Grounding & Bonding Definitions

- What is grounding: *grounding provides a path to earth for lightning & other high voltage surges*. *Grounding electrodes serve no part in clearing ground faults in premise wiring systems operating at under 600V. Electrical systems are grounded to earth in a manner that will limit voltages imposed by lightning, line surges, or unintentional contact with higher voltage lines. Grounding will stabilize voltage to earth during normal operations. Non-current carrying conductive materials & equipment are connected to earth to limit voltage to ground on them.*
- What is bonding: *Bonding provides a low impedance path necessary to quickly remove dangerous voltage from metal parts of the system by quickly opening the circuit protection device. Non-current carrying conductive materials & equipment are connected together & to the electric supply source in a manner that establishes an effective ground fault current path. An effective ground fault current path is an intentional constructed, permanent, low impedance, electrically conductive path designed & intended to carry fault current from the point of a fault on*

See the definition of *authority having jurisdiction* and 110.2 for a better understanding of the approval process. Typically, approval of listed equipment is more readily given by an AHJ where the authority accepts a laboratory's listing mark. Other options may be available for the jurisdiction to approve equipment, including evaluation by the inspection authority or field evaluation by a qualified laboratory or individual. Where an evaluation is conducted on site, industry standards such as NFPA 79, *Electrical Standard for Industrial Machinery,* if applicable, can be used. NFPA 790, *Standard for Competency of Third Party Field Evaluation Bodies,* can be used to qualify evaluation services. NFPA 791, *Recommended Practice and Procedures for Unlabeled Electrical Equipment Evaluation,* can be used to evaluate unlabeled equipment in accordance with nationally recognized standards and any requirements of the AHJ.

Arc-Fault Circuit Interrupter (AFCI). A device intended to provide protection from the effects of arc faults by recognizing characteristics unique to arcing and by functioning to de-energize the circuit when an arc fault is detected.

Arc-fault circuit interrupters are evaluated in accordance with UL 1699, *Standard for Arc-Fault Circuit-Interrupters*, using testing methods that create or simulate arcing conditions to determine a product's ability to detect and interrupt arcing faults. These devices are also tested to verify that arc detection is not inhibited by the presence of loads and circuit characteristics that mask the hazardous arcing condition. In addition, these devices are evaluated to determine resistance to unwanted tripping due to the presence of arcing that occurs in equipment under normal operating conditions or to a loading condition that closely mimics an arcing fault, such as a solid-state electronic ballast or a dimmed load.

Askarel. A generic term for a group of nonflammable synthetic chlorinated hydrocarbons used as electrical insulating media.

Informational Note: Askarels of various compositional types are used. Under arcing conditions, the gases produced, while consisting predominantly of noncombustible hydrogen chloride, can include varying amounts of combustible gases, depending on the askarel type.

Attachment Plug (Plug Cap) (Plug). A device that, by insertion in a receptacle, establishes a connection between the conductors of the attached flexible cord and the conductors connected permanently to the receptacle.

See 406.7 for requirements pertaining to attachment plugs and the configuration charts from NEMA WD 6, *Wiring Devices – Dimensional Requirements,* for general-purpose nonlocking and specific-purpose locking plugs and receptacles shown in Exhibit 406.3.

Authority Having Jurisdiction (AHJ). An organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, an installation, or a procedure.

Informational Note: The phrase "authority having jurisdiction," or its acronym AHJ, is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

In the North American safety system, the importance of the role of the AHJ cannot be overstated. The AHJ verifies that an installation complies with the *Code*. See also the definition of *approved*, 90.7, and 110.2.

Automatic. Performing a function without the necessity of human intervention.

Bathroom. An area including a basin with one or more of the following: a toilet, a urinal, a tub, a shower, a bidet, or similar plumbing fixtures.

Battery System. Interconnected battery subsystems consisting of one or more storage batteries and battery chargers, and can include inverters, converters, and associated electrical equipment.

This definition is suitable for use with all types of storage batteries. The system consists of all of the major components that are necessary to supply the desired output. A battery system can contain multiple batteries. Other equipment can include chargers, inverters, converters, and overcurrent protective devices.

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

Bonding Conductor or Jumper. A reliable conductor to ensure the required electrical conductivity between metal parts required to be electrically connected.

Either of the two terms *bonding conductor* or *bonding jumper* may be used. The term *bonding jumper* is sometimes interpreted to mean a short conductor, although some bonding jumpers may be several feet in length. The primary purpose of a bonding conductor or jumper is to ensure electrical conductivity between two conductive bodies, such as between a box and a metal raceway. Bonding jumpers are particularly important where a box has either concentric- or eccentric-type knockouts. These knockouts can impair the electrical conductivity between metal parts and may actually introduce unnecessary impedance into the grounding path. Bonding jumpers may be found at service equipment [250.92(B)], equipment operating over 250 volts (250.97), and expansion fittings in metal raceways (250.98). Exhibit 100.4 shows the difference between concentric- and eccentric-type knockouts and illustrates one method of applying bonding jumpers at these types of knockouts.

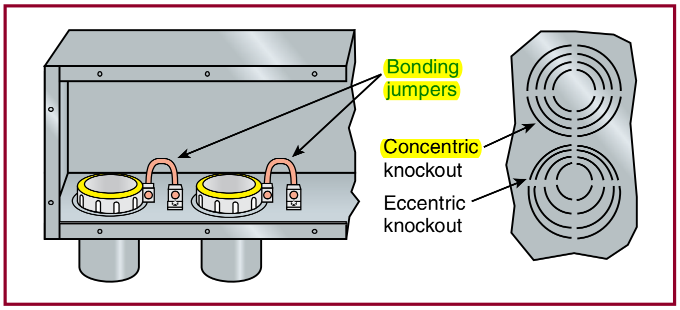


EXHIBIT 100.4 Bonding jumpers installed around concentric or eccentric knockouts.

Bonding Jumper, Equipment. The connection between two or more portions of the equipment grounding conductor.

Equipment bonding jumpers ensure that an effective ground-fault current path is not compromised by an interruption in mechanical or electrical continuity. For example, conduits entering an open-bottom switchboard are usually not mechanically connected to the switchboard. Bonding jumpers provide electrical continuity. An example of potential loss of both mechanical and electrical continuity would be an installation of an expansion fitting intended to allow for movement in a metal conduit system as illustrated in Exhibit 100.5. Expansion fittings consist of loosely joined raceways that allow expansion without deformation of the raceway. Some expansion fittings for metal conduit have an internal bonding jumper that is integral to the fitting, eliminating the need for the external bonding jumpers shown in Exhibit 100.5. Equipment bonding jumpers are also used to connect the grounding terminal of a receptacle to a metal box that in turn is grounded via an equipment grounding conductor (the raceway system).

EXHIBIT 100.5 Equipment bonding jumpers installed to maintain electrical continuity around conduit expansion fittings. (Courtesy of the International Association of Electrical Inspectors)

Bonding Jumper, Main. The connection between the grounded circuit conductor and the equipment grounding conductor at the service.

Exhibit 100.6 shows a main bonding jumper that provides the connection between the grounded service conductor and the equipment grounding conductor at the service. Bonding jumpers may be located throughout the electrical system, but a main bonding jumper is located only at the service. Main bonding jumper requirements are found in 250.28.

Bonding Jumper, System. The connection between the grounded circuit conductor and the supply-side bonding jumper, or the equipment grounding conductor, or both, at a separately derived system.

The system bonding jumper can be installed in several ways. For example, if a multi-barrel lug is connected to the XO terminal of a transformer, the system bonding jumper, grounding electrode conductor, grounded conductor, and bonding jumper can be connected at that connector. If a multi-barrel lug is connected to the transformer or generator enclosure, a common practice is to connect the system bonding jumper, the grounding electrode conductor, and the bonding jumper or conductor to that connector. The grounded conductor should always connect directly to the XO terminal. A system bonding jumper is used to connect the equipment grounding conductor(s) or the supply-side bonding jumper to the grounded conductor of a separately derived system

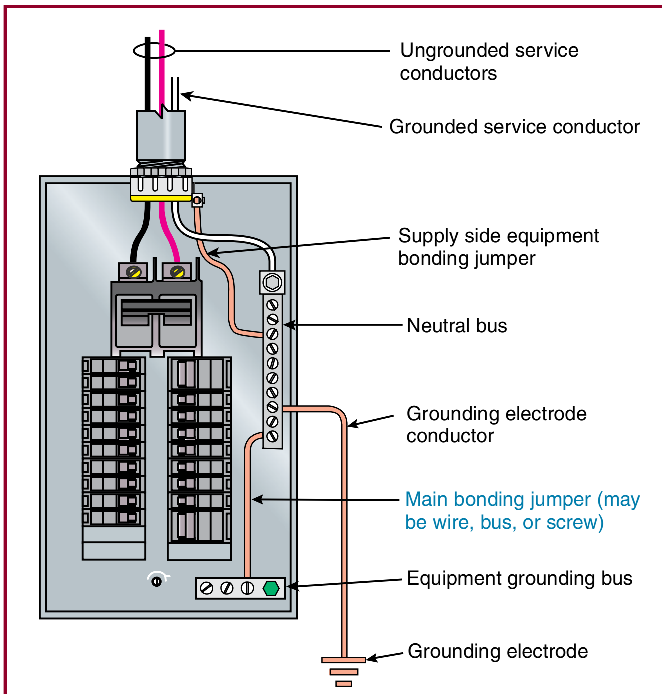


EXHIBIT 100.6 A main bonding jumper installed at the service between the grounded service conductor and the equipment grounding conductor.

either at the source (see Exhibit 250.13) or at the first system disconnecting means (see Exhibit 250.14). A system bonding jumper is used at the derived system if the derived system contains a grounded conductor.

Like the main bonding jumper at the service equipment, the system bonding jumper provides the necessary link between the equipment grounding conductors and the system grounded conductor in order to establish an effective path for ground-fault current to return to the source. The requirements for system bonding jumper(s) are found in 250.30(A)(1).

Branch Circuit. The circuit conductors between the final overcurrent device protecting the circuit and the outlet(s).

Exhibit 100.7 shows the difference between branch circuits and feeders. Conductors between the overcurrent devices in the panelboards and the duplex receptacles are branch-circuit conductors. Conductors between the service equipment or source of separately derived systems and the panelboards are feeders.

Branch Circuit, Appliance. A branch circuit that supplies energy to one or more outlets to which appliances are to be connected and that has no permanently connected luminaires that are not a part of an appliance.

Two or more 20-ampere small-appliance branch circuits are required by 210.11(C)(1) for dwelling units. Section 210.52(B)(1) requires that these circuits supply receptacle outlets located in rooms such as the kitchen and pantry. These small-appliance branch circuits are not permitted to supply other outlets or permanently connected luminaires. (See 210.52 for details.)

Branch Circuit, General-Purpose. A branch circuit that supplies two or more receptacles or outlets for lighting and appliances.

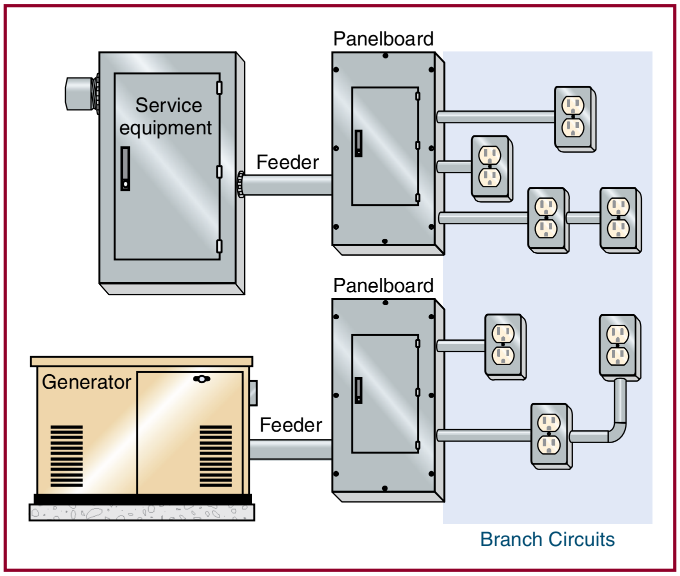


EXHIBIT 100.7 *Feeder (circuits) and branch circuits.*

Branch Circuit, Individual. A branch circuit that supplies only one utilization equipment.

Exhibit 100.8 illustrates an individual branch circuit with a single receptacle for connection of one piece of utilization equipment (e.g., one dryer, one range, one space heater, one motor). See 210.23 for permissible loads on individual branch circuits and see 210.21(B)(1), which requires the single receptacle to have an ampere rating not less than that of the branch circuit. A branch circuit supplying one duplex receptacle that supplies two cord-and-plug-connected appliances or similar equipment is not an individual branch circuit.

Branch Circuit, Multiwire. A branch circuit that consists of two or more ungrounded conductors that have a voltage between them, and a grounded conductor that has equal voltage between it and each ungrounded conductor of the circuit and that is connected to the neutral or grounded conductor of the system.

See 210.4, 240.15(B)(1), and 300.13(B) for specific information about multiwire branch circuits.

Building. A structure that stands alone or that is cut off from adjoining structures by fire walls with all openings therein protected by approved fire doors.

A building is generally considered to be a roofed or walled structure that is intended for supporting or sheltering any use or occupancy. However, a separate structure such as a pole, billboard sign, or water tower may also be a building. Definitions of the terms *fire walls* and *fire doors* are the responsibility of building codes. Generically, a fire wall may be defined as a wall that separates buildings or subdivides a building to prevent the spread of fire and that has a fire resistance rating and structural stability. Fire doors (and fire windows) are used to protect openings in

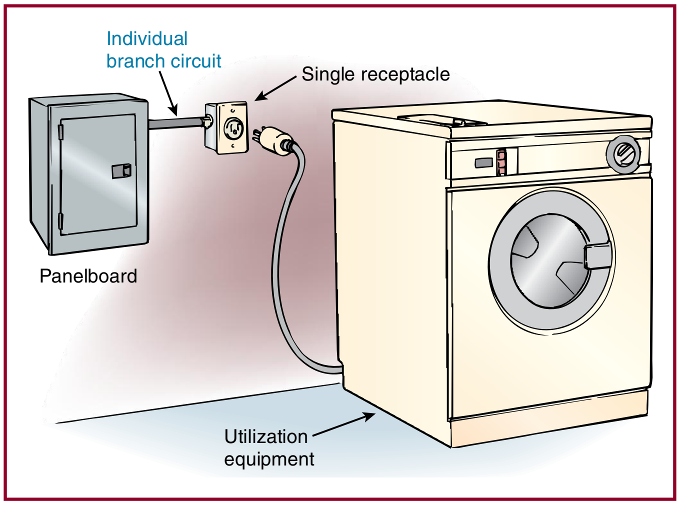


EXHIBIT 100.8 *An individual branch circuit, supplying only one piece of utilization equipment via a single receptacle.*

Electric Sign. A fixed, stationary, or portable self-contained, electrically illuminated utilization equipment with words or symbols designed to convey information or attract attention.

Electric-Discharge Lighting. Systems of illumination utilizing fluorescent lamps, high-intensity discharge (HID) lamps, or neon tubing.

Electronically Actuated Fuse. An overcurrent protective device that generally consists of a control module that provides current-sensing, electronically derived time–current characteristics, energy to initiate tripping, and an interrupting module that interrupts current when an overcurrent occurs. Such fuses may or may not operate in a current-limiting fashion, depending on the type of control selected.

Enclosed. Surrounded by a case, housing, fence, or wall(s) that prevents persons from accidentally contacting energized parts.

Enclosure. The case or housing of apparatus, or the fence or walls surrounding an installation to prevent personnel from accidentally contacting energized parts or to protect the equipment from physical damage.

Informational Note: See Table 110.28 for examples of enclosure types.

Enclosures are required by 110.28 to be marked with a number that identifies the environmental conditions in which that type of enclosure can be used. Enclosures that comply with the requirements for more than one type of enclosure are marked with multiple designations. See the commentary following 110.28 for details on enclosure markings and types as well as Table 110.28, which lists the types of enclosures required to be used in specific locations.

Energized. Electrically connected to, or is, a source of voltage.

The term *energized* is not limited to equipment that is "connected to a source of voltage." Equipment such as batteries, capacitors, and conductors with induced voltages must also be considered energized. Also see the definitions of *exposed (as applied to live parts)* and *live parts*.

Equipment. A general term, including fittings, devices, appliances, luminaires, apparatus, machinery, and the like used as a part of, or in connection with, an electrical installation.

This definition clarifies that machinery is considered equipment. For further information on machinery, see Article 670 and NFPA 79, *Electrical Standard for Industrial Machinery*.

Explosionproof Equipment. Equipment enclosed in a case that is capable of withstanding an explosion of a specified gas or vapor that may occur within it and of preventing the ignition of a specified gas or vapor surrounding the enclosure by sparks, flashes, or explosion of the gas or vapor within, and that operates at such an external temperature that a surrounding flammable atmosphere will not be ignited thereby.

Informational Note: For further information, see ANSI/UL 1203-2009, *Explosion-Proof and Dust-Ignition-Proof Electrical Equipment for Use in Hazardous (Classified) Locations.*

Exposed (as applied to live parts). Capable of being inadvertently touched or approached nearer than a safe distance by a person.

The installation instructions should be consulted to ensure that live parts are properly guarded. See 110.27 for the requirements for guarding live parts. Also see the definitions of *energized* and *live parts*.

Informational Note: This term applies to parts that are not suitably guarded, isolated, or insulated.

Exposed (as applied to wiring methods). On or attached to the surface or behind panels designed to allow access.

See Exhibit 100.2, which illustrates wiring methods that would be considered exposed because they are located above a suspended ceiling with lift-out panels.

Externally Operable. Capable of being operated without exposing the operator to contact with live parts.

Feeder. All circuit conductors between the service equipment, the source of a separately derived system, or other power supply source and the final branch-circuit overcurrent device.

See the commentary following the definition of *branch circuit*, including Exhibit 100.7, which illustrates the difference between branch circuits and feeders.

Festoon Lighting. A string of outdoor lights that is suspended between two points.

Fitting. An accessory such as a locknut, bushing, or other part of a wiring system that is intended primarily to perform a mechanical rather than an electrical function.

Condulets, conduit couplings, EMT connectors and couplings, and threadless connectors are considered fittings.

Garage. A building or portion of a building in which one or more self-propelled vehicles can be kept for use, sale, storage, rental, repair, exhibition, or demonstration purposes.

Informational Note: For commercial garages, repair and storage, see Article 511.

Ground. The earth.

Ground Fault. An unintentional, electrically conductive connection between an ungrounded conductor of an electrical circuit and the normally non–current-carrying conductors, metallic enclosures, metallic raceways, metallic equipment, or earth.

Grounded (Grounding). Connected (connecting) to ground or to a conductive body that extends the ground connection.

Grounded, Solidly. Connected to ground without inserting any resistor or impedance device.

Grounded Conductor. A system or circuit conductor that is intentionally grounded.

Ground-Fault Circuit Interrupter (GFCI). A device intended for the protection of personnel that functions to de-energize a circuit or portion thereof within an established period of time when a current to ground exceeds the values established for a Class A device.

Informational Note: Class A ground-fault circuit interrupters trip when the current to ground is 6 mA or higher and do not trip when the current to ground is less than 4 mA. For further information, see UL 943, *Standard for Ground-Fault Circuit Interrupters.*

The commentary following 210.8 contains a list of applicable cross-references for GFCIs. See Exhibits 210.6 through 210.8 for further information on GFCIs.

Ground-Fault Current Path. An electrically conductive path from the point of a ground fault on a wiring system through normally non–current-carrying conductors, equipment, or the earth to the electrical supply source.

Informational Note: Examples of ground-fault current paths are any combination of equipment grounding conductors, metallic raceways, metallic cable sheaths, electrical equipment, and any other electrically conductive material such as metal, water, and gas piping; steel framing members; stucco mesh; metal ducting; reinforcing steel; shields of communications cables; and the earth itself.

Ground-Fault Protection of Equipment. A system intended to provide protection of equipment from damaging line-to-ground fault currents by operating to cause a disconnecting means to open all ungrounded conductors of the faulted circuit. This protection is provided at current levels less than those required to protect conductors from damage through the operation of a supply circuit overcurrent device.

See the commentary following 230.95, 426.28, and 427.22.

Grounding Conductor, Equipment (EGC). The conductive path(s) that provides a ground-fault current path and connects normally non–current-carrying metal parts of equipment together and to the system grounded conductor or to the grounding electrode conductor, or both.

Informational Note No. 1: It is recognized that the equipment grounding conductor also performs bonding.

Informational Note No. 2: See 250.118 for a list of acceptable equipment grounding conductors.

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

Grounding Electrode Conductor. A conductor used to connect the system grounded conductor or the equipment to a grounding electrode or to a point on the grounding electrode system.

Grounding electrode conductors are covered extensively in Article 250, Part III. These conductors are required by 250.62 to be copper, aluminum, or copper-clad aluminum and are required to be sized according to 250.66 and Table 250.66. Exhibit 100.6 and Exhibit 250.1 show a grounding electrode conductor in a typical grounding system for a single-phase, 3-wire service.

Guarded. Covered, shielded, fenced, enclosed, or otherwise protected by means of suitable covers, casings, barriers, rails, screens, mats, or platforms to remove the likelihood of approach or contact by persons or objects to a point of danger.

Guest Room. An accommodation combining living, sleeping, sanitary, and storage facilities within a compartment.

Guest Suite. An accommodation with two or more contiguous rooms comprising a compartment, with or without doors between such rooms, that provides living, sleeping, sanitary, and storage facilities.

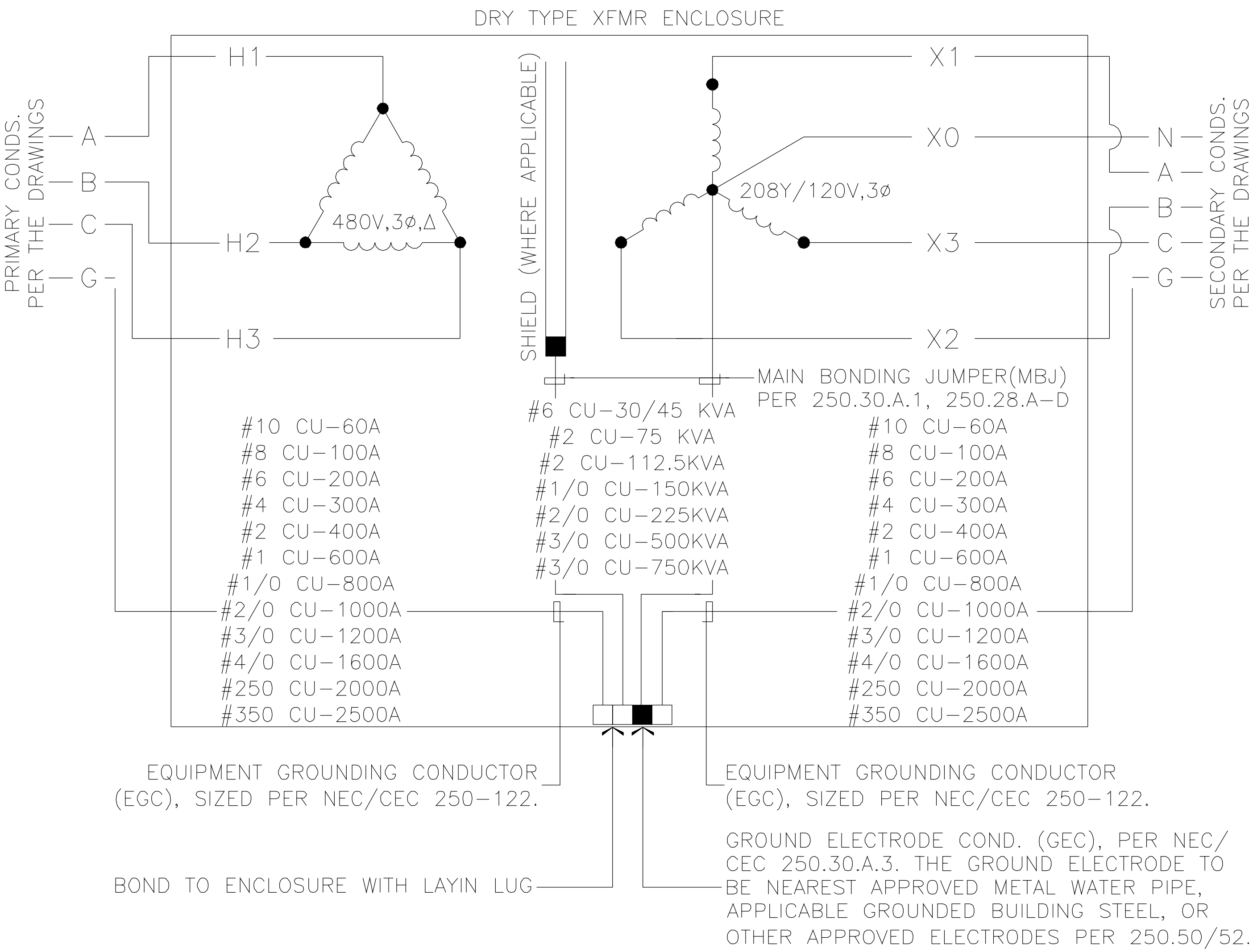
Some requirements for guest rooms in hotels, motels, and similar occupancies are found in 210.60. If a guest room or guest suite meets the definition of a dwelling unit, additional dwelling unit requirements may apply.

Handhole Enclosure. An enclosure for use in underground systems, provided with an open or closed bottom, and sized to allow personnel to reach into, but not enter, for the purpose of installing, operating, or maintaining equipment or wiring or both.

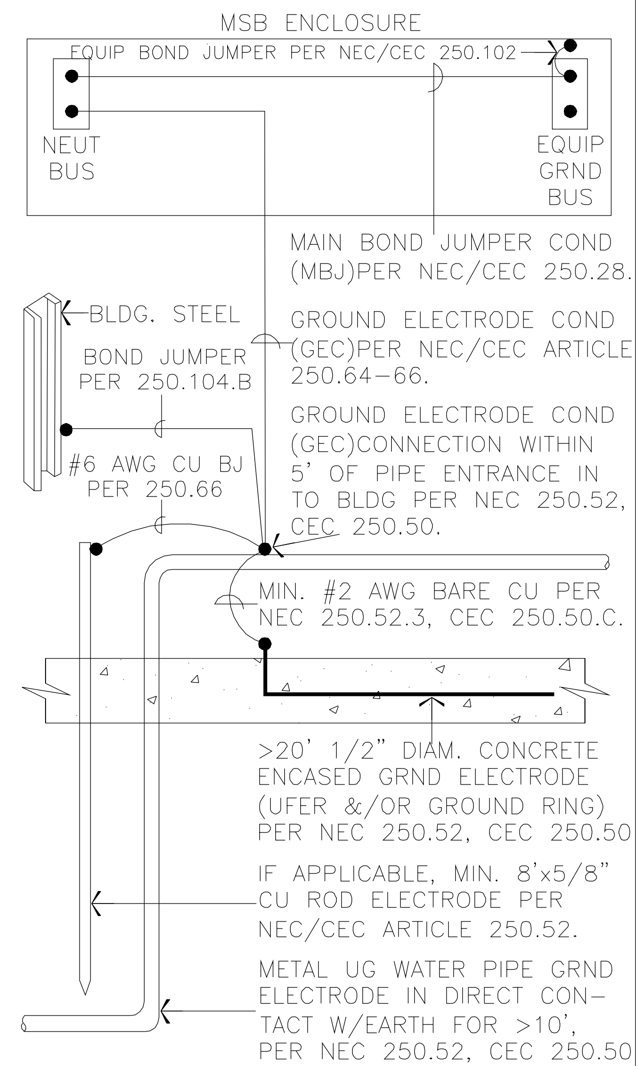
Exhibit 100.11 shows the installation of one type of handhole enclosure. Handhole enclosures are required by 314.30 to be "identified" for use in underground systems.

Hermetic Refrigerant Motor-Compressor. A combination consisting of a compressor and motor, both of which are enclosed in the same housing, with no external shaft or shaft seals, with the motor operating in the refrigerant.

EXHIBIT 100.11 *An example of a handhole enclosure. (Courtesy of Quazite/Hubbell Lenoir City, Inc.)*



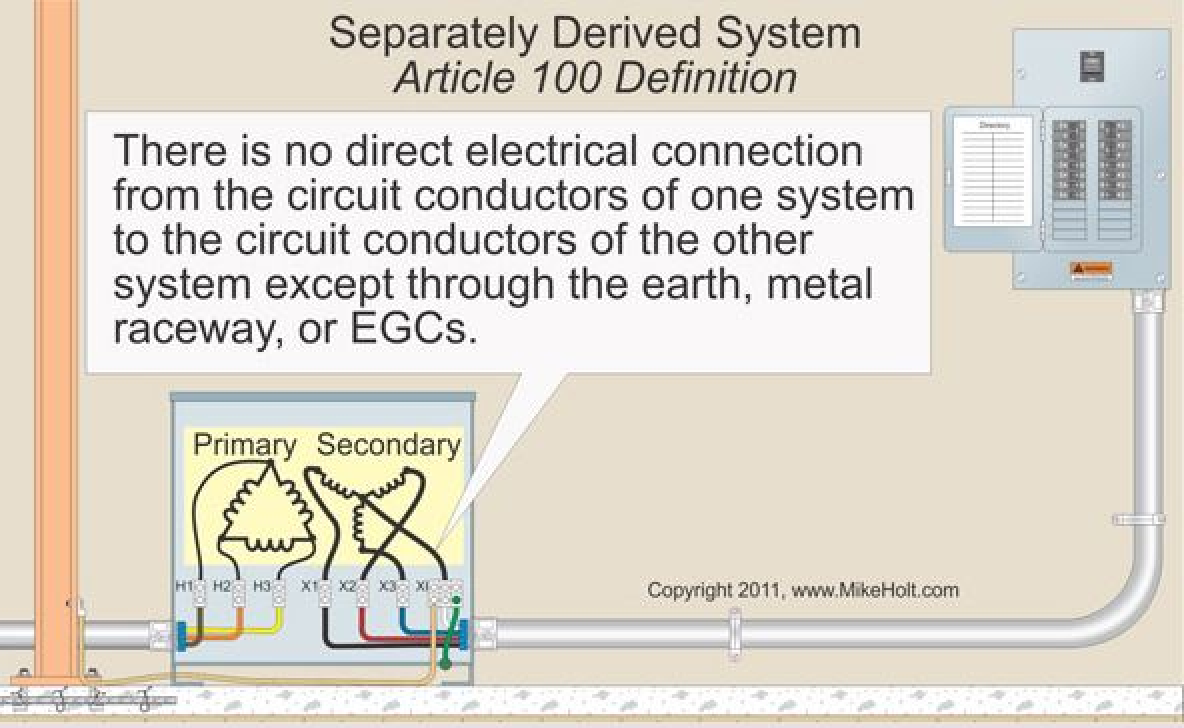
TYPICAL DRY TYPE XFMR GROUNDING DETAIL



TYPICAL SERVICE GROUNDING DETAIL

SEE SLD ON SHEET E0.1 FOR ALL GROUNDING METHODS & GROUND CONDUCTOR SIZES. ALL XFMR & SERVICE GROUNDING & BONDING & CONNECTIONS SHALL COMPLY W/2008 NEC (2010 CEC) ART 250, & SPECIFICALLY W/250.28, 250.30, 250.50, 250.53, 250.64 & 250.104.

USE IF &/OR AS APPLICABLE



Separately Derived System
Article 100 Definition
There is no direct electrical connection from the circuit conductors of one system to the circuit conductors of the other system except through the earth, metal raceway, or EGCs.
Primary
Secondary
H1
H2
H3
X1
X2
X3
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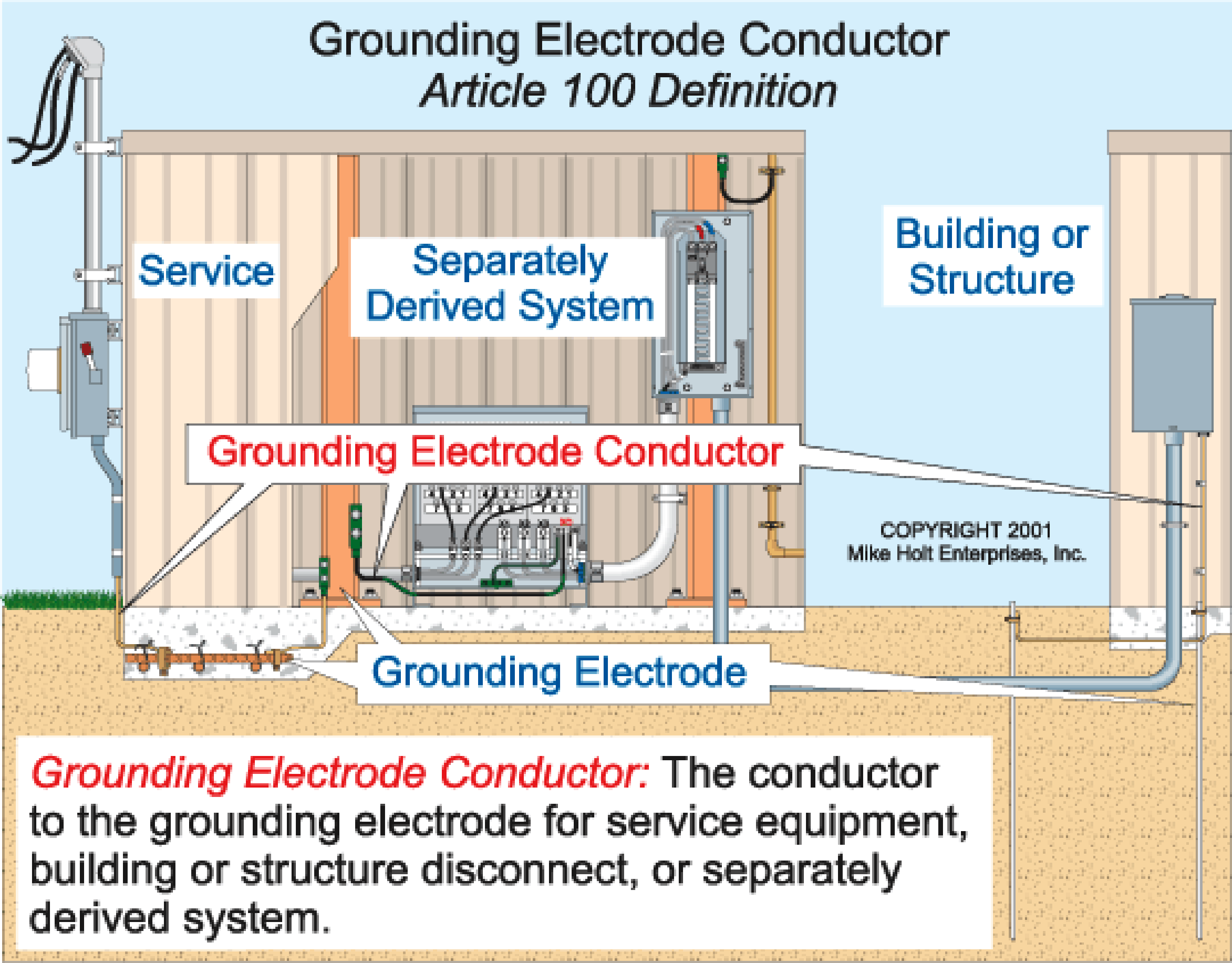
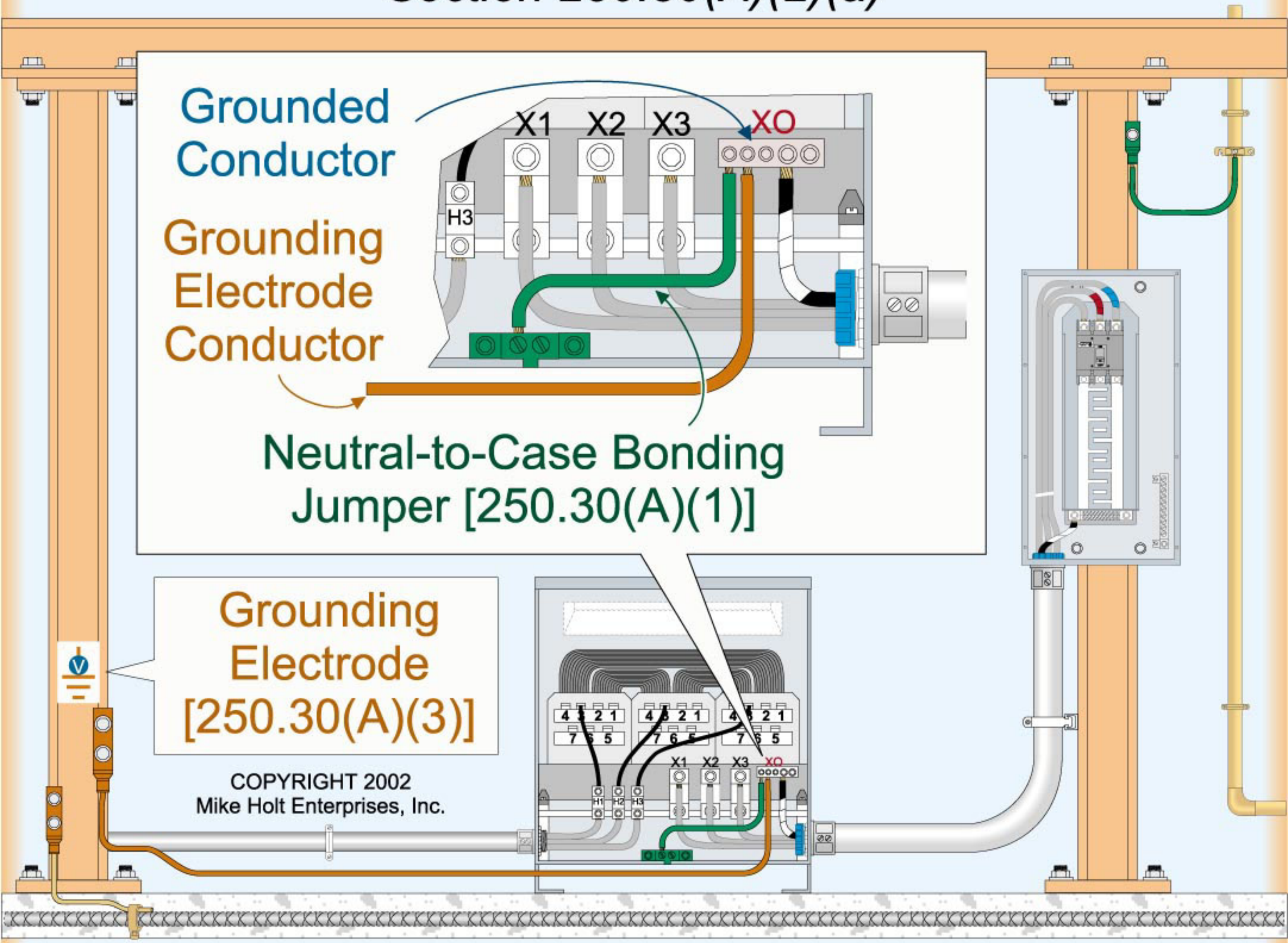

Grounding Electrode Conductor
Article 100 Definition
Service
Separately Derived System
Building or Structure
Grounding Electrode Conductor
COPYRIGHT 2001 Mike Holt Enterprises, Inc.
Grounding Electrode
Grounding Electrode Conductor: The conductor to the grounding electrode for service equipment, building or structure disconnect, or separately derived system.

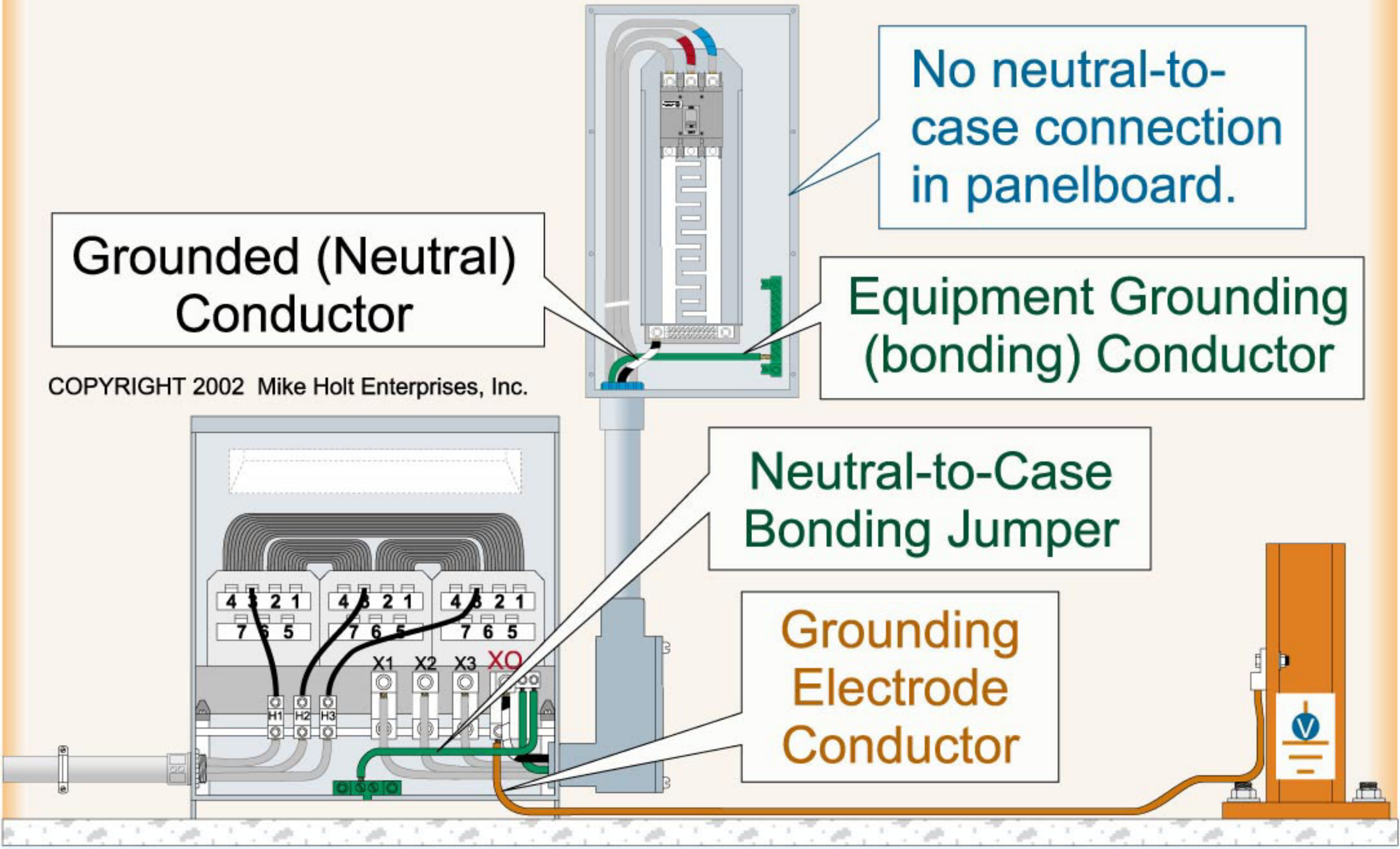
Grounding Single Separately Derived System

Section 250.30(A)(2)(a)



The grounding electrode conductor must connect the grounded (neutral) conductor of the separately derived system to the grounding electrode.

