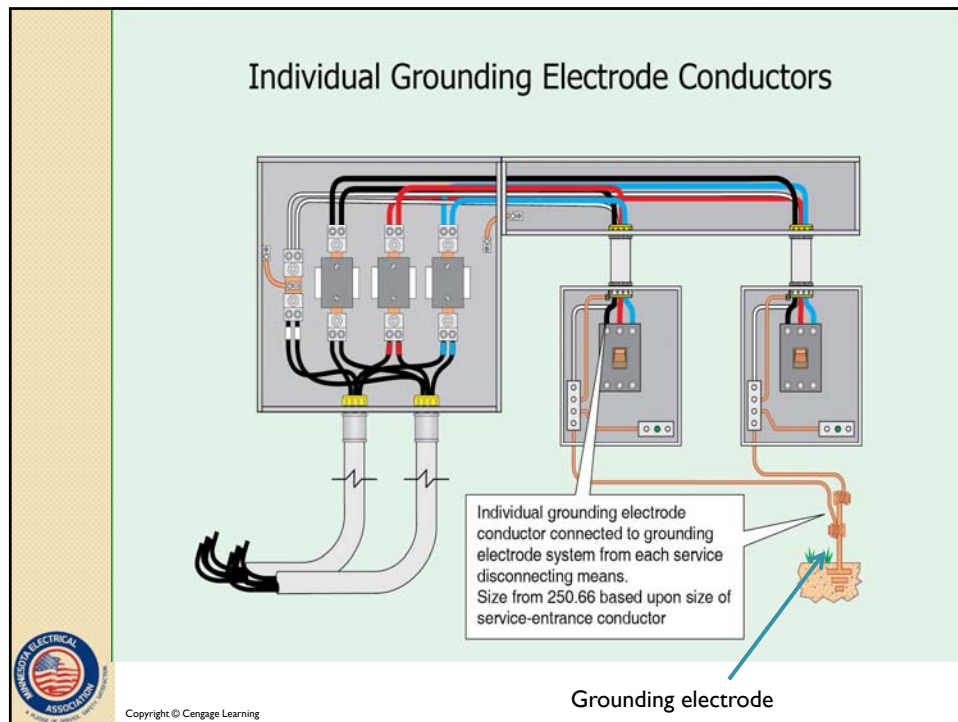
73

250.64(D)(2) Individual Grounding Electrode Conductors

- Next figure represents service with 2 service disconnecting means enclosures (6 permitted)
- A GEC shall be connected between grounding electrode system & one or more of following:
 - (1) GC in each service equipment disconnecting means enclosure
 - (2) EGC installed with the Feeder
 - (3) Supply-side bonding jumper
- Each GEC shall be sized in accordance with 250.66 based on the service-entrance or feeder conductor(s) **supplying the individual disconnecting means.**

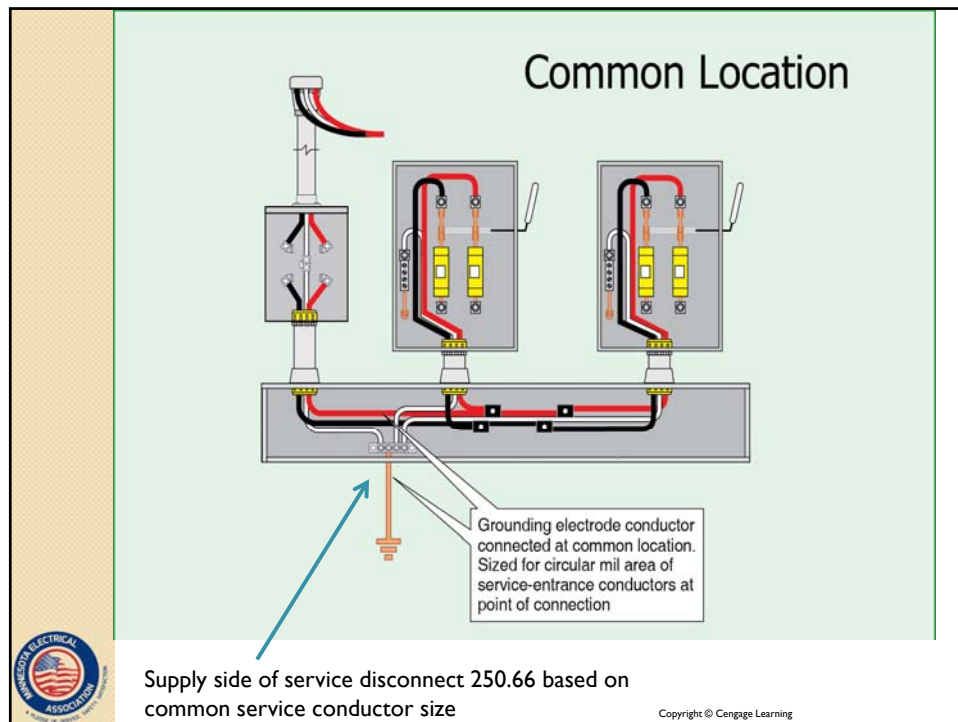


74



250.64(D)(3) Common Location

- Next figure represents a service with 2 service disconnecting means enclosures (6 permitted)
- A GEC shall be connected in a wireway or other accessible enclosure on supply side of disconnecting means to one or more of following:
 - (1) Grounded service conductor(s)
 - (2) EGC installed with the feeder
 - (3) Supply-side bonding jumper
- GEC sized from Table 250.66 based upon circular mil area of the ungrounded service-entrance conductors at point of connection



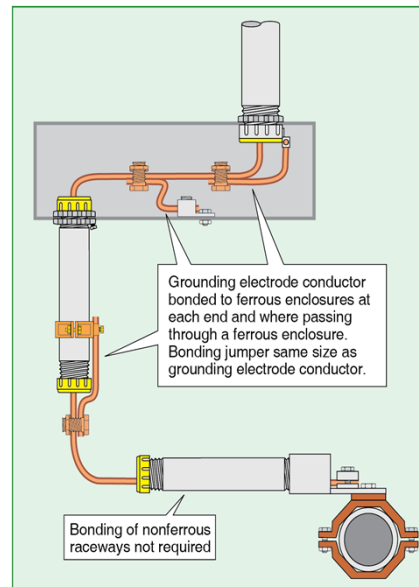
250.64(E) Raceways and Enclosures for Grounding Electrode Conductors.

- Ferrous metal Raceways & enclosures for grounding electrode conductors are required to be electrically continuous from point of connection to cabinets or equipment to the grounding electrode and must be securely fastened to the ground clamp or fitting
- Ferrous metal raceways and enclosures shall be bonded at each end of the raceway or enclosure to the grounding electrode or grounding electrode conductor to create a parallel path
- Nonferrous metal raceways and enclosures shall not be required to be electrically continuous.

78

250.64(E) Bonding Requirements

Bonding requirements apply to both ends and to all intervening ferrous raceways, boxes and enclosures between the service and grounding electrode for enclosing a GEC



79



Copyright © Cengage Learning

250.64(E) Raceways and Enclosures for Grounding Electrode Conductors.

- (2) Methods. Bonding shall be in compliance with 250.92(B) and ensured by one of the methods in 250.92(B)(2) through (B)(4). (bonding a service)
- (3) Size. **The bonding jumper for a grounding electrode conductor raceway or cable armor shall be the same size as, or larger than, the enclosed grounding electrode conductor.**
- (4) Wiring Methods. If a raceway is used as protection for a grounding electrode conductor, the installation shall comply with the requirements of the appropriate raceway article.



80

250.64(F) Installation to Electrode(s)

- Grounding electrode conductors, and bonding jumpers interconnecting grounding electrodes, are required to be installed as provided in (F)(1), (F)(2), or (F)(3).
- The **grounding electrode conductor must be sized for the largest grounding electrode conductor required among all the electrodes connected to it.**



81

250.64(F)(1) Installation to Electrode(s)

The grounding electrode conductor is permitted to be run to any convenient grounding electrode available in the grounding electrode system if the other electrodes, if any, are connected by bonding jumpers in accordance with the rules in 250.53(C).


See 250.50 and Figure 3-1 and 250.53(C) and Figure 3-15



82

250.64(F)(2) Installation to Electrode(s)

- Grounding electrode conductors are permitted to be run to one or more grounding electrodes individually.
- Size the individual grounding electrode conductor from Table 250.66 and written article based on the type grounding electrode being connected.




83

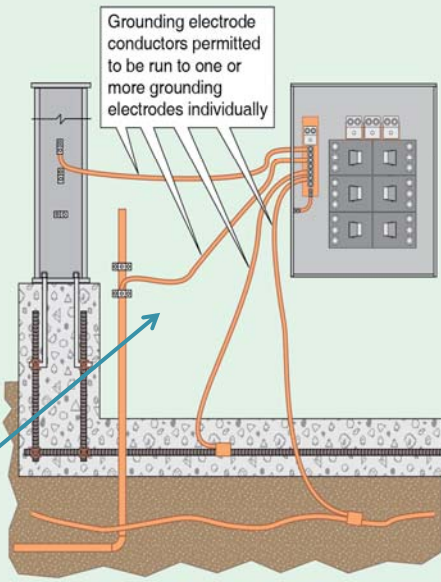
Installation to Electrodes

Grounding Electrode	Grounding Electrode Conductor for Service, Separately Derived System, or Feeder Supply		
	200 A 3/0 AWG	400 A 500 kcmil	800 A (2) 600 kcmil
Mtl Wtr Pipe, Mtl Bldg Frm	4 AWG	1/0 AWG	3/0 AWG
Concrete Encased	4 AWG	4 AWG	4 AWG
Ground Ring (2 AWG)	4 AWG	2 AWG	2 AWG
Rod, Pipe, Plate	6 AWG	6 AWG	6 AWG

GEC based on type of electrode



Copyright © Cengage Learning



84

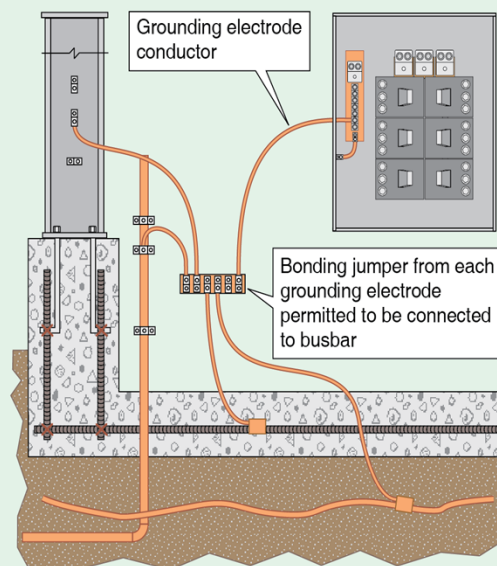
250.64(F)(3)

- Bonding jumpers from grounding electrodes and grounding electrode conductors are permitted to be connected to an aluminum or copper busbar.
- The busbar must be securely fastened and be installed in an accessible location.
- Connections are required to be made by a listed connector or by the exothermic welding process.
- If aluminum busbars are used, the installation is required to comply with 250.64(A)



85

Installation to Electrodes



Copyright © Cengage Learning

250.66 Size of AC Grounding Electrode Conductor

- Size of Grounding Electrode Conductor for a service, at building disconnecting means and for separately derived systems not smaller than Table 250.66
- The table is modified for the specific grounding electrodes by 250.66(A), (B) and (C)



87

Table 250.66 Grounding Electrode Conductor for Alternating-Current Systems

Size of the Largest Ungrounded Service-Entrance Conductor or Equivalent Area for Parallel Conductors (AWG/kcmil)		Size of Grounding Electrode Conductor (AWG/kcmil)	
Copper	Aluminum or Copper-Clad Aluminum	Copper	Aluminum or Copper-Clad Aluminum
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



Notes to Table 250.66

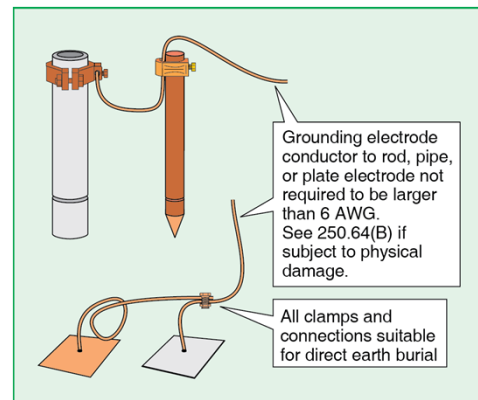
- If multiple sets of service-entrance conductors connect directly to a service drop, set of overhead service conductors, set of underground service conductors, or service lateral, the equivalent size of the largest **service-entrance conductor shall be determined by the largest sum of the areas of the corresponding conductors** of each set.
- Where there are no service-entrance conductors, the grounding electrode conductor size shall be determined by the equivalent size of the largest service-entrance conductor required for the load to be served.
 - ^a This table also applies to the derived conductors of separately derived ac systems
 - ^b See installation restrictions in 250.64(A)



89

250.66(A) Connections to Rod, Pipe, or Plate Electrodes

That portion of the grounding electrode conductor that connects directly to a single or multiple rod, pipe, or plate electrode **and does not extend to other electrodes that would require larger conductors**, the grounding conductor need not be larger than # 6 AWG

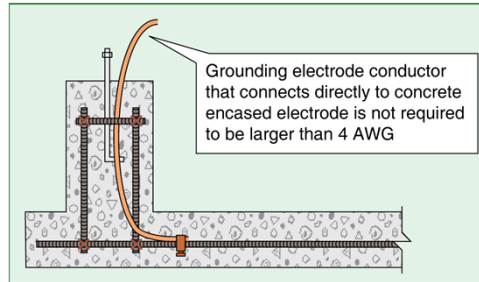


Copyright © Cengage Learning

90

250.66(B) Connections to Concrete-Encased Electrodes

That portion of the grounding electrode conductor that connects directly to single or multiple concrete encased electrode **and does not extend to other types of electrodes that would require larger conductors** is not required to be larger than # 4 AWG

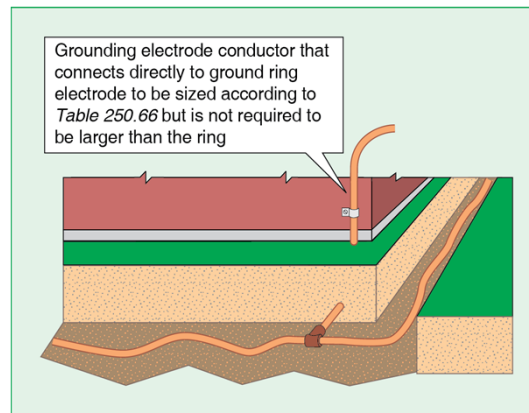


Copyright © Cengage Learning

91

250.66(C) Connections to Ground Rings

That portion of the grounding electrode conductor that connects directly to the ground ring electrode, **and does not extend to other electrodes that would require a larger conductor**, is not required to be larger than the ground ring conductor

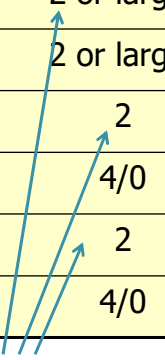



Copyright © Cengage Learning


92

Table 3-5 Size GEC for Ground Rings

Service-Entrance Conductor	Ground-Ring Conductor	Grounding Electrode Conductor
2 or smaller	2 or larger	8 AWG
2/0 or 3/0	2 or larger	4 AWG
> 350 to 600	2	2 AWG
> 350 to 600	4/0	1/0 AWG
Over 1100	2	2 AWG
Over 1100	4/0	3/0 AWG



 As specified by designer but not required to be larger than #2 AWG


 250.66 copper but not larger than Ring


93

250.68 Grounding Electrode Conductor Connections

The connection of a grounding electrode conductor at the service, **at each building or structure where supplied by a feeder(s) or branch circuit(s)**, or at a separately derived system and associated bonding jumper(s) shall be made as specified 250.68(A)-(C).


94

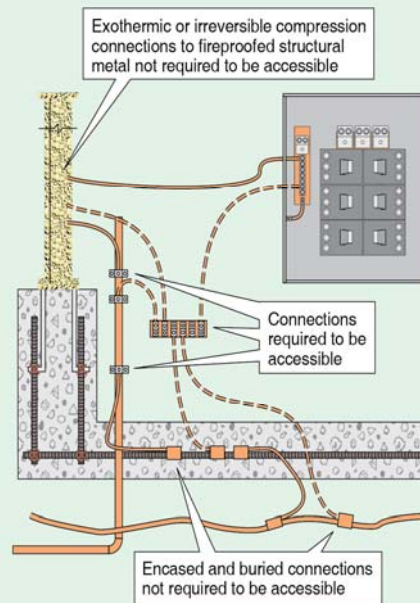
250.68(A) Accessibility

- All mechanical devices (elements) used to terminate the connection of a grounding electrode conductor or bonding jumper to a grounding electrode are required to be accessible
- *Exception: An encased or buried connection to a concrete-encased, driven or buried grounding electrode.*
- *Exception: Exothermic or irreversible compression connections used at terminations together with the mechanical means used to attach these terminations to fireproofed connections*



95

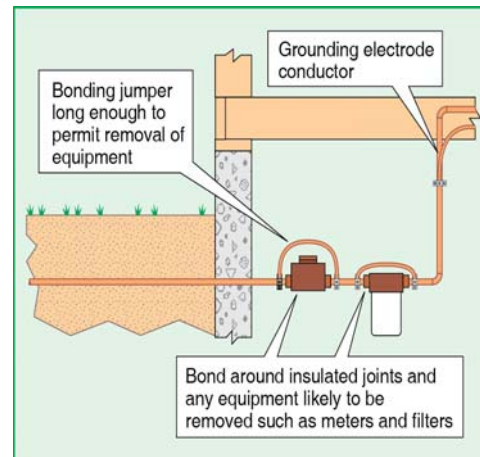
Grounding Electrode and Bonding Jumper Connections



Copyright © Cengage Learning

250.68(B) Effective Grounding Path

- Connection that ensures permanent and effective path is required.
- Bonding is required around insulated joints and any equipment likely to be disconnected for repairs



Copyright © Cengage Learning

97

250.68(C) Grounding Electrode Connections.