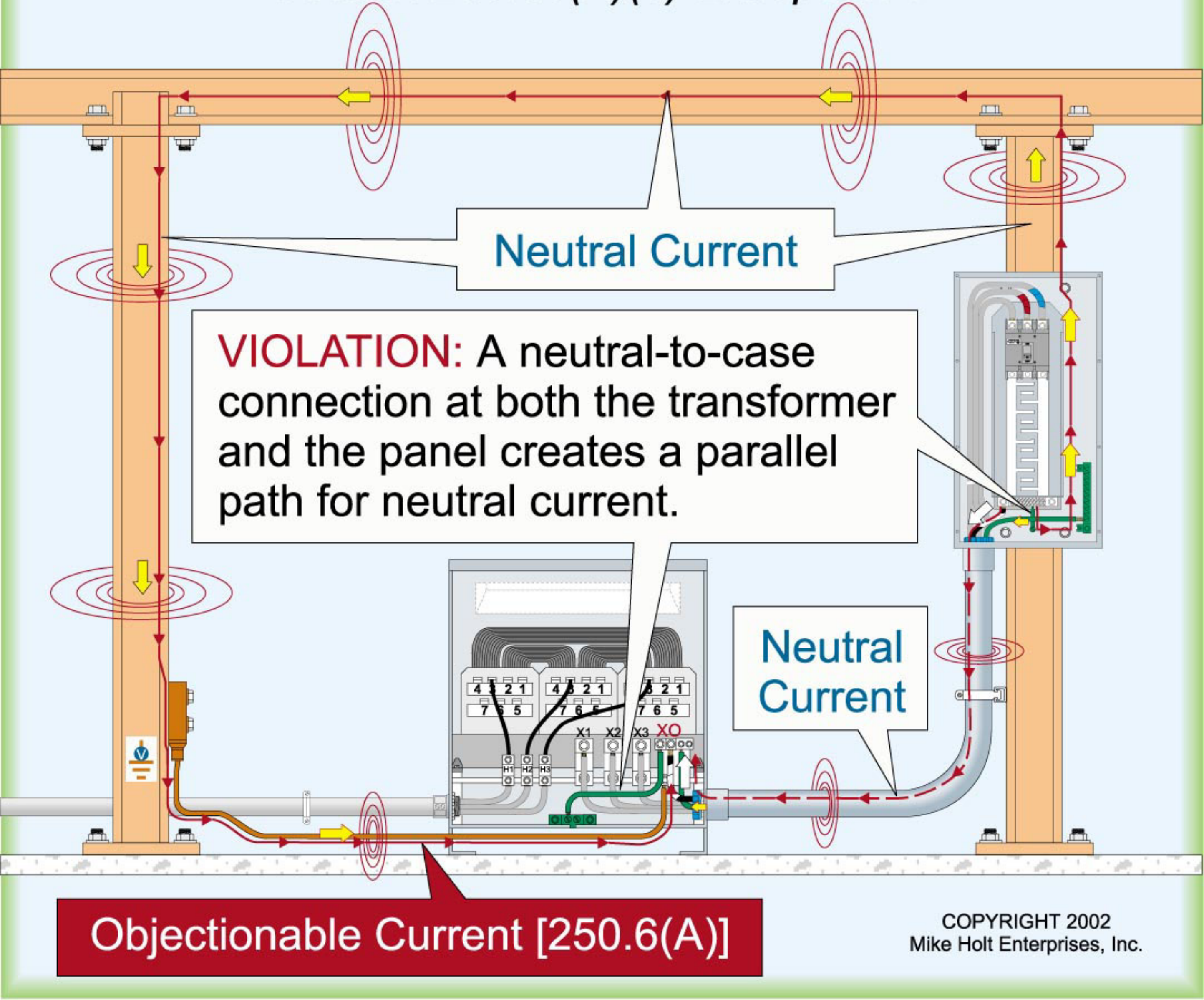
Single Separately Derived System
Grounding Electrode Conductor Connection Point
Section 250.30(A)(2)(a)



To prevent objectionable current on metal parts, the grounding connection must be at the same point where the bonding jumper is installed.

Neutral-to-Case Bond - Multiple Neutral Return Paths

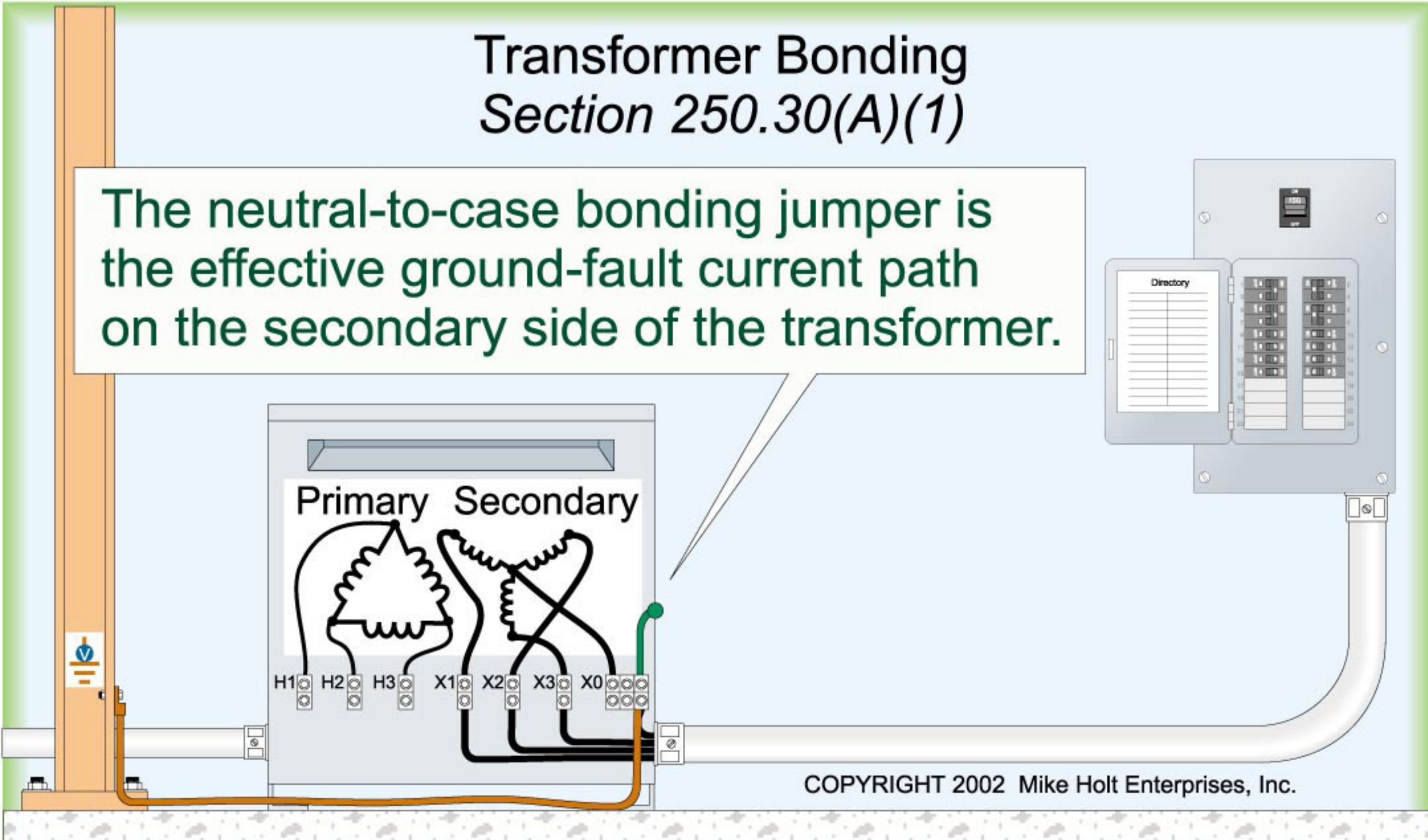
Section 250.30(A)(1) Exception 1



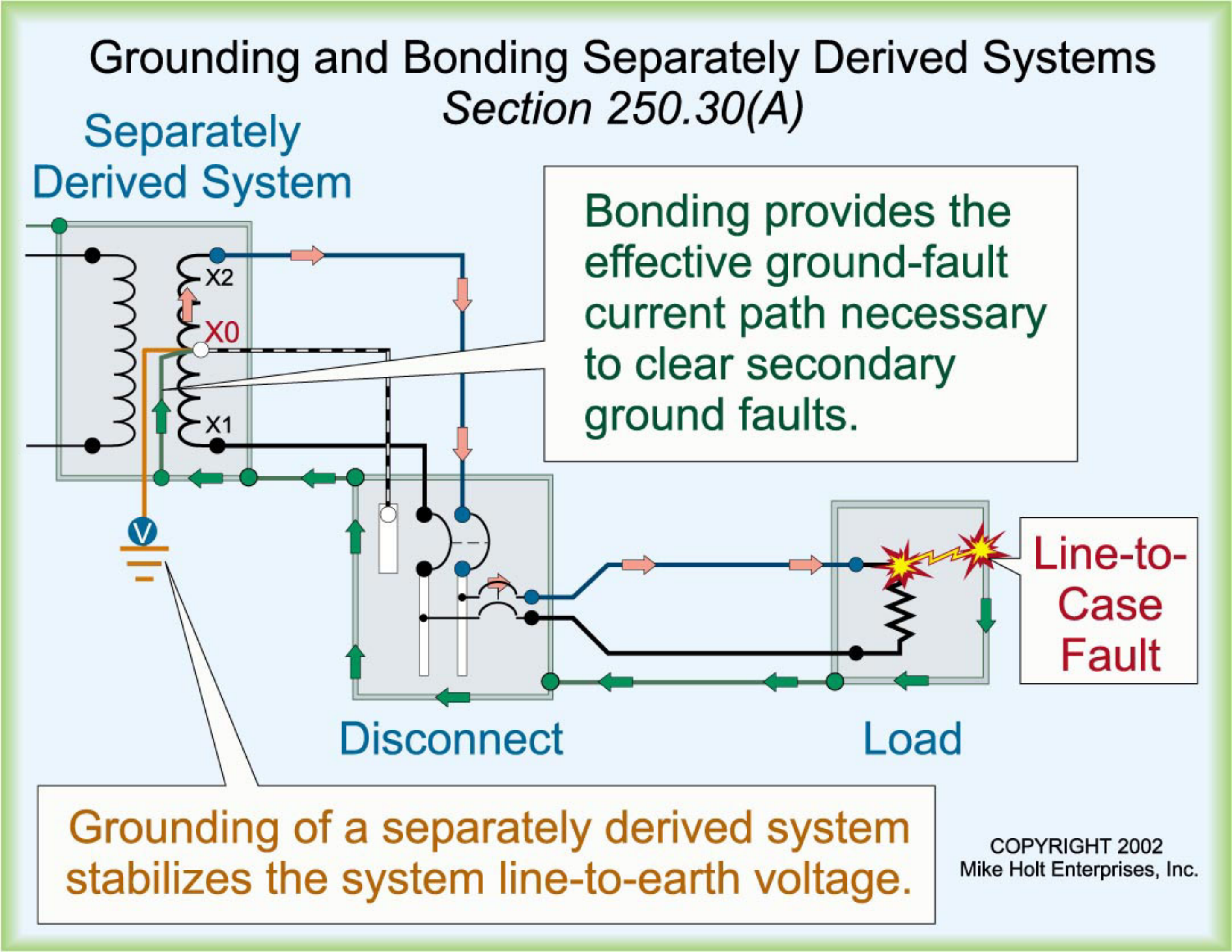
Transformer Bonding

Section 250.30(A)(1)

The neutral-to-case bonding jumper is the effective ground-fault current path on the secondary side of the transformer.



The metal parts of electrical equipment shall be bonded to the grounded (neutral) terminal of the separately derived system. The bonding jumper shall be sized in accordance with Table 250.66.



Grounding and Bonding Separately Derived Systems
Section 250.30(A)
Separately Derived System
Bonding provides the effective ground-fault current path necessary to clear secondary ground faults.
X2
X0
X1
V
Disconnect
Load
Line-to-Case Fault
Grounding of a separately derived system stabilizes the system line-to-earth voltage.
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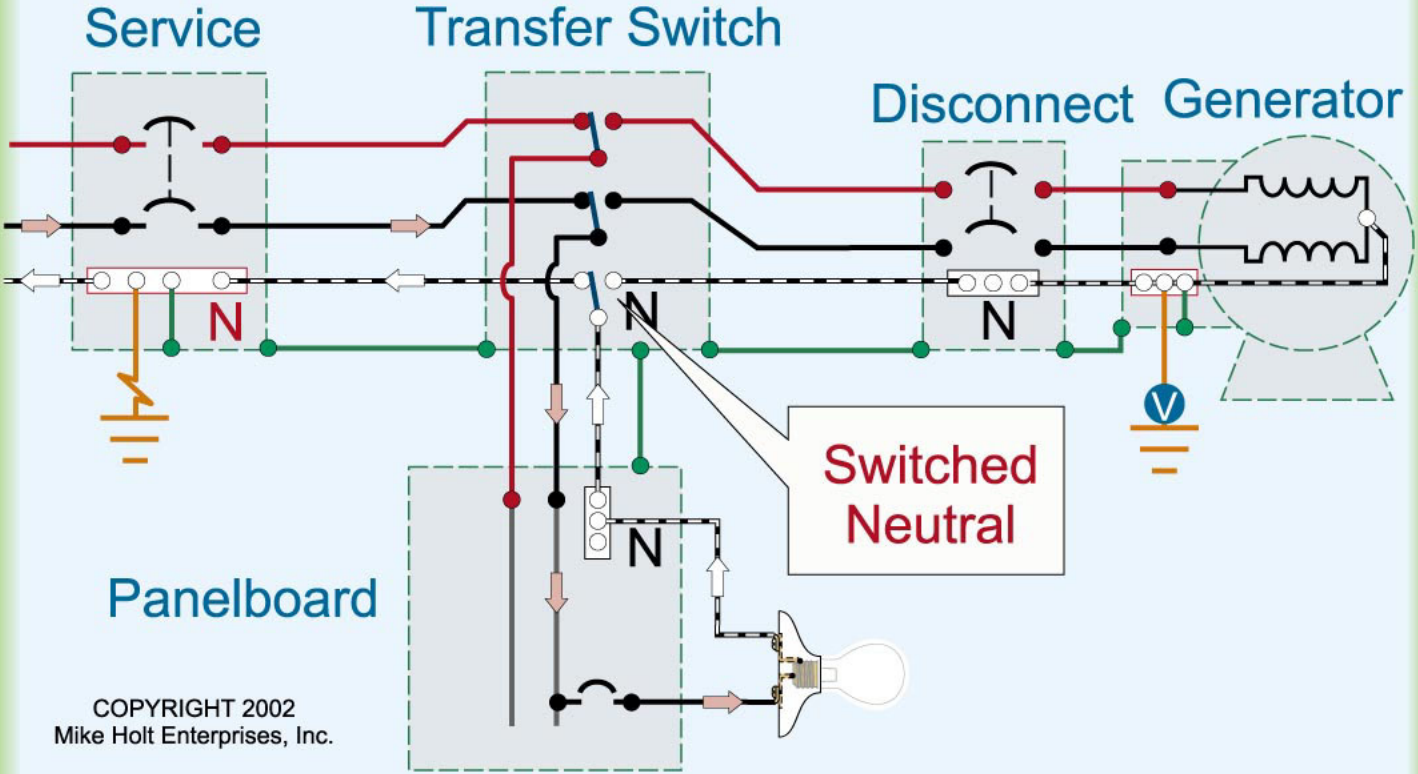
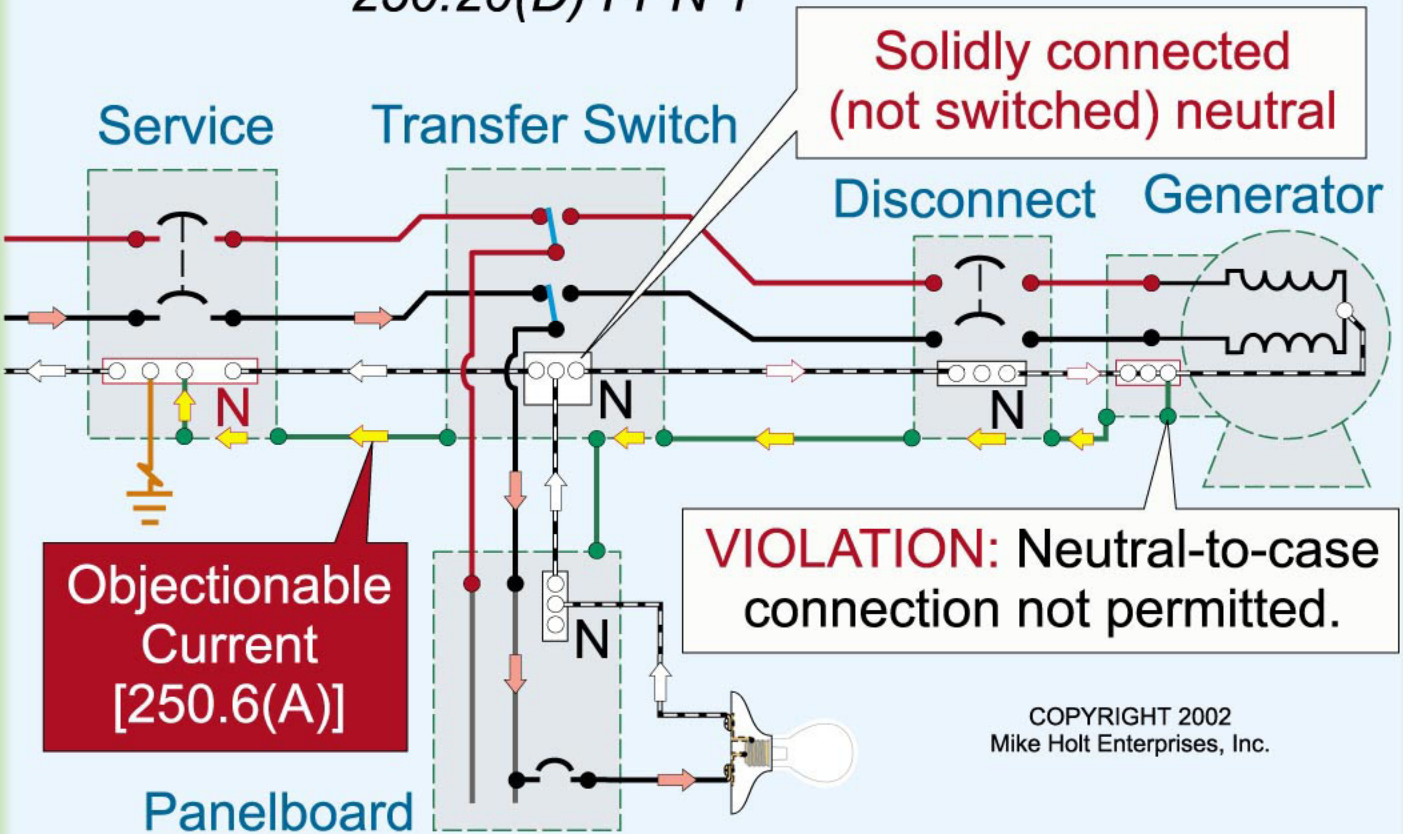
Separately Derived System - Generator
Section 250.30(A)(1)



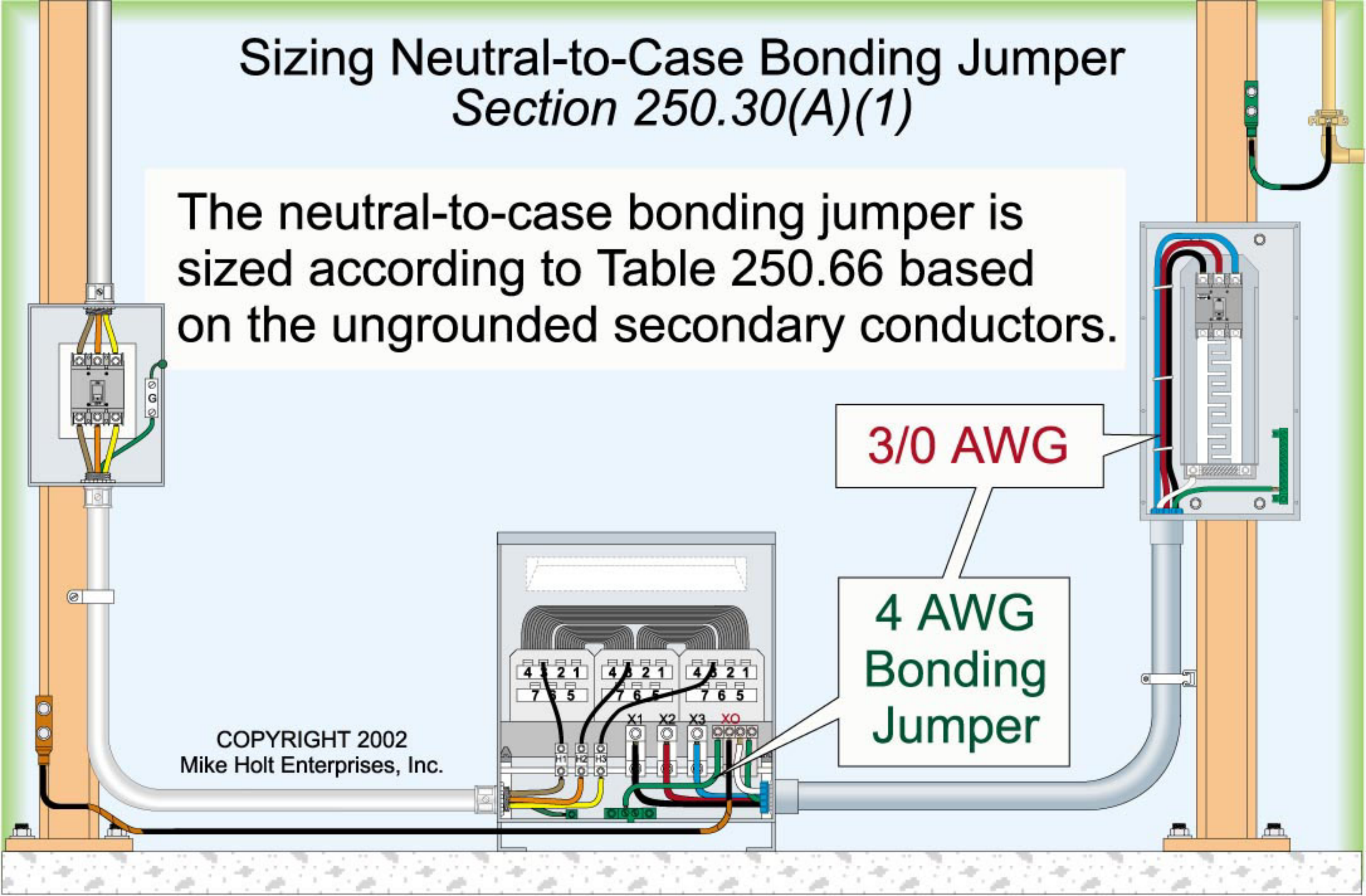
A generator can be a separately derived system if the grounded conductor is opened in the transfer switch.

Generator - Not Separately Derived System

250.20(D) FPN 1



A generator is not a separately derived system if the grounded conductor is not opened in the transfer switch.



Sizing Neutral-to-Case Bonding Jumper
Section 250.30(A)(1)
The neutral-to-case bonding jumper is sized according to Table 250.66 based on the ungrounded secondary conductors.
G
3/0 AWG
4 AWG Bonding Jumper
4 3 2 1
7 6 5
H1
H2
H3
X1
X2
X3
XO
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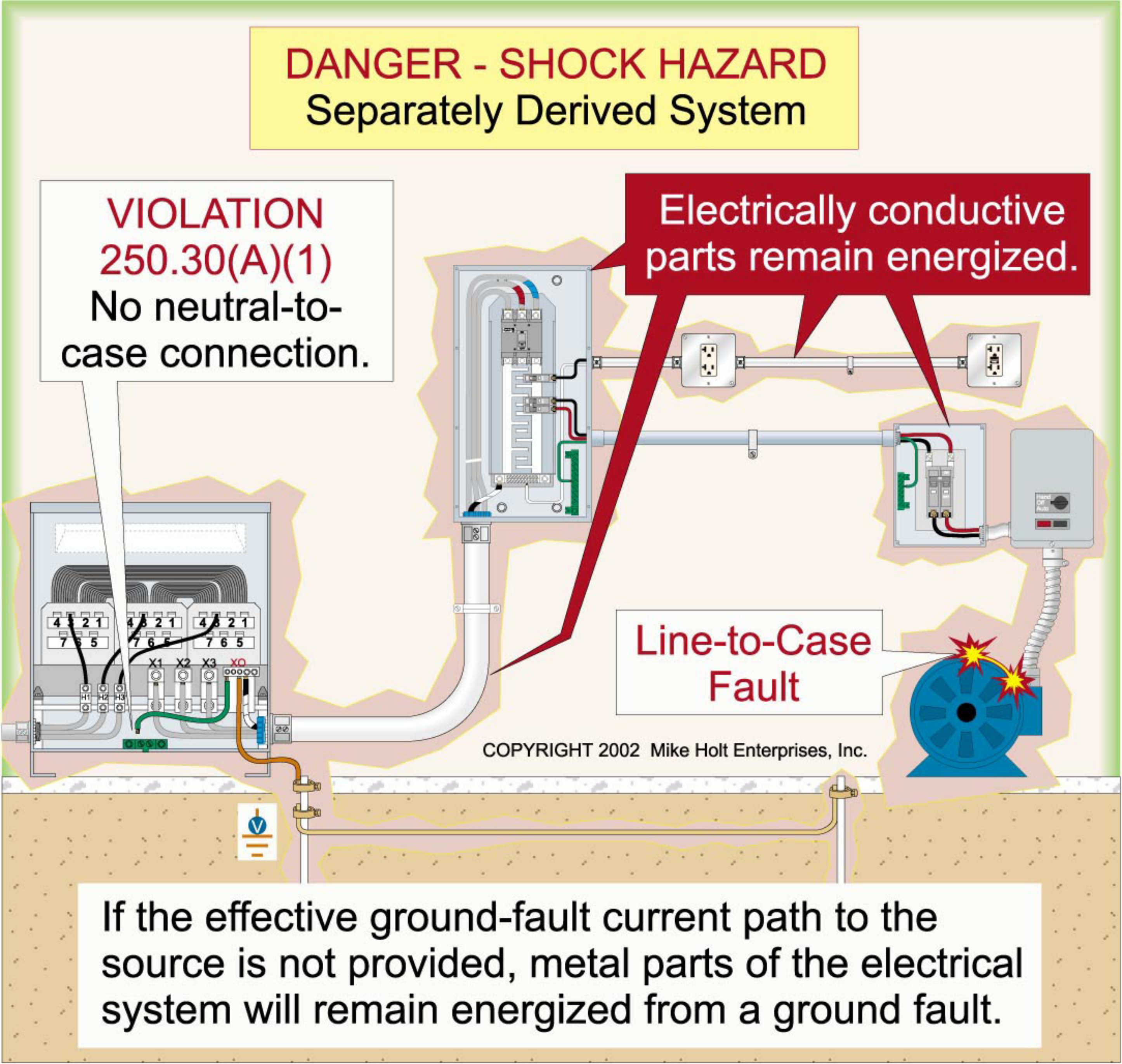
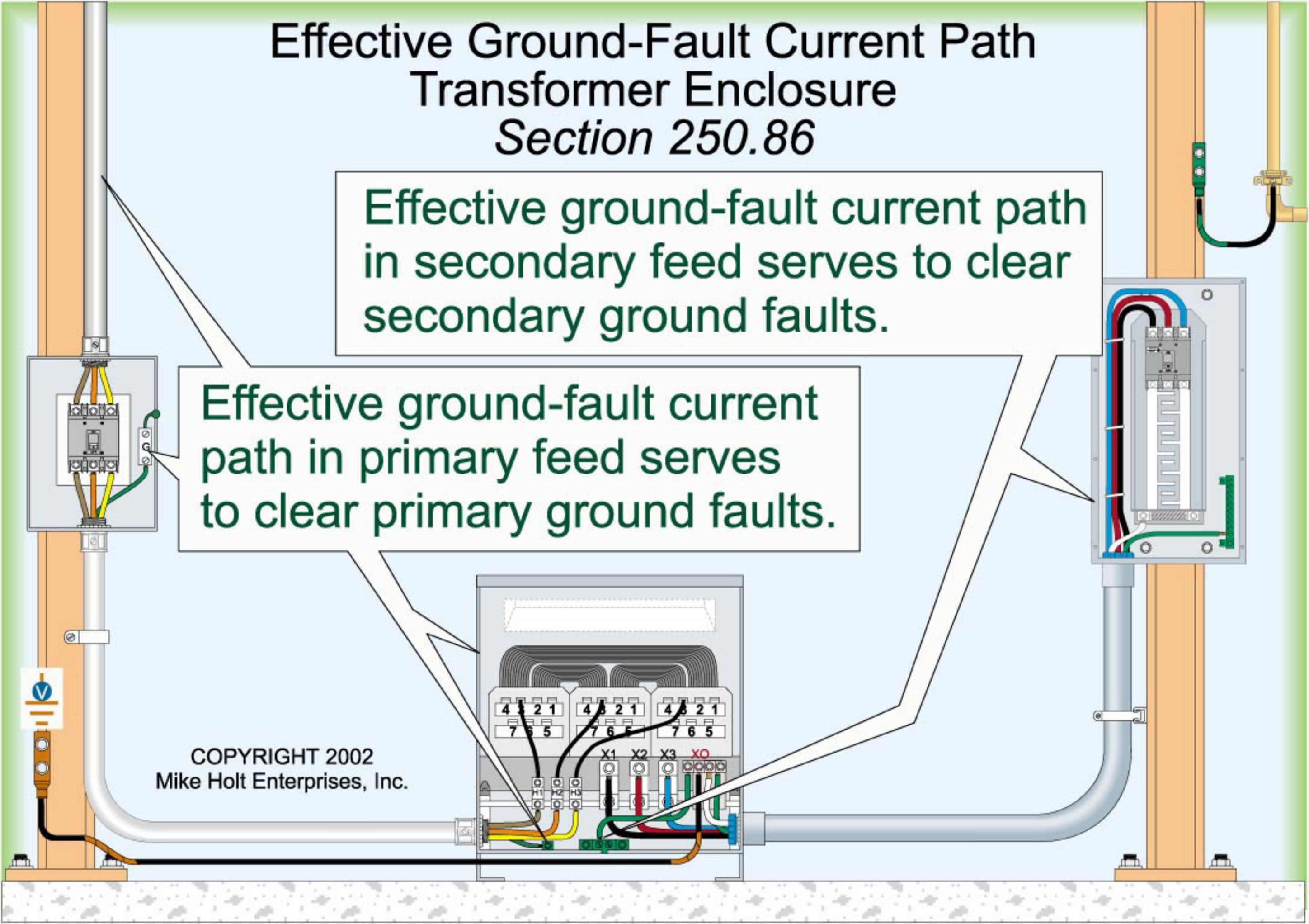


DANGER - SHOCK HAZARD
Separately Derived System
VIOLATION
250.30(A)(1)
No neutral-to-case connection.
Electrically conductive parts remain energized.
Line-to-Case Fault
COPYRIGHT 2002 Mike Holt Enterprises, Inc.
If the effective ground-fault current path to the source is not provided, metal parts of the electrical system will remain energized from a ground fault.



Effective Ground-Fault Current Path
Transformer Enclosure
Section 250.86
Effective ground-fault current path in secondary feed serves to clear secondary ground faults.
Effective ground-fault current path in primary feed serves to clear primary ground faults.
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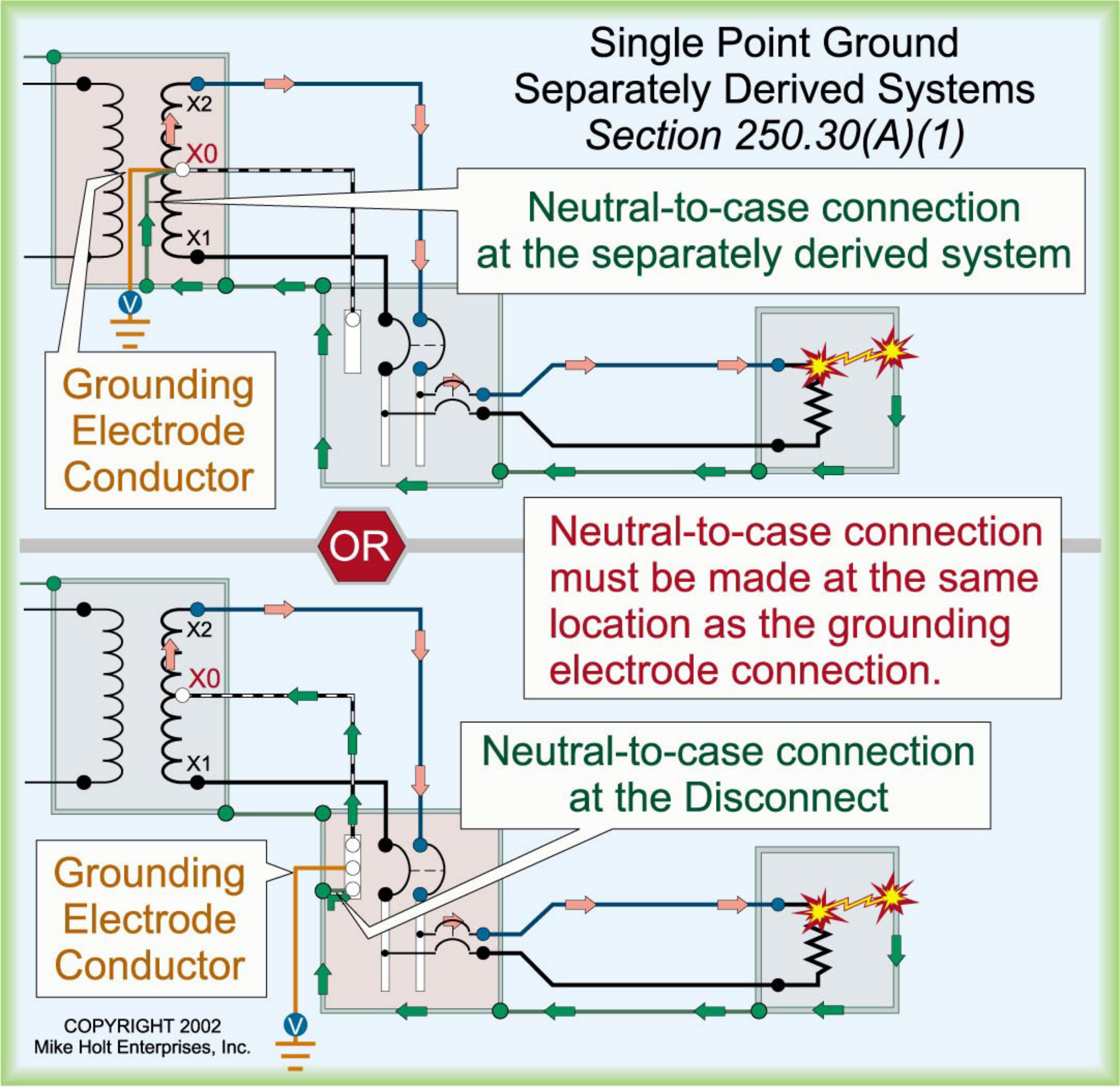
Mike Holt Enterprises, Inc.
H1
H2
H3
X1
X2
X3
XO


Single Point Ground
Separately Derived Systems
Section 250.30(A)(1)
X2
X0
X1
Neutral-to-case connection
at the separately derived system
Grounding
Electrode
Conductor
V
OR
Neutral-to-case connection
must be made at the same
location as the grounding
electrode connection.
X2
X0
X1
Neutral-to-case connection
at the Disconnect
Grounding
Electrode
Conductor
V
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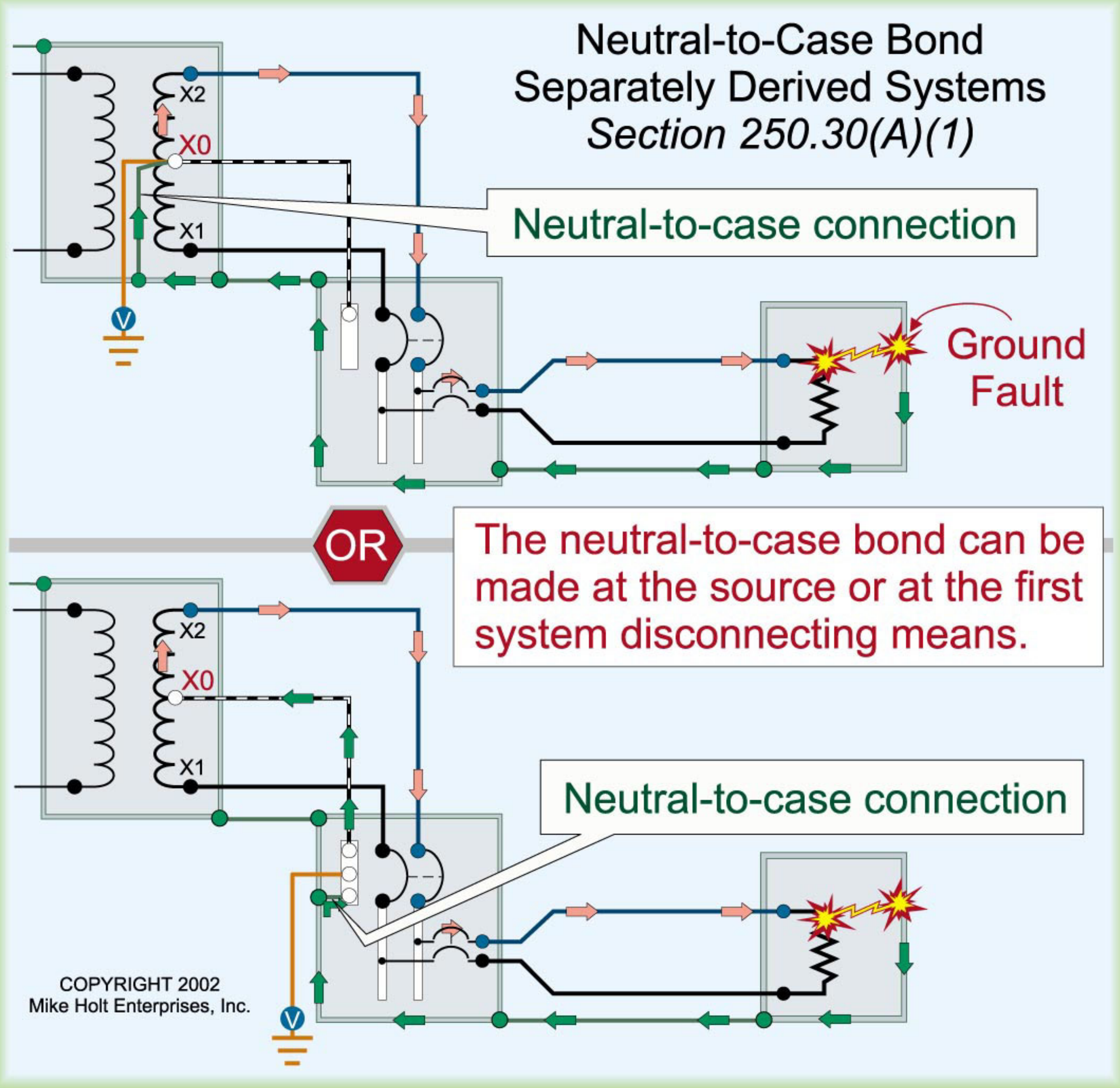

Neutral-to-Case Bond
Separately Derived Systems
Section 250.30(A)(1)
X2
X0
X1
Neutral-to-case connection
Ground
Fault
OR
The neutral-to-case bond can be made at the source or at the first system disconnecting means.
X2
X0
X1
Neutral-to-case connection
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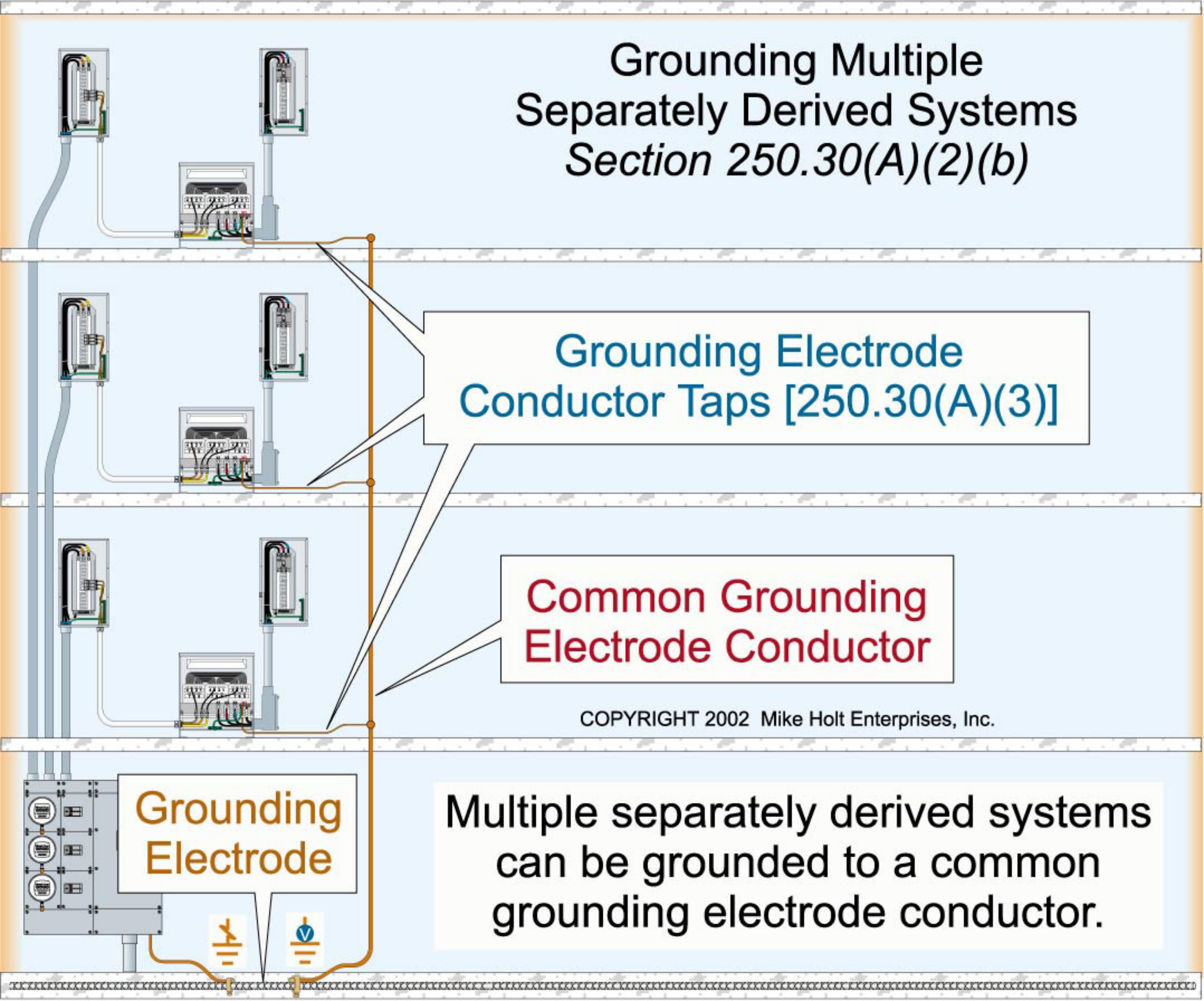
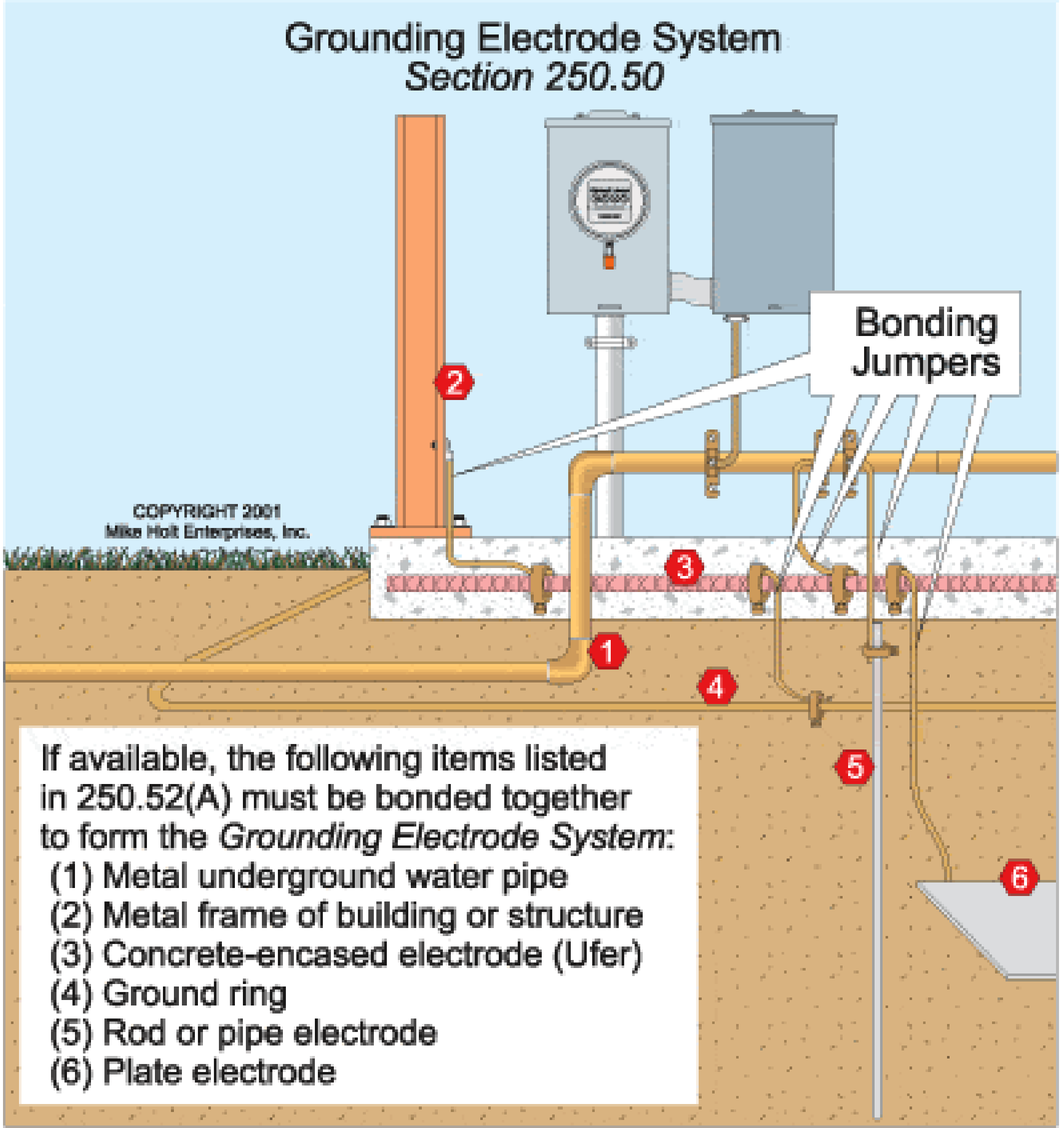


Grounding Multiple
Separately Derived Systems
Section 250.30(A)(2)(b)
Grounding Electrode Conductor Taps [250.30(A)(3)]
Common Grounding Electrode Conductor
Grounding Electrode
Multiple separately derived systems can be grounded to a common grounding electrode conductor.