- Grounding electrode conductors and bonding jumpers shall be permitted to be connected at the following locations and used to extend the connection to an electrode(s):
- (I) Interior metal water piping located not more than 5 ft from the point of entrance to the building shall be permitted to be used as a conductor to interconnect electrodes that are part of the grounding electrode system.



98

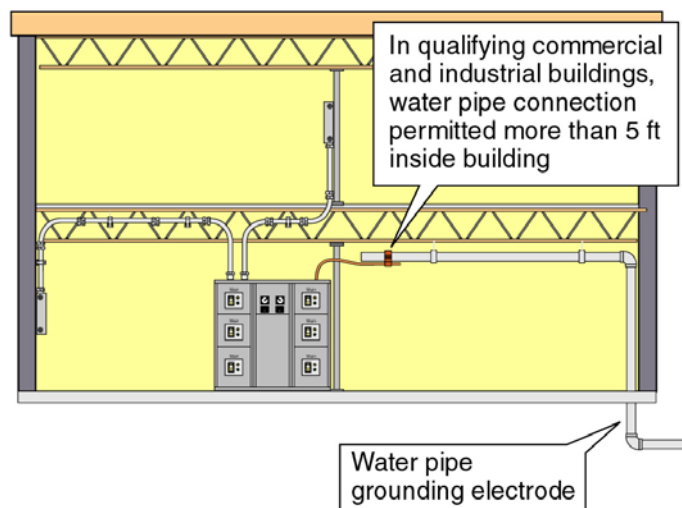
250.68(C) Exception

Exception: In industrial, commercial, and institutional buildings or structures, if conditions of maintenance and supervision ensure that only qualified persons service the installation, interior metal water piping located more than 1.52 m (5 ft) from the point of entrance to the building shall be permitted as a bonding conductor to interconnect electrodes that are part of the grounding electrode system, or as a grounding electrode conductor, if the entire length, other than short sections passing perpendicularly through walls, floors, or ceilings, of the interior metal water pipe that is being used for the conductor is exposed.



99

250.68(C) Exception



Copyright © Cengage Learning

100

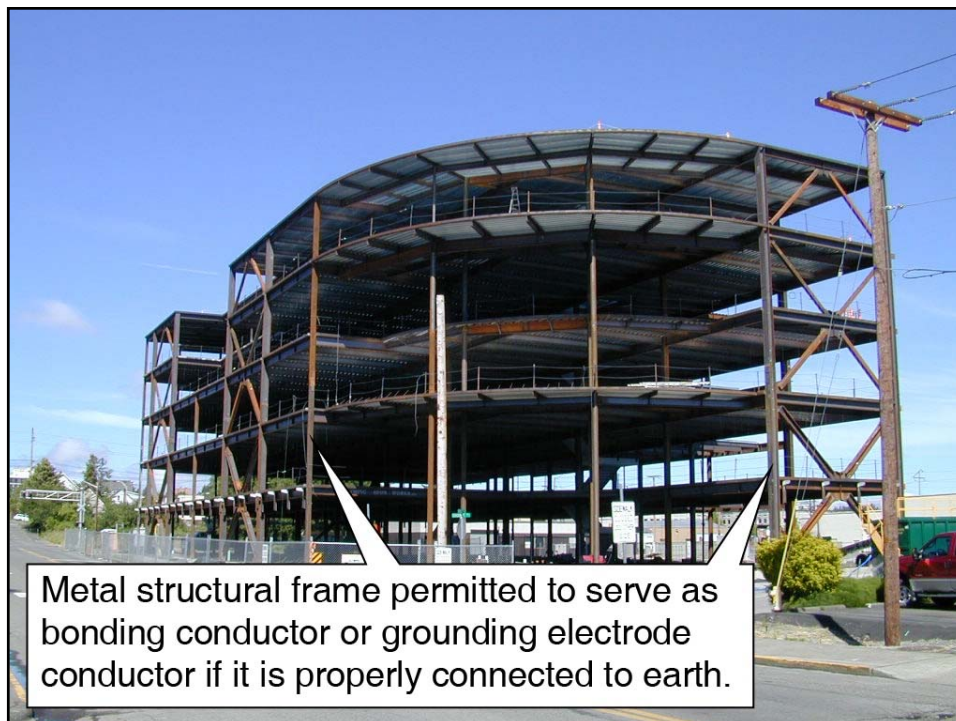
250.68(C)(2) Structural Metal

(2) The metal structural frame of a building shall be permitted to be used as a conductor to interconnect electrodes that are part of the grounding electrode system, or as a grounding electrode conductor. Hold down bolts are required to hold framing to concrete encased electrodes and shall be attached to the footings by exothermic welding, steel tie wire or other approved means.

(3) A concrete-encased electrode of either the conductor type, reinforcing rod or bar installed in accordance with 250.52(A)(3) extended from its location within the concrete to an accessible location above the concrete shall be permitted. If not subject to corrosion. The rebar shall not be exposed to earth without corrosion protection.

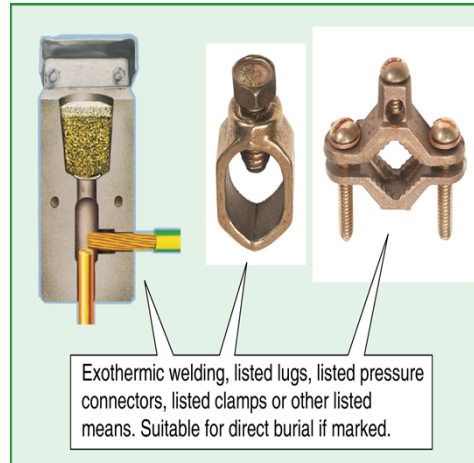


101



250.70 Methods of Grounding and Bonding Conductor Connection to Electrodes

- Connection by exothermic welding, listed lugs, pressure connectors, clamps or other listed means.
- Connections depending on solder are not permitted
- Suitable for direct burial if marked



Copyright © Cengage Learning

103

Enclosure, Raceway and Service Cable Grounding



104

Objectives:

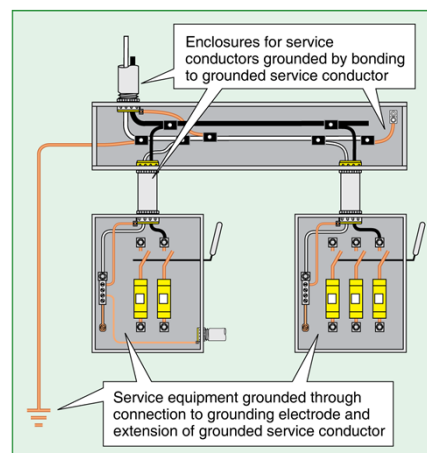
- Grounding requirements for service raceways and enclosures
- Grounding requirements for other conductor enclosures and raceways



105

Part IV- Enclosure, Raceway and Service Cable 250.80 Service Raceways and Enclosures

Metal enclosures and raceways for service conductors and equipment are required to be connected to the grounded system conductor or - (connected to earth or to some conducting body that serves in place of the earth)

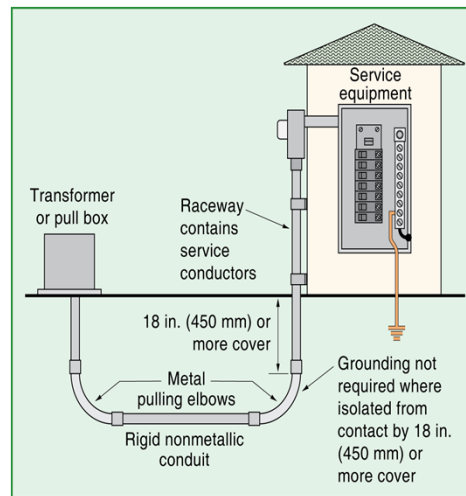


Copyright © Cengage Learning

106

250.80 Service Raceways and Enclosures, Exception

A metal elbow in a run of PVC conduit that is isolated from contact by a minimum cover of 18 in. is not required to be grounded



Copyright © Cengage Learning

107

250.84 Underground service entrance

(A) Underground service cable: The sheath of the underground cable that is connected on the supply side of the cable, is not required to be connected at the building or structure.

(B) An underground metal raceway that contains a metal sheathed cable that is connected to the grounded conductor, is not required to be connected to the raceway at the structure. It is permissible to isolate the metal sheath from the interior metal raceway.



Copyright © Cengage Learning

250.86 Other Conductor Enclosures and Raceways

Except as permitted in 250.112(I) (remote control, signal, and fire alarm circuits) metal enclosures and raceways for other than service conductors will be connected to the Equipment Grounding Conductor.



109

250.86 Other Conductor Enclosures and Raceways, Ex. I

Metal enclosures and raceways for conductors added to existing installations of open wire, knob-and-tube wiring and nonmetallic sheathed cable are not required to be grounded where these enclosures or wiring methods:



110

250.86 Other Conductor Enclosures and Raceways, **Ex. 1**

1. *Do not provide an equipment ground*
2. *Are in runs of less than 25 ft (7.6 m)*
3. *Are free from probable contact with ground, grounded metal, metal lath, or other conductive material; and*
4. *Are guarded against contact by persons*



111

250.86 Other Conductor Enclosures and Raceways, **Ex. 2**

Short sections of metal enclosures or raceways used to provide support or protection of cable assemblies from physical damage are not required to be grounded.



112

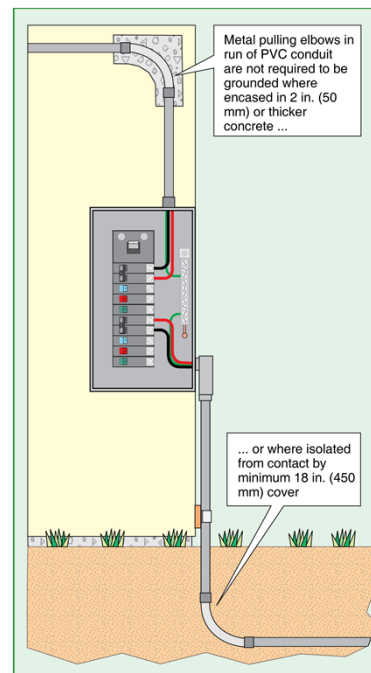
250.86 Other Conductor Enclosures and Raceways, **Ex. 3**

- (1) A metal elbow is not required to be grounded where it is installed in a run of nonmetallic raceway and is isolated from possible contact by a minimum cover of 18 in. to any part of the elbow –
- (2) or is encased in not less than 2 in. of concrete.




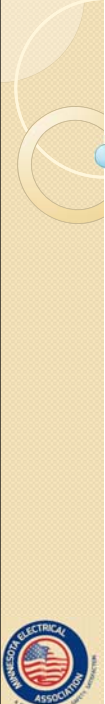
113

250.86 **Ex. 3** Other Conductor Enclosures and Raceways




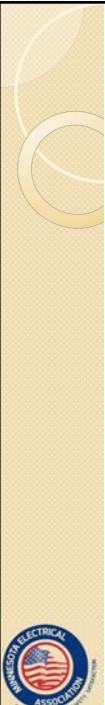
114





Part V Bonding

115



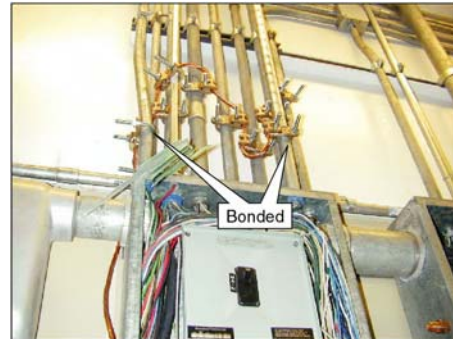
Objectives:

- General requirements for bonding
- General requirements for bonding services
- Bonding for other enclosures
- Bonding in hazardous locations (See Unit 8)
- Material for, attachment of and sizing equipment bonding jumpers
- Bonding of metal piping and exposed structural steel
- Bonding of lightning protection systems

116

250.90 General

- Bonding means “connecting metallic components together”
- Bonding is required where necessary to ensure electrical continuity and must have the capacity to conduct safely any fault current likely to be imposed



117

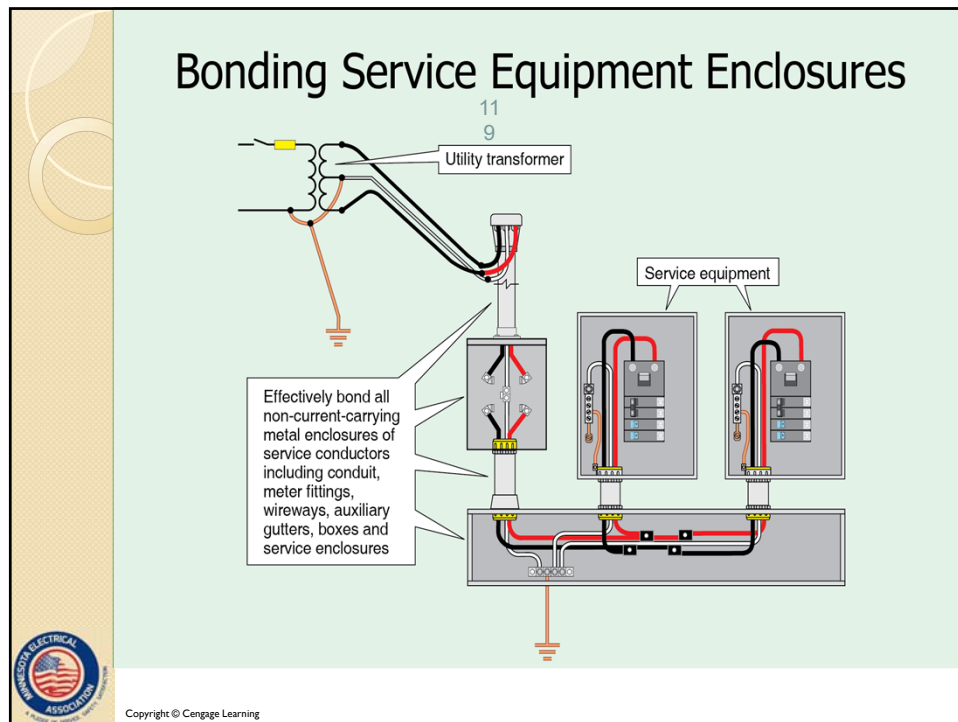
250.92(A) Bonding of Services

The normally non-current-carrying metal parts of the following equipment must be bonded together:

- I. All service raceways, cable trays, cablebus framework, auxiliary gutters, or service cable armor or sheath except as permitted in 250.80
- I. All enclosures containing service conductors, including meter fittings, boxes, or the like, interposed in the service raceway



118



250.92(B) Method of Bonding at Service

- **Bonding jumpers** meeting the requirements of this article **shall be used** around **impaired connections, such as reducing washers or oversized, concentric, or eccentric knockouts.**
- **Standard locknuts or bushings shall not** be the **only means for the bonding required by this section** but shall be permitted to be installed to make a mechanical connection of the raceway(s).

250.92(B) Method of Bonding at Service

At the service equipment, when using metal conduit or EMT, bond around all impaired connections such as reducing washers, oversized, concentric or eccentric knockouts

A standard lock nut is not to be the only bonding connection



121

250.92(B) Methods of Bonding at the Service

Bonding of these enclosures is to be ensured by one of the following:

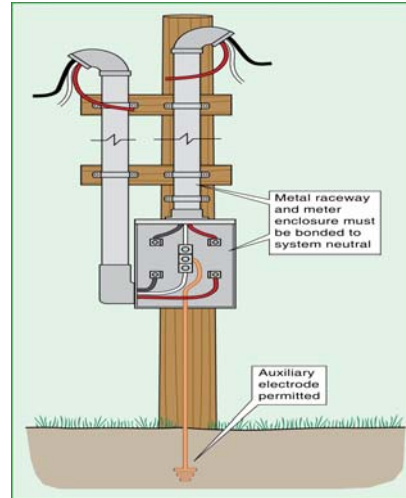
1. Bonding equipment to the grounded service conductor in a manner provided in 250.8 (methods of connecting)



122

Bonding of Remote Metering

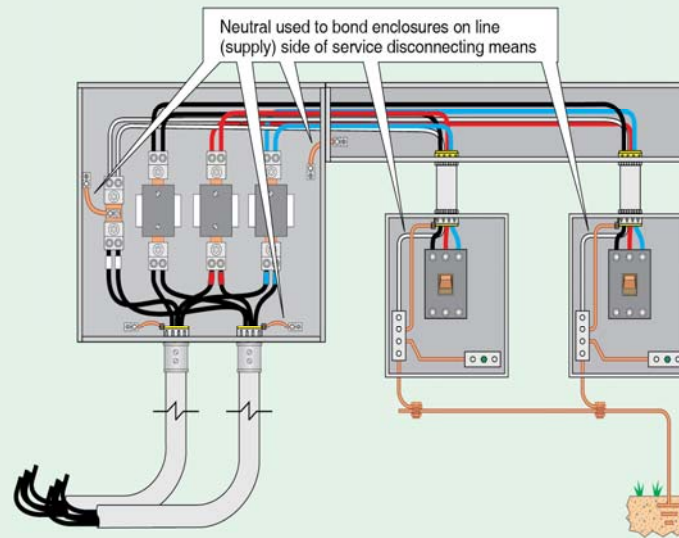
- Bond meter base to service neutral
- **Verify that neutral terminal is bonded to the enclosure**
- Connection to grounding electrode may be required by the serving electrical utility