Grounding Electrode System
Section 250.50
Bonding Jumpers
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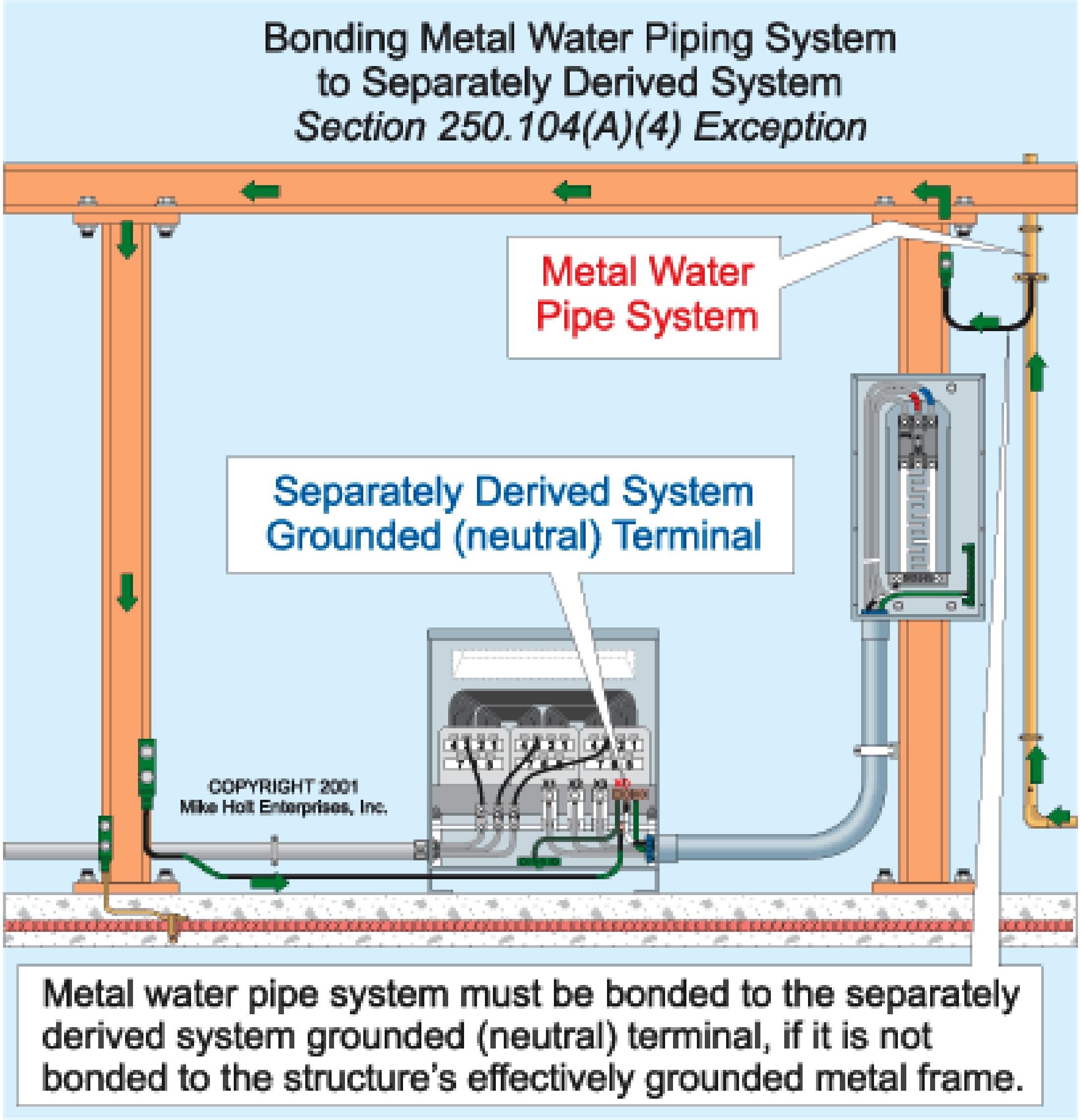
1
2
3
4
5
6
If available, the following items listed in 250.52(A) must be bonded together to form the Grounding Electrode System:
(1) Metal underground water pipe
(2) Metal frame of building or structure
(3) Concrete-encased electrode (Ufer)
(4) Ground ring
(5) Rod or pipe electrode
(6) Plate electrode



Bonding Metal Water Piping System
to Separately Derived System
Section 250.104(A)(4) Exception
Metal Water
Pipe System
Separately Derived System
Grounded (neutral) Terminal
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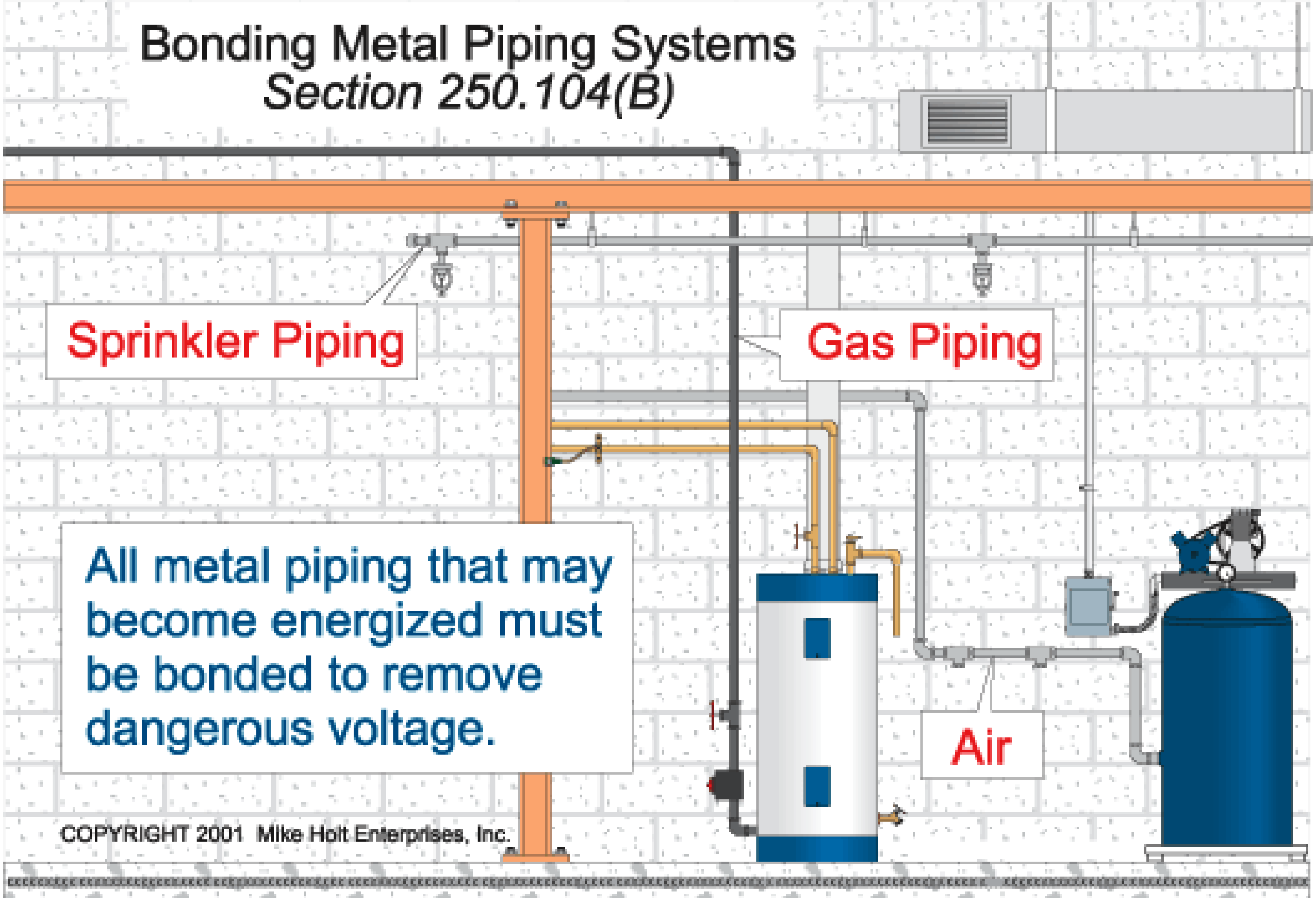
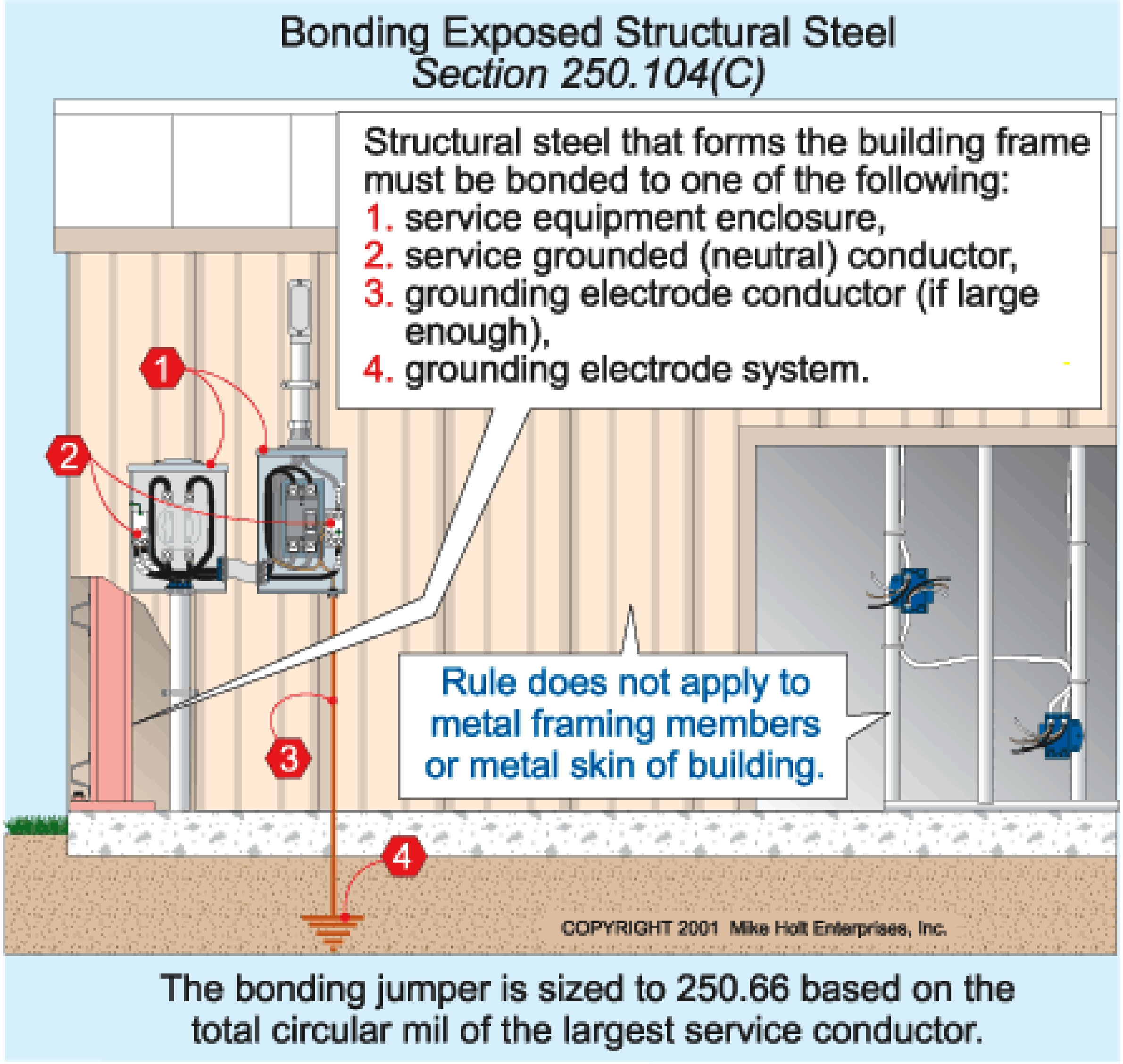
Metal water pipe system must be bonded to the separately derived system grounded (neutral) terminal, if it is not bonded to the structure's effectively grounded metal frame.



The equipment grounding conductor for the circuit that may energize the piping can serve as the bonding means.


Bonding Exposed Structural Steel
Section 250.104(C)
Structural steel that forms the building frame must be bonded to one of the following:
1. service equipment enclosure,
2. service grounded (neutral) conductor,
3. grounding electrode conductor (if large enough),
4. grounding electrode system.
1
2
3
4
Rule does not apply to metal framing members or metal skin of building.
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The bonding jumper is sized to 250.66 based on the total circular mil of the largest service conductor.

250.26 Conductor to Be Grounded — Alternating-Current Systems

For ac premises wiring systems, the conductor to be grounded shall be as specified in the following:

(1) Single-phase, 2-wire — one conductor
(2) Single-phase, 3-wire — the neutral conductor
(3) Multiphase systems having one wire common to all phases — the neutral conductor
(4) Multiphase systems where one phase is grounded — one phase conductor
(5) Multiphase systems in which one phase is used as in (2) — the neutral conductor

250.28 Main Bonding Jumper and System Bonding Jumper

For a grounded system, main bonding jumpers and system bonding jumpers shall be installed as follows:

The system bonding jumper performs the same electrical function as the main bonding jumper in a grounded ac system by connecting the EGC(s) to the grounded circuit conductor either at the source of a separately derived system or at the first disconnecting means supplied by the source. The term *system bonding jumper* is used to distinguish it from the main bonding jumper, which is installed in service equipment. See the commentary following the definition of *bonding jumper, system* in Article 100.

(A) Material. Main bonding jumpers and system bonding jumpers shall be of copper or other corrosion-resistant material. A main bonding jumper and a system bonding jumper shall be a wire, bus, screw, or similar suitable conductor.

(B) Construction. Where a main bonding jumper or a system bonding jumper is a screw only, the screw shall be identified with a green finish that shall be visible with the screw installed.

This identification requirement makes it possible to readily distinguish the bonding jumper screw from other screws in the grounded conductor terminal bar, to ensure that the required bonding connection has been made.

(C) Attachment. Main bonding jumpers and system bonding jumpers shall be connected in the manner specified by the applicable provisions of 250.8.

(D) Size. Main bonding jumpers and system bonding jumpers shall be sized in accordance with 250.28(D)(1) through (D)(3).

(1) General. Main bonding jumpers and system bonding jumpers shall not be smaller than specified in Table 250.102(C)(1).

In a grounded system, the primary function of the main bonding jumper and of the system bonding jumper is to create the link for ground-fault current between the EGCs and the grounded conductor. Table 250.102(C)(1) is used to establish the minimum size of main and system bonding jumpers where the ungrounded conductors do not exceed 1100 kcmil copper or 1750 kcmil aluminum. Unlike the grounding electrode conductor, which carries current to the ground (via connection to a grounding electrode), the main and system bonding jumpers are placed directly in the supply-side ground-fault current return path. Where the largest ungrounded supply conductor exceeds the parameters of Table 250.102(C)(1), a proportional relationship between the ungrounded conductor and the main or system bonding jumper is necessary to be maintained.

Where large capacity services or separately derived systems are installed, the main or system bonding jumper is likely to be larger than the grounding electrode conductor. Section 250.28(D)(1) requires that where the service-entrance conductors are larger than 1100 kcmil copper or 1750 kcmil aluminum, the bonding jumper must have a cross-sectional area of not less than 12½ percent of the cross-sectional area of the largest phase conductor or largest phase conductor set. In equipment such as panelboards or switchboards that are listed for use as service equipment, the manufacturer provides a bonding jumper that can be installed as the main or system bonding jumper. Thus, it is not necessary to duplicate this bonding jumper with another one sized in accordance with 250.28(D)(1).

(2) Main Bonding Jumper for Service with More Than One Enclosure. Where a service consists of more than a single enclosure as permitted in 230.71(A), the main bonding jumper for each enclosure shall be sized in accordance with 250.28(D)(1) based on the largest ungrounded service conductor serving that enclosure.

Where a service consists of more than one disconnecting means in separate enclosures, each line-side service equipment enclosure is treated separately, as depicted in Exhibit 250.11. The main bonding jumper in the left enclosure is a 4 AWG copper conductor. Based on the 3/0 AWG ungrounded service conductors supplying the 200 ampere circuit breaker and Table 250.102(C), the minimum-size main bonding jumper for this service equipment enclosure is 4 AWG copper. Similarly, the 1/0 AWG main bonding jumper for the enclosure on the right is derived from Table 250.102(C)(1) using the 500 kcmil ungrounded service conductors.

The main bonding jumpers and the grounded conductors for the two disconnecting means enclosures shown in Exhibit 250.11 are sized using Table 250.102(C)(1) and the grounding electrode conductor is sized using Table 250.66. First, the grounding electrode conductor at 2/0 AWG is full-sized based on Table 250.66 using the 750 kcmil ungrounded service conductor as the basis for selection. In some conditions, the grounding electrode conductor is permitted to be sized smaller than what is required in the table, which depends on the type of electrode that is used.

Next, the grounded conductor run to each enclosure in accordance with 250.24(B) is sized using Table 250.102(C)(1) as the minimum size permitted. For each enclosure, the minimum size grounded conductor is established based on the largest ungrounded conductor serving that enclosure. The grounded

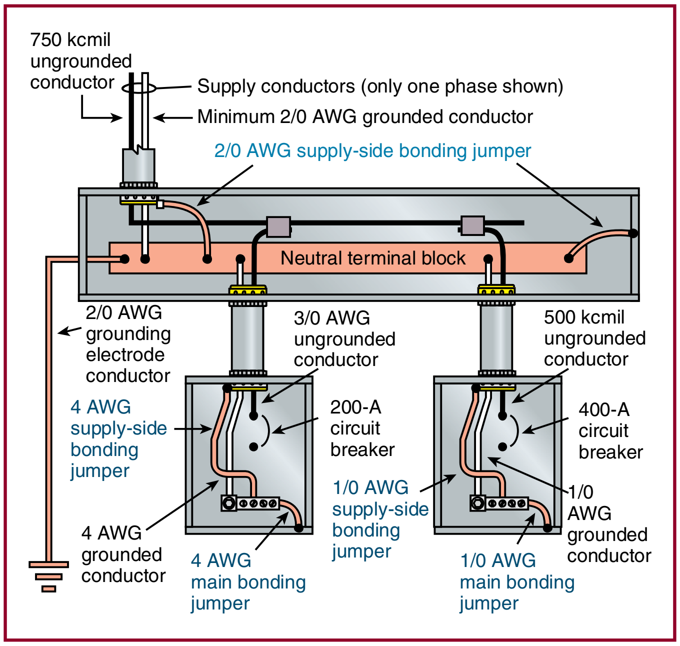

EXHIBIT 250.11 *An example of the bonding requirements for service equipment.*

conductor is also subject to the requirements of 220.61 covering the conductor's capacity for unbalanced load, which could result in having to increase the size to larger than what was determined from Table 250.102(C)(1).

Finally, supply-side bonding jumpers are used to bond the three metal conduits containing service conductors and the metal wireway located above the two service equipment enclosures. These bonding jumpers are also sized from Table 250.102(C)(1). The bonding jumpers for the raceways are sized based on the ungrounded conductors contained in each metal service raceway.

For the metal conduit entering the top of the wireway and for the wireway itself shown in Exhibit 250.11, the bonding jumper is sized from Table 250.102(C)(1) based on the 750 kcmil main service-entrance conductors and cannot be less than a 2/0 AWG copper conductor. The service-entrance conductors to the enclosures are 3/0 AWG and 500 kcmil copper, based on the loads supplied from each enclosure. The supply-side bonding jumpers for the short nipples are sized based on the size of the phase conductors supplying each disconnecting means. In this case, the metal raceway nipples containing the 3/0 AWG and 500 kcmil ungrounded service conductors require minimum 4 AWG and 1/0 AWG copper supply-side bonding jumpers, respectively.

Application Example

A service is supplied by four 500 kcmil conductors in parallel for each phase; the minimum cross-sectional area of the bonding jumper is calculated as follows:

$$4 \times 500 \text{ kcmil} = 2000 \text{ kcmil}$$

Therefore, the main or system bonding jumper cannot be less than 12½ percent of 2000 kcmil, which results in a 250 kcmil copper conductor. The copper grounding electrode conductor for this set of conductors, based on Table 250.66, is not required to be larger than 3/0 AWG.

(3) Separately Derived System with More Than One Enclosure. Where a separately derived system supplies more than a single enclosure, the system bonding jumper for each enclosure shall be sized in accordance with 250.28(D)(1) based on the largest ungrounded feeder conductor serving that enclosure, or a single system bonding jumper shall be installed at the source and sized in accordance with 250.28(D)(1) based on the equivalent size of the largest supply conductor determined by the largest sum of the areas of the corresponding conductors of each set.

To determine the size of the system bonding jumper, all of the ungrounded conductors serving the multiple enclosures must be evaluated and the phase that yields the largest collective circular mil area is the basis for sizing the system bonding jumper.

Calculation Example 1

A 225-kVA transformer supplies three, 3-phase, 208Y/120-volt secondary feeders that terminate in panelboards with 200-ampere main breakers. The ungrounded conductors for all three phases are 3/0 AWG copper with THHW insulation. A system bonding jumper is installed at each of the panelboards. Determine the size of the system bonding jumpers at each enclosure using Option 1.

Solution

Size of largest ungrounded conductor supplying individual panelboard:

3/0 AWG copper

System bonding jumper [from Table 250.102(C)(1)]:

3/0 AWG copper ungrounded conductors → 4 AWG copper

or 2 AWG aluminum system bonding jumper

Depending on how the transformer and the panelboards are arranged to prevent parallel neutral current paths on raceways and enclosures, the system bonding jumper may be internal to the panelboard using the manufacturer-supplied equipment or it may be installed in the transformer enclosure so that it connects any supply-side bonding jumpers to the neutral terminal (XO) of the transformer.

Calculation Example 2

The same electrical equipment arrangement as in the previous example applies. In this case, however, the system bonding jumper is installed at the transformer and connects the transformer neutral terminal (XO) to individual supply-side bonding jumpers that are installed between the panelboard EGC terminals and a terminal bus attached to the transformer enclosure. Determine the size of the system bonding jumper using Option 2.

TABLE 250.102(C)(1) *Grounded Conductor, Main Bonding Jumper, System Bonding Jumper, and Supply-Side Bonding Jumper for Alternating-Current Systems*

Size of Largest Ungrounded Conductor or Equivalent Area for Parallel Conductors (AWG/kcmil)		Size of Grounded Conductor or Bonding Jumper* (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	See Notes	

Notes:

1. If the ungrounded supply conductors are larger than 1100 kcmil copper or 1750 kcmil aluminum, the grounded conductor or bonding jumper shall have an area not less than 12½ percent of the area of the largest ungrounded supply conductor or equivalent area for parallel supply conductors. The grounded conductor or bonding jumper shall not be required to be larger than the largest ungrounded conductor or set of ungrounded conductors.

2. If the ungrounded supply conductors and the bonding jumper are of different materials (copper, aluminum, or copper-clad aluminum), the minimum size of the grounded conductor or bonding jumper shall be based on the assumed use of ungrounded supply conductors of the same material as the grounded conductor or bonding jumper and will have an ampacity equivalent to that of the installed ungrounded supply conductors.

3. If multiple sets of service-entrance conductors are used as permitted in 230.40, Exception No. 2, or if multiple sets of ungrounded supply conductors are installed for a separately derived system, the equivalent size of the largest ungrounded supply conductor(s) shall be determined by the largest sum of the areas of the corresponding conductors of each set.

4. If there are no service-entrance conductors, the supply conductor size shall be determined by the equivalent size of the largest service-entrance conductor required for the load to be served.

*For the purposes of this table, the term *bonding jumper* refers to main bonding jumpers, system bonding jumpers, and supply-side bonding jumpers.

Similar to the way that the main bonding jumper is sized per 250.28(D), supply-side bonding jumpers are sized based on the size of the ungrounded conductors of which they are associated. For small capacity installations, the bonding jumper size is based on the size of the largest ungrounded conductor in the supply circuit. The supply-side bonding jumper is selected from Table 250.102(C)(1). If the ungrounded conductors are larger than 1100 kcmil copper or 1750 kcmil aluminum, the size of the supply-side bonding jumper(s) is calculated based on a 12.5-percent sizing relationship between it and the ungrounded conductor. Where an installation consists of multiple raceways for parallel conductors, an individual supply-side bonding jumper can be installed for each raceway, and this jumper is sized based on the size of the ungrounded conductors in that raceway.

Application Example

A 3-phase, 1600-ampere service is supplied using five 350 kcmil THWN conductors per phase. The parallel conductors are installed in five separate runs of rigid metal conduit. In accordance with 300.12, Exception No. 2, a supply-side bonding jumper is needed for each raceway at the point it enters the open-bottom switchboard. Using 250.102(C)(2), determine the size of the supply-side bonding jumper for each raceway.

Step 1. Determine the size of the largest ungrounded conductor in each raceway — 350 kcmil.

Step 2. Determine the size of the supply-side bonding jumper for each raceway using the "over 3/0 through 350" row in Table 250.102(C). This results in a 2 AWG copper or 1/0 AWG aluminum supply-side bonding jumper.

Solution

If a single supply-side bonding jumper is used to bond all five raceways, the size is determined in accordance with 250.102(C)(1) using the following calculation:

5 parallel 350 kcmil conductors:

$$5 \times 350 = 1750 \text{ kcmil}$$

This total exceeds 1100 kcmil; therefore, the total is multiplied by 0.125 (12.5 percent)

$$1750 \text{ kcmil} \times 0.125 = 218.75 \text{ kcmil}$$

Solution

STEP 1. Size the individual supply-side bonding jumpers from each of the panelboard equipment grounding terminals to the terminal bus in the transformer.

From Table 250.102(C)(1):

3/0 AWG copper ungrounded conductors → 4 AWG copper

or 2 AWG aluminum system bonding jumper

STEP 2. Size the system bonding jumper from the terminal bus in the transformer to the transformer neutral terminal (XO). There are three secondary feeder circuits with 3/0 AWG ungrounded conductors for all phases. Find the cumulative circular mil area of one phase.

From Chapter 9, Table 8:

3/0 AWG = 167,800 circular mils

167,800 circular mils × 3 (number of sets of secondary conductors) = 503,400 circular mils

From Table 250.102(C):

503,400 circular mils copper ungrounded conductors → 1/0 AWG copper

or 3/0 AWG aluminum system bonding jumper

250.30 Grounding Separately Derived Alternating-Current Systems

In addition to complying with 250.30(A) for grounded systems, or as provided in 250.30(B) for ungrounded systems, separately derived systems shall comply with 250.20, 250.21, 250.22, or 250.26, as applicable. Multiple separately derived systems that are connected in parallel shall be installed in accordance with 250.30.

Informational Note No. 1: An alternate ac power source, such as an on-site generator, is not a separately derived system if the grounded conductor is solidly interconnected to a service-supplied system grounded conductor. An example of such a situation is where alternate source transfer equipment does not include a switching action in the grounded conductor and allows it to remain solidly connected to the service-supplied grounded conductor when the alternate source is operational and supplying the load served.

Informational Note No. 2: See 445.13 for the minimum size of conductors that carry fault current.

Exhibits 250.12 and 250.13 depict a 208Y/120-volt, 3-phase, 4-wire electrical service supplying a service disconnecting means to a building. The building also has an alternate or emergency electrical system. A feeder is installed from the service equipment to the normal power terminals of a transfer switch. The emergency or alternate power terminals of the transfer switch are supplied by a feeder that is supplied by a generator with a 208Y/120-volt, 3-phase output. Emergency, legally required standby, and/or optional standby loads can be supplied from the load terminals of the transfer switch in accordance with the applicable requirements of Articles 700, 701, and 702.

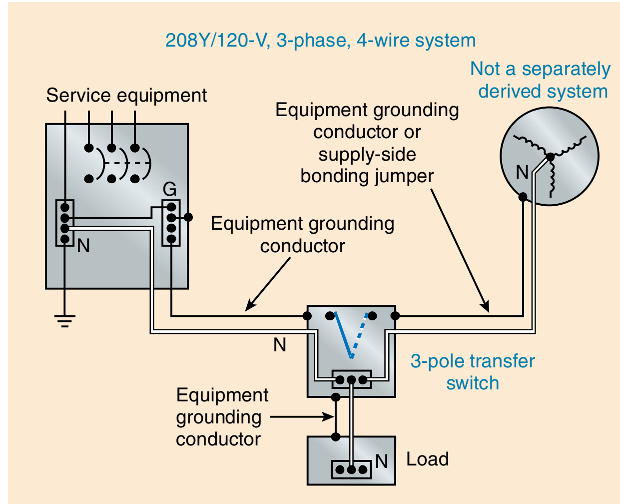

EXHIBIT 250.12 *A 208Y/120-volt, 3-phase, 4-wire system that has a direct electrical connection of the grounded circuit conductor (neutral) to the generator and is therefore not considered a separately derived system.*

In Exhibit 250.12, the neutral conductor from the generator to the load is not disconnected by the transfer switch. The system has a direct electrical connection between the normal grounded system conductor (neutral) and the generator neutral through the neutral bus in the transfer switch, thereby grounding the generator neutral. Because the generator is grounded by connection to the normal system ground, it is not a separately derived system and there are no requirements for grounding the neutral at the generator (see Informational Note No. 1 to 250.30). The conductor installed between the equipment grounding terminal of the transfer switch and the generator frame/equipment grounding terminal is either an EGC or a supply-side bonding jumper, depending on where the first overcurrent device in the generator feeder circuit is located. See 250.35(B) for the requirement covering generators supplying systems that are not separately derived.

In Exhibit 250.13, the grounded conductor (neutral) is connected to the switching contacts of a 4-pole transfer switch. Therefore, the generator system does not have a direct electrical connection to the other supply system grounded conductor (neutral), and the system supplied by the generator is considered separately derived. This separately derived system (3-phase, 4-wire, wye-connected system that supplies line-to-neutral loads) is required to be grounded in accordance with 250.20(B). The methods for grounding the system are specified in 250.30(A).

Section 250.30(A)(1) requires separately derived systems to have a system bonding jumper connected between the generator frame and the grounded circuit conductor (neutral). The grounding electrode conductor from the generator is required to be connected to a grounding electrode. This conductor and the grounding electrode are required to be located as close to the generator as practicable, according to 250.30(A)(4). However,

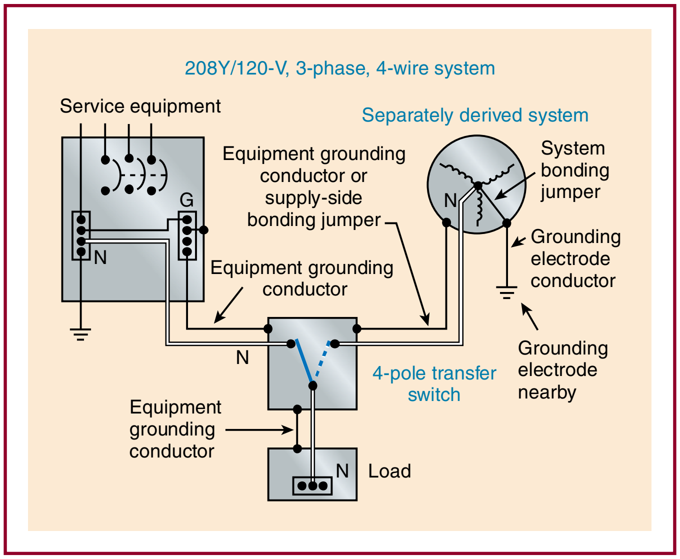

EXHIBIT 250.13 *A 208Y/120-volt, 3-phase, 4-wire system that does not have a direct electrical connection of the grounded circuit conductor (neutral) to the generator and is therefore considered a separately derived system.*

because the generator feeder is supplying a building that is also supplied by an ac service, 250.58 requires both supply systems to be connected to the same grounding electrode system. As is the case with the generator supplying the system in Exhibit 250.12 that is not separately derived, the conductor installed between the equipment grounding terminal of the transfer switch and the generator frame/equipment grounding terminal is either an EGC or a supply-side bonding jumper, depending on where the first overcurrent device in the generator feeder circuit is located.

(A) Grounded Systems. A separately derived ac system that is grounded shall comply with 250.30(A)(1) through (A)(8). Except as otherwise permitted in this article, a grounded conductor shall not be connected to normally non–current-carrying metal parts of equipment, be connected to equipment grounding conductors, or be reconnected to ground on the load side of the system bonding jumper.

Informational Note: See 250.32 for connections at separate buildings or structures and 250.142 for use of the grounded circuit conductor for grounding equipment.

Exception: Impedance grounded neutral system grounding connections shall be made as specified in 250.36 or 250.187, as applicable.

Because separately derived systems have no direct electrical connection, including a solidly connected grounded circuit conductor, to supply conductors originating in another system, grounding and bonding connections for each separately derived system are necessary to establish. A common installation where the requirements in 250.30(A) are applied is a transformer installed as part of the premises wiring system. For example, if the service voltage is 480Y/277 V and loads in the building or structure operate at 120 volts, a transformer is commonly used to develop a separate 208Y/120-V system for lighting and appliance loads.

(1) System Bonding Jumper. An unspliced system bonding jumper shall comply with 250.28(A) through (D). This connection shall be made at any single point on the separately derived system from the source to the first system disconnecting means or overcurrent device, or it shall be made at the source of a separately derived system that has no disconnecting means or overcurrent devices, in accordance with 250.30(A)(1)(a) or (b). The system bonding jumper shall remain within the enclosure where it originates. If the source is located outside the building or structure supplied, a system bonding jumper shall be installed at the grounding electrode connection in compliance with 250.30(C).

See the commentary following 250.28(D) for further information on sizing the system bonding jumper.

Exception No. 1: For systems installed in accordance with 450.6, a single system bonding jumper connection to the tie point of the grounded circuit conductors from each power source shall be permitted.

Exception No. 2: If a building or structure is supplied by a feeder from an outdoor transformer, a system bonding jumper at both the source and the first disconnecting means shall be permitted if doing so does not establish a parallel path for the grounded conductor. If a grounded conductor is used in this manner, it shall not be smaller than the size specified for the system bonding jumper but shall not be required to be larger than the ungrounded conductor(s). For the purposes of this exception, connection through the earth shall not be considered as providing a parallel path.

Exception No. 3: The size of the system bonding jumper for a system that supplies a Class 1, Class 2, or Class 3 circuit, and is derived from a transformer rated not more than 1000 volt-amperes, shall not be smaller than the derived ungrounded conductors and shall not be smaller than 14 AWG copper or 12 AWG aluminum.

(a) *Installed at the Source.* The system bonding jumper shall connect the grounded conductor to the supply-side bonding jumper and the normally non–current-carrying metal enclosure.

(b) *Installed at the First Disconnecting Means.* The system bonding jumper shall connect the grounded conductor to the supply-side bonding jumper, the disconnecting means enclosure, and the equipment grounding conductor(s).

The supply-side bonding jumper installed between the separately derived system enclosure and the enclosure of the first system disconnecting means provides the circuit ground-fault current, whether the system bonding jumper is installed at the source enclosure or at the disconnecting means enclosure. The supply-side bonding jumper can be a wire that is sized per 250.102(C), or it can be rigid metal conduit, intermediate metal conduit, or electrical metallic tubing installed between the two enclosures. Where the system operates at over 250 volts to ground, the raceway connections to enclosures must be made as specified in 250.97.

Application Example

The source of a separately derived system is a 75-kVA dry-type transformer. Liquidtight flexible metal conduit is used as the wiring method between the transformer and the 200-ampere fusible safety switch that is the first system disconnecting means. The system bonding jumper is installed in the safety switch enclosure. The ungrounded conductors are 3/0 AWG copper. The wiring method necessitates the installation of a wire-type supply-side bonding jumper. What is the minimum size for this bonding jumper?

Solution

The requirement covering the minimum size for the supply-side bonding jumper is 250.102(C). This section refers to Table 250.102(C)(1) for sizing supply-side bonding jumpers where the ungrounded supply conductors are not greater than 1100 kcmil copper or 1750 kcmil aluminum. In this example, the largest ungrounded conductor size (3/0 AWG copper) is not greater than 1100 kcmil copper, which is the point at which 250.102(C) requires the bonding jumper size be calculated. Therefore, the supply-side bonding jumper size can be selected directly from Table 250.102(C)(1).

From Table 250.102(C)(1), 3/0 AWG ungrounded conductors = 4 AWG copper or 2 AWG aluminum supply-side bonding jumper. The bonding jumper installed can be a bare, covered, or insulated conductor and can be installed inside the raceway or, where the length of the bonding jumper does not exceed 6 feet, it can be installed outside and routed with the raceway.

(2) Supply-Side Bonding Jumper. If the source of a separately derived system and the first disconnecting means are located in separate enclosures, a supply-side bonding jumper shall be installed with the circuit conductors from the source enclosure to the first disconnecting means. A supply-side bonding jumper shall not be required to be larger than the derived ungrounded conductors. The supply-side bonding jumper shall be permitted to be of nonflexible metal raceway type or of the wire or bus type as follows:

(a) A supply-side bonding jumper of the wire type shall comply with 250.102(C), based on the size of the derived ungrounded conductors.

(b) A supply-side bonding jumper of the bus type shall have a cross-sectional area not smaller than a supply-side bonding jumper of the wire type as determined in 250.102(C).

Exception: A supply-side bonding jumper shall not be required between enclosures for installations made in compliance with 250.30(A)(1), Exception No. 2.

(3) Grounded Conductor. If a grounded conductor is installed and the system bonding jumper connection is not located at the source, 250.30(A)(3)(a) through (A)(3)(d) shall apply.

(a) *Sizing for a Single Raceway.* The grounded conductor shall not be smaller than specified in Table 250.102(C)(1).

(b) *Parallel Conductors in Two or More Raceways.* If the ungrounded conductors are installed in parallel in two or more raceways, the grounded conductor shall also be installed in parallel. The size of the grounded conductor in each raceway shall be based on the total circular mil area of the parallel derived ungrounded conductors in the raceway as indicated in 250.30(A)(3)(a), but not smaller than 1/0 AWG.

Informational Note: See 310.10(H) for grounded conductors connected in parallel.

(c) *Delta-Connected System.* The grounded conductor of a 3-phase, 3-wire delta system shall have an ampacity not less than that of the ungrounded conductors.

(d) *Impedance Grounded System.* The grounded conductor of an impedance grounded neutral system shall be installed in accordance with 250.36 or 250.187, as applicable.

The requirements of 250.30(A)(3)(a) and (b) are similar to those in 250.24(C)(1) and (C)(2) for the grounded service conductor. In addition, grounded and neutral conductors that carry current as part of normal circuit operation are required to be sized in accordance with 220.61.

(4) Grounding Electrode. The grounding electrode shall be as near as practicable to, and preferably in the same area as, the grounding electrode conductor connection to the system. The grounding electrode shall be the nearest of one of the following:

(1) Metal water pipe grounding electrode as specified in 250.52(A)(1)
(2) Structural metal grounding electrode as specified in 250.52(A)(2)

Exception No. 1: Any of the other electrodes identified in 250.52(A) shall be used if the electrodes specified by 250.30(A)(4) are not available.

Exception No. 2 to (1) and (2): If a separately derived system originates in listed equipment suitable for use as service equipment, the grounding electrode used for the service or feeder equipment shall be permitted as the grounding electrode for the separately derived system.

Informational Note No. 1: See 250.104(D) for bonding requirements for interior metal water piping in the area served by separately derived systems.