Copyright © Cengage Learning

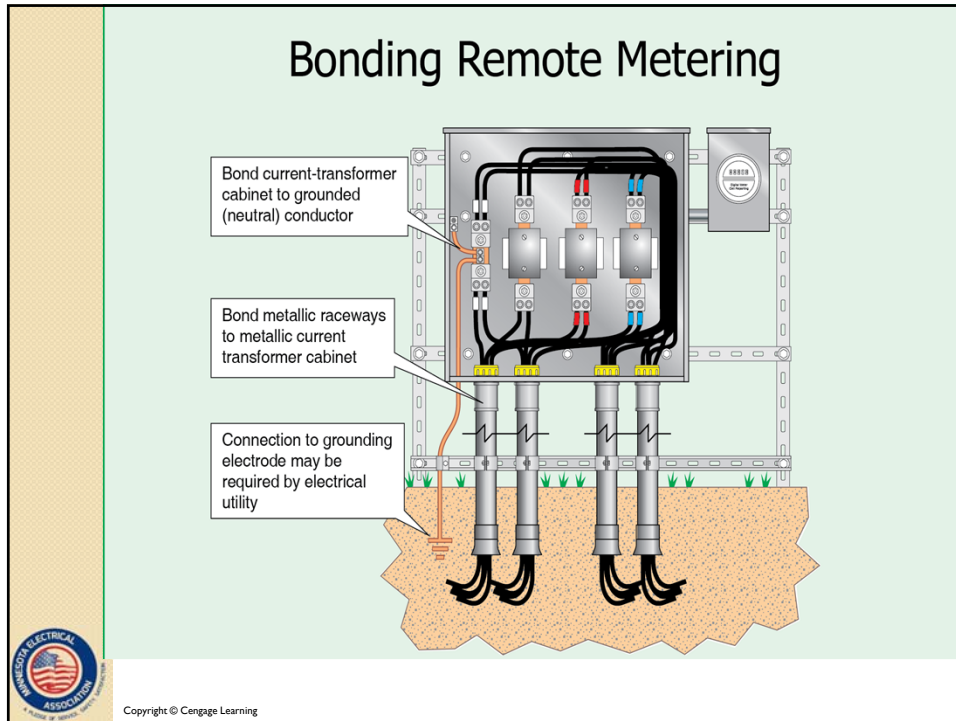
123

Use of Neutral for Bonding




Copyright © Cengage Learning

124



250.92(B) Methods of Bonding at the Service

2. Connections utilizing threaded couplings or threaded hubs on enclosures if made up wrench tight



Threaded conduit couplings, bolt-on hubs and weatherproof hubs listed for grounding used for bonding at service

Copyright © Cengage Learning

250.92(B) Methods of Bonding at the Service

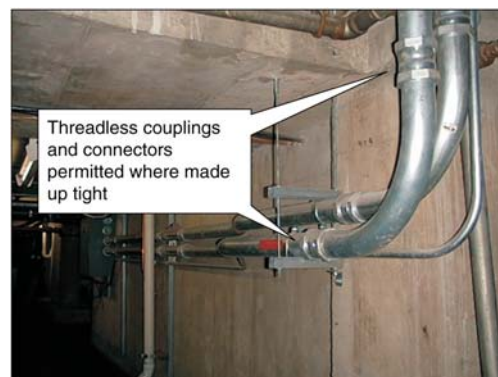
- Weatherproof hubs
- May be suitable for installation at service equipment
- To be Listed as compliant with UL-467



127

250.92(B) Methods of Bonding at the Service

3. Threadless couplings and connectors where made up tight for metal raceways and metal-clad cable



123

250.92(B) Methods of Bonding at the Service

4. Other listed devices such as bonding-type locknuts, bushings, or bushings with bonding jumpers



124

250.94 Bonding for Communication Systems

Communication system bonding as per (A) –(B) below:

(A) An intersystem bonding termination (IBT) for connecting intersystem bonding **conductors shall be provided external to enclosures at the service equipment or metering equipment enclosure** and at the disconnecting means for any additional buildings or structures.

- If an (IBT) is used the **intersystem bonding termination** shall comply with the following:.



130

250.94(A) Bonding for Communication Systems

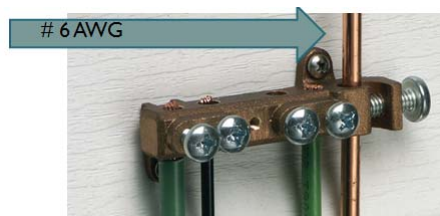
1. Be accessible for connection and inspection.
2. Consist of a set of terminals with the capacity for connection of not less than three intersystem bonding conductors.
3. Not interfere with opening the enclosure for a service, building or structure disconnecting means, or metering equipment.



131

250.94(A) Bonding for Communication Systems

4. At the **service equipment**, be securely mounted and electrically connected to an enclosure for the service equipment, to the meter enclosure, or to an exposed nonflexible metallic service raceway, **or be mounted at one of these enclosures and be connected to the enclosure or to the grounding electrode conductor with a minimum 6 AWG copper conductor.**



132

250.94 Bonding for Communication Systems

5. At the **disconnecting means for a building or structure**, be securely mounted and electrically connected to the metallic enclosure for the building or structure disconnecting means, or be mounted at the disconnecting means and be connected to the metallic enclosure or to the grounding electrode conductor with a minimum 6 AWG copper conductor.



133

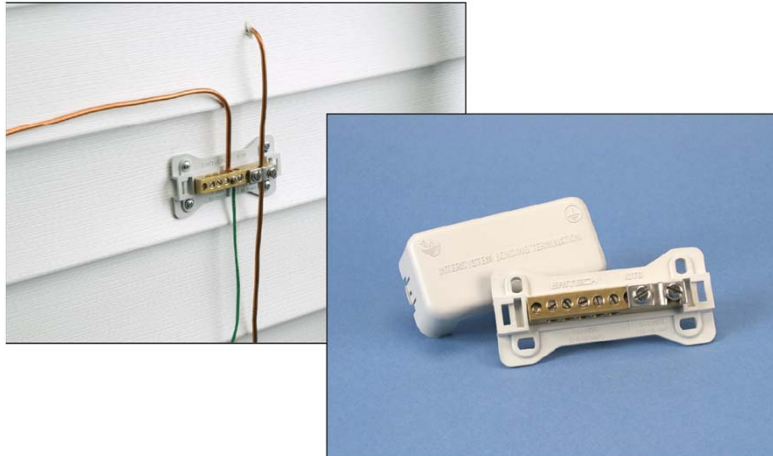
250.94(A) Bonding for Communication Systems

6. The terminals shall be listed as grounding and bonding equipment.



134

250.94 Bonding for Communication Systems



Copyright © Cengage Learning

135

250.94 Bonding for Communication systems

Exception: In existing buildings or structures, an accessible means external to enclosures for connecting intersystem bonding and grounding electrode conductors shall be permitted at the service equipment and at the disconnecting means for any additional buildings or structures by at least one of the following means:



136

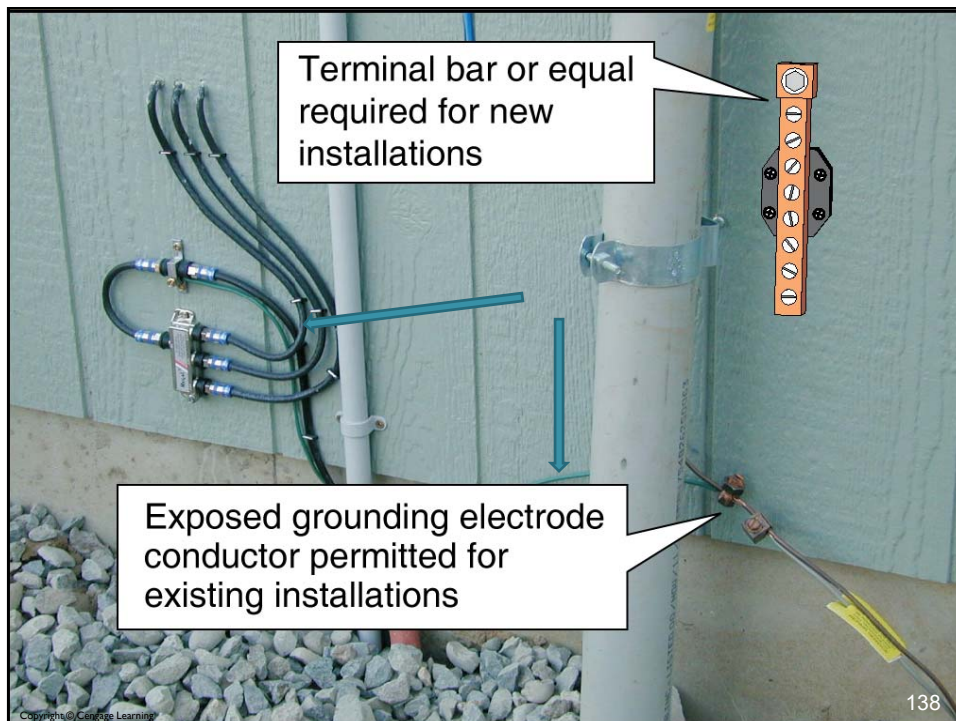
250.94 Bonding for Communication Systems

Exception

- (1) Exposed nonflexible metallic raceways
- (2) An exposed grounding electrode conductor
- (3) Approved means for the external connection of a copper or other corrosion-resistant bonding or grounding electrode conductor to the grounded raceway or equipment



137



250.94 NEW (B) Other means

Connection to an aluminum or copper bus bar of standard dimensions shall be permitted.