Informational Note No. 2: See 250.50 and 250.58 for requirements for bonding all electrodes together if located at the same building or structure.

The impedance of the connection to the grounding electrode is important to minimize, which is why this section specifies connection to the nearest of the specified electrodes. Where an effectively grounded metal water pipe is used as the grounding electrode for a separately derived system, 250.68(C)(1) specifies that only the first 5 feet of water piping entering the building can be used as the point to make grounding electrode conductor connections or as a conductor to interconnect grounding electrodes.

The exception to 250.68(C)(1) permits metal water piping beyond the first 5 feet of where it enters the building to be used as a bonding conductor to interconnect other electrodes or as a grounding electrode conductor. This enables grounding electrode conductor connections to be made at other locations in the building or structure. However, the piping has to meet all of the conditions specified in this exception from the point where the piping enters the building to the point where the grounding electrode conductor connection is made. The other grounding electrodes covered in 250.52(A) can be used, but only where a structural metal or metal water pipe–type grounding electrode is not available.

The practice of grounding the secondary of an isolating transformer to a ground rod or running the grounding electrode conductor back to the service ground (usually to reduce electrical noise on data-processing systems) is not permitted where either of the electrodes covered in item (1) or item (2) of 250.30(A)(4) is available. An isolation transformer that is part of a listed power supply for a data-processing room is not required to be grounded in accordance with 250.30(A)(4), but it must be grounded in accordance with the manufacturer's instructions.

(5) Grounding Electrode Conductor, Single Separately Derived System. A grounding electrode conductor for a single separately derived system shall be sized in accordance with 250.66 for the derived ungrounded conductors. It shall be used to connect the grounded conductor of the derived system to the grounding electrode as specified in 250.30(A)(4). This connection shall be made at the same point on the separately derived system where the system bonding jumper is connected.

Exception No. 1: If the system bonding jumper specified in 250.30(A)(1) is a wire or busbar, it shall be permitted to connect the grounding electrode conductor to the equipment grounding terminal, bar, or bus, provided the equipment grounding terminal, bar, or bus is of sufficient size for the separately derived system.

Exception No. 2: If the source of a separately derived system is located within equipment listed and identified as suitable for use as service equipment, the grounding electrode conductor from the service or feeder equipment to the grounding electrode shall be permitted as the grounding electrode conductor for the separately derived system, provided that the grounding electrode conductor is of sufficient size for the separately derived system. If the equipment grounding bus internal to the equipment is not smaller than the required grounding electrode conductor for the separately derived system, the grounding electrode connection for the separately derived system shall be permitted to be made to the bus.

Exception No. 3: A grounding electrode conductor shall not be required for a system that supplies a Class 1, Class 2, or Class 3 circuit and is derived from a transformer rated not more than 1000 volt-amperes, provided the grounded conductor is bonded to the transformer frame or enclosure by a jumper sized in accordance with 250.30(A)(1), Exception No. 3, and the transformer frame or enclosure is grounded by one of the means specified in 250.134.

If a separately derived system is required to be grounded, the conductor to be grounded is allowed to be connected to the grounding electrode system at any location between the source terminals (such as the transformer or generator) and the first disconnecting means or overcurrent device. The location of the grounding electrode conductor connection to the grounded conductor must be at the point at which the system bonding jumper is connected to the grounded conductor, so that normal neutral current will be carried only on the system grounded conductor and will not be imposed on parallel paths such as metal raceways, piping systems, and structural steel. Exhibits 250.14 and 250.15 illustrate two acceptable locations for connecting the grounding electrode conductor to the grounded conductor of a separately derived system. These exhibits depict typical wiring arrangements for dry-type transformers supplied from a 480-V, 3-phase feeder to derive a 208Y/120-V or 480Y/277-V secondary.

In Exhibit 250.14, the grounding electrode conductor connection is made at the source of the separately derived system (in the

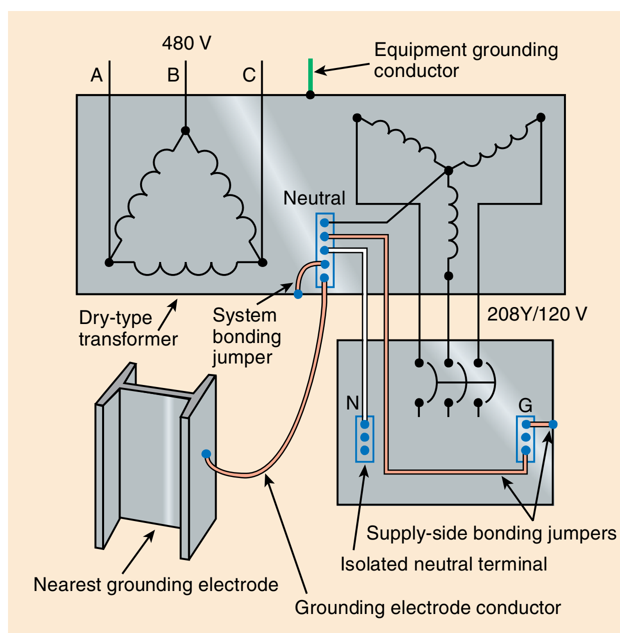

EXHIBIT 250.14 *A grounding arrangement for a separately derived system in which the grounding electrode conductor connection is made at the source of the separately derived system (transformer).*

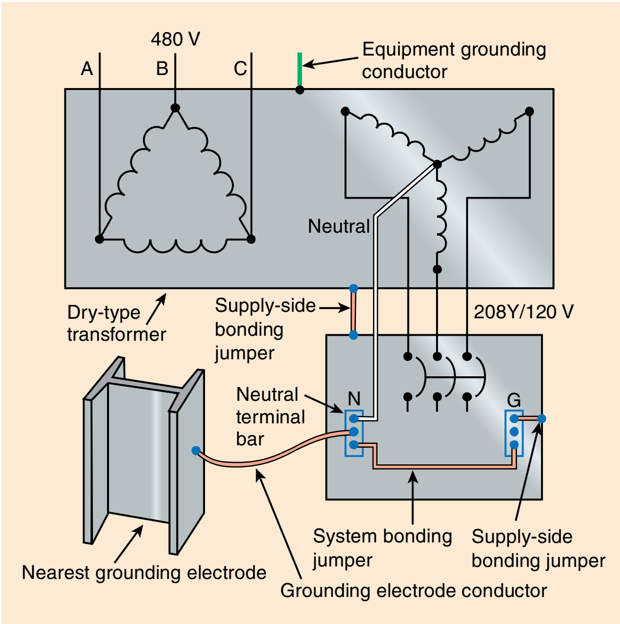

EXHIBIT 250.15 *A grounding arrangement for a separately derived system in which the grounding electrode conductor connection is made at the first system disconnecting means.*

EXHIBIT 250.16 *Listed connectors used to connect the common grounding electrode conductor and individual taps to a centrally located copper busbar with a minimum dimension of ¼ inch thick by 2 inches wide.*

transformer enclosure where the system bonding jumper is also installed). In Exhibit 250.15, the grounding electrode conductor connection is made at the first disconnecting means where the system bonding jumper is installed. With the grounding electrode conductor, the bonding jumper, and the bonding of the grounded circuit conductor (neutral) connected as shown, line-to-ground fault currents are able to return to the supply source through a short, low-impedance path. A path of lower impedance is provided that facilitates the operation of overcurrent devices, in accordance with 250.4(A)(5). The grounding electrode conductor connected to the secondary grounded circuit conductor is sized according to Table 250.66.

(6) Grounding Electrode Conductor, Multiple Separately Derived Systems. A common grounding electrode conductor for multiple separately derived systems shall be permitted. If installed, the common grounding electrode conductor shall be used to connect the grounded conductor of the separately derived systems to the grounding electrode as specified in 250.30(A)(4). A grounding electrode conductor tap shall then be installed from each separately derived system to the common grounding electrode conductor. Each tap conductor shall connect the grounded conductor of the separately derived system to the common grounding electrode conductor. This connection shall be made at the same point on the separately derived system where the system bonding jumper is connected.

A common grounding electrode conductor serving several separately derived systems is an alternative to installing individual grounding electrode conductors from each separately derived system to the grounding electrode system. In such an arrangement, a tapped grounding electrode conductor is installed from the common grounding electrode conductor to the point of connection to the individual separately derived system grounded conductor. This tap is sized from Table 250.66 based on the size of the ungrounded conductors for that individual separately derived system.

The minimum size for this conductor is 3/0 AWG copper or 250 kcmil aluminum so that the grounding electrode conductor always is of sufficient size to accommodate the multiple separately derived systems it serves. This minimum size for the common grounding electrode conductor correlates with the maximum size grounding electrode conductor required by Table 250.66. Therefore, the 3/0 AWG copper or 250 kcmil aluminum becomes the maximum size required for the common grounding electrode conductor. The sizing requirement for the common grounding electrode conductor is specified in 250.30(A)(6)(a), and the sizing requirement for the individual taps to the common grounding electrode conductor is specified in 250.30(A)(6)(b).

The methods of connecting the individual tap conductor(s) to the common grounding electrode conductor are specified in 250.30(A)(6)(c). The permitted methods include the use of busbar as a point of connection between the taps and the common grounding electrode conductor. The connections to the busbar must be made using a listed means. Exhibit 250.16 shows a copper busbar used as a connection point for the individual taps from multiple separately derived systems to be connected to the common grounding electrode.

Exception No. 1: If the system bonding jumper specified in 250.30(A)(1) is a wire or busbar, it shall be permitted to connect the grounding electrode conductor tap to the equipment grounding terminal, bar, or bus, provided the equipment grounding terminal, bar, or bus is of sufficient size for the separately derived system.

Exception No. 2: A grounding electrode conductor shall not be required for a system that supplies a Class 1, Class 2, or Class 3 circuit and is derived from a transformer rated not more than 1000 volt-amperes, provided the system grounded conductor is bonded to the transformer frame or enclosure by a jumper sized in accordance with 250.30(A)(1), Exception No. 3, and the transformer frame or enclosure is grounded by one of the means specified in 250.134.

(a) *Common Grounding Electrode Conductor.* The common grounding electrode conductor shall be permitted to be one of the following:

(1) A conductor of the wire type not smaller than 3/0 AWG copper or 250 kcmil aluminum
(2) The metal frame of the building or structure that complies with 250.52(A)(2) or is connected to the grounding electrode system by a conductor that shall not be smaller than 3/0 AWG copper or 250 kcmil aluminum

(b) *Tap Conductor Size.* Each tap conductor shall be sized in accordance with 250.66 based on the derived ungrounded conductors of the separately derived system it serves.

Exception: If the source of a separately derived system is located within equipment listed and identified as suitable for use as service equipment, the grounding electrode conductor from the service or feeder equipment to the grounding electrode shall be permitted as the grounding electrode conductor for the separately derived system, provided that the grounding electrode conductor is of sufficient size for the separately derived system. If the equipment grounding bus internal to the equipment is not smaller than the required grounding electrode conductor for the separately derived system, the grounding electrode connection for the separately derived system shall be permitted to be made to the bus.

(c) *Connections.* All tap connections to the common grounding electrode conductor shall be made at an accessible location by one of the following methods:

(1) A connector listed as grounding and bonding equipment.
(2) Listed connections to aluminum or copper busbars not smaller than 6 mm × 50 mm (¼ in. × 2 in.). If aluminum busbars are used, the installation shall comply with 250.64(A).
(3) The exothermic welding process.

Tap conductors shall be connected to the common grounding electrode conductor in such a manner that the common grounding electrode conductor remains without a splice or joint.

(7) Installation. The installation of all grounding electrode conductors shall comply with 250.64(A), (B), (C), and (E).

(8) Bonding. Structural steel and metal piping shall be connected to the grounded conductor of a separately derived system in accordance with 250.104(D).

(B) Ungrounded Systems. The equipment of an ungrounded separately derived system shall be grounded and bonded as specified in 250.30(B)(1) through (B)(3).

(1) Grounding Electrode Conductor. A grounding electrode conductor, sized in accordance with 250.66 for the largest derived ungrounded conductor (s) or set of derived ungrounded conductors, shall be used to connect the metal enclosures of the derived system to the grounding electrode as specified in 250.30(A)(5) or (6), as applicable. This connection shall be made at any point on the separately derived system from the source to the first system disconnecting means. If the source is located outside the building or structure supplied, a grounding electrode connection shall be made in compliance with 250.30(C).

For ungrounded separately derived systems, a grounding electrode conductor is required to be connected to the metal enclosure of the system disconnecting means. The grounding electrode conductor is sized from Table 250.66 based on the largest ungrounded supply conductor. This connection establishes a reference to ground for all exposed non–current-carrying metal equipment supplied from the ungrounded system. The EGCs of circuits supplied from the ungrounded system are connected to ground via this grounding electrode conductor connection.

(2) Grounding Electrode. Except as permitted by 250.34 for portable and vehicle-mounted generators, the grounding electrode shall comply with 250.30(A)(4).

(3) Bonding Path and Conductor. A supply-side bonding jumper shall be installed from the source of a separately derived system to the first disconnecting means in compliance with 250.30(A)(2).

(C) Outdoor Source. If the source of the separately derived system is located outside the building or structure supplied, a grounding electrode connection shall be made at the source location to one or more grounding electrodes in compliance with 250.50. In addition, the installation shall comply with 250.30(A) for grounded systems or with 250.30(B) for ungrounded systems.

Exception: The grounding electrode conductor connection for impedance grounded neutral systems shall comply with 250.36 or 250.187, as applicable.

This exception is similar in function to the requirement of 250.24(A)(2) in that it allows an outdoor grounding connection at the source of a separately derived system. This connection provides a first line of defense for the system against the effects of overvoltages due to lightning, transients, or accidental contact between conductors of systems operating at different voltages.

250.32 Buildings or Structures Supplied by a Feeder(s) or Branch Circuit(s)

(A) Grounding Electrode. Building(s) or structure(s) supplied by feeder(s) or branch circuit(s) shall have a grounding electrode its connection point to the grounding impedance shall be fully insulated.

The grounded system conductor shall have an ampacity of not less than the maximum current rating of the grounding impedance but in no case shall the grounded system conductor be smaller than 8 AWG copper or 6 AWG aluminum or copper-clad aluminum.

The size of the neutral conductor is determined by the amount of ground-fault current that can be conducted through the grounding impedance. The minimum 8 AWG copper or 6 AWG aluminum conductor sizes reflect the minimum sizes specified in Table 250.102(C)(1), which is referred to by 250.24(C)(1) and 250.30(A)(3)(a) for sizing grounded (neutral) conductors.

(C) System Grounding Connection. The system shall not be connected to ground except through the grounding impedance.

Informational Note: The impedance is normally selected to limit the ground-fault current to a value slightly greater than or equal to the capacitive charging current of the system. This value of impedance will also limit transient overvoltages to safe values. For guidance, refer to criteria for limiting transient overvoltages in ANSI/IEEE 142-2007, *Recommended Practice for Grounding of Industrial and Commercial Power Systems*.

(D) Neutral Point to Grounding Impedance Conductor Routing. The conductor connecting the neutral point of the transformer or generator to the grounding impedance shall be permitted to be installed in a separate raceway from the ungrounded conductors. It shall not be required to run this conductor with the phase conductors to the first system disconnecting means or overcurrent device.

(E) Equipment Bonding Jumper. The equipment bonding jumper (the connection between the equipment grounding conductors and the grounding impedance) shall be an unspliced conductor run from the first system disconnecting means or overcurrent device to the grounded side of the grounding impedance.

(F) Grounding Electrode Conductor Connection Location. For services or separately derived systems, the grounding electrode conductor shall be connected at any point from the grounded side of the grounding impedance to the equipment grounding connection at the service equipment or the first system disconnecting means of a separately derived system.

(G) Equipment Bonding Jumper Size. The equipment bonding jumper shall be sized in accordance with (1) or (2) as follows:

(1) If the grounding electrode conductor connection is made at the grounding impedance, the equipment bonding jumper shall be sized in accordance with 250.66, based on the size of the service entrance conductors for a service or the derived phase conductors for a separately derived system.

(2) If the grounding electrode conductor is connected at the first system disconnecting means or overcurrent device, the equipment bonding jumper shall be sized the same as the neutral conductor in 250.36(B).

III. Grounding Electrode System and Grounding Electrode Conductor

250.50 Grounding Electrode System

All grounding electrodes as described in 250.52(A)(1) through (A)(7) that are present at each building or structure served shall be bonded together to form the grounding electrode system. 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.

Section 250.50 introduces the important concept of a *grounding electrode system,* in which all electrodes that are present at a building or structure are bonded together, as illustrated in Exhibit 250.22. Rather than total reliance on a single grounding electrode to perform its function over the life of the electrical installation, the *NEC* requires the formation of a system of electrodes where multiple grounding electrodes are at the building being served. Metal structural members, metal water pipe, and concrete footings or foundations are found in many buildings and structures and are required to be integrated into the grounding electrode system if they qualify under the conditions specified in 250.52(A). The *Code* does not specify that metal water pipe, structural metal frame, or concrete-encased–type electrodes have to be

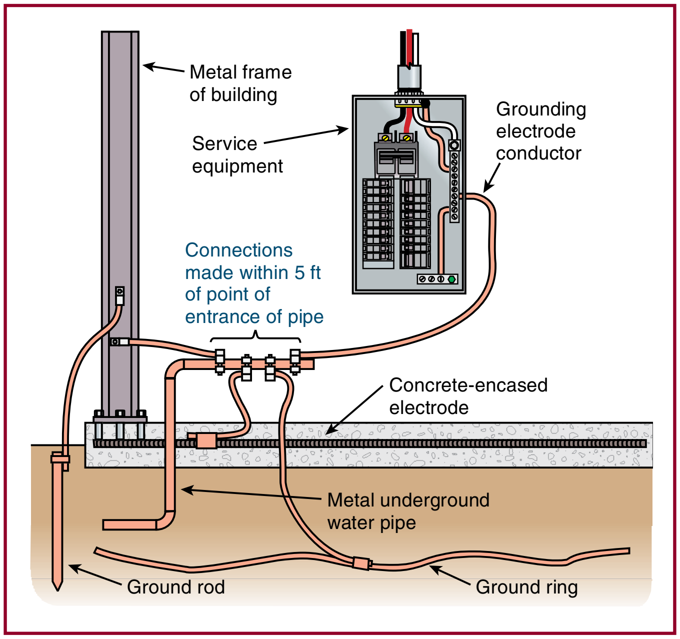

***EXHIBIT 250.22** A grounding electrode system that uses the metal frame of a building, a ground ring, a concrete-encased electrode, a metal underground water pipe, and a ground rod.*

installed, only that where they have been installed as part of the building construction they are to be used as components of the grounding electrode system. A system of electrodes adds a level of reliability and helps ensure system performance over a long period of time.

Exception: Concrete-encased electrodes of existing buildings or structures shall not be required to be part of the grounding electrode system where the steel reinforcing bars or rods are not accessible for use without disturbing the concrete.

The exception exempts existing buildings and structures where access to the concrete-encased electrode would involve some type of demolition or similar activity that would damage the existing construction. Because the installation of the footings and foundation is one of the first elements of a construction project, one that in most cases has long been completed by the time the electric service is installed, this rule necessitates an awareness and coordinated effort on the part of designers and the construction trades to make sure that the concrete-encased electrode is incorporated into the grounding electrode system.

250.52 Grounding Electrodes

(A) Electrodes Permitted for Grounding.

(1) Metal Underground Water Pipe. A metal underground water pipe in direct contact with the earth for 3.0 m (10 ft) or more (including any metal well casing bonded to the pipe) and electrically continuous (or made electrically continuous by bonding around insulating joints or insulating pipe) to the points of connection of the grounding electrode conductor and the bonding conductor(s) or jumper(s), if installed.

In the early years of the *NEC,* concerns over the effect of electric current on metal water piping created some uncertainty as to whether metal water piping systems should be used as grounding electrodes. To address those concerns, the electrical industry and the waterworks industry formed a committee to evaluate the use of metal underground water piping systems as grounding electrodes. Based on its findings, the committee issued an authoritative report on the subject. The International Association of Electrical Inspectors published the report, *Interim Report of the American Research Committee on Grounding*, in January 1944 (reprinted March 1949). This report serves as part of the basis for the continuation of the practice of using metal water pipes as part of the grounding electrode system.

(2) Metal Frame of the Building or Structure. The metal frame of the building or structure that is 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) Hold-down bolts securing the structural steel column that are connected to a concrete-encased electrode that complies with 250.52(A)(3) and is located in the support footing or foundation. The hold-down bolts shall be connected to the concrete-encased electrode by welding, exothermic welding, the usual steel tie wires, or other approved means.

Connection to more than one building column or structural member is not necessary. As long as electrical continuity is through the entire metal frame of the building, the single connection to earth allows the entire structural metal building frame to be used as a grounding electrode. Building steel connected to earth using means other than those specified in 250.52(A)(2) is not permitted to be used as a grounding electrode. Such steel can, however, be used as a bonding conductor or grounding electrode conductor in accordance with the requirements of 250.68(C)(2).

(3) Concrete-Encased Electrode. A concrete-encased electrode shall consist of at least 6.0 m (20 ft) of either (1) or (2):

(1) One or more bare or zinc galvanized or other 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 if in multiple pieces connected together by the usual steel tie wires, exothermic welding, welding, or other effective means to create a 6.0 m (20 ft) or greater length; or
(2) Bare copper conductor not smaller than 4 AWG

Metallic components shall be encased by at least 50 mm (2 in.) of concrete and shall be located horizontally within that portion of a concrete foundation or footing that is in direct contact with the earth or within vertical foundations or structural components or members that are in direct contact with the earth. If multiple concrete-encased electrodes are present at a building or structure, it shall be permissible to bond only one into the grounding electrode system.

Informational Note: Concrete installed with insulation, vapor barriers, films or similar items separating the concrete from the earth is not considered to be in “direct contact” with the earth.

To qualify as a grounding electrode, the horizontal or vertical installation of the steel reinforcing rod or the 4 AWG bare copper conductor within the concrete encasement is required to be in one continuous 20-foot length so that a 20-foot-long electrode is in contact with the earth. Shorter lengths of reinforcing rod can be connected together to form an electrode 20 feet or longer using the connection methods identified in this requirement. Section 250.52(A)(3) requires that only a single concrete-encased electrode be incorporated into the grounding electrode system. Some buildings or structures may have discontinuous segments of a footing or foundation that individually qualify as grounding electrodes per this section, and once one has been bonded to the grounding electrode system, the remaining ones are exempt from any bonding or grounding requirements. Exhibit 250.23 shows an example of a concrete-encased electrode embedded horizontally. As indicated in the informational note, direct contact with

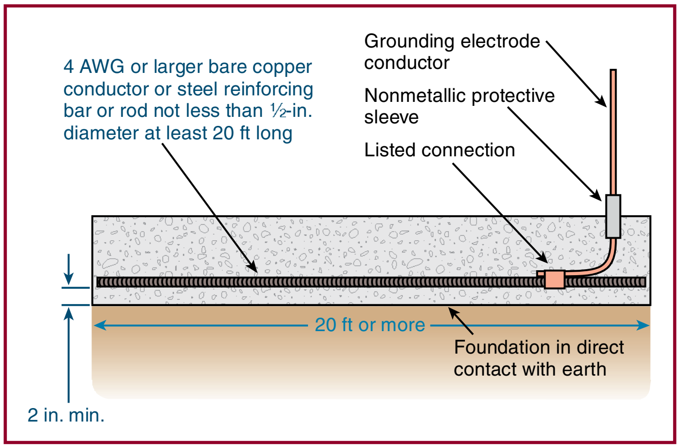

EXHIBIT 250.23 *An example of a concrete-encased electrode that is required to be incorporated into the grounding electrode system.*

the earth means that no medium is between the concrete and the earth that impedes the grounding connection or insulates the concrete from being in direct contact with the earth.

(4) Ground Ring. 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.

(5) Rod and Pipe Electrodes. Rod and pipe electrodes shall not be less than 2.44 m (8 ft) in length and shall consist of the following materials.

(a) Grounding electrodes of pipe or conduit shall not be smaller than metric designator 21 (trade size ¾) and, where of steel, shall have the outer surface galvanized or otherwise metal-coated for corrosion protection.

(b) Rod-type grounding electrodes of stainless steel and copper or zinc coated steel shall be at least 15.87 mm (⅝ in.) in diameter, unless listed.

(6) Other Listed Electrodes. Other listed grounding electrodes shall be permitted.

(7) Plate Electrodes. Each plate electrode shall expose not less than 0.186 m^2 (2 ft^2) of surface to exterior soil. Electrodes of bare or conductively coated iron or steel plates shall be at least 6.4 mm (¼ in.) in thickness. Solid, uncoated electrodes of nonferrous metal shall be at least 1.5 mm (0.06 in.) in thickness.

(8) Other Local Metal Underground Systems or Structures. Other local metal underground systems or structures such as piping systems, underground tanks, and underground metal well casings that are not bonded to a metal water pipe.

(B) Not Permitted for Use as Grounding Electrodes. The following systems and materials shall not be used as grounding electrodes:

(1) Metal underground gas piping systems
(2) Aluminum

Informational Note: See 250.104(B) for bonding requirements of gas piping.

250.53 Grounding Electrode System Installation

•

(A) Rod, Pipe, and Plate Electrodes. Rod, pipe, and plate electrodes shall meet the requirements of 250.53(A)(1) through (A)(3).

(1) Below Permanent Moisture Level. If practicable, rod, pipe, and plate electrodes shall be embedded below permanent moisture level. Rod, pipe, and plate electrodes shall be free from nonconductive coatings such as paint or enamel.

(2) Supplemental Electrode Required. A single rod, pipe, or plate electrode 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: 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.

(3) Supplemental Electrode. If multiple rod, pipe, or plate electrodes are installed to meet the requirements of this section, they shall not be less than 1.8 m (6 ft) apart.

Informational Note: The paralleling efficiency of rods is increased by spacing them twice the length of the longest rod.

The spacing requirement in 250.53(A)(3) for multiple auxiliary rod, pipe, or plate electrodes is illustrated in Exhibit 250.24. The direct-buried clamps shown are required to be listed for underground installation per 250.70.

Several methods measure the resistance to ground of a rod, pipe, or plate electrode. Exhibit 250.25 illustrates one method of determining the ground resistance of a rod-type electrode in which a ground tester is used to measure the "fall of potential" between the rod being tested and the reference rod (stake) connected to the "P_1" or "P_2" terminal of the tester. The clamp-on ground resistance tester is a simpler method of testing the earth resistance of a grounding electrode, as it does not involve the use of reference electrodes to perform the earth resistance test.

(B) Electrode Spacing. Where more than one of the electrodes of the type specified in 250.52(A)(5) or (A)(7) are used, each electrode of one grounding system (including that used for strike

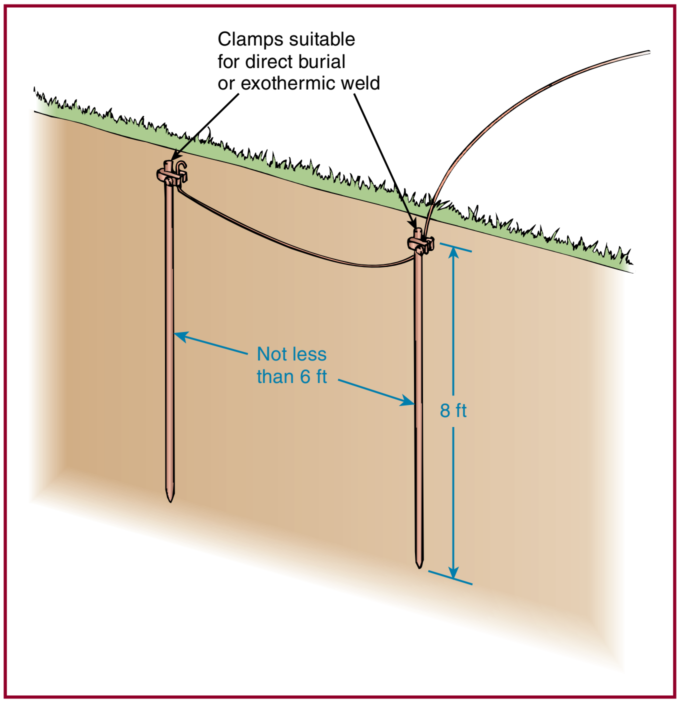

EXHIBIT 250.24 *The 6-foot spacing required between electrodes.*

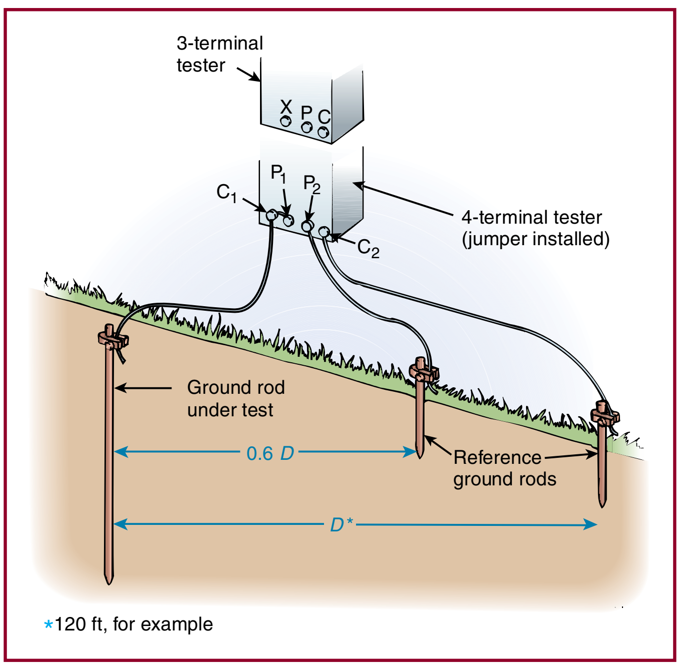

EXHIBIT 250.25 *The resistance to ground of a ground rod being measured using a fall of potential ground tester. The clamp-on tester is another method of determining the earth resistance of a grounding electrode.*

termination devices) shall not be less than 1.83 m (6 ft) from any other electrode of another grounding system. Two or more grounding electrodes that are bonded together shall be considered a single grounding electrode system.

(C) Bonding Jumper. The bonding jumper(s) used to connect the grounding electrodes together to form the grounding electrode system shall be installed in accordance with 250.64(A), (B), and (E), shall be sized in accordance with 250.66, and shall be connected in the manner specified in 250.70.

(D) Metal Underground Water Pipe. If used as a grounding electrode, metal underground water pipe shall meet the requirements of 250.53(D)(1) and (D)(2).

(1) 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.

(2) Supplemental Electrode Required. A metal underground water pipe shall be supplemented by an additional electrode of a type specified in 250.52(A)(2) through (A)(8). If the supplemental electrode is of the rod, pipe, or plate type, it shall comply with 250.53(A). The supplemental electrode shall be bonded to one of the following:

(1) Grounding electrode conductor
(2) Grounded service-entrance conductor
(3) Nonflexible grounded service raceway
(4) Any grounded service enclosure
(5) As provided by 250.32(B)

Exception: The supplemental electrode shall be permitted to be bonded to the interior metal water piping at any convenient point as specified in 250.68(C)(1), Exception.

This requirement clarifies that the supplemental electrode system must be installed as if it were the sole grounding electrode for the system. As specified in the exception to 250.53(A)(2), if a single rod, pipe, or plate electrode has a resistance to earth of 25 ohms or less, it is not necessary to supplement that electrode with one of the types from 250.52(A)(2) through (A)(8). In other words, a single rod, pipe, or plate electrode being used to supplement a metal underground water pipe–type electrode is itself required to be provided with a supplemental electrode unless the condition of 250.53(A)(2), Exception, can be met. One of the permitted methods of bonding a supplemental grounding electrode conductor to the grounding electrode system is to connect it to the grounded service enclosure.

The need for supplemental electrodes for metal water pipe is due to the common practice of using a plastic pipe for replacement when the original metal water pipe fails. Plastic replacement pipe leaves the system without a grounding electrode unless a supplemental electrode is provided.

(E) Supplemental Electrode Bonding Connection Size. Where the supplemental electrode is a rod, pipe, or plate electrode, that portion of the bonding jumper that is the sole connection to the supplemental grounding electrode shall not be required to be larger than 6 AWG copper wire or 4 AWG aluminum wire.

Section 250.53(E) correlates with 250.52(A)(5) or (A)(7) and with 250.66(A). For example, if a metal underground water pipe or the metal frame of the building or structure is used as the grounding electrode or as part of the grounding electrode system, Table 250.66 must be used for sizing the grounding electrode conductor. The size of the grounding electrode conductor or bonding jumper that is the sole connection to the supplemental electrode is not required to be larger than 6 AWG copper or 4 AWG aluminum.

(F) Ground Ring. The ground ring shall be buried at a depth below the earth's surface of not less than 750 mm (30 in.).

(G) Rod and Pipe Electrodes. The electrode shall be installed such that at least 2.44 m (8 ft) of length is in contact with the soil. It shall be driven to a depth of not less than 2.44 m (8 ft) except that, where rock bottom is encountered, the electrode shall be driven at an oblique angle not to exceed 45 degrees from the vertical or, where rock bottom is encountered at an angle up to 45 degrees, the electrode shall be permitted to be buried in a trench that is at least 750 mm (30 in.) deep. The upper end of the electrode shall be flush with or below ground level unless the aboveground end and the grounding electrode conductor attachment are protected against physical damage as specified in 250.10.

Where rock bottom is encountered, the electrodes must be either driven at not more than a 45-degree angle or buried in a 2 ½-foot-deep trench. Driving the rod at an angle is permitted only if it is not possible to drive the rod vertically to obtain at least 8 feet of earth contact. Burying the ground rod is permitted only if driving the rod vertically or at an angle is not possible. Exhibit 250.26 illustrates these requirements.

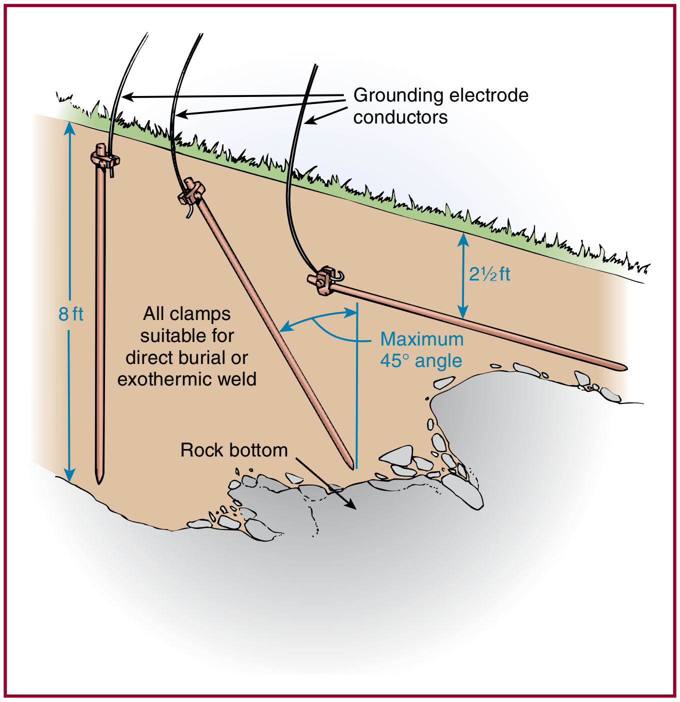

EXHIBIT 250.26 Installation requirements for rod and pipe electrodes.

Section 250.70 requires ground clamps used on buried electrodes to be listed for direct earth burial. Ground clamps installed above ground must be protected where subject to physical damage per 250.53(G).

(H) Plate Electrode. Plate electrodes shall be installed not less than 750 mm (30 in.) below the surface of the earth.

250.54 Auxiliary Grounding Electrodes

One or more grounding electrodes shall be permitted to be connected to the equipment grounding conductors specified in 250.118 and shall not be required to comply with the electrode bonding requirements of 250.50 or 250.53(C) or the resistance requirements of 250.53(A)(2) Exception, but the earth shall not be used as an effective ground-fault current path as specified in 250.4(A)(5) and 250.4(B)(4).

Grounding electrodes, such as ground rods, that are connected to equipment are not permitted to be used in lieu of the EGC, but they may be used to provide a local earth reference connection at electrical equipment locations. For example, grounding electrodes may be used for lightning protection or to establish a reference to ground in the area of electrically operated equipment. The earth may not be used as the sole EGC or effective (ground) fault current path. Auxiliary grounding electrodes are not required to be incorporated into the grounding electrode system for the service or other source of electrical supply.

250.58 Common Grounding Electrode

Where an ac system is connected to a grounding electrode in or at a building or structure, the same electrode shall be used to ground conductor enclosures and equipment in or on that building or structure. Where separate services, feeders, or branch circuits supply a building and are required to be connected to a grounding electrode(s), the same grounding electrode(s) shall be used.

Two or more grounding electrodes that are bonded together shall be considered as a single grounding electrode system in this sense.

250.60 Use of Strike Termination Devices

Conductors and driven pipes, rods, or plate electrodes used for grounding strike termination devices shall not be used in lieu of the grounding electrodes required by 250.50 for grounding wiring systems and equipment. This provision shall not prohibit the required bonding together of grounding electrodes of different systems.

Informational Note No. 1: See 250.106 for spacing from strike termination devices. See 800.100(D), 810.21(J), and 820.100(D) for bonding of electrodes.

Informational Note No. 2: Bonding together of all separate grounding electrodes will limit potential differences between them and between their associated wiring systems.

250.66 Size of Alternating-Current Grounding Electrode Conductor

The size of the 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 of a grounded or ungrounded ac system shall not be less than given in Table 250.66, except as permitted in 250.66(A) through (C).

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(A) Connections to a Rod, Pipe, or Plate Electrode(s). Where the grounding electrode conductor is connected to a single or multiple rod, pipe, or plate electrode(s), or any combination thereof, as permitted in 250.52(A)(5) or (A)(7), that portion of the conductor that is the sole connection to the grounding electrode(s) shall not be required to be larger than 6 AWG copper wire or 4 AWG aluminum wire.

(B) Connections to Concrete-Encased Electrodes. Where the grounding electrode conductor is connected to a single or multiple concrete-encased electrode(s) as permitted in 250.52(A)(3), that portion of the conductor that is the sole connection to the grounding electrode(s) shall not be required to be larger than 4 AWG copper wire.

(C) Connections to Ground Rings. Where the grounding electrode conductor is connected to a ground ring as permitted in 250.52(A)(4), that portion of the conductor that is the sole connection to the grounding electrode shall not be required to be larger than the conductor used for the ground ring.

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

Notes:
1. 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.
2. 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).

Exhibit 250.30 illustrates a grounding electrode conductor (GEC) installed from service equipment or from a separately derived system to a water pipe grounding electrode. The grounding electrode conductor between the service equipment or separately derived system and the water pipe is required to be a full-sized conductor based on the size of the ungrounded supply conductors, per Table 250.66. The bonding jumpers that connect the other grounding electrodes together are also sized using 250.53(C), which refers to Table 250.66, but they are not necessarily required to be full sized if they are covered by 250.66(A), (B), or (C). In this illustration, the size of the GEC and bonding jumpers is dependent on the electrode to which the GEC is connected. For example, if the GEC from the service equipment is run to the ground rod first and then to the water pipe, the GEC to the ground rod is required to be full sized per Table 250.66. In this illustration, it can be no smaller than a 4 AWG copper conductor. Exhibit 250.30 is not intended to show a mandatory physical routing and connection order of the bonding jumpers and the grounding electrode conductor, since the *Code* does not specify an order or hierarchy for these connections. The sizes for the bonding jumpers to the ground rod and the concrete-encased electrode shown in Exhibit 250.30 are the maximum sizes

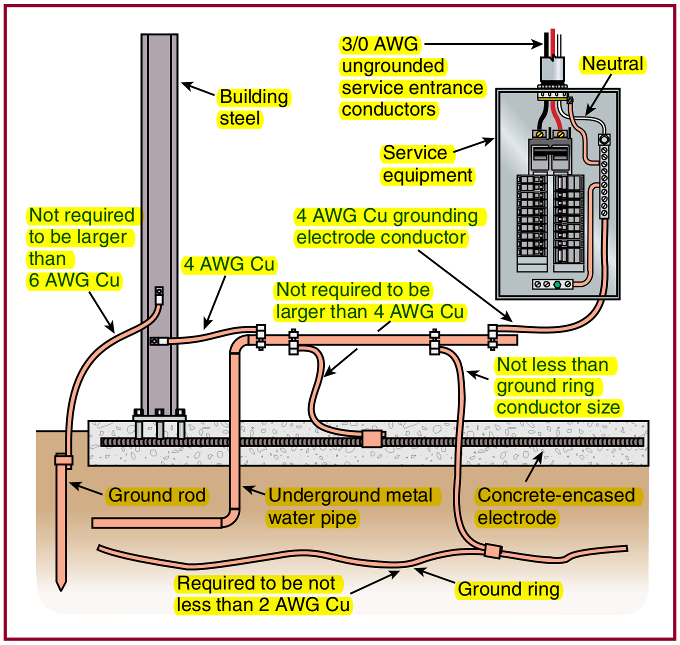

EXHIBIT 250.30 *Grounding electrode conductor and bonding jumpers sized in accordance with 250.66 for a service supplied by 3/0 AWG copper ungrounded conductors.*

required by the *Code* based on 250.66. The use of bonding jumpers or grounding electrode conductors larger than required by 250.66 is not prohibited.

250.68 Grounding Electrode Conductor and Bonding Jumper Connection to Grounding Electrodes

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) through (C).

(A) Accessibility. All mechanical elements used to terminate a grounding electrode conductor or bonding jumper to a grounding electrode shall be accessible.

Exception No. 1: An encased or buried connection to a concrete-encased, driven, or buried grounding electrode shall not be required to be accessible.

Exception No. 2: Exothermic or irreversible compression connections used at terminations, together with the mechanical means used to attach such terminations to fireproofed structural metal whether or not the mechanical means is reversible, shall not be required to be accessible.

Where the exposed portion of an encased, driven, or buried electrode is used for the termination of a grounding electrode conductor, the terminations must be accessible. However, if the connection is buried or encased, Exception No. 1 does not require the terminations to be accessible. Ground clamps and other connectors suitable for use where buried in earth or embedded in concrete must be listed for such use per 250.70. Indication of this listing is either by a marking on the connector or by a tag attached to the connector. See Exhibits 250.22 and 250.24 for illustrations of encased and buried electrodes. Connections, including the mechanical attachment of a compression lug to structural steel, are permitted to be encapsulated by fireproofing material and are not required to be accessible for inspection. This recognizes the importance of maintaining the integrity of the structural fireproofing.

(B) Effective Grounding Path. The connection of a grounding electrode conductor or bonding jumper to a grounding electrode shall be made in a manner that will ensure an effective grounding path. Where necessary to ensure the grounding path for a metal piping system used as a grounding electrode, bonding shall be provided around insulated joints and around any equipment likely to be disconnected for repairs or replacement. Bonding jumpers shall be of sufficient length to permit removal of such equipment while retaining the integrity of the grounding path.

Water meters and water filter systems are examples of equipment likely to be disconnected for repairs or replacement. Shorter bonding jumpers are more likely to be disconnected to facilitate removal or reinstallation of a water meter or filter cartridge. This section specifies that the bonding jumper must be long enough to permit removal of such equipment without disconnecting or otherwise interrupting the bonding jumper.

(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):

(1) Interior metal water piping located not more than 1.52 m (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.

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.