250.96 Bonding Other Enclosures, (A) General

Metal raceways, cable trays, cable armor, cable sheath, enclosures, frames, fittings, and other metal non-current-carrying parts that are to serve as equipment grounding conductors, **with or without the use of supplementary equipment grounding conductors, shall be effectively bonded where necessary to ensure electrical continuity** and the capacity to conduct safely any fault current likely to be imposed on them.



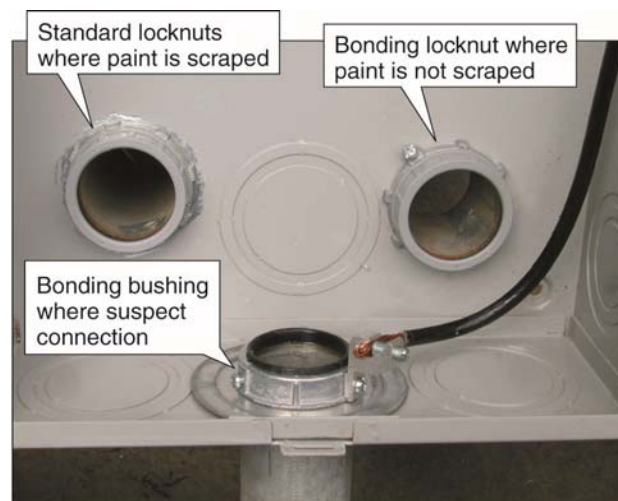
250.96(A) Bonding Other Enclosures, General

Any nonconductive paint, enamel, or similar coating shall be removed at threads, contact points, and contact surfaces or be connected by means or fittings designed so as to make such removal unnecessary.



141

250.96(A) Bonding Other Enclosures, General

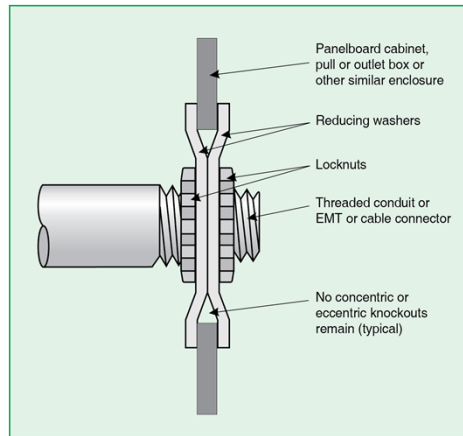


Copyright © Cengage Learning

142

Reducing Washers

- Reducing washers are used when the knockout opening in an enclosure is larger than the conduit or fitting to be connected
 - **Not permitted as bonding means at services**
 - UL: Reducing washers are approved for less than 250V and may be used for over 250V with specifications
- Next slide



Copyright © Cengage Learning

143

Reducing Washers

- Covered in UL White Book at (QCRV) '15-'16
- **Suitable for grounding and bonding if installed in compliance with NEC**
- Remove all remaining concentric knockouts

TABLE 5-1
Reducing Washer Application Trade Size ½ in. to 2 in.

	½	¾	1	1¼	1½	2
½	•	•	•	•	•	•
¾	•		•	•	•	•
1	•	•		•	•	•
1¼	•	•	•		•	•
1½	•	•	•	•		•
2	•	•	•	•	•	



144

Reducing Washers

Reducing washers permitted for connection at boxes **listed as having knockouts** that provide permanent, reliable bond



Copyright © Cengage Learning

145

250.96(B) Isolated Grounding Circuits

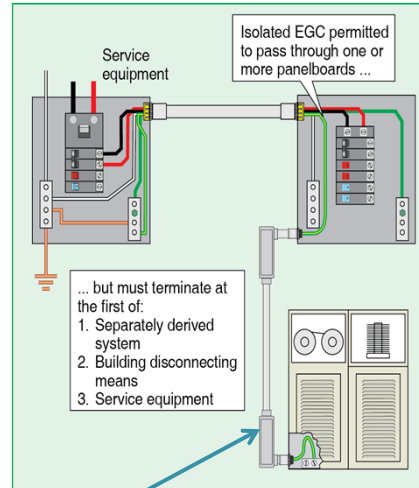
- The equipment is supplied by a branch circuit and the isolation applies to a raceway containing circuits supplying only that individual equipment.
- The isolation is permitted to be accomplished by one or more listed nonmetallic raceway fittings located where the raceway connects to the equipment



146

250.96(B) Isolated Grounding Circuits

- Isolated equipment grounding is permitted for reduction of electrical noise
- (EMI: electromagnetic interference) in accordance with the following:



Isolated (non grounded) raceway fitting for this apparatus

147



Copyright © Cengage Learning

250.96(B) Isolated Grounding Circuits

4. The installation of a metal raceway is required to comply with the provisions of Article 250
5. The **raceway must be supplemented** by an **internal insulated equipment grounding conductor in accordance with 250.146(D)**



148

250.97 Bonding for Over 250 Volts

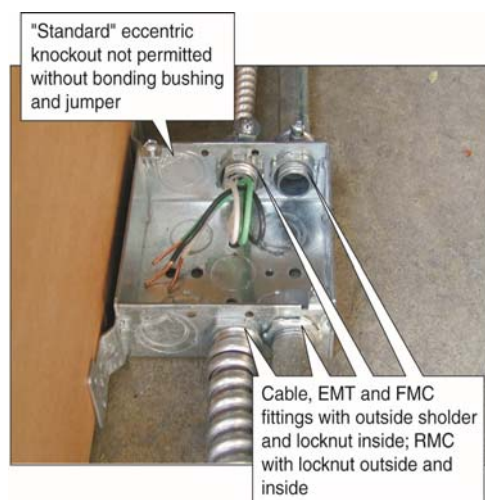
- For circuits over 250 volts, **electrical continuity of metal raceways and cables with metal sheaths that contain other than service conductors is required to be assured**
- Generally, use methods for services in 250.92(B) except for (B)(1)
- Generally applies to 480Y/277-volt systems



149

250.97 Bonding for Over 250 Volts

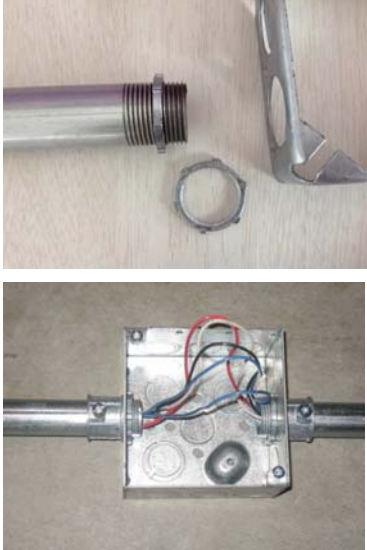

Where standard concentric or **eccentric knockouts are not at the connection point**, several wiring methods are acceptable for the bonding required



Copyright © Cengage Learning


150

1. Threadless couplings or connectors are permitted for cables with metal sheaths
2. Two locknuts, one inside and one outside on RMC or IMC
3. Fittings with shoulders that fit up tight to the enclosure
4. Listed fittings





250.97 Bonding for Over 250 Volts

Listed outlet or junction boxes that have knockouts designed so a bonding jumper is not required for direct connection for circuits over 250 volts to ground are not required to have a bonding jumper



Box with eccentric knockouts listed to provide permanent, reliable bond

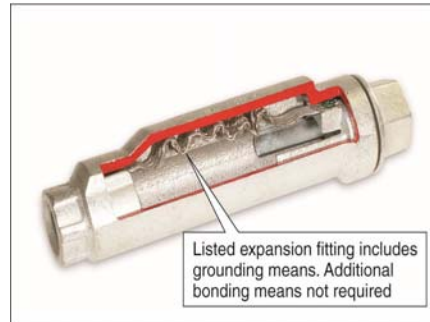


Copyright © Cengage Learning

152

250.98 Bonding Loosely Jointed Metal Raceways

Expansion fittings and telescoping sections of metal raceways are required to be made electrically continuous by equipment bonding jumpers or other means

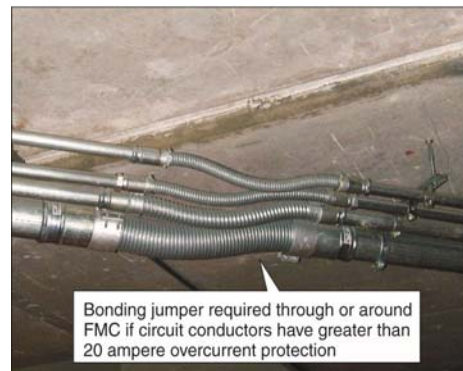


Copyright © Cengage Learning

153

Bonding Jumper Required

- Bonding jumper required for **FMC** if over **20-ampere OCP**, or **6 ft long**
- Bonding jumper required for **LFMC** if over **6 ft long** and over **20-A OCP** ($\frac{1}{2}$ in.) or **60-A OCP** ($\frac{3}{4}$ - $1\frac{1}{4}$ in.)



Copyright © Cengage Learning

154

250.100 Bonding in Hazardous (Classified) Locations

- Regardless of the system voltage, bonding is required of **non-current-carrying metal parts of equipment, raceways and other enclosures in any hazardous location** defined in 500.5, 505.5 & 506.50
- Any of the methods specified in 250.92(B)(2) through (4) is permitted (**threaded hubs, threadless fittings, bonding locknuts-etc.**)
- Bonding is required even though equipment grounding conductors are installed



155

Bonding in Hazardous (Classified) Locations

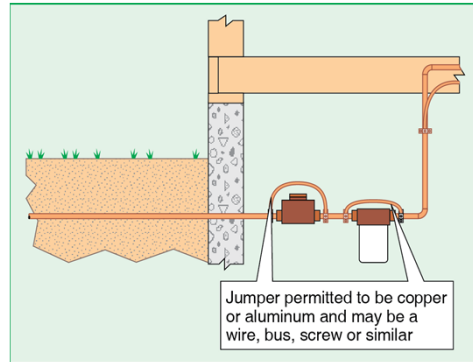
Informational Note: See 501.30, 502.30, 503.30, 505.25, or 506.25 for specific bonding requirements.



156

250.102(A) Equipment Bonding Jumpers, Material

- Required to be of copper, aluminum or copper clad aluminum, or other corrosion resistant material
- Permitted to consist of a wire, bus, screw, or other similar suitable conductor



157

250.102(B) Attachment

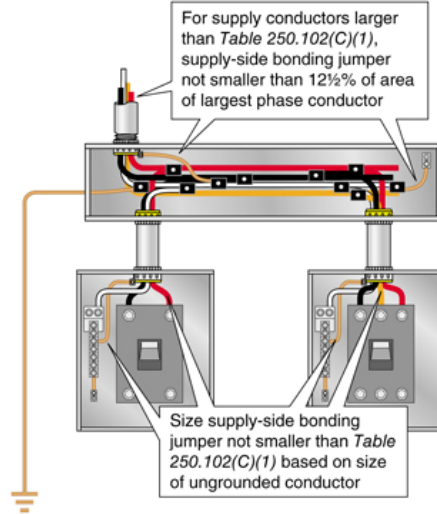
Equipment bonding jumpers are to be attached according to **250.8** for circuits and equipment and by **250.70** for **grounding electrodes**



158

250.102(C)(1) Size Supply-Side Bonding Jumper

- Size according to Table 250.102(C)(1) based on size of service conductors
- For larger conductors than in the table, size not smaller than 12½ percent of largest phase conductor



Copyright © Cengage Learning

159

Table: Example of Size of Supply-Side Bonding Jumper

TABLE 5-2

Size of Supply-Side Bonding Jumpers for 800 through 2000 Ampere Services or Separately Derived Systems.

SERVICE OR SUPPLY SIZE	SERVICE-ENTRANCE CONDUCTORS	TOTAL CIRCULAR MIL AREA	MINIMUM AREA OF BONDING JUMPER	NEXT STANDARD SIZE*	PARALLEL CONDUITS ARE USED†
800 Amp	2 sets, 500 kcmil	1000 kcmil		2/0 [Table 250.102(C)(1)]	(2) 1/0
1000 Amp	3 sets, 400 kcmil	1200 kcmil	150,000 cm	3/0	(3) 1/0
1200 Amp	4 sets, 350 kcmil	1400 kcmil	175,000 cm	4/0	(4) 2
1600 Amp	5 sets, 350 kcmil	1750 kcmil	218,750 cm	250 kcmil	(5) 2
2000 Amp	6 sets, 400 kcmil	2400 kcmil	300,000 cm	300 kcmil	(6) 1/0

*All conductors are in one raceway such as a wireway, or a single bonding jumper is used for multiple conduits.
 †Conduits are in individual raceways with an individual bonding jumper to the raceway.

Over 1,100 KCM copper use 12.5% rule and Chap 9 table 8



160

Other Uses of Table 250.102C 1

- Size of bonding jumper for grounding electrodes 250.53(C)
- Size of bonding jumper for ferrous metal raceway 250.64(E)
- Size of conductor for load side bonding 250.102(D)
- Size of conductor for bonding metal water piping 250.104(A)(1)
- Size of bonding jumper for bonding exposed structural metal 250.104(C)
- Bonding on secondary side of separately derived systems 250.104(D)



161

250.102(C)(2) Size of Supply-Side Bonding Jumper, in Two or More Raceways.

If the ungrounded supply conductors are paralleled in two or more raceways or cables, and an individual supply-side bonding jumper is used for bonding these raceways or cables, **the size of the supply-side bonding jumper for each raceway or cable is required to be selected from Table 250.102(C)(1) based on the size of the ungrounded supply conductors in each raceway or cable.**



162

250.102(C)(2) Size of Supply-Side Bonding Jumper, in Two or More Raceways.

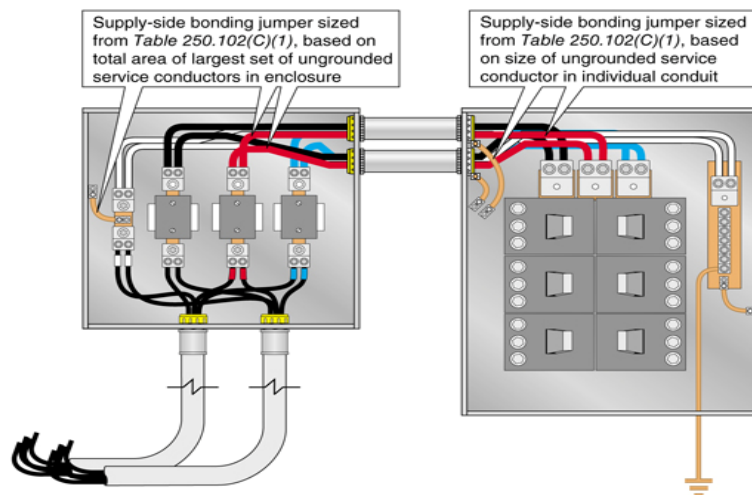
A single bonding jumper is permitted in compliance with (C)(1)

Informational Note: The term supply conductors includes ungrounded conductors that do not have overcurrent protection on their supply side and terminate at service equipment or the first disconnecting means of a separately derived system.



163

Parallel Conductors Bonding

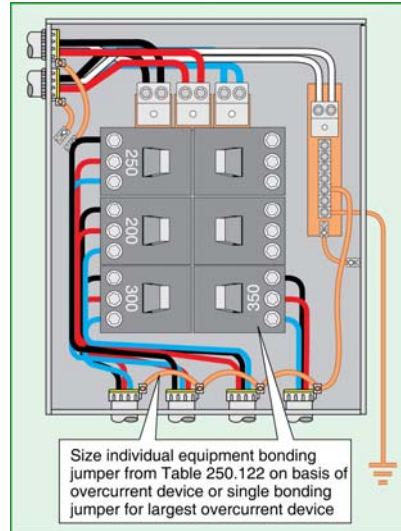


Copyright © Cengage Learning

164

250.102(D) Equipment Bonding Jumper on **Load Side** of Service

- Size per 250.122 (both written sections and table)
- Need not be larger than the largest circuit conductor but not smaller than 14 AWG
- Single bonding jumper permitted for multiple circuits



165

Copyright © Cengage Learning



Example: (Motors)

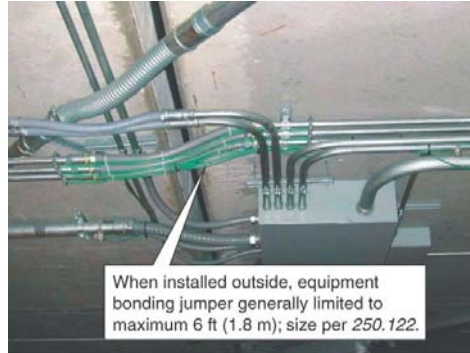
- 2 hp, 230-volt motor
 - Table 430.248, FLA = 12 A
- Minimum circuit conductor = $12\text{ A} \times 125\% = 15\text{ A}$ [430.22(A)]
 - Table 310.15(B)(16) = 14 AWG copper
- OCP permitted to be 250%, 430.52(C)(1)
 - $12\text{ A} \times 250\% = 30\text{ A}$ Max OCP permitted
- **Table 250.122 EGC = 10 AWG --- First look**
- **Not required to be larger than 14 AWG based on the motor circuit conductor size**

166



250.102(E) Installation

- Install inside or outside raceway or enclosure
- Where installed outside, the length is generally limited to not more than 6 ft **with exceptions**
- More than 6 ft permitted on poles
- Size protection per 250.64



Copyright © Cengage Learning

167

250.104 Bonding of piping and exposed structural metal

250.104(A) Metal Water Piping A1 –A3

- **Metal water piping system required to be bonded to:**
 - Service equipment enclosure
 - Grounded conductor at service
 - Grounding electrode conductor
 - One or more grounding electrodes
- Bonding jumpers to be installed per 250.64(A), (B), and (E)
- The connection points are required to be accessible