The piping at this point is not a grounding electrode [only the underground portion is an electrode per 250.52(A)(1)]. Rather, it is used to extend grounding and bonding conductor connections to the grounding electrode. The exception permits connections beyond the first 5 feet, and at that point the water piping is considered a conductor used for bonding grounding electrodes together or is considered the actual grounding electrode conductor. All of the conditions of the exception, including the use of qualified persons to service the water piping system, must be met in order to extend the permitted point of connection beyond the first 5 feet of where the piping enters the building.

(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.

The structural metal frame of a building is not a grounding electrode unless it is connected to earth by one or more of the means specified in 250.52(A)(2). The required bonding of metal water piping and metal structural frames is covered in 250.104(A) and (C).

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(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.

250.70 Methods of Grounding and Bonding Conductor Connection to Electrodes

The grounding or bonding conductor shall be connected to the grounding electrode by exothermic welding, listed lugs, listed pressure connectors, listed clamps, or other listed means. Connections depending on solder shall not be used. Ground clamps shall be listed for the materials of the grounding electrode and the grounding electrode conductor and, where used on pipe, rod, or other buried electrodes, shall also be listed for direct soil burial or concrete encasement. Not more than one conductor shall be connected to the grounding electrode by a single clamp or fitting unless the clamp or fitting is listed for multiple conductors. One of the following methods shall be used:

(1) A pipe fitting, pipe plug, or other approved device screwed into a pipe or pipe fitting
(2) A listed bolted clamp of cast bronze or brass, or plain or malleable iron
(3) For indoor communications purposes only, a listed sheet metal strap-type ground clamp having a rigid metal base that seats on the electrode and having a strap of such material and dimensions that it is not likely to stretch during or after installation
(4) An equally substantial approved means

Where a ground clamp terminates on a galvanized water pipe, the clamp must be of a material compatible with steel to prevent galvanic corrosion. The same requirement applies to ground clamps used with grounding electrodes made of other materials such as copper or steel reinforcing rods or bars. The clamp must also be compatible with the material for the grounding electrode conductor and, if buried, listed for that use.

Exhibit 250.31 shows a listed water pipe ground clamp generally used with 8 AWG through 4 AWG grounding electrode conductors. Exothermic weld kits acceptable for this purpose are commercially available.

EXHIBIT 250.31 *An application of a listed ground clamp.*

IV. Enclosure, Raceway, and Service Cable Connections

250.80 Service Raceways and Enclosures

Metal enclosures and raceways for service conductors and equipment shall be connected to the grounded system conductor if the electrical system is grounded or to the grounding electrode conductor for electrical systems that are not grounded.

Exception: A metal elbow that is installed in an underground nonmetallic raceway and is isolated from possible contact by a minimum cover of 450 mm (18 in.) to any part of the elbow shall not be required to be connected to the grounded system conductor or grounding electrode conductor.

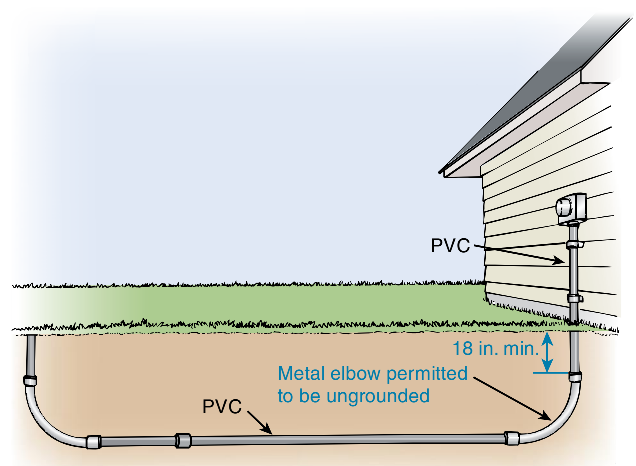


EXHIBIT 250.32 *Metal elbows permitted to be ungrounded, provided they are isolated from contact by a minimum cover of 18 inches to any part of the elbow.*

Metal elbows are installed because nonmetallic elbows can be damaged from the friction caused by taut conductor pull lines or ropes rubbing against the interior of the elbow throat. The elbows are isolated from physical contact by burying the entire elbow at a depth not less than 18 inches below grade. This exception applies where isolated metal elbows are used in a service raceway installation. Installations of raceways containing other than service conductors can be found in 250.86, Exception No. 3. See Exhibit 250.32 for an example of this application.

250.84 Underground Service Cable or Raceway

(A) Underground Service Cable. The sheath or armor of a continuous underground metal-sheathed or armored service cable system that is connected to the grounded system conductor on the supply side shall not be required to be connected to the grounded system conductor at the building or structure. The sheath or armor shall be permitted to be insulated from the interior metal raceway or piping.

(B) Underground Service Raceway Containing Cable. An underground metal service raceway that contains a metal-sheathed or armored cable connected to the grounded system conductor shall not be required to be connected to the grounded system conductor at the building or structure. The sheath or armor shall be permitted to be insulated from the interior metal raceway or piping.

250.86 Other Conductor Enclosures and Raceways

Except as permitted by 250.112(I), metal enclosures and raceways for other than service conductors shall be connected to the equipment grounding conductor.

Exception No. 1: Metal enclosures and raceways for conductors added to existing installations of open wire, knob-and-tube wiring, and nonmetallic-sheathed cable shall not be required to be connected to the equipment grounding conductor where these enclosures or wiring methods comply with (1) through (4) as follows:

(1) Do not provide an equipment ground
(2) Are in runs of less than 7.5 m (25 ft)
(3) Are free from probable contact with ground, grounded metal, metal lath, or other conductive material
(4) Are guarded against contact by persons

Exception No. 2: Short sections of metal enclosures or raceways used to provide support or protection of cable assemblies from physical damage shall not be required to be connected to the equipment grounding conductor.

Exception No. 3: A metal elbow shall not be required to be connected to the equipment grounding conductor where it is installed in a run of nonmetallic raceway and is isolated from possible contact by a minimum cover of 450 mm (18 in.) to any part of the elbow or is encased in not less than 50 mm (2 in.) of concrete.

Connectors, couplings, or other similar fittings that perform mechanical and electrical functions must ensure bonding and grounding continuity between the fitting, the metal raceway, and the enclosure. Metal enclosures must be grounded so that when a fault occurs between an ungrounded (hot) conductor and ground, the potential difference between the non–current-carrying parts of the electrical installation is minimized, thereby reducing the risk of shock.

V. Bonding

250.90 General

Bonding shall be provided where necessary to ensure electrical continuity and the capacity to conduct safely any fault current likely to be imposed.

250.92 Services

(A) Bonding of Equipment for Services. The normally non–current-carrying metal parts of equipment indicated in 250.92(A)(1) and (A)(2) shall be bonded together.

(1) All raceways, cable trays, cablebus framework, auxiliary gutters, or service cable armor or sheath that enclose, contain, or support service conductors, except as permitted in 250.80
(2) All enclosures containing service conductors, including meter fittings, boxes, or the like, interposed in the service raceway or armor

(B) Method of Bonding at the 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).

Standard locknuts, sealing locknuts, and metal bushings are not acceptable as the sole means for bonding a raceway or cable to an enclosure on the line side of the service disconnecting means, regardless of the type of or condition of the knockout. For knockouts that are concentric, eccentric, or oversized, electrical continuity must be ensured through the use of a supply-side bonding jumper that connects the raceway to the enclosure. Oversized, concentric, and eccentric knockouts in service enclosures impede the bonding connections. Bonding jumpers are required in these situations and also where reducing washers are used to ensure that any bonding connection provides a suitable path for the high level of ground-fault current that is available on the line side of the service disconnecting means and OCPD. For the same reason, standard locknuts and metal bushings — which may be a suitable bonding connection at some locations on the load side of the service equipment — are not considered to be a reliable bonding connection at this point in the electrical system and cannot be relied upon as the sole bonding connection. For further information on concentric and eccentric knockouts, see the commentary following the definition of *bonding jumper* in Article 100 and the example shown in Exhibit 100.4.

Electrical continuity at service equipment, service raceways, and service conductor enclosures shall be ensured by one of the following methods:

(1) Bonding equipment to the grounded service conductor in a manner provided in 250.8

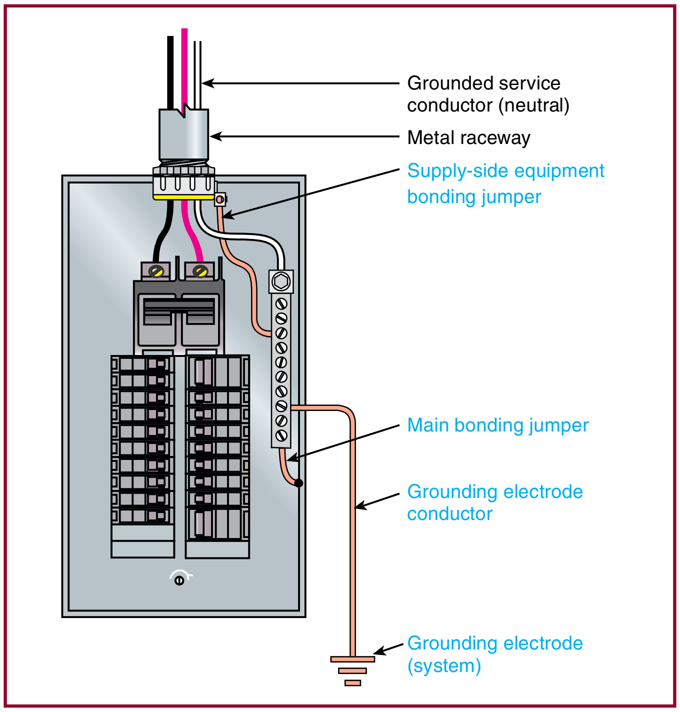


EXHIBIT 250.33 Grounding and bonding arrangement for a service with one disconnecting means.

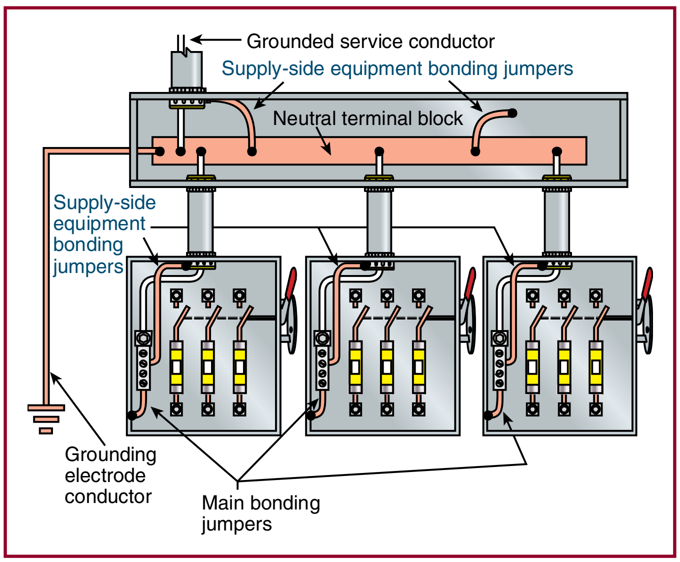


EXHIBIT 250.34 Grounding and bonding arrangement for a service with three disconnecting means.

Exhibit 250.33 illustrates one acceptable grounding and bonding arrangement at a service that has one disconnecting means. Exhibit 250.34 illustrates one acceptable grounding and bonding arrangement for a service that has three disconnecting means as permitted by 230.71(A). Section 250.24(C) specifies that the grounded service conductor must be run to each service disconnecting means and be bonded to the disconnecting means enclosure, as illustrated in Exhibit 250.34. Section 250.92(B)(1) permits

EXHIBIT 250.35 Grounding bushings used to connect a copper bonding or grounding wire to conduits. (Courtesy of Thomas & Betts Corp.)

the bonding of service equipment enclosures to be accomplished by bonding the grounded service conductor to the enclosure.

(2) Connections utilizing threaded couplings or threaded hubs on enclosures if made up wrenchtight
(3) Threadless couplings and connectors if made up tight for metal raceways and metal-clad cables
(4) Other listed devices, such as bonding-type locknuts, bushings, or bushings with bonding jumpers

Bonding-type locknuts and grounding and bonding bushings for use with rigid or intermediate metal conduit are provided with means (usually one or more set screws that make positive contact with the conduit) for reliably bonding the bushing and the conduit on which it is threaded to the metal equipment enclosure or box.

Grounding bushings used with fittings for rigid or intermediate metal conduit or with EMT have means for connecting a bonding jumper or have means provided by the manufacturer for use in mounting a wire connector. (See Exhibit 250.35.) This type of bushing may also have one or more set screws to reliably bond the bushing to the conduit. Exhibit 250.36 shows a listed bonding-type wedge lug used to connect a conduit to a box and provide the bonding connection required by 250.92(B).

250.94 Bonding for Other Systems

An intersystem bonding termination for connecting intersystem bonding conductors required for other systems 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. The intersystem bonding termination shall comply with the following:

(1) Be accessible for connection and inspection.

EXHIBIT 250.36 *A grounding wedge lug used to provide an electrical connection between a conduit and a box. (Courtesy of Thomas & Betts Corp.)*

EXHIBIT 250.37 *A listed intersystem bonding termination providing the required number of terminals (minimum of three) for connecting other building systems to the grounding system of the electrical power supply.*

(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.

Intersystem means that the electrical system and other systems such as optical fiber (Article 770), communications (Article 800), CATV (Article 820), and broadband systems (Articles 830 and 840) are bonded together to minimize the occurrence of potential differences between equipment of different systems. Exhibit 250.37 is an example of an intersystem bonding termination that is to be installed and connected as specified in 250.94(1) through (6).

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

Exception: In existing buildings or structures where any of the intersystem bonding and grounding electrode conductors required by 770.100(B)(2), 800.100(B)(2), 810.21(F)(2), 820.100(B)(2), and 830.100(B)(2) exist, installation of the intersystem bonding termination is not required. 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:

(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

The intersystem bonding points at an existing building or structure can be installed with the connection points as shown in Exhibit 250.38. An intersystem bonding termination of the type shown in Exhibit 250.37 is not required to be installed under the conditions of this exception.

Informational Note No. 1: A 6 AWG copper conductor with one end bonded to the grounded nonflexible metallic raceway or equipment and with 150 mm (6 in.) or more of the other end made accessible on the outside wall is an example of the approved means covered in 250.94, Exception item (3).

Informational Note No. 2: See 770.100, 800.100, 810.21, 820.100, and 830.100 for intersystem bonding and grounding requirements for conductive optical fiber cables, communications circuits, radio and television equipment, CATV circuits and network-powered broadband communications systems, respectively.

Lightning protection systems, communications, radio and TV, and CATV systems are required to be bonded together to minimize the potential differences between the systems that can occur where there is a common interface. Lack of interconnection can

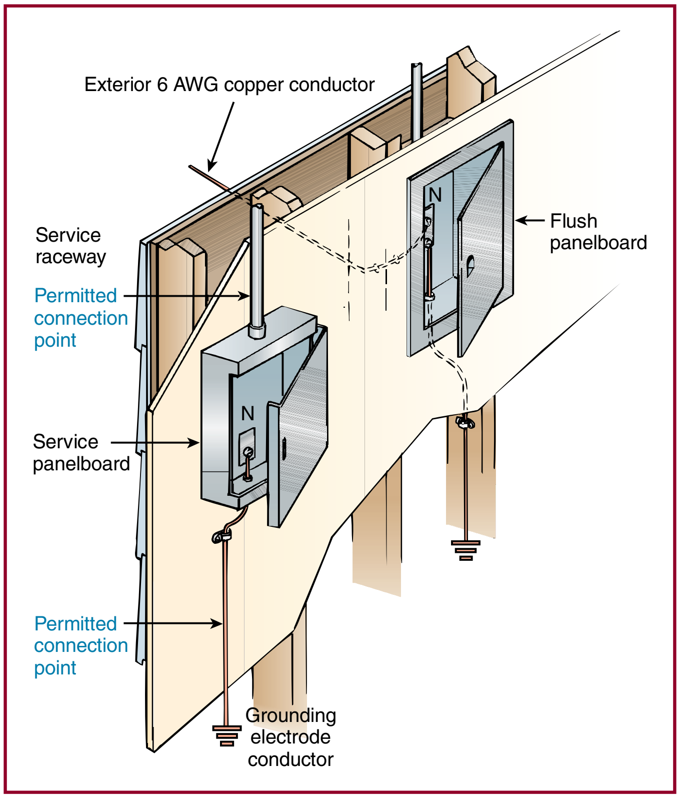


EXHIBIT 250.38 *Methods of providing intersystem bonding at an existing building or structure.*

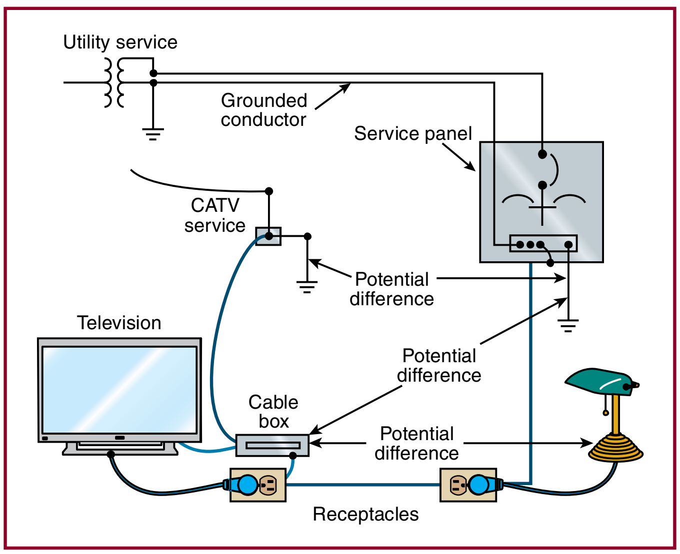


EXHIBIT 250.39 *A CATV installation that does not comply with the* Code, *illustrating why bonding between different systems is necessary.*

result in a severe shock and fire hazard due to these differences in potential. The hazard is illustrated in Exhibit 250.39. In this exhibit, the CATV cable is connected to the cable decoder and the tuner of a television set. Also connected to the decoder and the television is the 120-volt supply, with one conductor grounded at the service (the power ground). In each case, resistance to ground is present at the grounding electrode. This resistance to ground varies depending on soil conditions and the type of grounding electrode. The resistance at the CATV ground is likely to be higher than the ground resistance of the service, because the service grounding electrode is often an underground metal water piping system or concrete-encased electrode, whereas the CATV grounding electrode is commonly a ground rod.

For example, for the CATV installation shown in Exhibit 250.39, assume that a current is induced in the power line by a switching surge or a nearby lightning strike, so that a momentary current of 1000 amperes occurs over the power line to the power line ground. This amount of current is not unusual under such circumstances — the current could be, and often is, considerably higher. Also assume that the service grounding electrode has a resistance of 10 ohms, which is a very low value in most circumstances (a single ground rod in average soil typically has a higher resistance to ground).

Using Ohm's law, we can calculate that the current through the equipment connected to the electrical system will be raised momentarily to a potential of 10,000 volts (1000 amperes × 10 ohms). This potential of 10,000 volts would exist between the CATV system and the electrical system and between the grounded conductor within the CATV cable and the grounded surfaces in the walls of the home, such as water pipes (which are connected to the power ground), over which the cable runs. This potential could also appear across a person with one hand on the CATV cable and the other hand on a metal surface connected to the power ground (such as a radiator or a refrigerator).

Actual voltage is likely to be many times the 10,000 volts calculated, because extremely low (below normal) values were assumed for both resistance to ground and current. Most insulation systems, however, are not designed to withstand even 10,000 volts. Even if the insulation system does withstand a 10,000-volt surge, it is likely to be damaged, and breakdown of the insulation system will result in sparking.

The same situation would exist if the current surge were on the CATV cable or a telephone line. The only difference would be the voltage involved, which would depend on the individual resistance to ground of the grounding electrodes.

The solution required by the *Code* is to bond the two grounding electrode systems together, as shown in Exhibit 250.40, or to connect the CATV cable jacket to the power ground. When one system is raised above ground potential, the second system rises to the same potential, and no voltage exists between the two grounding systems.

The bonding requirement of 250.94 addresses the difficulties sometimes encountered by communications and CATV installers trying to properly bond their respective systems together and to the electrical supply system. In the past, bonding between communications, CATV, and power systems was usually achieved by connecting the communications protector grounds or cable shield to an interior metal water pipe, because the pipe was often used as the power grounding electrode. Thus, the requirement that the power, communications, CATV cable shield, and metal water piping systems be bonded together was easily satisfied. If the power

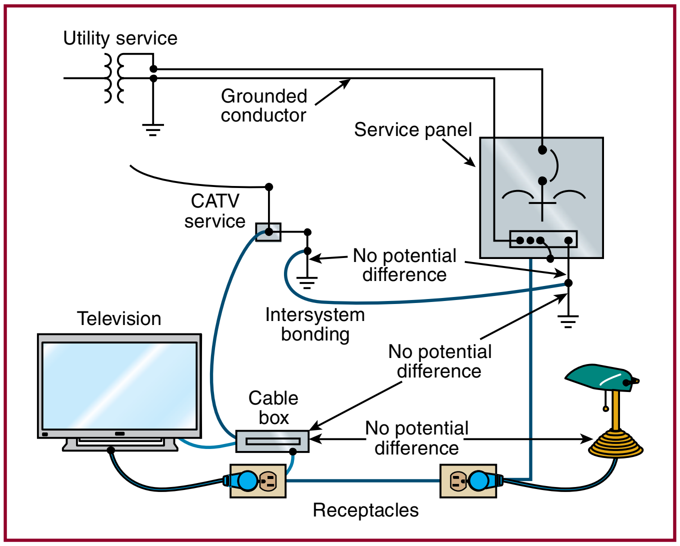


EXHIBIT 250.40 *A cable TV installation that complies with 250.94.*

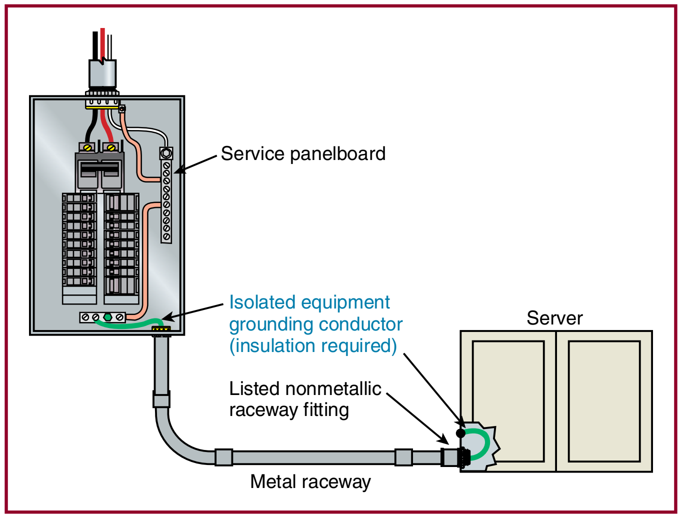


EXHIBIT 250.41 *An installation in which the electronic equipment is grounded through the isolated EGC.*

system was grounded to one of the other electrodes permitted by the *Code* (usually by a made electrode such as a ground rod), the bond was connected to the power grounding electrode conductor or to a metal service raceway, since at least one of these was usually accessible.

With the proliferation of plastic water pipe and the service equipment sometimes being installed in finished areas (often flush-mounted), where the grounding electrode conductor is typically concealed, as well as with the increased use of nonmetallic service-entrance conduit, communications and CATV installers often do not have access to a suitable point for connecting bonding jumpers or grounding electrode conductors. For further information, see the commentary following 820.100(D), Informational Note No. 2.

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 bonded where necessary to ensure electrical continuity and the capacity to conduct safely any fault current likely to be imposed on them. Any nonconductive paint, enamel, or similar coating shall be removed at threads, contact points, and contact surfaces or be connected by means of fittings designed so as to make such removal unnecessary.

(B) Isolated Grounding Circuits. Where installed for the reduction of electrical noise (electromagnetic interference) on the grounding circuit, an equipment enclosure supplied by a branch circuit shall be permitted to be isolated from a raceway containing circuits supplying only that equipment by one or more listed nonmetallic raceway fittings located at the point of attachment of the raceway to the equipment enclosure. The metal raceway shall comply with provisions of this article and shall be supplemented by an internal insulated equipment grounding conductor installed in accordance with 250.146(D) to ground the equipment enclosure.

Informational Note: Use of an isolated equipment grounding conductor does not relieve the requirement for grounding the raceway system.

To reduce electromagnetic interference, electronic equipment is permitted to be isolated from the raceway in a manner similar to that for cord-and-plug-connected equipment. A metal equipment enclosure supplied by a branch circuit is covered by this requirement. Additional wiring, raceways, or other equipment beyond the insulating fitting is not permitted.

Exhibits 250.41 and 250.42 illustrate installations with isolated EGCs. In Exhibit 250.41, the metal raceway is bonded through its attachment to the grounded service equipment enclosure, which provides equipment grounding for the raceway. In Exhibit 250.42, the isolated EGC (which is required to be insulated in order to prevent inadvertent contact with grounded enclosures and raceways) passes through the downstream feeder panelboard and terminates in the service equipment, as permitted by 408.40, Exception. In order to meet the performance objectives for the grounding and bonding of electrical equipment specified in 250.4 and more specifically 250.4(A)(5), the insulated EGC, regardless of where it terminates in the distribution system, must be connected in a manner that creates an effective path for ground-fault current.

250.97 Bonding for Over 250 Volts

For circuits of over 250 volts to ground, the electrical continuity of metal raceways and cables with metal sheaths that contain any conductor other than service conductors shall be ensured by one or more of the methods specified for services in 250.92(B), except for (B)(1).

ARTICLE

250 Grounding and Bonding

INTRODUCTION TO ARTICLE 250—GROUNDING AND BONDING

No other article can match Article 250 for misapplication, violation, and misinterpretation. Terminology used in this article has been a source for much confusion, but that has improved during the last few *NEC* revisions. It's very important to understand the difference between grounding and bonding in order to correctly apply the provisions of Article 250. Pay careful attention to the definitions that apply to grounding and bonding both here and in Article 100 as you begin the study of this important article. Article 250 covers the grounding requirements for providing a path to the earth to reduce overvoltage from lightning, and the bonding requirements for a low-impedance fault current path back to the source of the electrical supply to facilitate the operation of overcurrent devices in the event of a ground fault.

Over the past five Code cycles, this article was extensively revised to organize it better and make it easier to understand and implement. It's arranged in a logical manner, so it's a good idea to just read through Article 250 to get a big picture view—after you review the definitions. Next, study the article closely so you understand the details. The illustrations will help you understand the key points.

PART I. GENERAL

250.1 Scope. Article 250 contains the following grounding and bonding requirements:

(1) What systems and equipment are required to be grounded.

(3) Location of grounding connections.

(4) Types of electrodes and sizes of grounding and bonding conductors.

(5) Methods of grounding and bonding.

250.2 Definitions.

Bonding Jumper, Supply-Side. A conductor on the supply side or within a service or separately derived system to ensure the electrical conductivity between metal parts required to be electrically connected. Figures 250–1 and 250–2

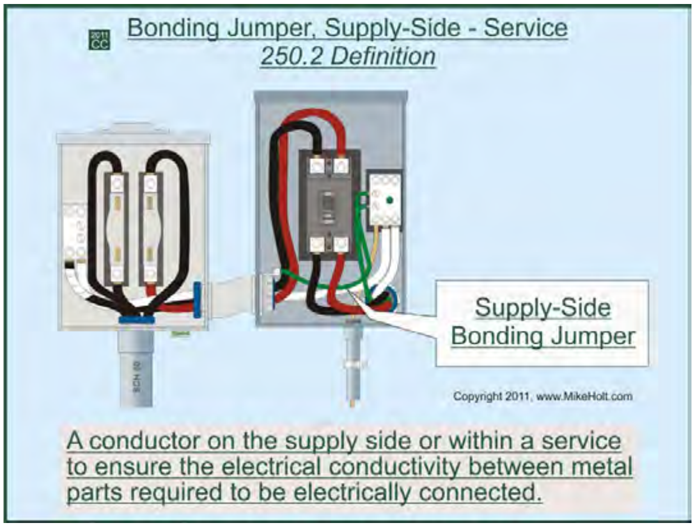


Figure 250–1

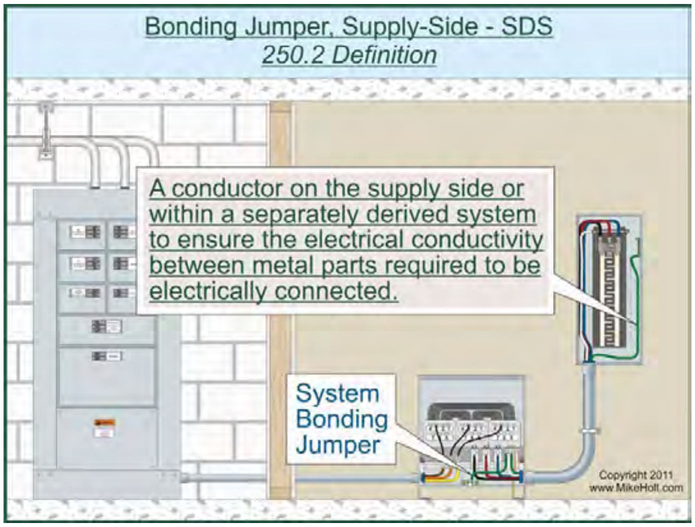


Figure 250–2

Effective Ground-Fault Current Path. An intentionally constructed low-impedance conductive path designed to carry fault current from the point of a ground fault on a wiring system to the electrical supply source. Figure 250–3

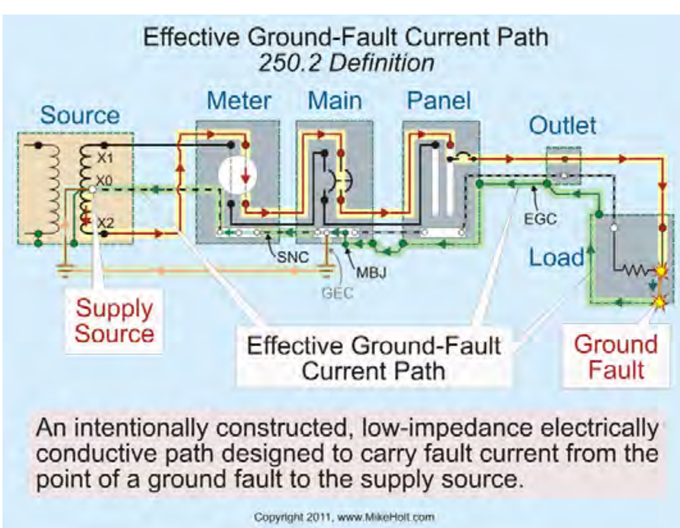


Figure 250–3

Author's Comment: In Figure 250–3, EGC represents the equipment grounding conductor [259.118], MBJ represents the main bonding jumper, SNC represents the service neutral conductor (grounded service conductor), GEC represents the grounding electrode conductor.

The current path shown between the supply source grounding electrode and the grounding electrode at the service main shows that some current will flow through the earth but the earth is not part of the effective ground-fault current path.

The effective ground-fault current path is intended to help remove dangerous voltage from a ground fault by opening the circuit overcurrent device. Figure 250–4

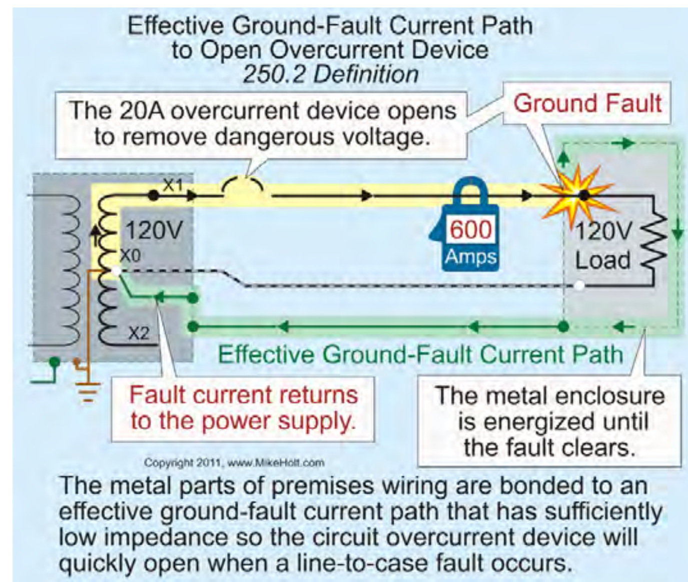


Figure 250–4

Ground-Fault Current Path. An electrically conductive path from a ground fault to the electrical supply source.

Note: The ground-fault current path could be metal raceways, cable sheaths, electrical equipment, or other electrically conductive materials, such as metallic water or gas piping, steel-framing members, metal ducting, reinforcing steel, or the shields of communications cables. Figure 250–5

Author's Comment: The difference between an "effective ground-fault current path" and a "ground-fault current path" is the effective ground-fault current path is "intentionally" constructed to provide a low-impedance fault current path to the electrical supply source for the purpose of clearing a ground fault. A ground-fault current path is all of the available conductive paths over which fault current flows on its return to the electrical supply source during a ground fault.

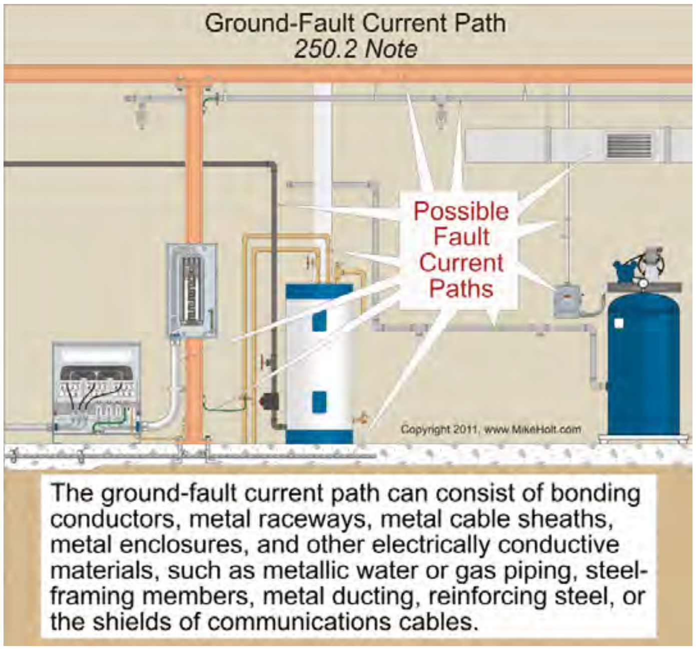


Figure 250–5

250.4 General Requirements for Grounding and Bonding.

(A) Solidly Grounded Systems.

(1) Electrical System Grounding. Electrical power systems, such as the secondary winding of a transformer are grounded (connected to the earth) to limit the voltage induced by lightning, line surges, or unintentional contact by higher-voltage lines. Figure 250–6

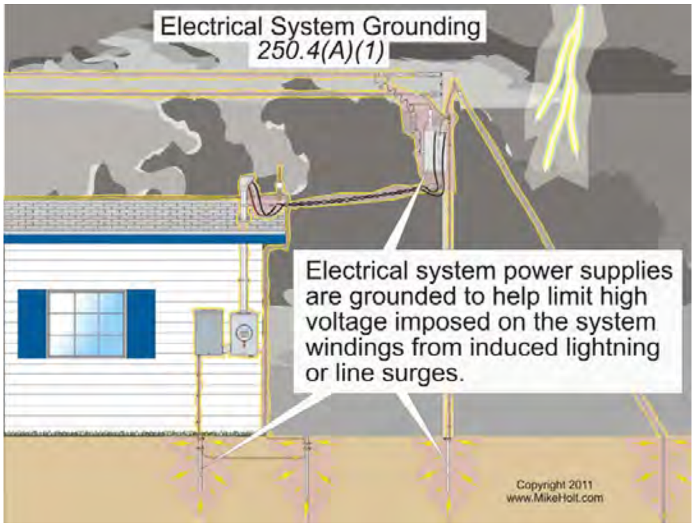


Figure 250–6

Author's Comment: System grounding helps reduce fires in buildings as well as voltage stress on electrical insulation, thereby ensuring longer insulation life for motors, transformers, and other system components. Figure 250–7

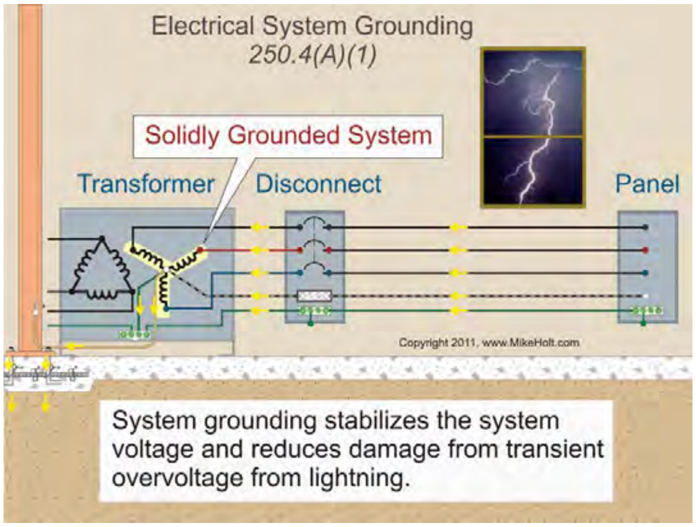


Figure 250–7

Note: An important consideration for limiting imposed voltage is to remember that grounding electrode conductors shouldn't be any longer than necessary and unnecessary bends and loops should be avoided. Figure 250–8

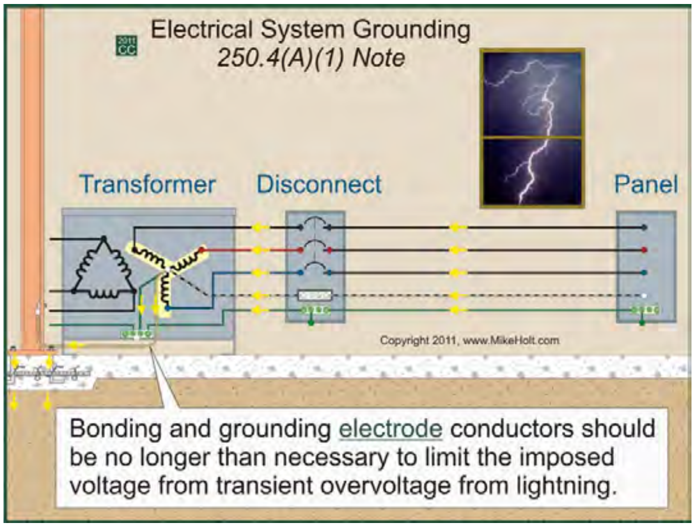


Figure 250–8

(2) Equipment Grounding. Metal parts of electrical equipment are grounded (connected to the earth) to reduce induced voltage on metal parts from exterior lightning so as to prevent fires from an arc within the building/structure. Figure 250–9

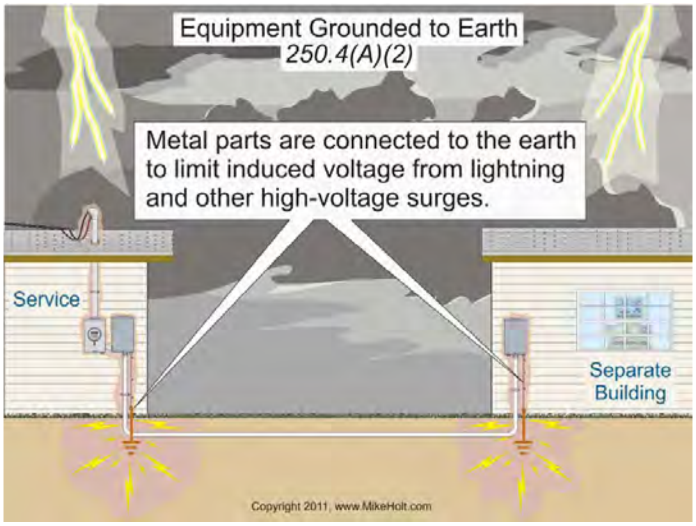


Figure 250–9

DANGER: *Failure to ground the metal parts can result in high voltage on metal parts from an indirect lightning strike to seek a path to the earth within the building—possibly resulting in a fire and/or electric shock.* Figure 250–10

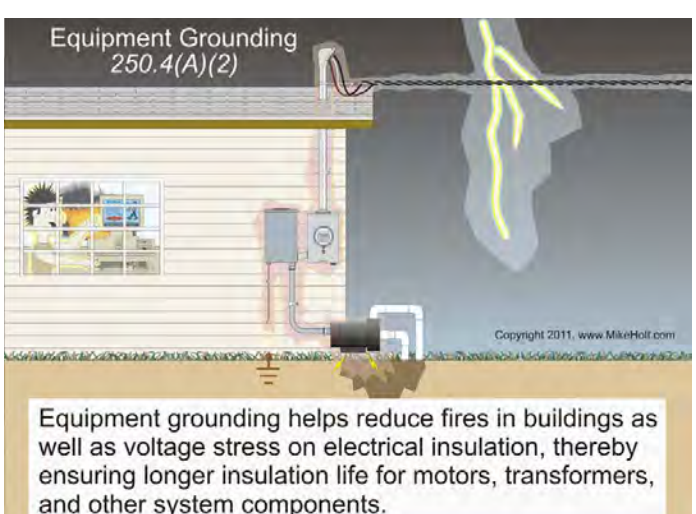


Figure 250–10

Author's Comment: Grounding metal parts helps drain off static electricity charges before flashover potential is reached. Static grounding is often used in areas where the discharge (arcing) of the voltage buildup (static) can cause dangerous or undesirable conditions [500.4 Note 3].