168

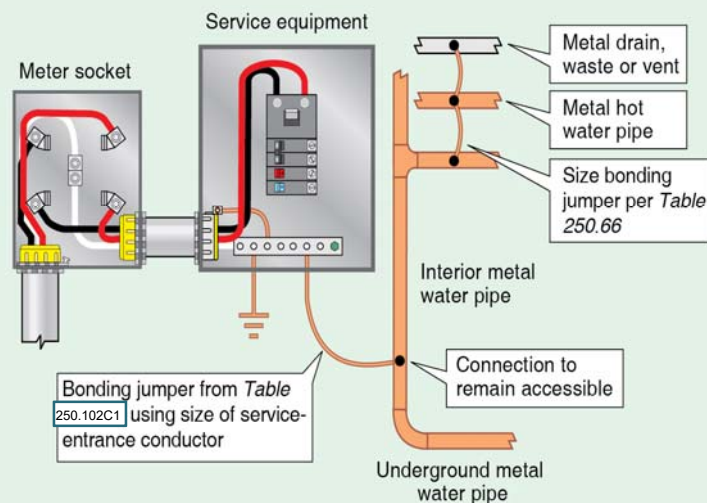
250.104(A)(1) General

- Water piping system(s) installed in or attached to a building or structure is required to be bonded to the service equipment enclosure, the grounded conductor at the service, the grounding electrode conductor where large enough or to one or more grounding electrodes
- Size per Table 250.102(C)(1) **except as permitted in 250.104 A2 (multiple occupancy) and A3 (multiple building served by feeders)**



169

Bonding of Metal Water Piping

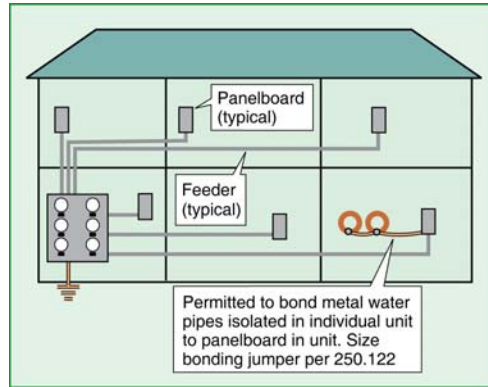


Copyright © Cengage Learning

170

250.104(A)(2) Buildings of Multiple Occupancy

Bonding of metal water piping in individual units permitted from equipment grounding terminal bar if piping is metallically isolated from other units by non-metallic water pipes

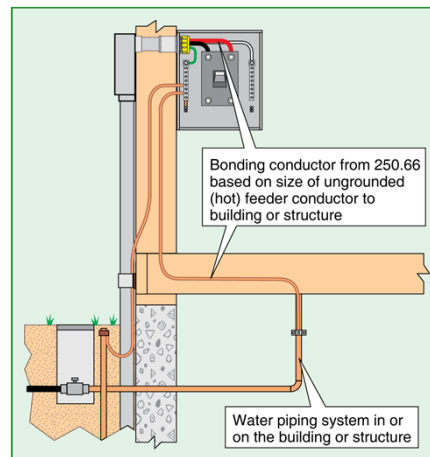


Copyright © Cengage Learning

171

250.104(A)(3) Bonding of Piping at Multiple Buildings

Bonding jumper sized from Table 250.66 based on size of ungrounded conductor in feeder or branch circuit



Copyright © Cengage Learning

172

250.104(B) Other Metal Piping

Other metal piping, including gas piping is **required to be bonded** if

- “likely to become energized” to any of the following:
 - (1) Equipment grounding conductor for the circuit that is likely to energize the piping system
 - (2) Service equipment enclosure
 - (3) Grounded conductor at the service
 - (4) Grounding electrode conductor, if of sufficient size
 - (5) One or more grounding electrodes used if of sufficient size



173

250.104(B) Other Metal Piping

Size bonding jumper from Table 250.122 on rating of OC device supplying equipment

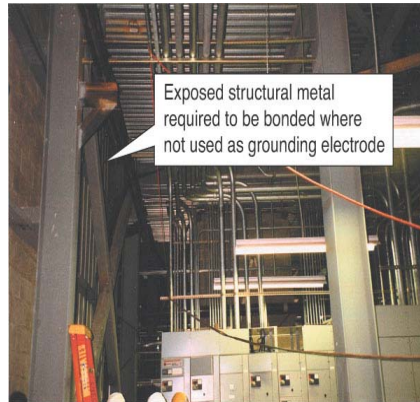


Copyright © Cengage Learning

174

250.104(C) Structural Metal

- Exposed structural metal that is interconnected to form a building frame is required to be bonded
- Size per Table 250.66
- Point of bonding to be accessible



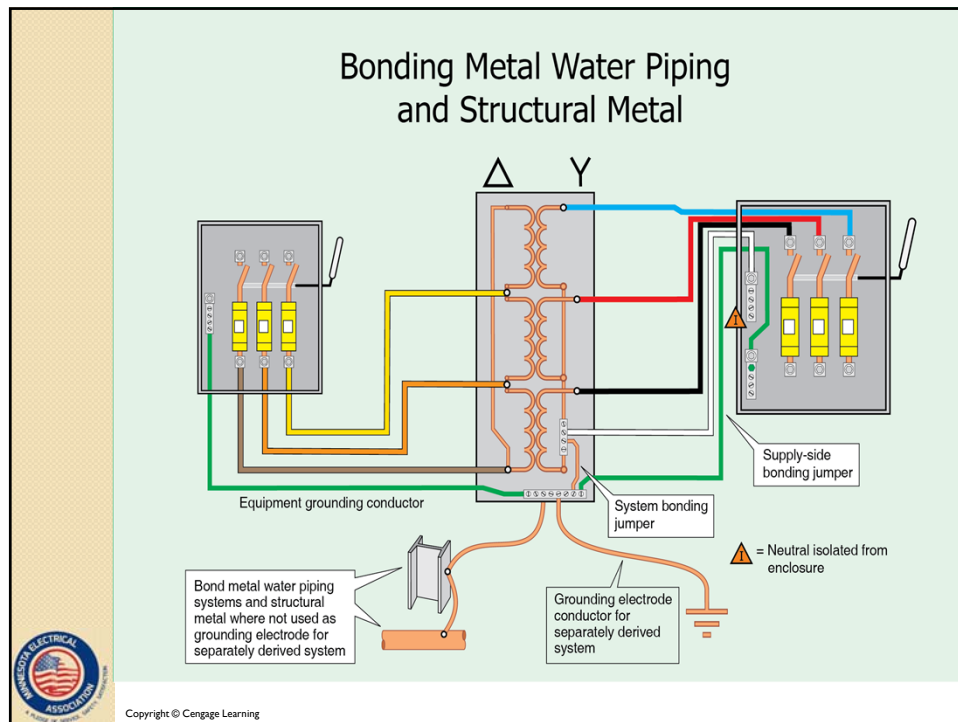
175

250.104(D) Separately Derived Systems

- Metal water piping and structural metal members that are interconnected to form a building frame are required to be bonded per 250.104(D)(1) through (D)(3)
- Grounded conductor required to be bonded in area served
- Connect at same point where grounding electrode conductor is connected
- Size per Table 250.102(C)(1) based on derived conductors



176

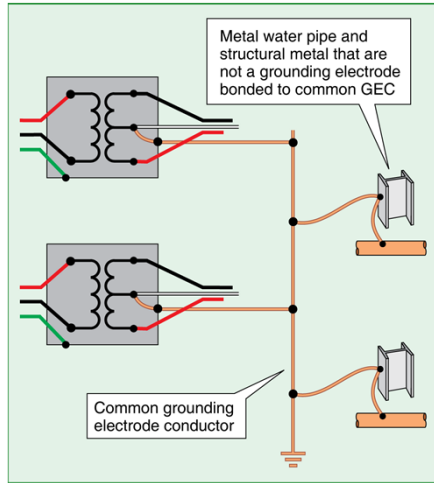


250.104(D)(2) Structural Metal

- Grounded conductor required to be bonded in area served
- Connect at same point where grounding electrode conductor is connected
- Size per Table 250.102 C 1 on derived conductors

250.104(D)(3) Common Grounding Electrode Conductor

If a common grounding electrode conductor serves multiple separately derived systems, it is required to connect a bonding jumper to the water piping and exposed structural steel

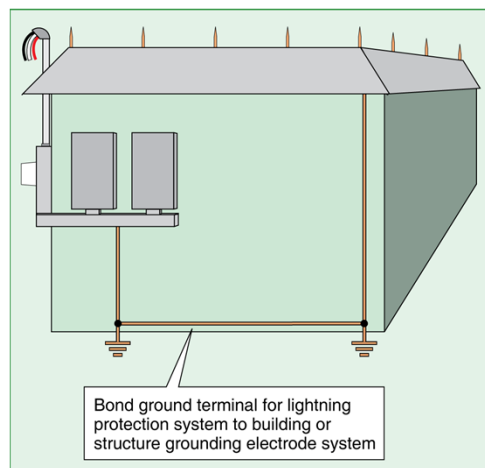


Copyright © Cengage Learning


179

250.106 Lightning Protection Systems

The lightning protection system **ground terminals** are required to be bonded to the **building or structure** grounding electrode system



180



End of Part 3