DANGER: *Because the contact resistance of an electrode to the earth is so high, very little fault current returns to the power supply if the earth is the only fault current return path. Result—the circuit overcurrent device won't open and clear the ground fault, and all metal parts associated with the electrical installation, metal piping, and structural building steel will become and remain energized.* Figure 250–11

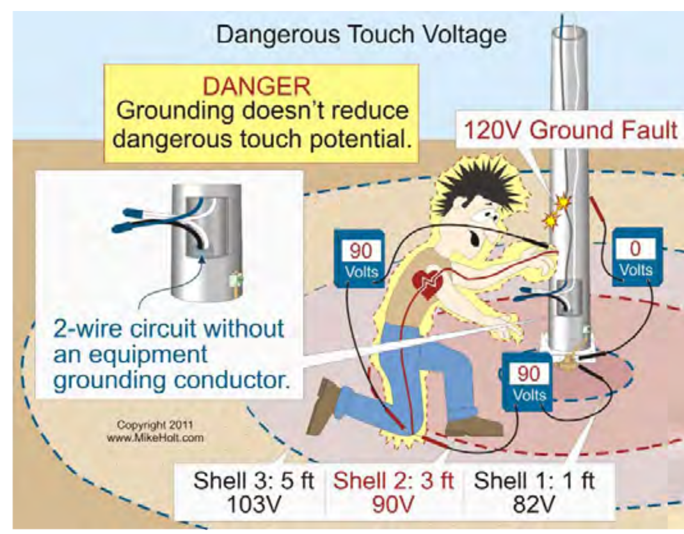


Figure 250–11

(3) Equipment Bonding. Metal parts of electrical raceways, cables, enclosures, and equipment must be connected to the supply source via the effective ground-fault current path. Figures 250–12 and 250–13

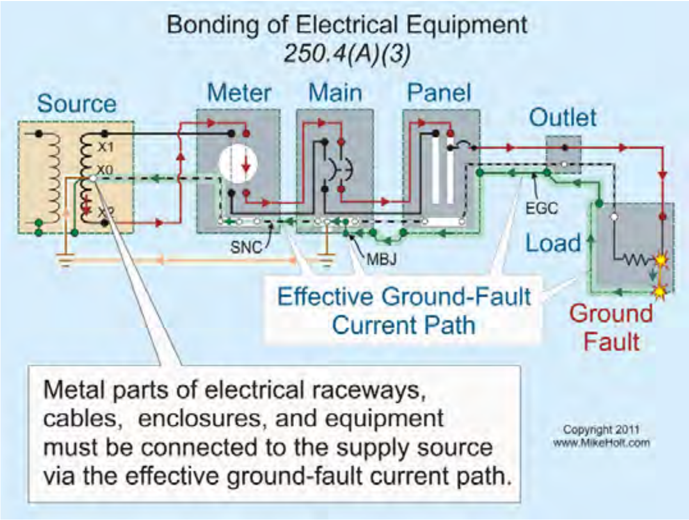


Figure 250–12

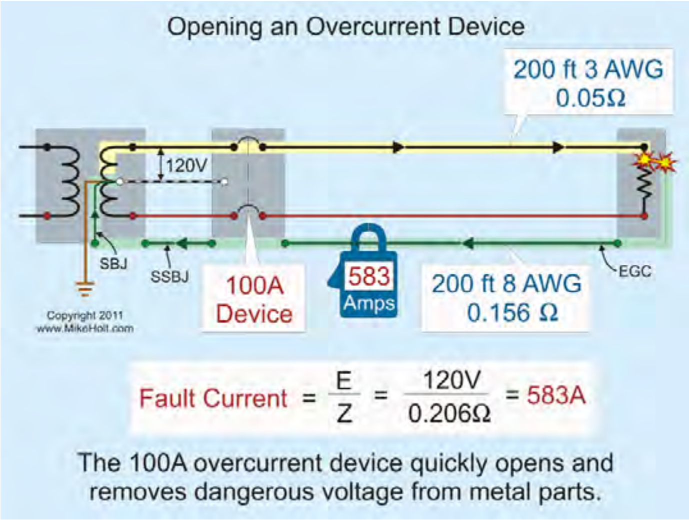


Figure 250–14

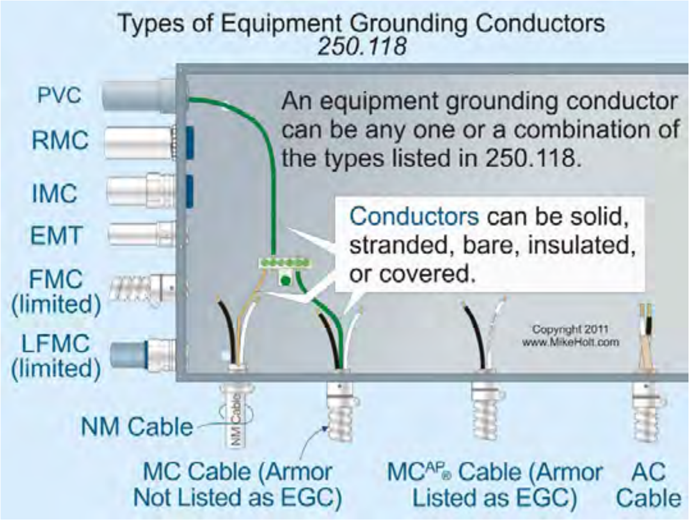


Figure 250–13

Author's Comments:

- To quickly remove dangerous touch voltage on metal parts from a ground fault, the fault current path must have sufficiently low impedance to the source so that fault current will quickly rise to a level that will open the branch-circuit overcurrent device. **Figure 250–14**

- The time it takes for an overcurrent device to open is inversely proportional to the magnitude of the fault current. This means the higher the ground-fault current value, the less time it will take for the overcurrent device to open and clear the fault. For example, a 20A circuit with an overload of 40A (two times the 20A rating) takes 25 to 150 seconds to open the overcurrent device. At 100A (five times the 20A rating) the 20A breaker trips in 5 to 20 seconds. **Figure 250–15**

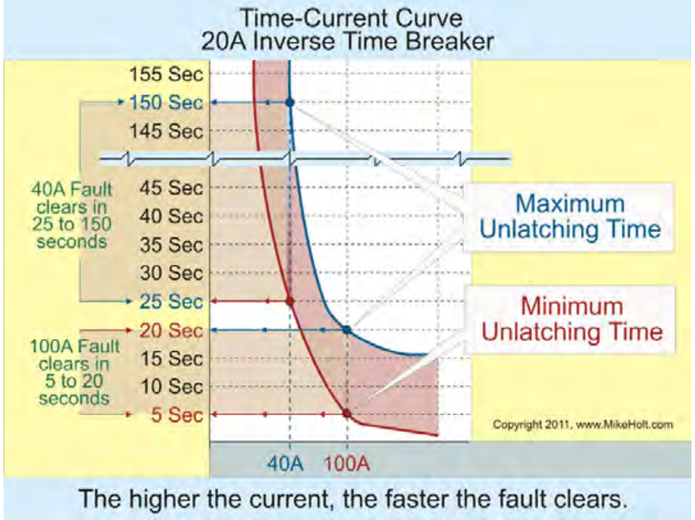


Figure 250–15

(4) Bonding Conductive Materials. Electrically conductive materials such as metal water piping systems, metal sprinkler piping, metal gas piping, and other metal-piping systems, as well as exposed structural steel members likely to become energized, must be connected to the supply source via an equipment grounding conductor of a type recognized in 250.118. Figure 250–16

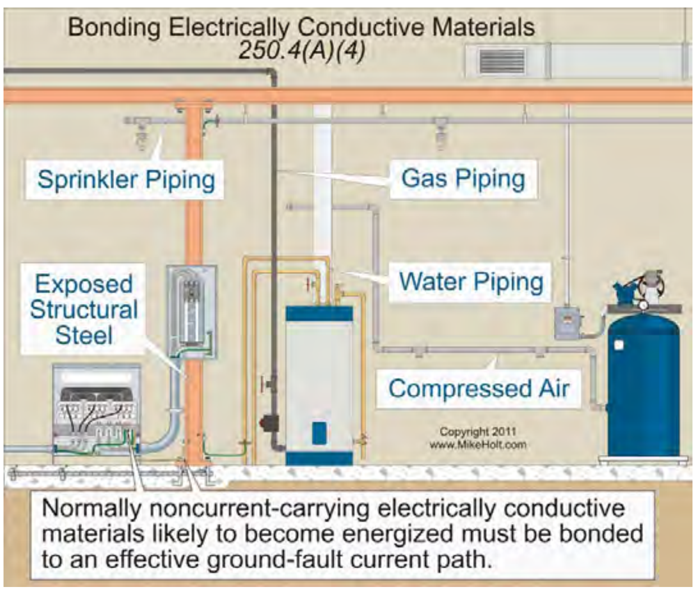


Figure 250–16

> **Author's Comment:** The phrase "likely to become energized" is subject to interpretation by the authority having jurisdiction.

(5) Effective Ground-Fault Current Path. Metal parts of electrical raceways, cables, enclosures, or equipment must be bonded together and to the supply system in a manner that creates a low-impedance path for ground-fault current that facilitates the operation of the circuit overcurrent device. Figure 250–17

> **Author's Comment:** To ensure a low-impedance ground-fault current path, all circuit conductors must be grouped together in the same raceway, cable, or trench [300.3(B), 300.5(I), and 300.20(A)]. Figure 250–18

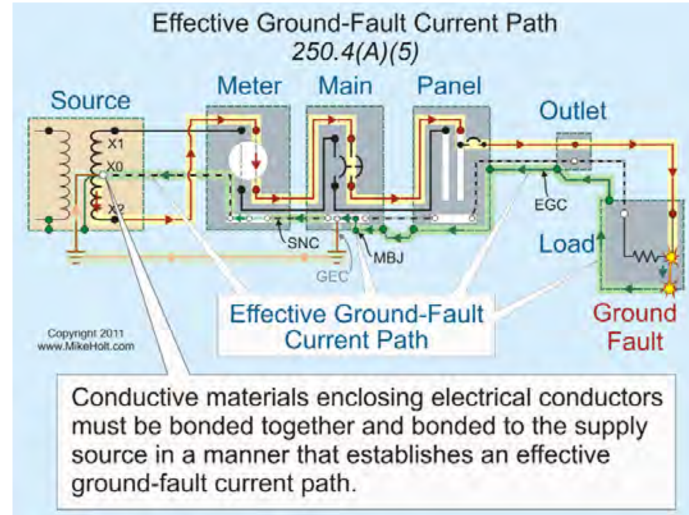


Figure 250–17

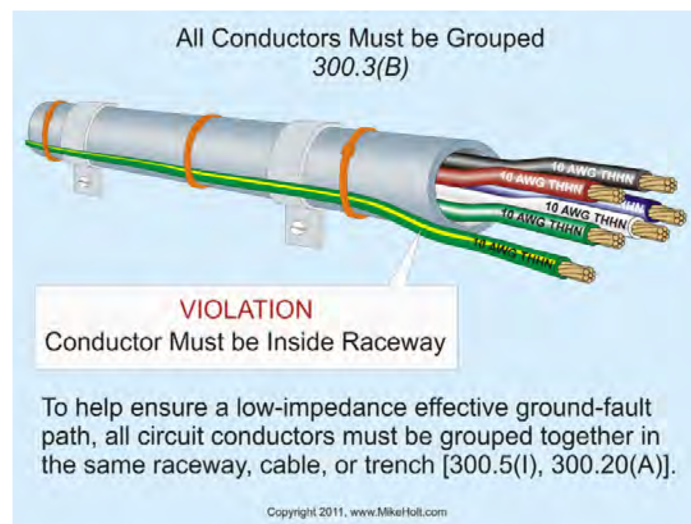


Figure 250–18

Because the earth isn't suitable to serve as the required effective ground-fault current path, an equipment grounding conductor is required to be installed with all circuits. Figure 250–19

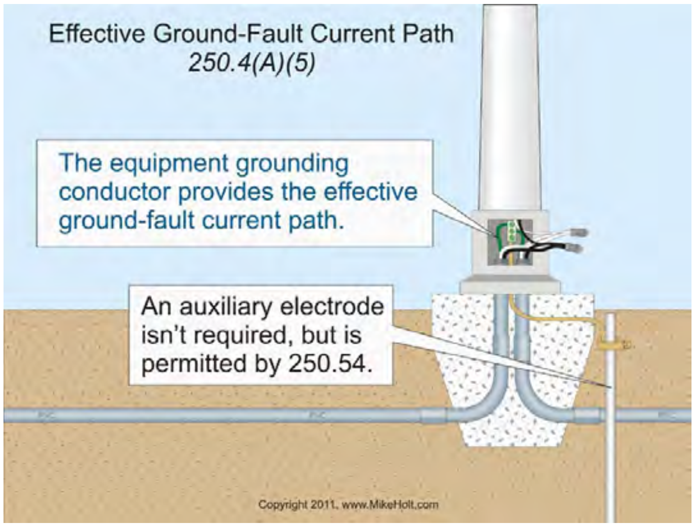


Figure 250–19

Question: *What's the maximum fault current that can flow through the earth to the power supply from a 120V ground fault to metal parts of a light pole that's grounded (connected to the earth) via a ground rod having a contact resistance to the earth of 25 ohms?* Figure 250–20

(a) 4.80A (b) 20A (c) 40A (d) 100A

Answer: *(a) 4.80A*

I = E/R

I = 120V/25 ohms

I = 4.80A

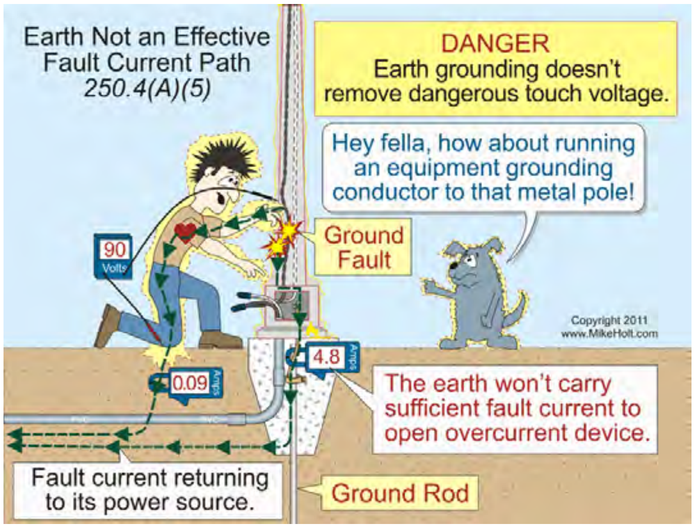


Figure 250–20

DANGER: *Because the contact resistance of an electrode to the earth is so high, very little fault current returns to the power supply if the earth is the only fault current return path. Result—the circuit overcurrent device won't open and all metal parts associated with the electrical installation, metal piping, and structural building steel will become and remain energized.* Figure 250–21

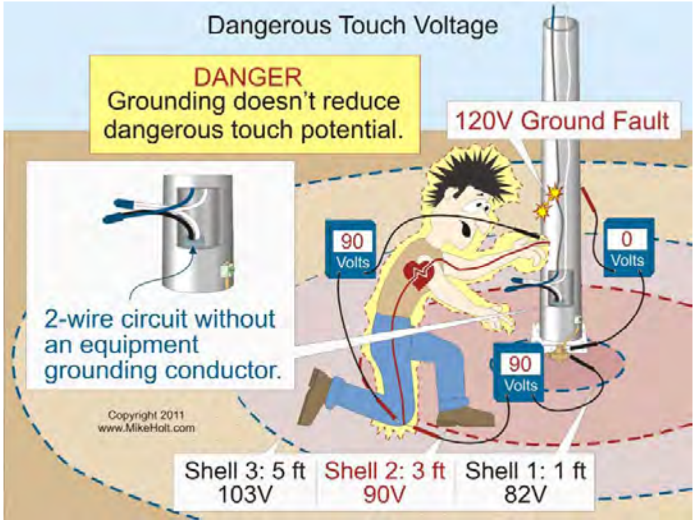


Figure 250–21

EARTH SHELLS

According to ANSI/IEEE 142, *Recommended Practice for Grounding of Industrial and Commercial Power Systems* (Green Book) [4.1.1], the resistance of the soil outward from a ground rod is equal to the sum of the series resistances of the earth shells. The shell nearest the rod has the highest resistance and each successive shell has progressively larger areas and progressively lower resistances. Don't be concerned if you don't understand this statement; just review the table below. Figure 250–22

Distance from Rod	Soil Contact Resistance
1 ft (Shell 1)	68% of total contact resistance
3 ft (Shells 1 and 2)	75% of total contact resistance
5 ft (Shells 1, 2, and 3)	86% of total contact resistance

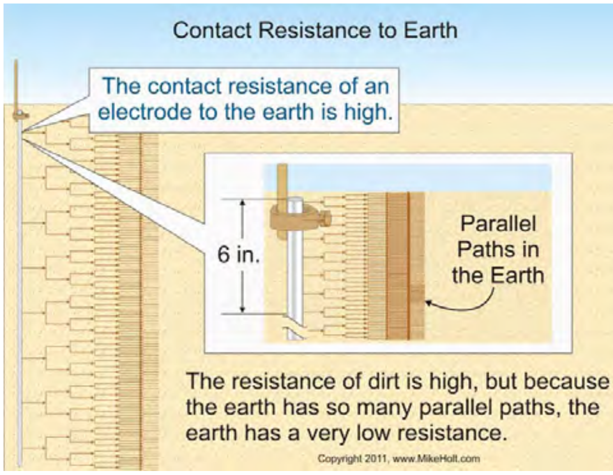


Figure 250–22

Since voltage is directly proportional to resistance, the voltage gradient of the earth around an energized ground rod will be as follows, assuming a 120V ground fault:

Distance from Rod	Soil Contact Resistance	Voltage Gradient
1 ft (Shell 1)	68%	82V
3 ft (Shells 1 and 2)	75%	90V
5 ft (Shells 1, 2, and 3)	86%	103V

(B) Ungrounded Systems.

Author's Comment: Ungrounded systems are those systems with no connection to the ground or to a conductive body that extends the ground connection [Article 100]. Figure 250–23

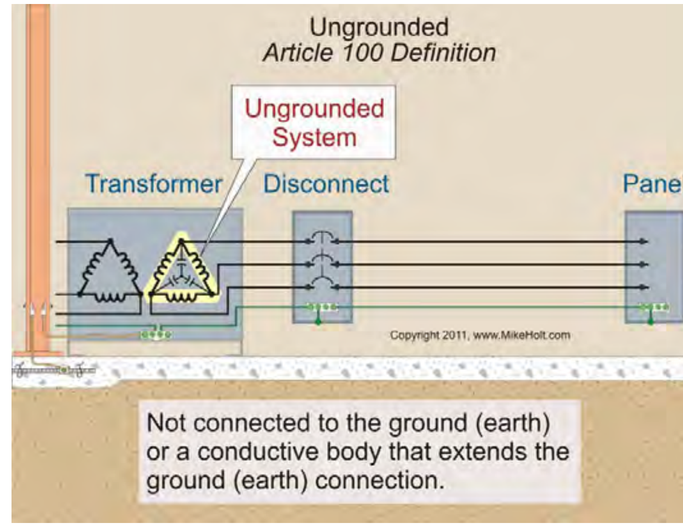


Figure 250–23

(1) Equipment Grounding. Metal parts of electrical equipment are grounded (connected to the earth) to reduce induced voltage on metal parts from exterior lightning so as to prevent fires from an arc within the building/structure. Figure 250–24

Author's Comment: Grounding metal parts helps drain off static electricity charges before an electric arc takes place (flashover potential). Static grounding is often used in areas where the discharge (arcing) of the voltage buildup (static) can cause dangerous or undesirable conditions [500.4 Note 3].

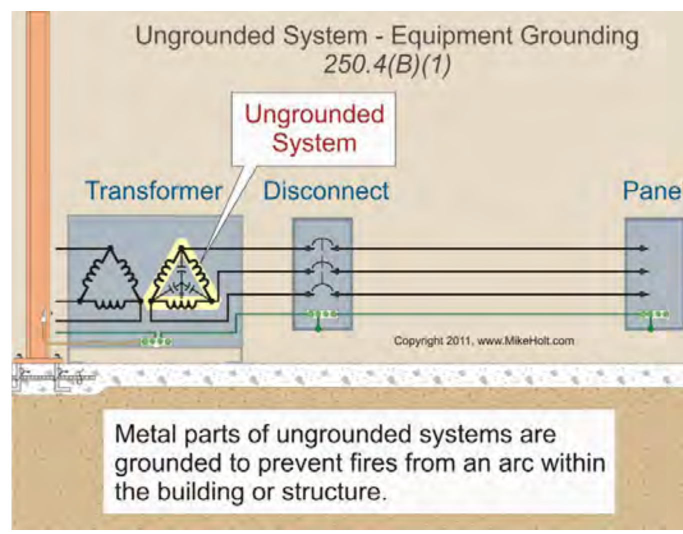


Figure 250–24

CAUTION: *Connecting metal parts to the earth (grounding) serves no purpose in electrical shock protection.*

(2) Equipment Bonding. Metal parts of electrical raceways, cables, enclosures, or equipment must be bonded together in a manner that creates a low-impedance path for ground-fault current to facilitate the operation of the circuit overcurrent device.

The fault current path must be capable of safely carrying the maximum ground-fault current likely to be imposed on it from any point on the wiring system where a ground fault may occur to the electrical supply source.

(3) Bonding Conductive Materials. Conductive materials such as metal water piping systems, metal sprinkler piping, metal gas piping, and other metal-piping systems, as well as exposed structural steel members likely to become energized must be bonded together in a manner that creates a low-impedance fault current path that's capable of carrying the maximum fault current likely to be imposed on it. Figure 250–25

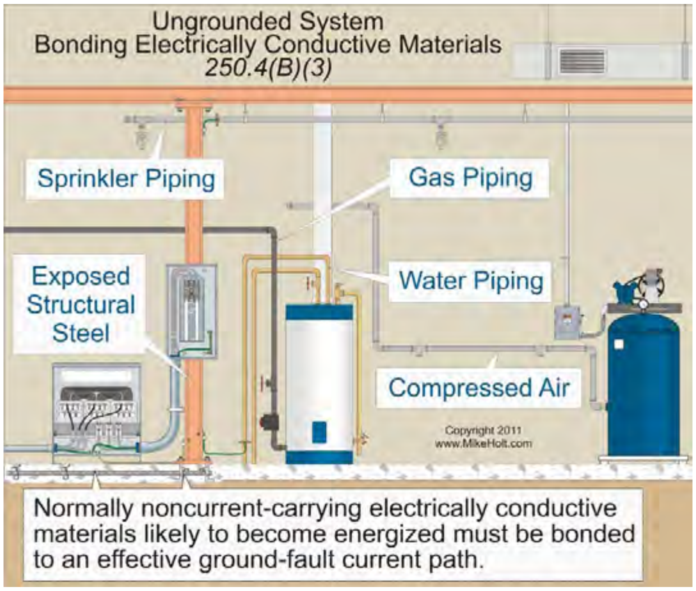


Figure 250–25

Author's Comment: The phrase "likely to become energized" is subject to interpretation by the authority having jurisdiction.

(4) Fault Current Path. Electrical equipment, wiring, and other electrically conductive material likely to become energized must be installed in a manner that creates a low-impedance fault current path to facilitate the operation of overcurrent devices should a second ground fault from a different phase occur. Figure 250–26

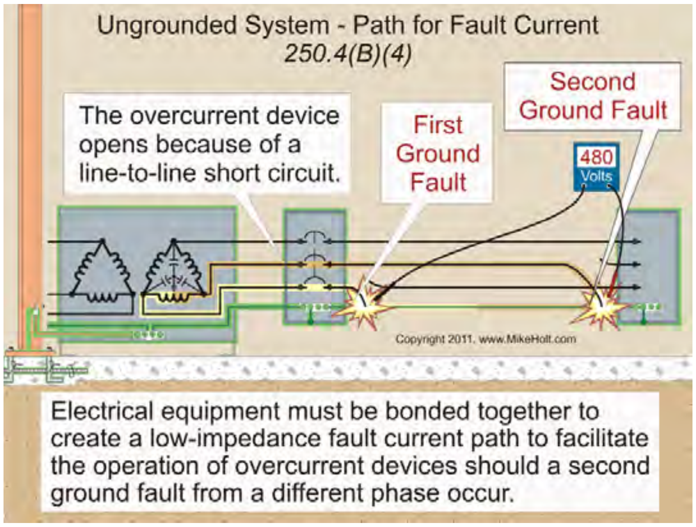


Figure 250–26

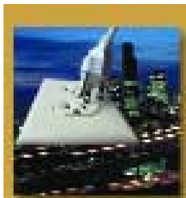
Author's Comment: A single ground fault can't be cleared on an ungrounded system because there's no low-impedance fault current path to the power source. The first ground fault simply grounds the previously ungrounded system. However, a second ground fault on a different phase results in a line-to-line short circuit between the two ground faults. The conductive path, between the ground faults, provides the low-impedance fault current path necessary so the overcurrent device will open.

250.6 Objectionable Current.

(A) Preventing Objectionable Current. To prevent a fire, electric shock, or improper operation of circuit overcurrent devices or electronic equipment, electrical systems and equipment must be installed in a manner that prevents objectionable neutral current from flowing on metal parts.

(C) Temporary Currents Not Classified as Objectionable Currents. Temporary currents from abnormal conditions, such as ground faults, aren't to be classified as objectionable current. Figure 250–27

(D) Limitations to Permissible Alterations. Currents that introduce noise or data errors in electronic equipment are not considered objectionable currents for the purposes of this section. Circuits that supply electronic equipment must be connected to an equipment grounding conductor.



Article 250 Grounding and Bonding

The purpose and objective of “Article 250 – Grounding” is to ensure that electrical installations are safe from electric shock and fires by limiting voltage imposed by lightning and line surges. Though not listed in the title of Article 250, yet included in the requirement, “bonding” is the intentional connection of metal parts to form a low-impedance effective ground-fault current path to remove dangerous voltage from metal parts from a ground fault.

AUTHOR’S COMMENT: The grounding and bonding rules covered in this book apply to solidly grounded alternating-current systems under 600V, such as 120/240V, 208Y/120V and 480Y/277V. Other system configurations, such as 3-wire corner-grounded delta systems, ungrounded systems, or high-impedance grounded neutral systems are permitted by the *National Electrical Code*, but they are typically limited to 3-phase industrial applications and not covered in this book.

Part I. General

250.1 Scope

Part I contains the general requirements for grounding and bonding and the remaining parts contain specific grounding and bonding requirements such as:

(1) Systems and equipment required, permitted, or not permitted to be grounded.

(2) Which circuit conductor is required to be grounded on grounded systems.

(3) The location of grounding (bonding) connections.

(4) How to size grounding and bonding conductors.

(5) Methods of grounding and bonding.

250.2 Definitions

Effective Ground-Fault Current Path. An intentionally constructed, permanent, low-impedance conductive path designed to carry fault current from the point of a ground fault on a wiring system to the grounded (neutral) point at the electrical supply source. Figure 250-17

An effective ground-fault current path is created when all non-current-carrying electrically conductive materials of an electrical installation are bonded together and to the grounded (neutral) conductor at the electric supply. Effective bonding is accomplished through the use of equipment grounding (bonding) conductors, metallic raceways, connectors, couplings, metallic-sheathed cable with approved fittings and other approved devices recognized for this purpose [250.18].

AUTHOR’S COMMENT: A ground-fault current path is only effective when it is properly sized so that it will safely carry the maximum fault current likely to be imposed on it. See 250.4(A)(5) and 250.122 for additional details.

Ground Fault (Line-to-Case Fault). An unintentional, electrically conducting connection between an ungrounded conductor of an electrical circuit and metallic enclosures, metallic raceways, or metallic equipment. Figure 250-18

AUTHOR’S COMMENT: Line-to-case ground faults are not always of the low-impedance type; they might be of the high-impedance arcing type, which are difficult to clear before a fire destroys the equipment as well as the property. High impedance, in this case, occurs when improper bonding techniques have been

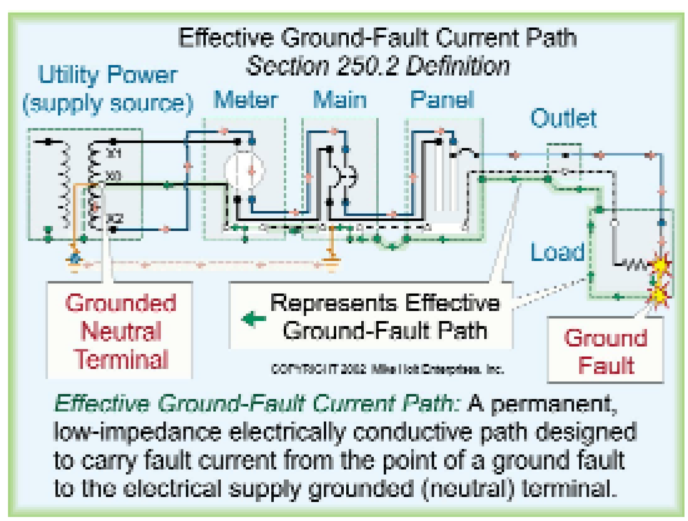


Figure 250–17

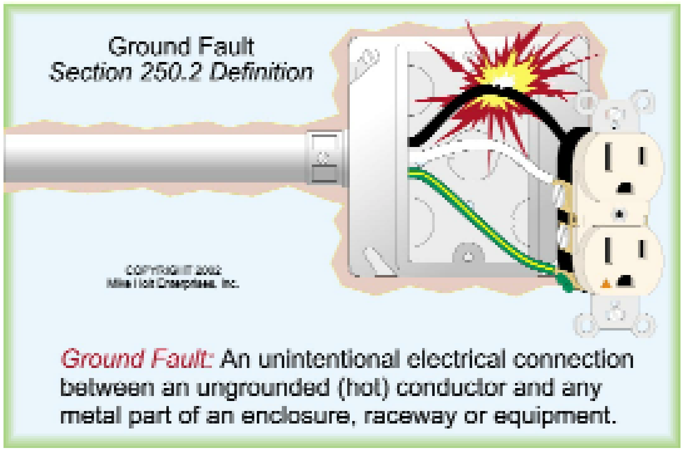


Figure 250–18

used. This is a particular problem for 480V solidly grounded systems and that is why the *NEC* requires equipment ground-fault protection for larger installations. See 230.95. Another way of reducing this hazard is by the installation of high-impedance neutral systems. See 250.36 for the use of current-limiting fuses. This topic is beyond the scope of this book.

Ground-Fault Current Path. An electrically conductive path from the point of a ground fault (line-to-case fault) on a wiring system through conductors, or equipment extending to the grounded (neutral) terminal at the electrical supply source.

FPN: The ground-fault current paths could consist of grounding and bonding conductors, metallic raceways, metallic cable sheaths, electrical equipment and other electrically conductive material, such as metallic water and gas piping, steel-framing members, stucco mesh, metal ducting, reinforcing steel, or shields of communications cables.

AUTHOR'S COMMENT: The difference between an "effective ground-fault current path" and "ground-fault current path" is that the effective ground-fault current path is "intentionally" made for the purpose of clearing a fault. The ground-fault current path is simply the path that ground-fault current will flow on to the power supply during a ground fault.

250.3 Other Code Sections

Other rules that contain additional grounding and bonding requirements listed in Table 250.3 include:

- Agricultural Building Equipotential Planes, 547.9 and 547.10. Figure 250-19
- Audio Equipment, 640.7
- Hazardous (classified) Locations, 501.16, 502.16 and 503.16

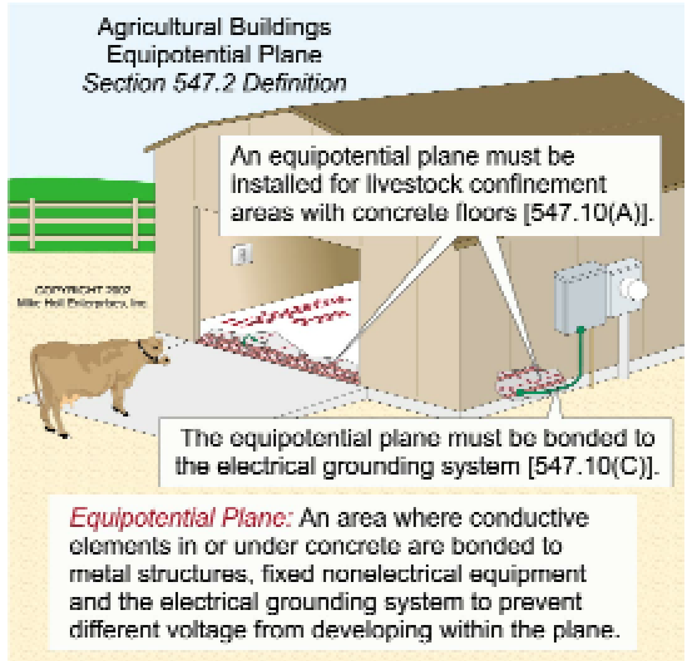


Figure 250–19

- Panelboards, 408.20
- Receptacles, 406.3, 406.9, 517.13
- Receptacle Cover Plates, 406.5
- Swimming Pools and Spas, 680.23(F)(2), 680.24(D) and 680.25(B)
- Switches, 404.9(B) and 517.13

250.4 General Requirements for Grounding and Bonding

The following explains the purpose of grounding and bonding of electrical systems and equipment to ensure a safe installation.

(A) Grounded Systems.

AUTHOR'S COMMENT: The term "electrical system" as used in this subsection refers to the "power source" such as a transformer, generator or photovoltaic system, not the circuit wiring and/or the equipment.

(1) Grounding of Electrical Systems. Electrical power supplies such as the utility transformer shall be grounded to earth to help limit high voltage imposed on the system windings from lightning or line surges. Figure 250-20

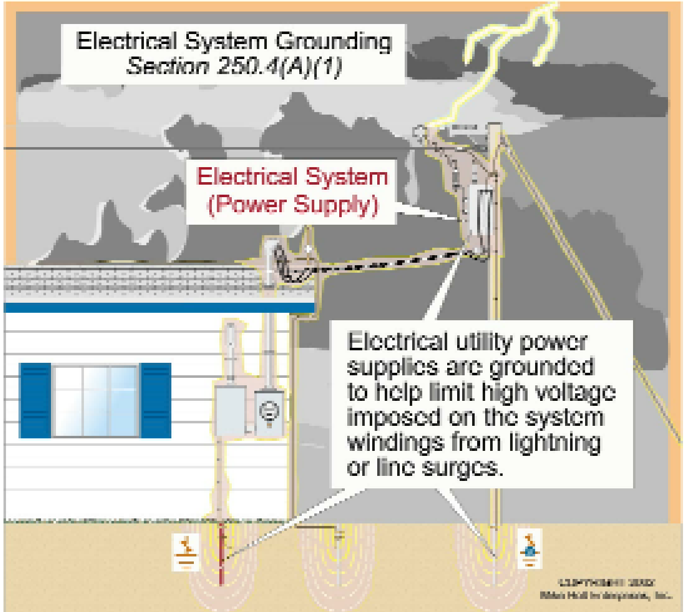


Figure 250–20

AUTHOR'S COMMENT: **Grounding System for Lightning** – The electric discharge from lightning is typically from a negative charged cloud to a positive charged earth surface, but it can be from the earth's surface to a cloud, or it can be from cloud to cloud as well as cloud to space. When the negative capacitive voltage charge of a cloud exceeds the dielectric strength of the air between the cloud and the earth, an arc will occur between the clouds and the earth in an attempt to equalize the difference of potential between the two objects. When this occurs, high voltages, often over 20,000V, drives high amperages of current (as much as 40,000A) into the earth for a fraction of a second. Figure 250-21

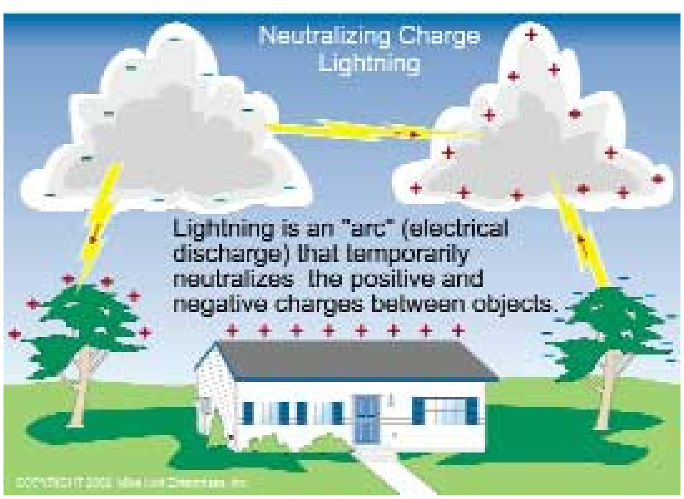


Figure 250–21

Typically, utility wiring outside will be struck by lightning and it's critical that these systems be grounded to the earth to assist the flow of lightning into the earth.

Grounding System for Line Surges – When a utility high-voltage ground fault occurs, the voltage on the other phases will rise for the duration of the fault (typically 3 to 12 cycles). This voltage surge during the utility ground fault will be transformed into an elevated surge voltage on the secondary, which can cause destruction of electrical and particularly electronic equipment in the premises. Studies have shown that the lower the resistance of the utility grounding system, the lower the voltage surge.

Electrical systems (power supplies) are grounded (actually bonded) to stabilize the system voltage during normal operation. Figure 250-22

CAUTION: According to IEEE Std. 242 "Buff Book," if a ground fault is intermittent or allowed to continue on an ungrounded system, the system could be subjected to possible severe system overvoltage-to-ground, which can be as high as six or eight times the phase voltage. This excessive voltage can puncture conductor insulation and result in additional ground faults. System overvoltage-to-ground is caused by repetitive charging of the system capacitance or by resonance between the system capacitance and the inductances of equipment in the system.

In addition, IEEE Std. 142 "Green Book" states that "Field experience and theoretical studies have shown that arcing, restriking, or vibrating ground faults on ungrounded systems (actually unbonded systems) can, under certain conditions, produce surge voltages as high as six times normal. Neutral (system) grounding (actually bonding) is effective in

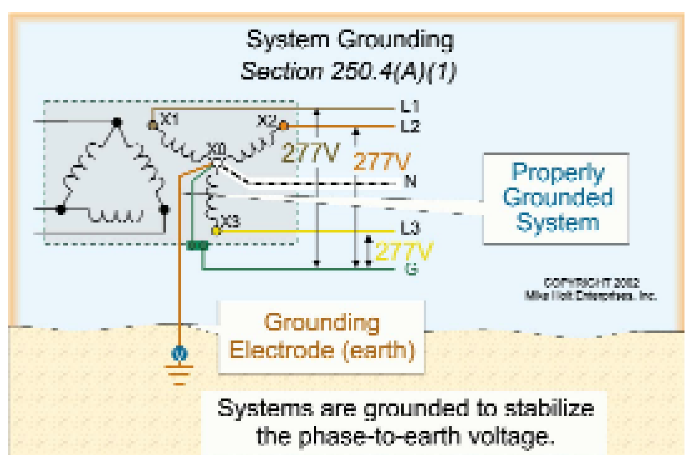


Figure 250–22

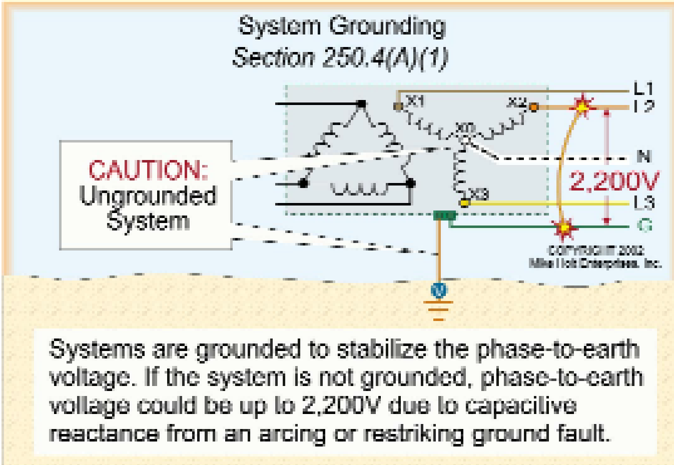


Figure 250–23

reducing transient voltage buildup from such intermittent ground faults by reducing neutral displacement from ground potential and reducing destructive effectiveness of any high-frequency voltage oscillations following each arc initiation or restrike." Figure 250-23

AUTHOR'S COMMENT: The danger of overvoltage occurs in systems that are intended to be ungrounded as well as those systems that were supposed to be grounded but were not. Elevated voltage-to-ground is beyond the scope of this book. To obtain more information on this subject, visit http://www.mike-holt.com/Newsletters/highvolt.htm.

(2) Grounding of Electrical Equipment. To help limit the voltage impressed on metal parts from lightning, non-current-carrying conductive metal parts of electrical equipment in or on a building or structure shall be grounded to earth. Figure 250-24

AUTHOR'S COMMENT: Grounding of electrical equipment to earth is not for the purpose of clearing a ground fault.

Metal parts of electrical equipment in a building or structure are grounded to earth by electrically connecting the building or structure disconnecting means [225.31 or 230.70] with a grounding electrode conductor [250.64(A)] to an appropriate grounding electrode (earth) identified in 250.52 [250.24(A) and 250.32(B)].

DANGER: Failure to ground the metal parts of electrical equipment to earth could result in elevated voltage from lightning entering the building or structure, via metal raceways or cables, seeking a path to the earth. The high voltage on the metal parts from

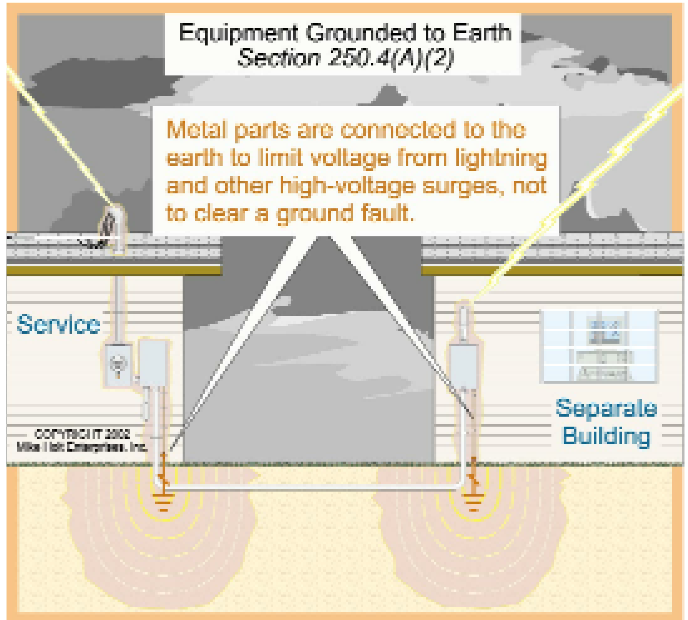


Figure 250–24

lightning can result in electric shock and fires, as well as the destruction of electrical equipment from lightning. Figure 250-25

Grounding of metal parts of electrical equipment also helps prevent the buildup of high-voltage static charges on metal parts. Grounding is often required in areas where the discharge (arcing) of the voltage buildup could cause failure of electronic equipment being assembled on a production line or a fire and explosion in a hazardous classified area. See 500.4 FPN 3.

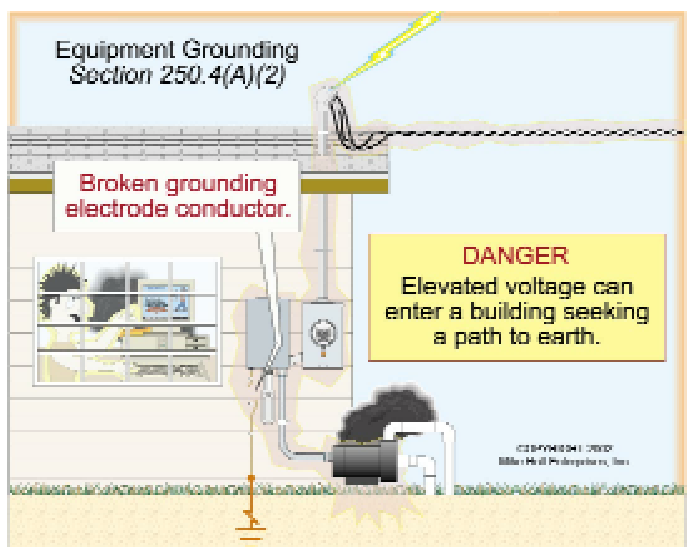


Figure 250–25

AUTHOR'S COMMENT: Grounding metal parts of electrical equipment to earth does not protect electrical or electronic equipment from lightning voltage transients (high-frequency voltage impulses) on the circuit conductors inside the building or structure. To protect electronic and electrical equipment from high-voltage transients, proper transient voltage surge protection devices should be installed in accordance with Article 280 at service equipment and Article 285 at the panelboards.

To provide proper operation of transient voltage surge protection devices, the resistance of the grounding electrode (earth) should be as low as practical. Most specifications for communications systems installations (cell towers) require the ground resistance to be 5Ω, sometimes as little as 3Ω and on some rare occasions 1Ω! To achieve and maintain a low resistive ground, special grounding configurations, design, equipment and measuring instruments must be used. This is beyond the scope of this book.

(3) Bonding of Electrical Equipment. To remove dangerous voltage caused by ground faults, the metal parts of electrical raceways, cables, enclosures or equipment shall be bonded together. In addition, the metal parts shall be bonded to the grounded (neutral) terminal of the electrical supply source in accordance with 250.142. Figure 250-26

AUTHOR'S COMMENT: An effective ground-fault current path [250.2] is created when all non-current-carrying electrically conductive materials are bonded together and to the grounded (neutral) terminal at the electric supply.

(4) Bonding of Electrically Conductive Materials. To remove dangerous voltage caused by ground faults, electrically conductive metal water piping, sprinkler piping, metal gas piping, and other metal piping as well as exposed structural steel members that are likely to become energized shall be bonded in accordance with 250.104. Figure 250-27

AUTHOR'S COMMENT: The phrase "that are likely to become energized" is subject to interpretation by the Authority Having Jurisdiction (AHJ). See 250.104 for additional details.

(5) Effective Ground-Fault Current Path. Electrical raceways, cables, enclosures and equipment as well as other electrically conductive material "likely to become energized" shall be installed in a manner that creates a permanent, low-impedance path that has the capacity to safely carry the maximum ground-fault current likely to be imposed on it [110.10]. The purpose of this path is to facilitate the operation of overcurrent devices if a ground fault occurs to the metal parts. Clearing ground faults is accomplished by bonding all of the metal parts of electrical equipment and conductive material likely to become energized to the power-supply grounded (neutral) terminal. Figure 250-28

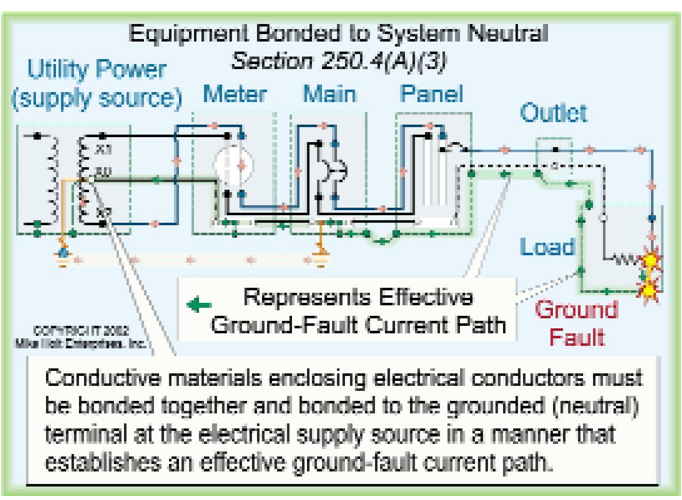


Figure 250–26

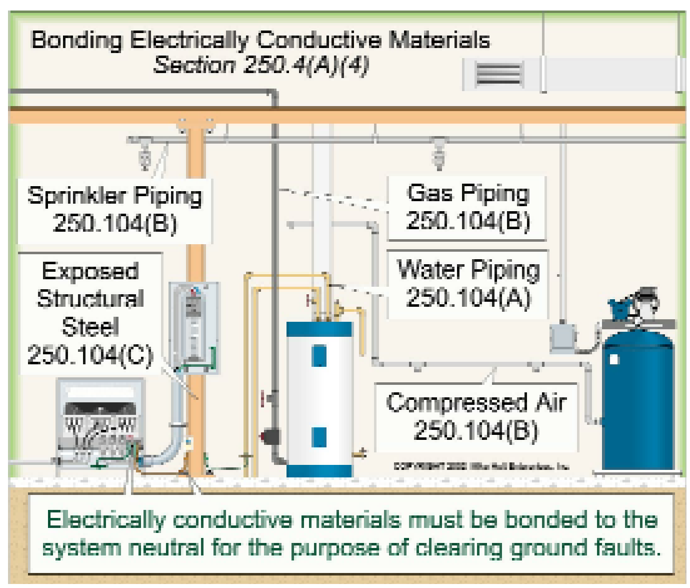


Figure 250–27

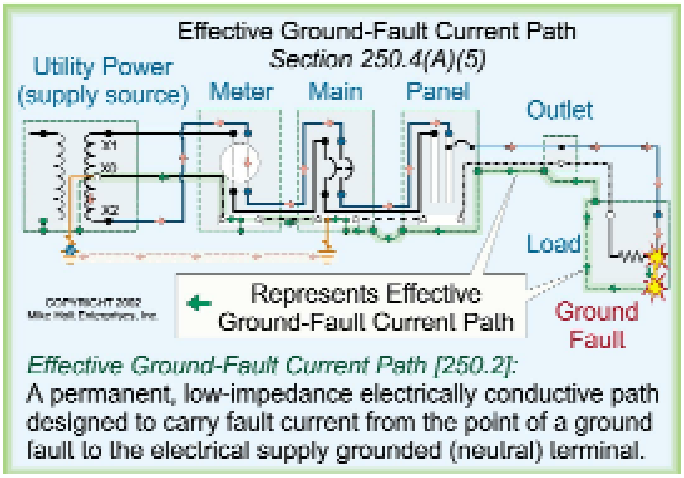


Figure 250–28

The *NEC* does permit a ground rod at a pole [250.54] but the *Code* does not allow the earth to be used as the sole equipment grounding (bonding) conductor. An equipment grounding (bonding) conductor of a type specified in 250.118 is ALWAYS required. Figure 250-29

CAUTION: Because the earth is a poor conductor whose resistivity does not permit sufficient fault current to flow back to the power supply [IEEE Std. 142 Section 2.2.8], a ground rod will not serve to clear a ground fault and dangerous touch voltage will remain on metal parts if an effective ground-fault current path is not provided. For more information on this topic, visit http://www.mikeholt.com/Newsletters/GroundResistance.htm. Figure 250-30

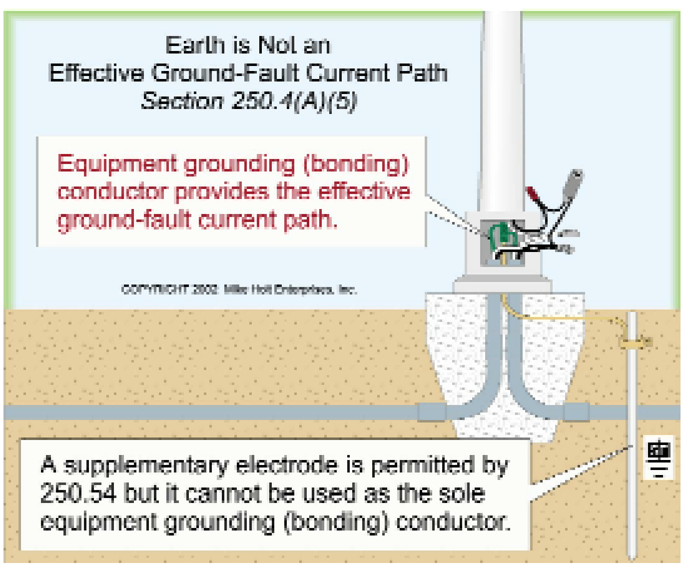


Figure 250–29

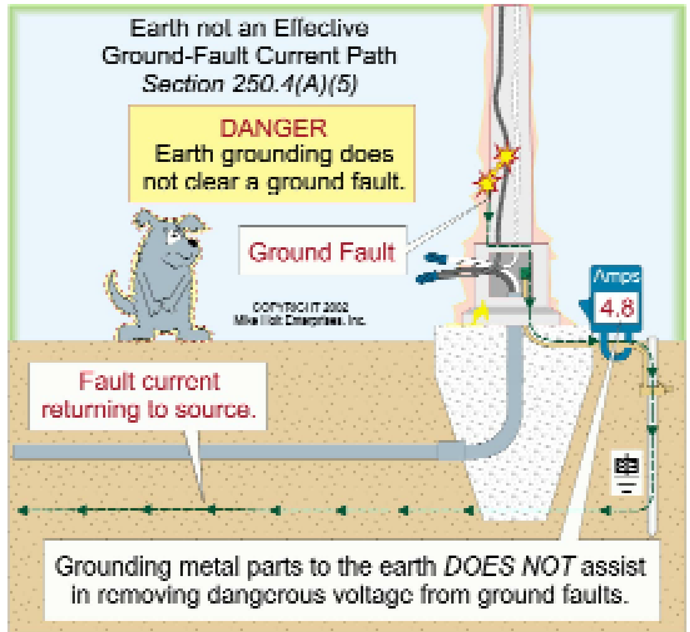


Figure 250–30

Question: What is the maximum current that could flow though a ground rod if the ground rod has an impedance of 25Ω and the system voltage is 120/240V?

(a) 4.8A (b) 24A

(c) 48A (d) 96A

Answer: (a) 4.8A

$I = E/Z$, $E = 120V$, $Z = 25\Omega$

$I = 120V/25\Omega = 4.8A$

DANGER: Because the resistance of the earth is so great (10 to 500Ω), very little current will return to the power supply via the earth if the earth is the only ground-fault return path. The result is that the circuit overcurrent protection device will not open and metal parts will remain energized at a lethal level waiting for someone to make contact with them and the earth. Therefore, a ground rod cannot be used to lower touch voltage to a safe value for metal parts that are not bonded to an effective ground-fault current path. To understand how a ground rod is useless in reducing touch voltage to a safe level, let's review the following:

- *What is touch voltage?*
- *At what level is touch voltage hazardous?*
- *How earth surface voltage gradients operate.*

1. Touch Voltage - The IEEE definition of touch voltage is "the potential (voltage) difference between a grounded (bonded) metallic structure and a point on the earth 3 ft from the structure."

2. Hazardous Level - NFPA 70E - Standard for Electrical Safety Requirements for Employee Workplaces, cautions that death and/or severe electric shock can occur whenever the touch voltage exceeds 30V.

3. Surface Voltage Gradients - According to IEEE Std. 142 "Green Book" [4.1.1], the resistance of the soil outward from a ground rod is equal to the sum of the series resistances of the earth shells. The shell nearest the rod has the highest resistance and each successive shell has progressively larger areas and progressively lower resistances. The following table lists the percentage of total resistance and the touch voltage based on a 120V fault. The table's percentage of resistance is based on a 10 ft ground rod having a diameter of 5/8 inches.

Don't worry if you don't understand the above statement, just review the table below with Figure 250-31

Distance from Rod	*Resistance*	*Touch Voltage*
1 Foot (Shell 1)	*68%*	*82V*
3 Feet (Shells 1 and 2)	*75%*	*90V*
5 Feet (Shells 1, 2 and 3)	*86%*	*103V*

With the intention of providing a safer installation, many think a ground rod can be used to reduce touch voltage. However, as we can see in the above table, the voltage gradient of the earth drops off so rapidly that a person in contact with an energized object can receive a lethal electric shock one foot away from an energized object if the metal parts are not bonded to an effective ground-fault current path.

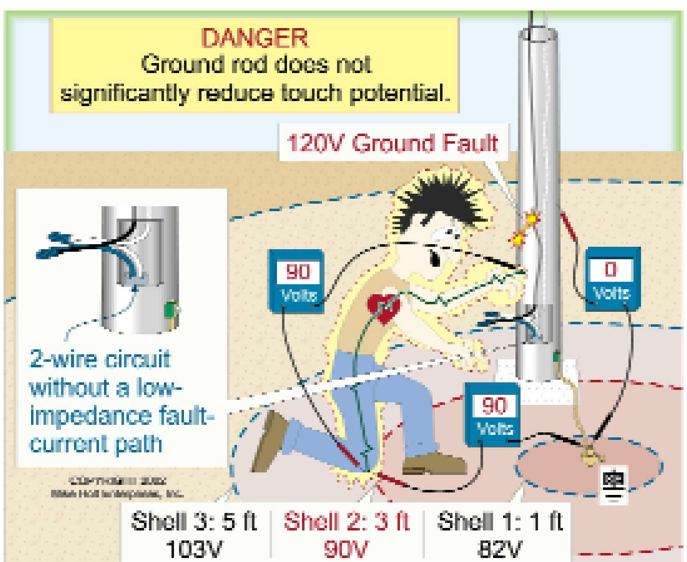


Figure 250–31

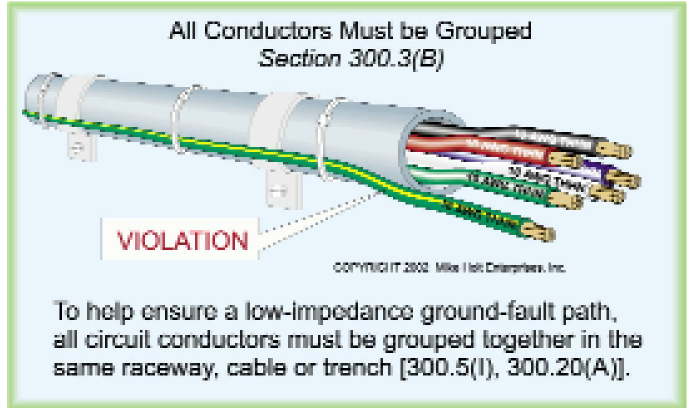


Figure 250–32

Scary as it might be, the accepted grounding practice for street lighting and traffic signaling for many parts of the United States was to use the ground rod as the only ground-fault current return path. That is, the metal pole of a light fixture or traffic signal is grounded to a ground rod and an effective ground-fault current path is not provided (no equipment grounding conductor)! I'm sure there are thousands of energized metal poles, just waiting for someone to make contact with them and this is one of the reasons so many people get killed with street lighting and traffic signal poles in the United States. For a case study on this subject, visit www.mikeholt.com/Newsletters/dadecounty.htm.

AUTHOR'S COMMENT: Another factor necessary to help ensure a low-impedance ground-fault path is that all circuit conductors, ungrounded, grounded and the equipment grounding (bonding) conductor shall be grouped together in the same raceway, cable or trench [300.3(B), 300.5(I), 300.20(A)]. Figure 250-32

250.4(A) Summary

(1) An electrical power supply shall be grounded to stabilize the system voltage.

(2) Metal parts of electrical equipment at a building or structure disconnect shall be grounded to assist lightning to earth.

(3) Electrically bonding non-current-carrying parts of the electrical wiring system to an effective ground-fault current path is required so that a ground fault can be quickly cleared by opening the circuit overcurrent protection device.

(4) Electrically bonding conductive piping and structure steel that may become energized to the effective

ground-fault current path is required so that a ground fault can be quickly cleared by opening the circuit overcurrent protection device.

(5) Create an effective ground-fault current path for metal parts of equipment enclosures, raceways, and equipment as well as metal piping and structural steel. The effective ground-fault current path shall be sized to withstand high fault current [110.10 and 250.122].

250.6. Objectionable (Neutral) Current

(A) Preventing Objectionable Current. To prevent a fire, electric shock, improper operation of circuit protection devices, as well as improper operation of sensitive equipment, the grounding of electrical systems and the bonding of equipment shall be done in a manner that prevents objectionable (neutral) current from flowing on conductive materials, electrical equipment, or on grounding and bonding paths.

Objectionable (Neutral) Current

Objectionable current on grounding and bonding paths occur when:

1. Improper neutral-to-case bonds are made.
2. There are errors in the wiring installation.
3. Using the equipment-grounding conductor to carry neutral current.

Improper Neutral-to-Case Bond [250.142]

Panelboards – Bonding of the neutral terminal to the case of a panelboard that is not part of service equipment or a separately derived system creates a parallel path, which allows objectionable neutral current to flow on the metal parts of electrical equipment as well as the grounding and bonding conductors. Figure 250-33

Disconnects – Where an equipment grounding (bonding) conductor is run with the feeder conductors to a separate building [250.32(B)(1)], a common and dangerous mistake is to make a neutral-to-case bond in the separate building disconnect, which allows objectionable neutral current to flow on the metal parts of electrical equipment as well as on the grounding and bonding conductors. Figure 250-34

Separately Derived Systems – The neutral-to-case bonding jumper for a separately derived system, such as that derived from a transformer, generator, or uninterruptible power supply (UPS) shall be installed either at the source of the separately derived system or at the first disconnect electrically downstream, but not at both locations in accordance with 250.30(A)(1).

Transformers – If a neutral-to-case bond is made at both the transformer and at the secondary panelboard/disconnect, then objectionable neutral current will flow on the metal parts of electrical equipment as well as the grounding and bonding conductors. Figure 250-35

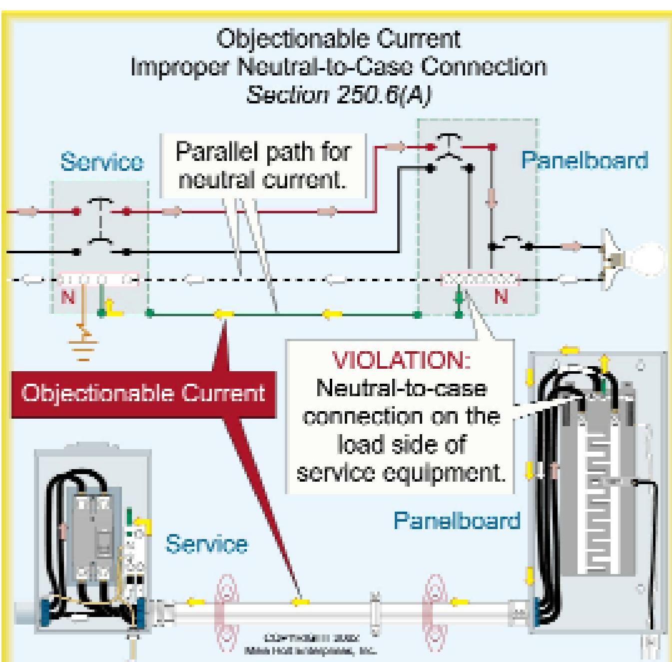


Figure 250–33

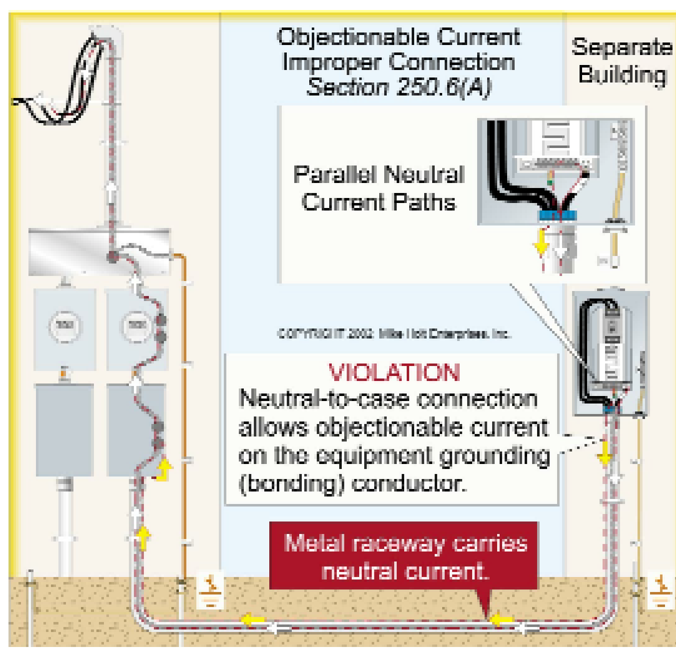


Figure 250–34

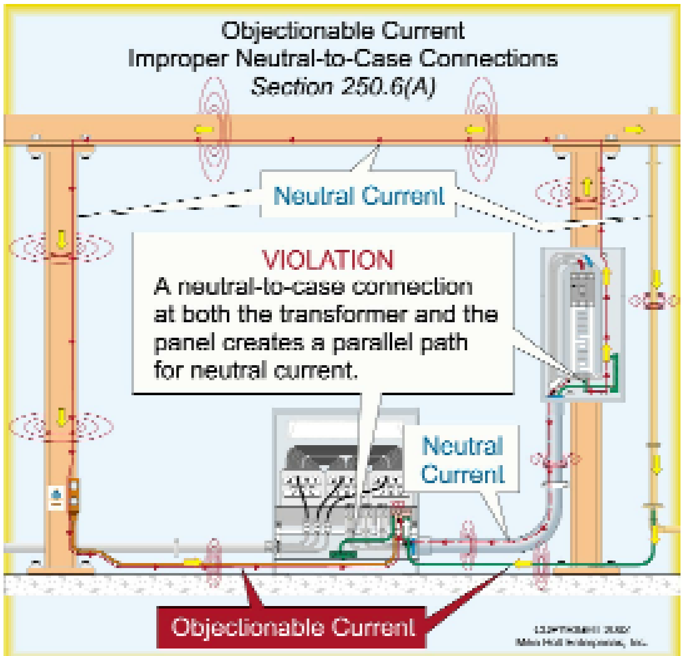


Figure 250–35

Generator – If the grounded (neutral) conductor in a transfer switch is not opened with the ungrounded conductors, then the grounded (neutral) from the generator will be solidly connected to the utility's service grounded (neutral) conductor. Under this condition, the generator is not a separately derived system, and a neutral-to-case bond shall not be made at the generator or at the generator disconnect [250.20(D) FPN 1]. If a neutral-to-case bond is made at the generator or generator disconnect, then objectionable neutral current will flow on the metal parts of electrical equipment as well as on the grounding and bonding conductors. Figure 250-36

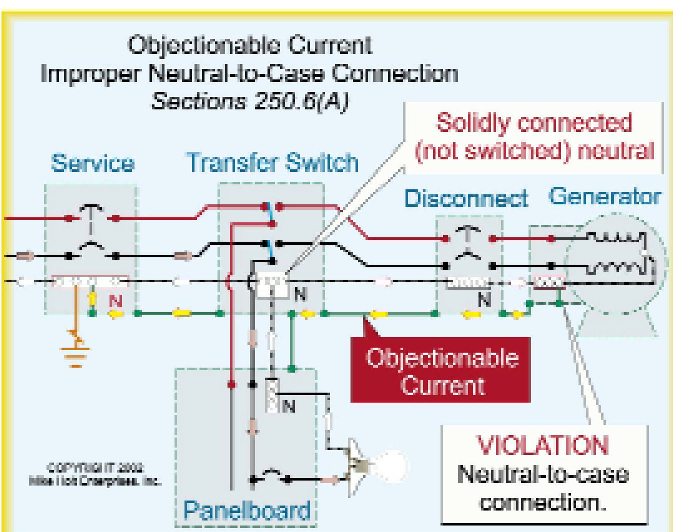


Figure 250–36

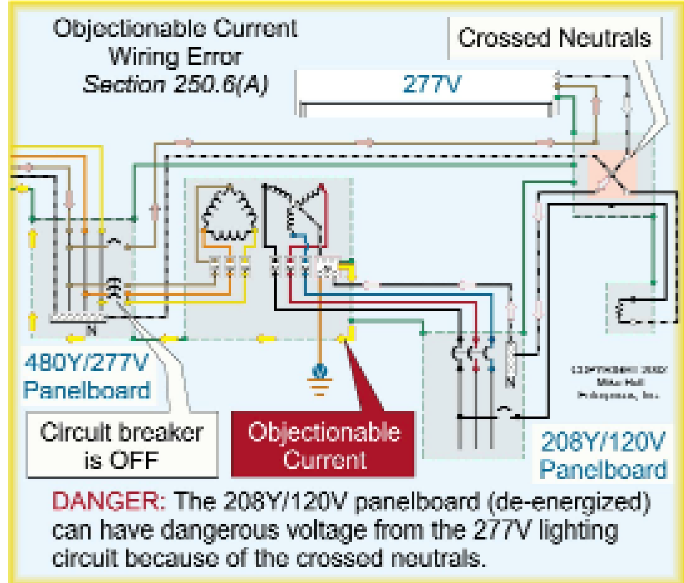


Figure 250–37

Errors in the Wiring Installation

Mixing Neutrals. The *NEC* does not prohibit the mixing of circuit conductors from different systems in the same raceway or enclosure [300.3(C)(1)]. As a result, mistakes can be made where the grounded (neutral) conductors from different systems are crossed (mixed). When this occurs, the grounding and bonding path will carry objectionable neutral current, even when it appears that all circuits have been de-energized. Figure 250-37

Using Equipment Grounding (Bonding) Conductor for Neutral Current

This often happens when a 120V circuit is required at a location where a neutral conductor is not available. Example: A 240V

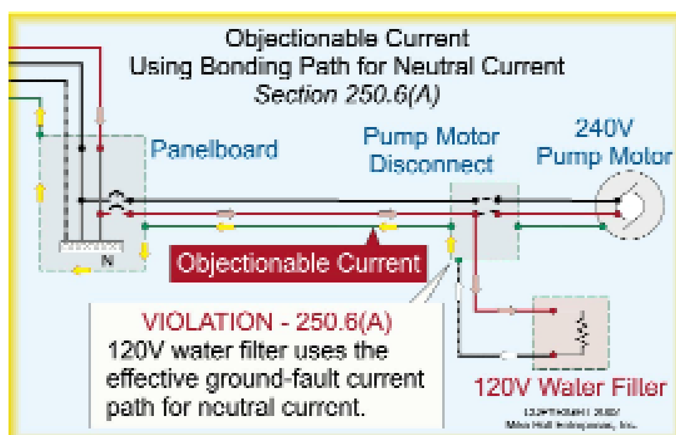


Figure 250–38

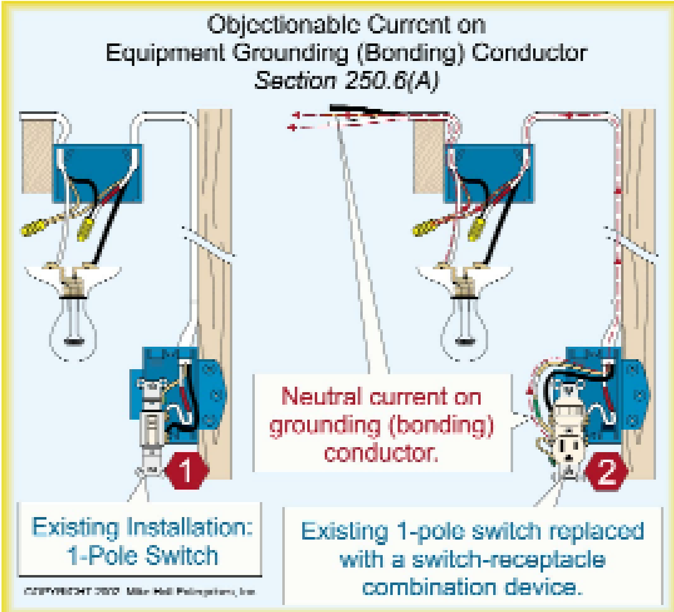


Figure 250–39

time clock motor is replaced with a 120V time clock motor and the equipment grounding conductor is used to feed one side of the 120V time clock. Another example is a 120V water filter wired to a 240V well-pump motor circuit and the equipment grounding conductor is used for the neutral. Figure 250-38

Using the bonding path for the neutral is also seen in ceiling fan installations where the equipment grounding (bonding) conductor is used as a neutral and the white wire is used as the switch leg for the light, or where a receptacle is added to a switch outlet that doesn't have a neutral conductor. Figure 250-39

AUTHOR'S COMMENT: Neutral currents always flow on a communiity metal underground water-piping system where the water service to all of the buildings is metallic. This occurs because the underground water pipe and the service neutral conductors are in parallel with each other. Figure 250-40

Dangers of Objectionable (neutral) Current

Objectionable neutral current can cause shock hazard, fire hazard, improper operation of sensitive electronic equipment, and improper operation of circuit protection devices.

Shock Hazard

Objectionable current on metal parts of electrical equipment can create a condition where electric shock and even death from ventricular fibrillation can occur. Figure 250-41 shows an example where a person becomes in series with the neutral current path of a 120V circuit.

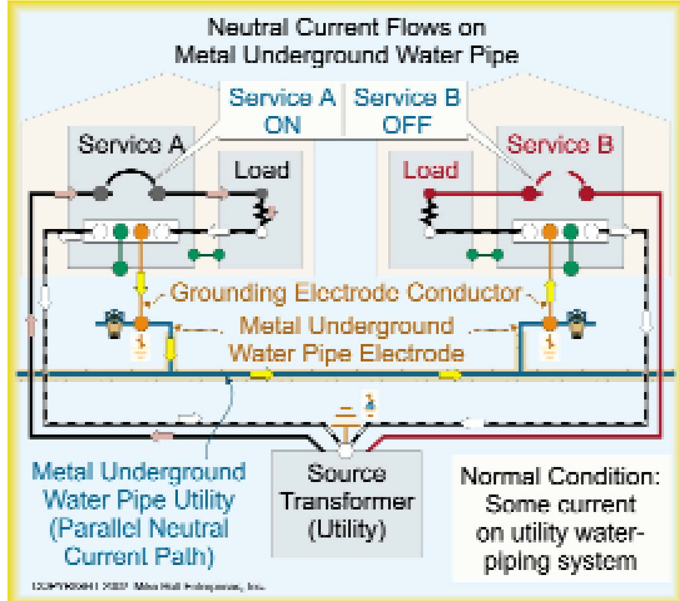


Figure 250–40

Fire Hazard

Fire occurs when the temperature rises to a level sufficient to cause ignition of adjacent combustible material in an area that contains sufficient oxygen. In an electrical system, heat is generated whenever current flows. Improper wiring, resulting in the flow of neutral current on grounding and bonding paths can cause

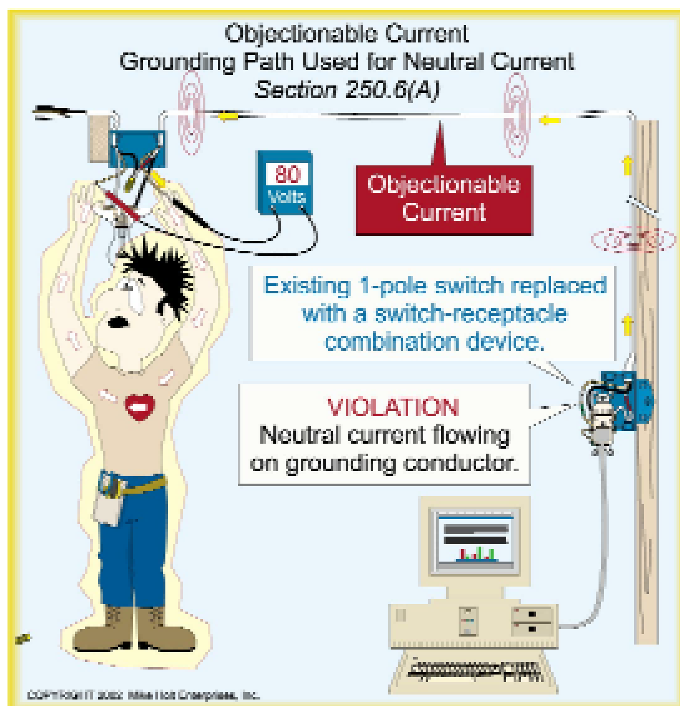


Figure 250–41

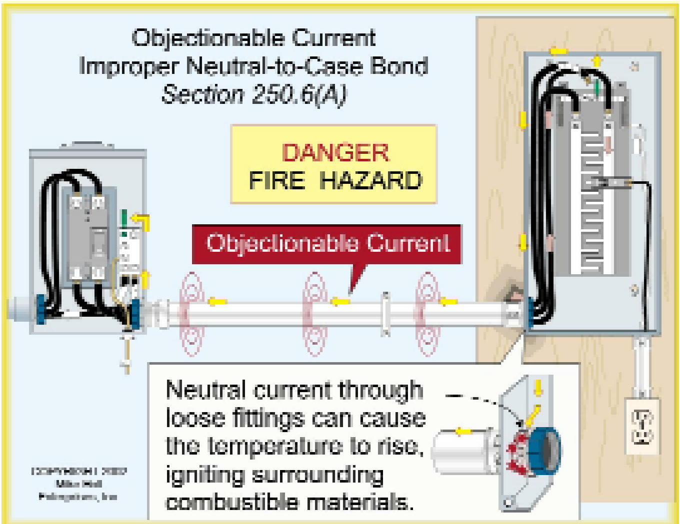


Figure 250–42

the temperature at loose connections to rise to a level that can cause a fire. In addition, arcing at loose connections is particularly dangerous in areas that contain easily ignitable and explosive gases, vapors, or dust. Figure 250-42

Improper Operation of Circuit Protection Devices

Nuisance tripping of a protection device equipped with ground-fault protection can occur if neutral current returns on the equipment grounding (bonding) conductor, instead of the neutral conductor because of improper neutral-to-case bonds. A circuit breaker with ground-fault protection (480Y/277V, 3-phase system over 1,000A per 230.95) uses either the residual current method or the zero sequence method to detect a ground fault. For the zero sequence method, the ground-fault trip unit sums the currents in the three phase conductors and the neutral. When no ground fault is present, the summation of currents flowing on A+B+C+N will equal zero. Any current flow not equal to zero is considered a ground fault. The residual method is used only at the service as it measures current flowing through the main bonding jumper.

Where improper neutral-to-case bonds have been made, objectionable neutral current will flow on the equipment grounding (bonding) conductor in parallel with the grounded (neutral) conductor. Depending on the impedance of this path versus the neutral conductor path, the ground-fault protective relay may see current flow above its pickup point and cause the protective device to open the circuit.

If a ground fault occurs and there are improper neutral-to-case bonds, the protection relay might not operate because some of the ground-fault current will return on the neutral conductor bypassing the ground-fault protective device.

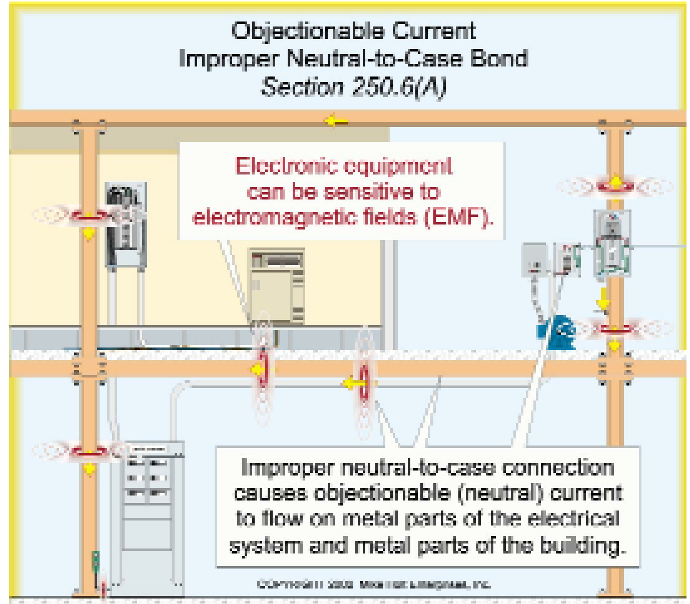


Figure 250–43

Improper Operation of Sensitive Electronic Equipment

When objectionable neutral current travels on the metal parts of electrical equipment, the electromagnetic field generated from alternating-circuit conductors will not cancel. This uncanceled current flowing on metal parts of electrical equipment and conductive building parts causes elevated electromagnetic fields in the building. These low frequency electromagnetic fields can negatively impact the performance of sensitive electronic devices, particularly video monitors and medical equipment. For more information visit www.mikeholt.com/Powerquality/Powerquality.htm. Figure 250-43

(B) Stopping Objectionable Current. If improper neutral-to-case bonds result in an objectionable flow of current on grounding or bonding conductors, simply remove or disconnect the improper neutral-to-case bonds.

(C) Temporary Currents Not Classified as Objectionable Currents. Temporary ground-fault current on the effective ground-fault current path until the circuit overcurrent protection device opens removing the fault, is not classified as objectionable current. Figure 250-44

(D) Electromagnetic Interference (Electrical Noise). Currents that cause noise or data errors in electronic equipment are not considered objectionable currents. Figure 250-45

AUTHOR'S COMMENT: Some sensitive electronic equipment manufacturers require their equipment to be isolated from the equipment bonding conductor, yet they require the equipment to be grounded to an inde-

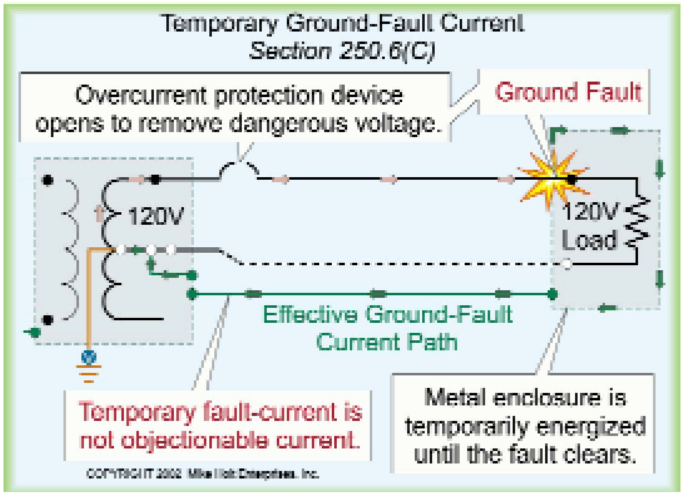


Figure 250–44

pendent grounding system. This practice is very dangerous and violates the *NEC* because the earth will not provide the low-impedance path necessary to clear a ground fault [250.4(A)(5)]. See 250.54 for the proper application of a supplementary electrode and 250.96(D) and 250.146(D) for the requirements of isolated equipment grounding (bonding) conductors for sensitive electronic equipment. Figure 250-46

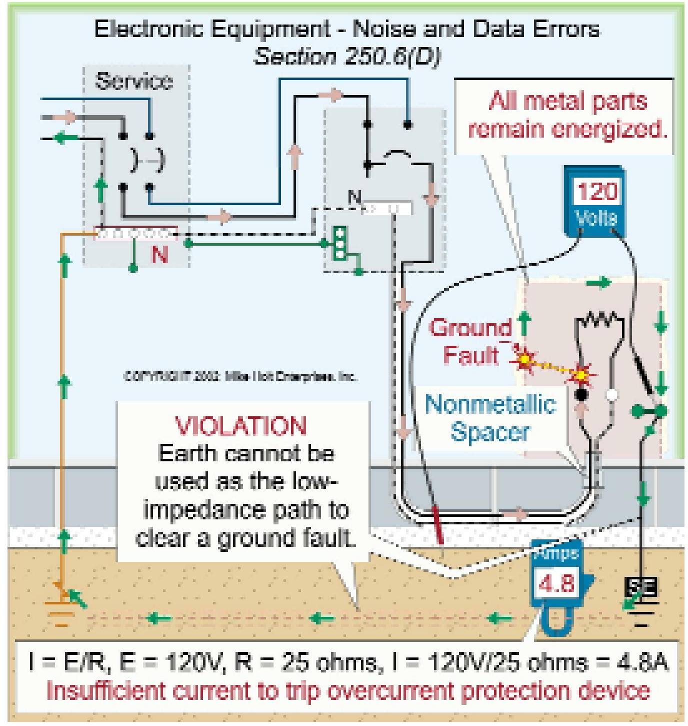


Figure 250–46

250.8 Termination of Grounding and Bonding Conductors

Equipment grounding (bonding) conductors, grounding electrode conductors and bonding jumpers shall terminate by exothermic welding, listed pressure connectors of the set screw or compression type, listed clamps, or other listed fittings. Sheet-metal screws shall not be used for the termination of grounding (or bonding) conductors. Figure 250-47

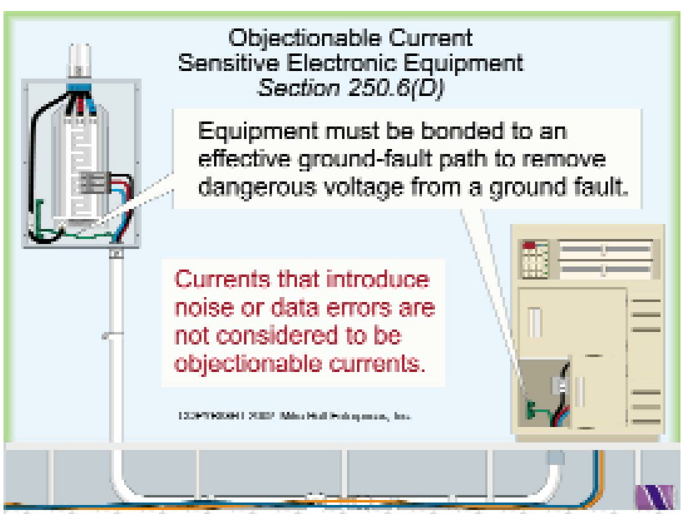


Figure 250–45

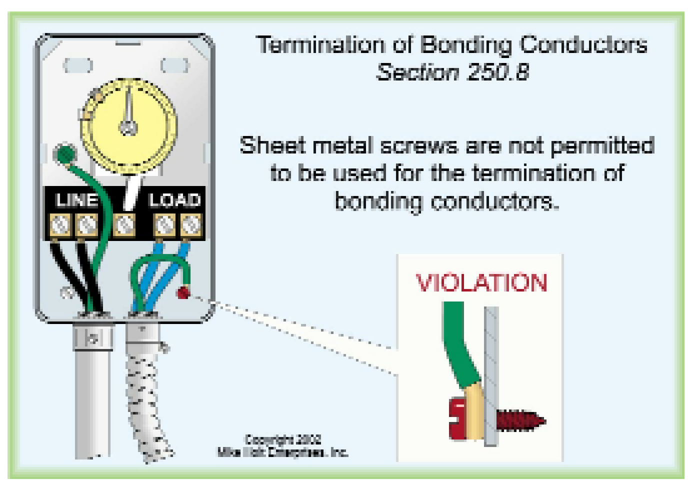


Figure 250–47

250.10 Protection of Grounding Fittings

Ground clamps and other grounding fittings shall be protected from physical damage by:

(1) Locating the grounding fitting where they are not likely to be damaged

(2) Enclosing the grounding fittings in metal, wood, or equivalent protective covering

AUTHOR'S COMMENT: Grounding fittings are permitted to be buried or encased in concrete if installed in accordance with 250.53(G), 250.68(A) Ex. and 250.70.

250.12 Clean Surface

Nonconductive coatings such as paint, lacquer and enamel shall be removed on equipment to be grounded or bonded to ensure good electrical continuity, or the termination fittings shall be designed so as to make such removal unnecessary [250.53(A) and 250.96(A)].

AUTHOR'S COMMENT: Some feel that "tarnish" on copper water pipe should be removed before making a grounding termination. This is a judgment call by the AHJ.

Part II. System and Equipment Grounding

250.20 Alternating-Current Systems to be Grounded

System (power supply) grounding is the intentional connection of one terminal of a power supply to the earth for the purpose of stabilizing the phase-to-earth voltage during normal operation [250.4(A)(1)].

(A) AC Circuits of Less than 50V. Alternating-current circuits supplied from a transformer that operate at less than 50V are not required to be grounded unless:

(1) The primary is supplied from a 277V or 480V circuit.

(2) The primary is supplied from an ungrounded power supply.

AUTHOR'S COMMENT: Typically, circuits operating at less than 50V are not grounded because they are not supplied from a 277V or 480V system, nor are they supplied from an ungrounded system. Figure 250-48

(B) AC Systems Over 50V. Alternating-current systems over 50V that require a grounded (neutral) conductor shall have the grounded neutral terminal of the power supply grounded

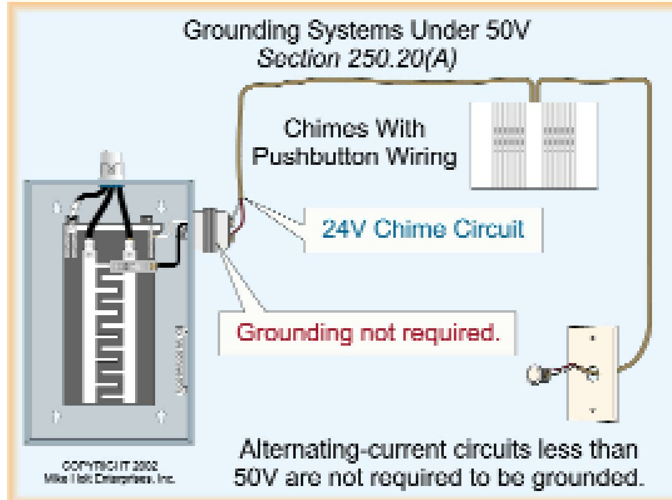


Figure 250–48

to earth in accordance with 250.4(A)(1) and 250.30(A)(1). Such systems include: Figure 250-49

- 120V or 120/240V single-phase systems
- 208Y/120V or 480Y/277V, 4-wire, 3-phase, wye-connected systems
- 120/240V 4-wire, 3-phase, delta-connected systems

AUTHOR'S COMMENT: Other power supply systems, such as a corner-grounded delta-connected system, are permitted to be grounded [250.26(4)], but this is beyond the scope of this book.

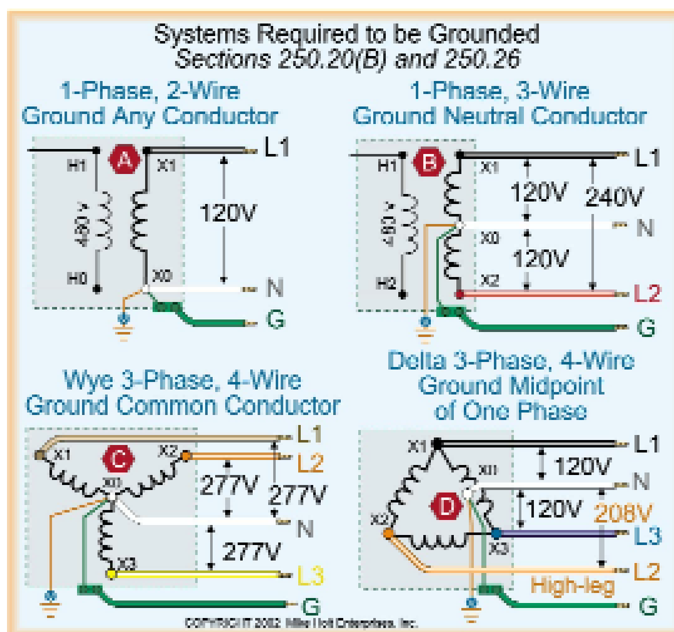


Figure 250–49

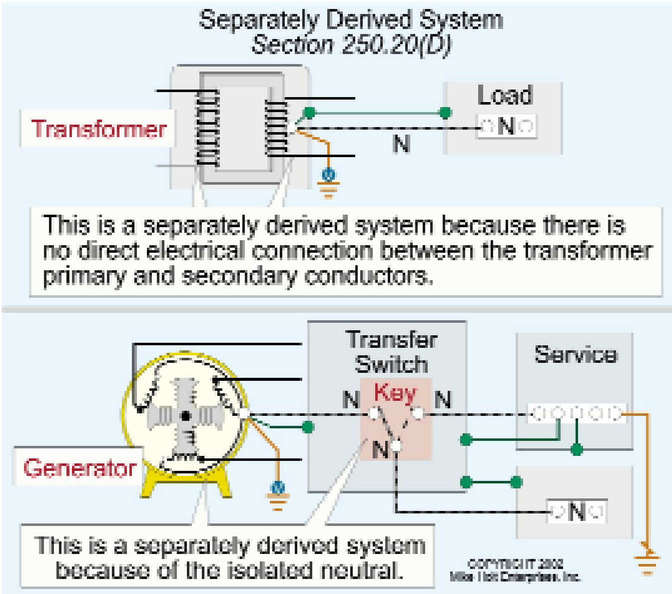


Figure 250–50

(D) Separately Derived Systems. Separately derived systems, which are required to be grounded by 250.20(A) or (B), shall be grounded (and bonded) in accordance with the requirements contained in 250.30.

AUTHOR'S COMMENT: According to Article 100, a separately derived system is a premises wiring system that has no direct electrical connection between the systems, including the grounded (neutral) conductor. Transformers are typically separately derived because the primary and secondary conductors are electrically isolated from each other. Generators that supply a transfer switch that opens the grounded (neutral) conductor are also separately derived. Figure 250-50

FPN 1: A generator is not a separately derived system if the grounded (neutral) conductor from the generator is solidly connected to the supply system grounded (neutral) conductor. In other words, if the transfer switch does not open the neutral conductor, then the generator will not be a separately derived system. Figure 250-51

AUTHOR'S COMMENT: This fine print note points out that when a generator is not a separately derived system, the grounding and bonding requirements contained in 250.30 do not apply and a neutral-to-case connection shall not be made at the generator [250.6(A) and 250.142].

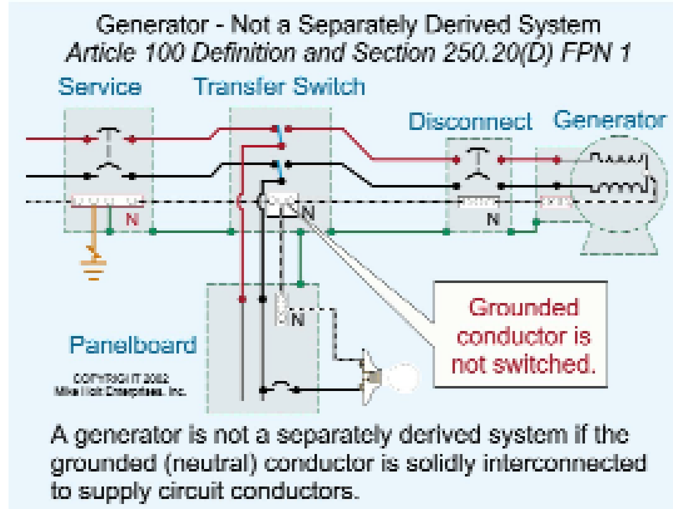


Figure 250–51

FPN 2: If the generator transfer switch does not open the grounded (neutral) conductor, then the grounded (neutral) conductor will be required to carry fault current back to the generator. Under this condition, the grounded (neutral) conductor shall be sized no smaller than required for the unbalanced load by 220.22 and in addition, it shall be sized no smaller than required by 250.24(B) [445.13]. Figure 250-52

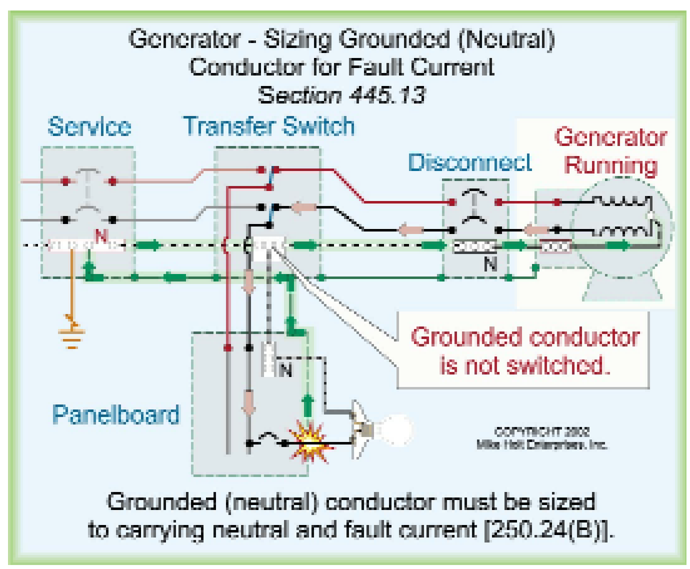


Figure 250–52

250.24 Grounding and Bonding at Service Equipment

The metal parts of electrical equipment shall be grounded to earth to protect persons from electric shock and to protect property from fires by limiting voltage on the metal parts from lightning [250.4(A)(2)].

(A) Grounding. Services supplied from a grounded utility transformer shall have the grounded (neutral) conductor grounded to any of the following grounding electrodes:

- Metal Underground Water Pipe [250.52(A)(1)]
- Effectively Grounded Metal Frame of the Building or Structure [250.52(A)(2)]
- Concrete-Encased Grounding Electrode [250.52(A)(3)]
- Ground Ring [250.52(A)(4)]

Where none of the above grounding electrodes are available, then one or more of the following grounding electrodes shall be installed:

- Ground Rod [250.52(A)(5)]
- Grounding Plate Electrodes 250.52(A)(6)]
- Other Local Metal Underground Systems or Structures [250.52(A)(7)]

AUTHOR'S COMMENT: The grounding of the grounded (neutral) conductor to earth at service equipment is intended to help the utility limit the voltage imposed by lightning, line surges, or unintentional contact with higher-voltage lines by shunting potentially dangerous energy into the earth. In addition, grounding of the grounded (neutral) conductor to earth helps the electric utility clear high-voltage ground faults when they occur.

(1) Accessible Location. A grounding electrode conductor shall connect the grounded (neutral) conductor at service equipment to the grounding electrode. This connection shall be at any accessible location, from the load end of the service drop or service lateral, up to and including the service disconnecting means. Figure 250-53

AUTHOR'S COMMENT: Some inspectors require the grounding electrode conductor to terminate to the grounded (neutral) conductor at the meter enclosure and others require this connection at the service disconnect. However, the *Code* allows this grounding connection at either the meter enclosure or the service disconnect.

(4) Main Bonding Jumper. The grounding electrode conductor can terminate to the equipment grounding terminal, if the equipment grounding terminal is bonded to the service equipment enclosure [250.28].

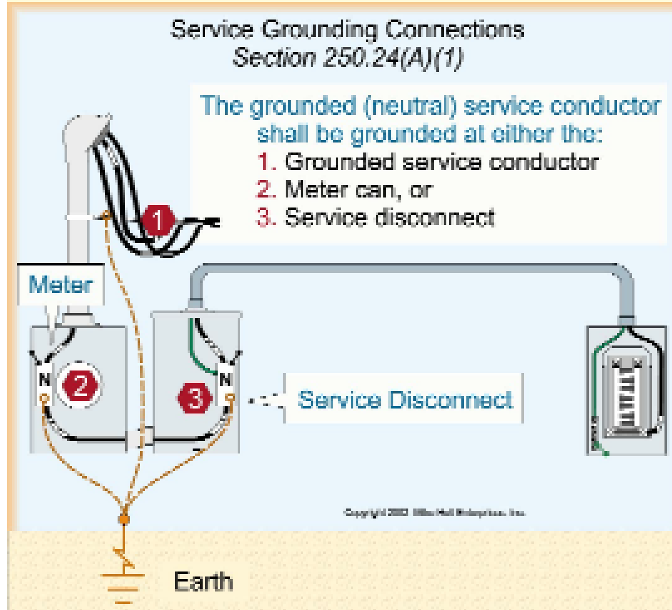


Figure 250–53

(5) Load-Side Bonding Connections. A neutral-to-case bond shall not be made on the load side of the service disconnecting means, except as permitted in 250.30(A)(1) for separately derived systems, 250.32(B)(2) for separate buildings, or 250.142(B) Ex. 2 for meter enclosures. Figure 250-54

AUTHOR'S COMMENT: If a neutral-to-case bond is made on the load side of service equipment, objectionable neutral current will flow on conductive metal parts of electrical equipment in violation of 250.6(A) [250.142]. Objectionable current on metal parts of electrical equipment can create a condition where

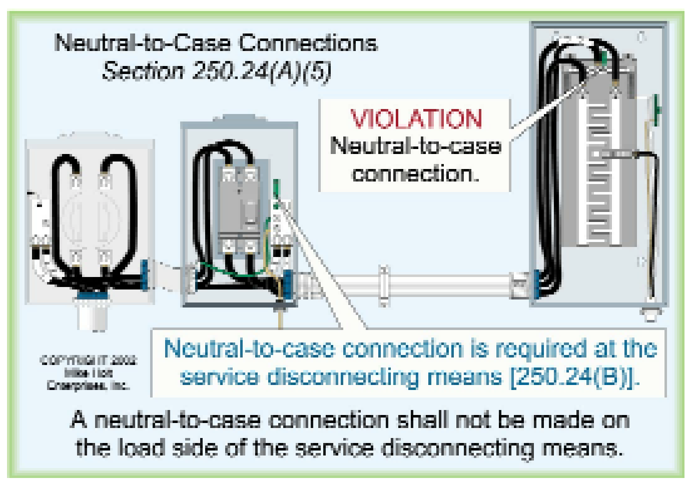


Figure 250–54

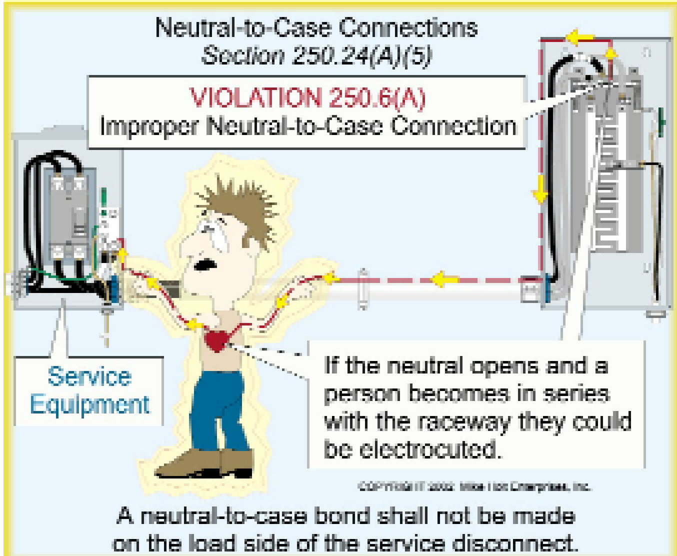


Figure 250–55

electric shock and even death from ventricular fibrillation can occur if a neutral-to-case connection is made. Figure 250-55

(B) Grounded (neutral) Conductor Brought to Each Service. Because electric utilities are not required to install an equipment grounding (bonding) conductor, services supplied from a grounded utility transformer shall have a grounded (neutral) conductor run from the electric utility transformer to each service disconnecting means. The grounded (neutral) conductor shall be bonded to the enclosure of each disconnecting means. Figures 250-56 and 250-57

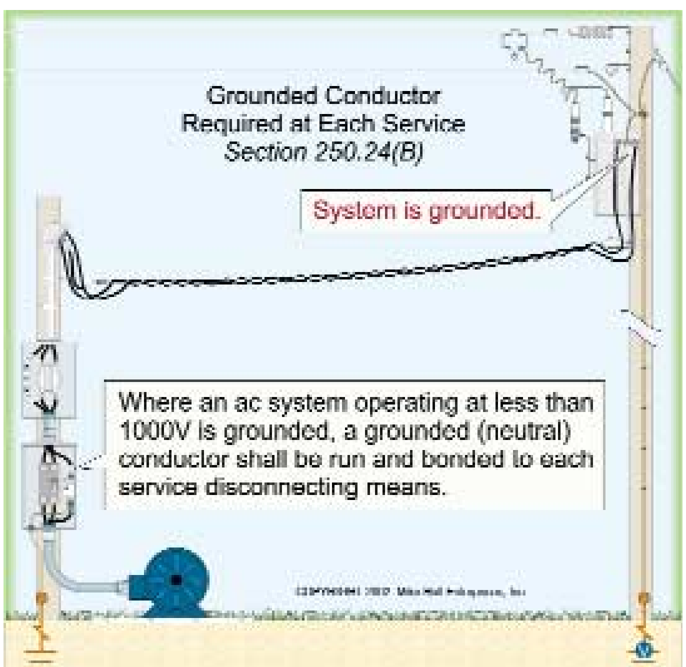


Figure 250–56

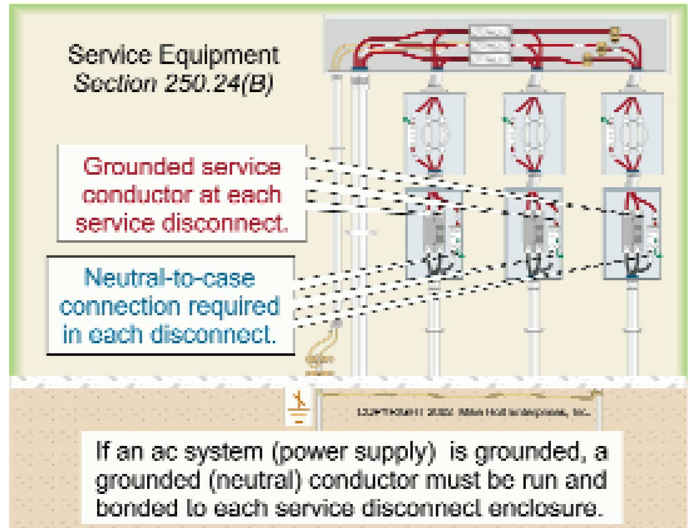


Figure 250–57

AUTHOR'S COMMENT: It is critical that the metal parts of service equipment be bonded to the grounded (neutral) conductor (effective ground-fault current path) to ensure that dangerous voltage from a ground fault will be quickly removed [250.4(A)(3) and 250.4(A)(5)]. To accomplish this, the grounded (neutral) conductor shall be run to service equipment from the electric utility, even

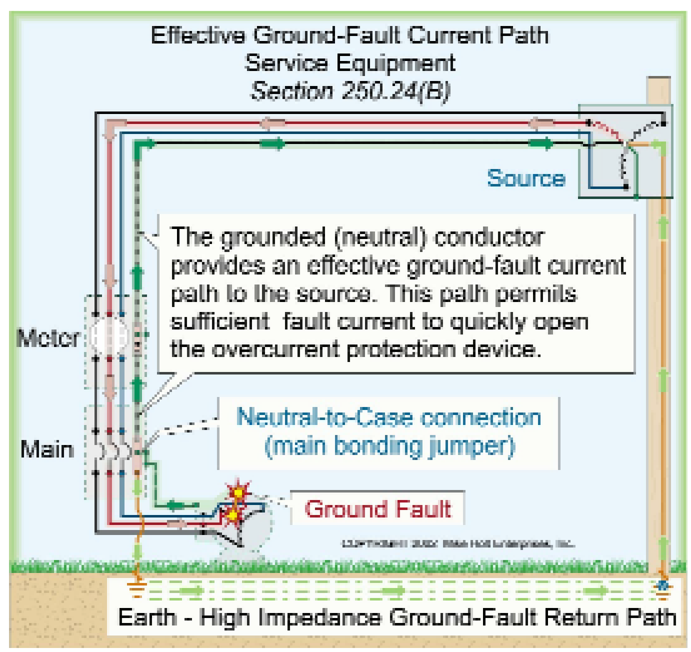


Figure 250–58

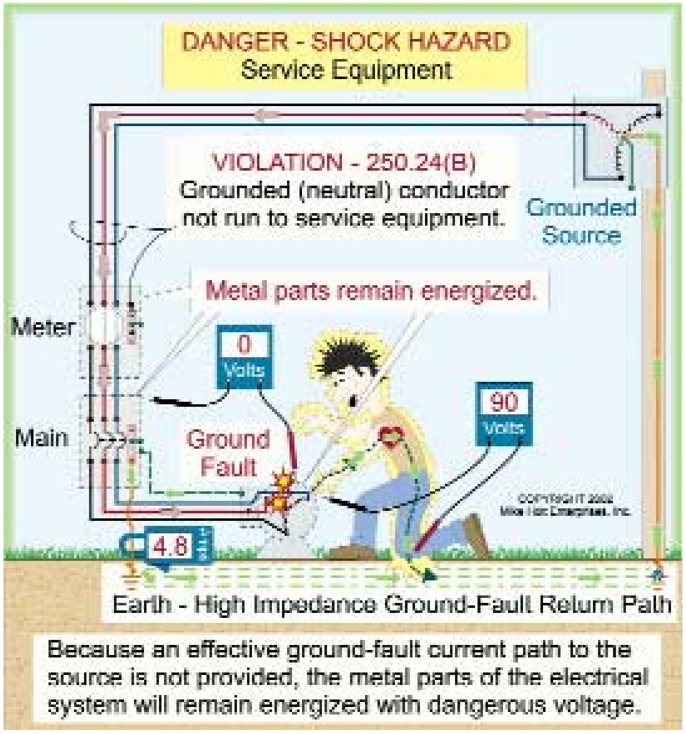


Figure 250–59

when there are no line-to-neutral loads being supplied! Figure 250-58

DANGER: If the grounded (neutral) service conductor is not run between the electric utility and service equipment, there would be no low-impedance effective ground-fault current path. In the event of a ground fault, the circuit protection device will not open and metal parts will remain energized. Figure 250-59

(1) Minimum Size Grounded (neutral) Conductor. Because the grounded (neutral) service conductor is required to serve as the effective ground-fault current path, it shall be sized so that it can safely carry the maximum ground-fault current likely to be imposed on it [110.10 and 250.4(A)(5)]. This is accomplished by sizing the grounded (neutral) conductor in accordance with Table 250.66, based on the total area of the largest ungrounded conductor. In addition, the grounded (neutral) conductors shall have the capacity to carry the maximum unbalanced neutral current in accordance with 220.22. Figure 250-60

Question: What is the minimum size grounded (neutral) service conductor required for a 400A, 3-phase, 480V service where the ungrounded service conductors are 500 kcmil and the maximum unbalanced load is 100A? Figure 250-61

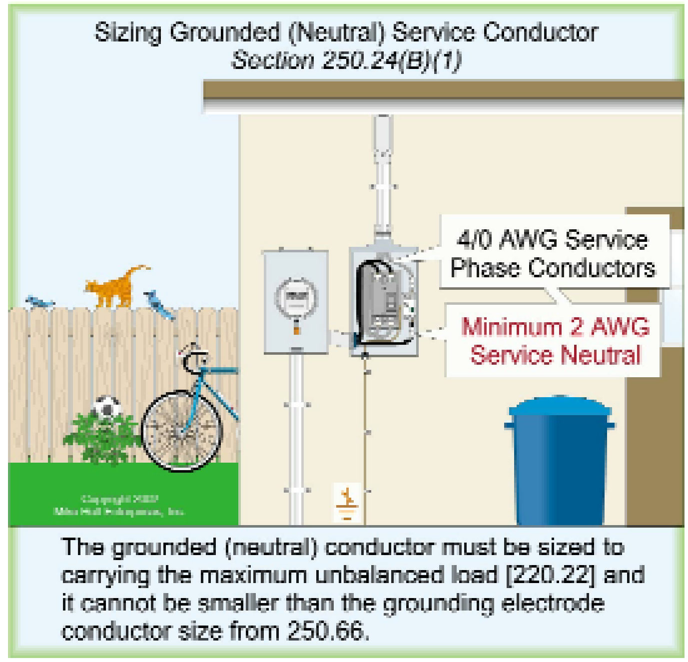


Figure 250–60

(a) 3 AWG (b) 2 AWG

(c) 1 AWG (d) 1/0 AWG

Answer: (d) 1/0 AWG

Table 250.66 = 1/0 AWG. The unbalanced load requires a 3 AWG rated for 100A in accordance with Table 310.16, but 1/0 AWG is required to accommodate the maximum possible fault current [310.4]. At the service, the grounded (neutral) conductor also serves as the effective ground-fault current path to the power source.

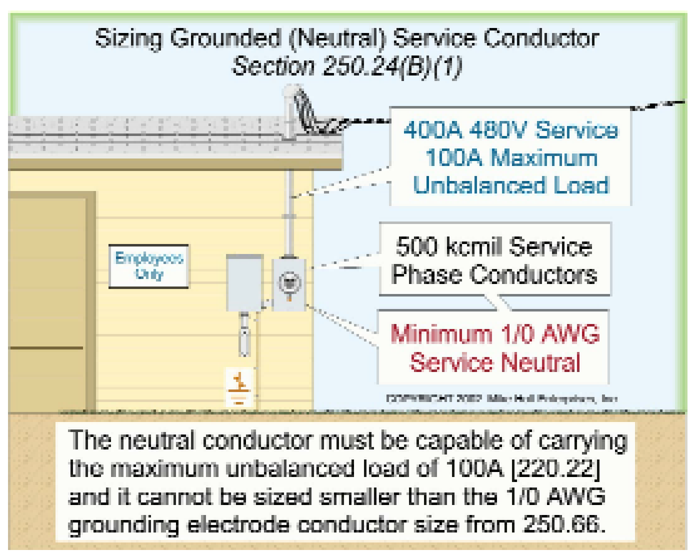


Figure 250–61

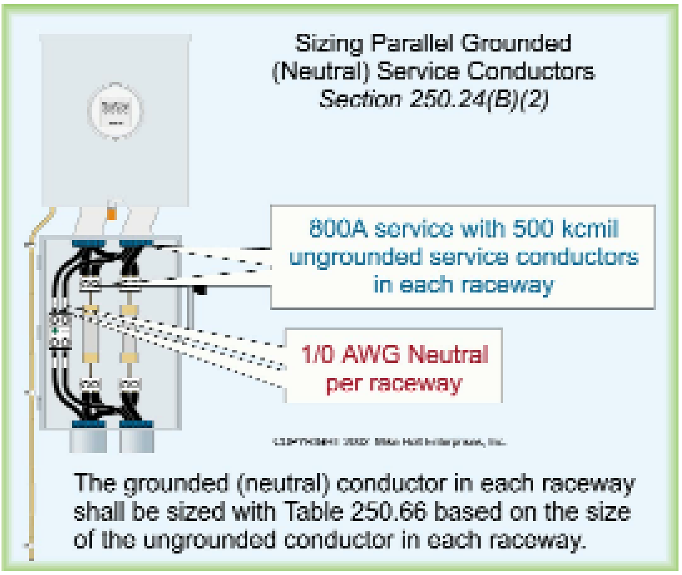


Figure 250–62

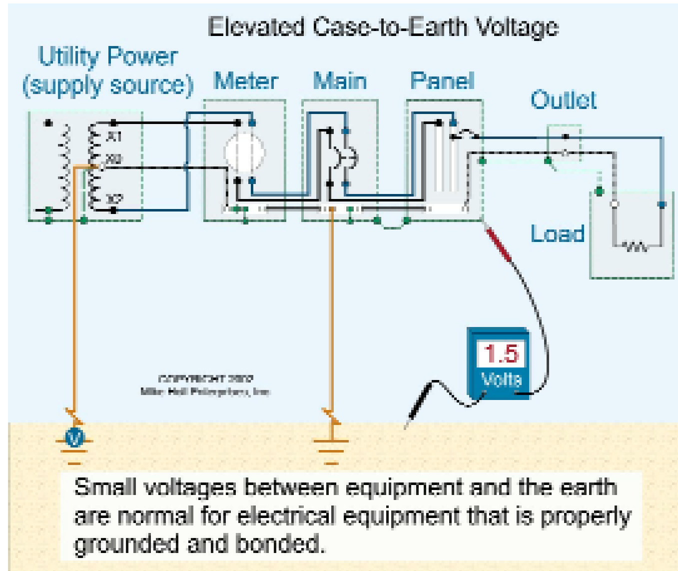


Figure 250–63

(2) Parallel Grounded Conductor. Where service conductors are installed in parallel, a grounded (neutral) conductor shall be installed in each raceway, and each grounded (neutral) conductor shall be sized in accordance with Table 250.66 based on the size of the largest ungrounded conductor in the raceway.

Question: What is the minimum size grounded (neutral) service conductor required for an 800A, 480V, 3Ø service installed in two raceways, if the maximum unbalanced neutral load is 100A? The ungrounded service conductors in each raceway are 500 kcmil. Figure 250-62

(a) 3 AWG (b) 2 AWG

(c) 1 AWG (d) 1/0 AWG

Answer: (d) 1/0 AWG per raceway, 310.4 and Table 250.66

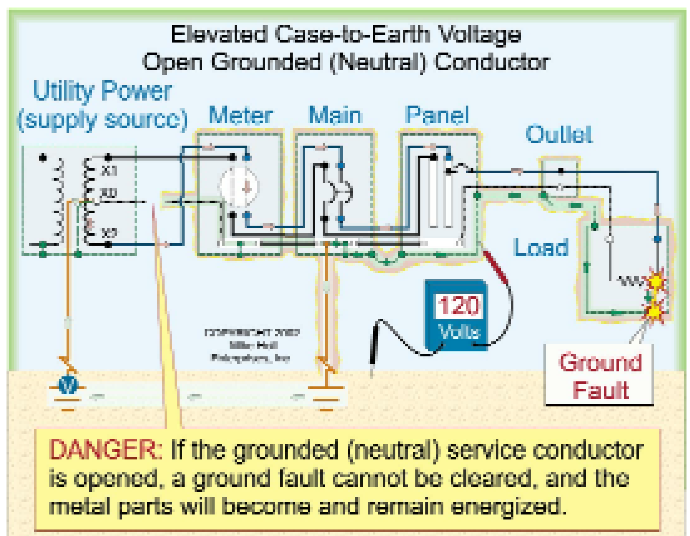


Figure 250–64

Danger of Open Service Neutral

The bonding of the grounded (neutral) conductor to the service disconnect enclosure creates a condition where ground faults can be quickly cleared and the elevated voltage on the metal parts will not be much more than a few volts. Figure 250-63

Shock Hazard. However, if the grounded (neutral) service conductor, which serves as the effective ground-fault current path, is opened, a ground fault cannot be cleared and the metal parts of electrical equipment, as well as metal piping and structural steel, will become and remain energized providing the potential for electric shock. Figure 250-64

When the service grounded (neutral) conductor is open, objectionable neutral current flows onto the metal parts of the electrical system because a neutral-to-case connection (main bonding jumper) is made at service equipment. Under this condition, dangerous voltage will be present on the metal parts providing the potential for electric shock as well as fires. This dangerous electrical shock condition is of particular concern in buildings with pools, spas and hot tubs. Figure 250-65

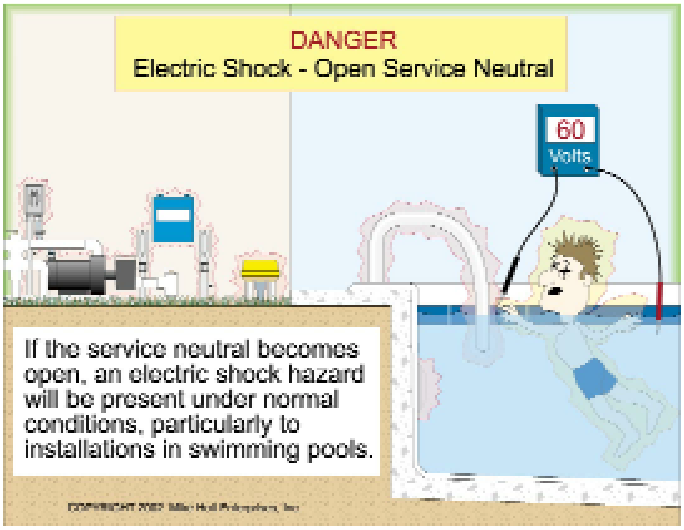


Figure 250–65

AUTHOR'S COMMENT: To determine the actual voltage on the metal parts from an open service grounded (neutral) conductor, you need to do some fancy math calculations with a spreadsheet to accommodate the variable conditions. Visit www.NECcode.com and go to the Free Stuff link to download a spreadsheet for this purpose.

Fire Hazard. If the grounded (neutral) service conductor is open, neutral current flows onto the metal parts of the electrical system. When this occurs in a wood frame construction building or structure, neutral current seeking a return path to the power supply travels into moist wood members. After many years of this current flow, the wood can be converted into charcoal (wood with no moisture) because of the neutral current flow, which can result in a fire. This condition is called pyroforic-carbonization. Figure 250-66

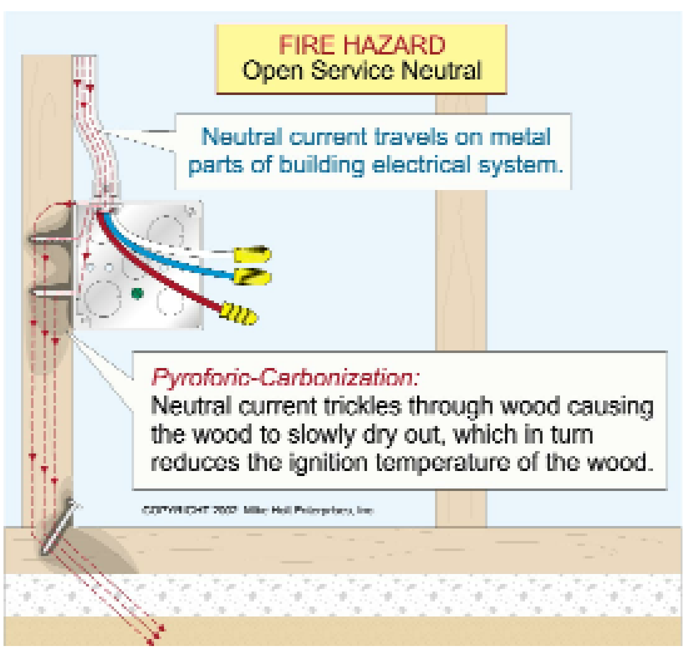


Figure 250–66

AUTHOR'S COMMENT: We can't create an acceptable graphic to demonstrate how pyroforic-carbonization causes a fire by an open service neutral. However, if you would like to order a video showing actual fires caused by pyroforic-carbonization, call 1-888-NEC-CODE.

250.28 Main Bonding Jumper

At service equipment, a main bonding jumper shall bond the metal service disconnect enclosure to the grounded (neutral) conductor. When equipment is listed for use as service equipment as required by 230.66, the main bonding jumper will be supplied by the equipment manufacturer [408.3(C)]. Figure 250-67

AUTHOR'S COMMENT: The main bonding jumper serves two very important needs. First, it establishes a connection between the equipment enclosure and the earth through the grounding electrode conductor to dissipate lightning and other high-voltage surges [250.4(A)(2)]. Secondly, it establishes a connection between the effective ground-fault current path and the service grounded (neutral) conductor to clear a ground fault. Figure 250-68

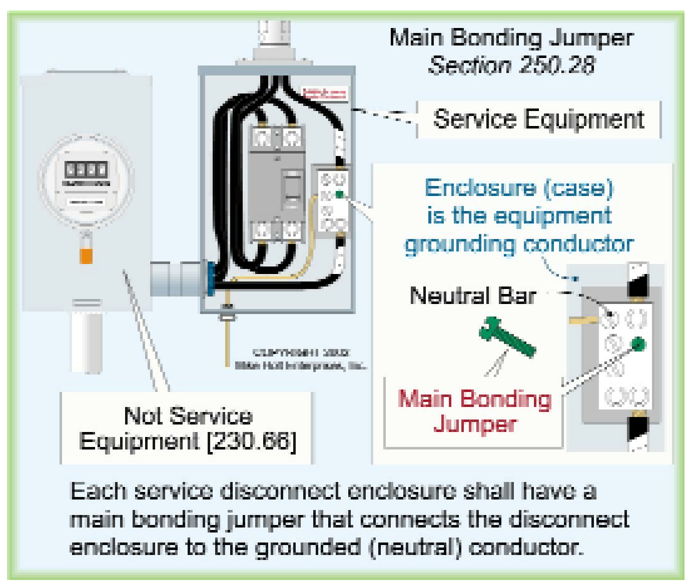


Figure 250–67

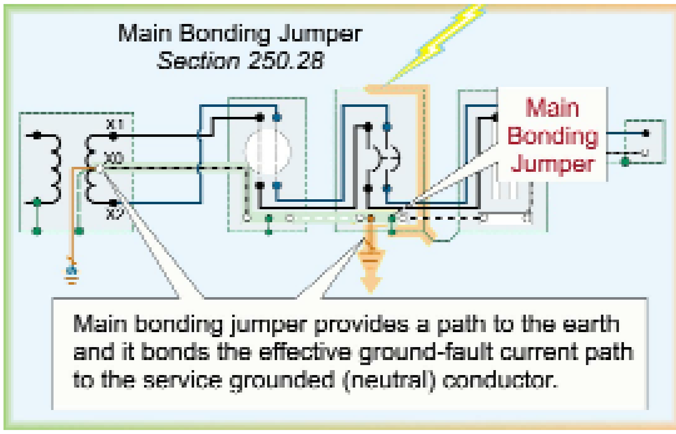


Figure 250–68

An effective ground-fault current path cannot be provided if a main bonding jumper is not installed in an installation where a CT enclosure is used. The result is that metal parts of the electrical installation will remain energized with dangerous voltage from a ground fault. Figure 250-69

(A) Material. The main bonding jumper shall be a wire, bus, or screw of copper or other corrosion-resistant material.

(B) Construction. Where a main bonding jumper is a screw, the screw shall be identified with a green finish that shall be visible with the screw installed.

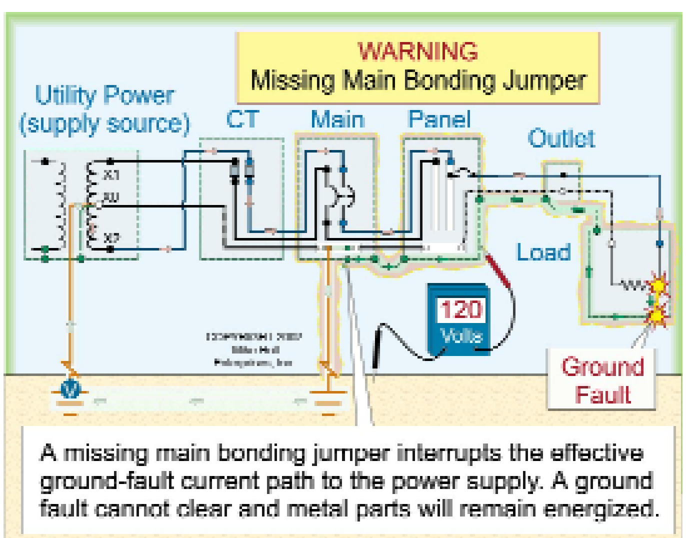


Figure 250–69

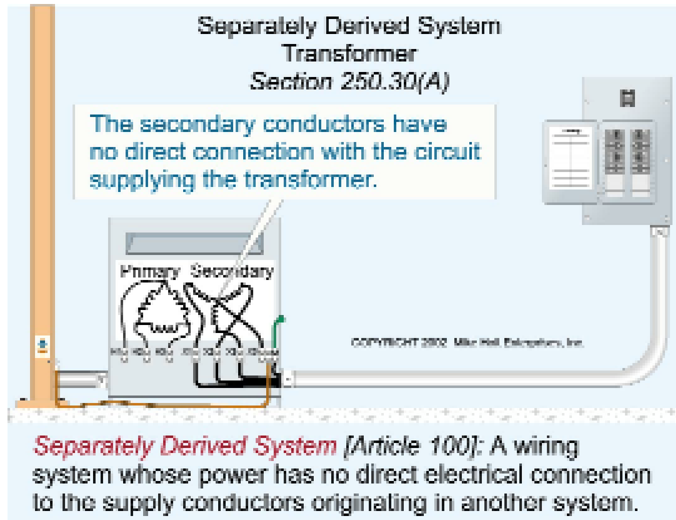


Figure 250–70

250.30 Grounding (and Bonding) Separately Derived Systems

AUTHOR'S COMMENT: A separately derived system is a premises wiring system that has no direct electrical connection to conductors originating from another system. See Article 100 definition and 250.20(D). All transformers, except an autotransformer, are separately derived because the primary supply conductors do not have any direct electrical connection to the secondary conductors. Figure 250-70

A generator, a converter winding or a solar photovoltaic system can only be a separately derived system if the grounded (neutral) conductor is opened in the transfer switch [250.20(D) FPN 1]. Figure 250-71

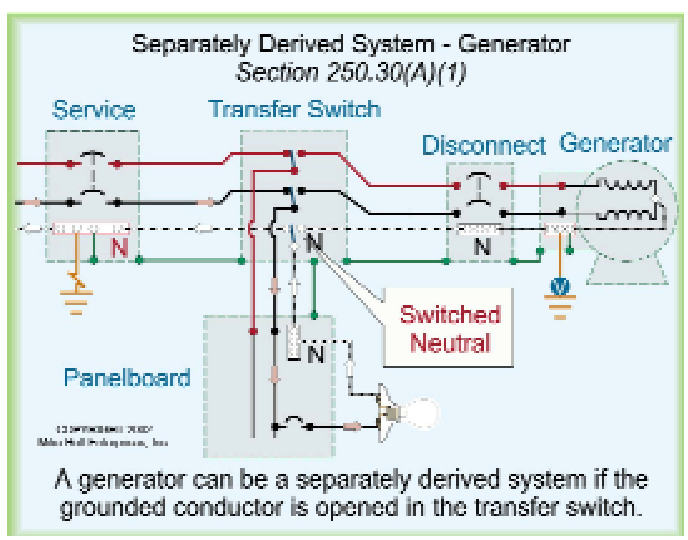


Figure 250–71

If a generator, which is not part of a separately derived system, is bonded in accordance with 250.30(A), dangerous objectionable neutral current will flow on the bonding paths in violation of 250.6(A). Figure 250-72

All online UPS systems are separately derived even if the input and output voltages are the same. An automatic transfer switch has no impact on this determination. This is because an isolation transformer is provided as part of the module. Utilize caution when connecting these systems.

(A) Grounded Systems. Separately derived systems that operate at over 50V [250.20(A) and 250.112(I)] shall comply with the bonding and grounding requirements of 250.30(A)(1) through (A)(6).

AUTHOR'S COMMENT: Bonding the metal parts on the secondary of the separately derived system to the secondary grounded (neutral) terminal ensures that dangerous voltage from a ground fault on the secondary can be quickly removed by opening the secondary circuit's overcurrent protection device [250.2(A)(3)]. In addition, separately derived systems are grounded to stabilize the line-to-earth voltage during normal operation [250.4(A)(1)]. Figure 250-73

(1) Bonding Jumper (Neutral-to-Case Connection). To provide the effective ground-fault current path necessary to clear a ground fault on the secondary side of the separately derived system, the metal parts of electrical equipment shall be bonded to the grounded (neutral) terminal of the separately derived system. The bonding jumper used for this purpose shall be sized in accordance with Table 250.66 based on the area of the largest derived ungrounded conductor. Figure 250-74

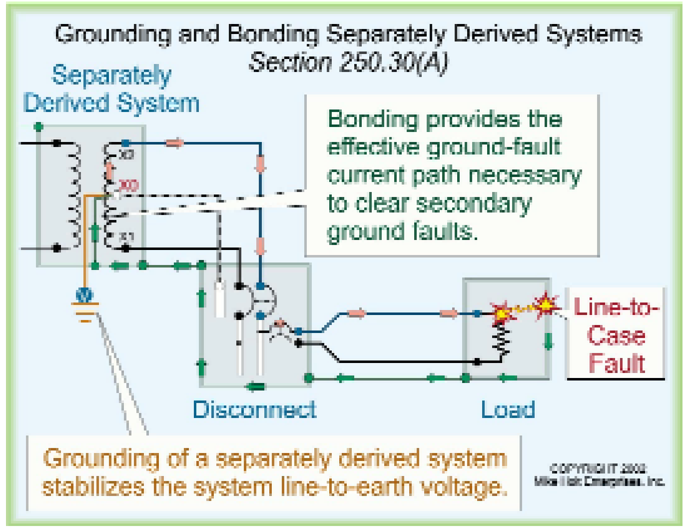


Figure 250–73

Question: What size bonding jumper is required for a 45 kVA transformer if the secondary conductors are 3/0 AWG? Figure 250-75

(a) 4 AWG (b) 3 AWG

(c) 2 AWG (d) 1 AWG

Answer: (a) 4 AWG, Table 250.66

DANGER: If a bonding jumper is not installed from the equipment grounding (bonding) conductor to the

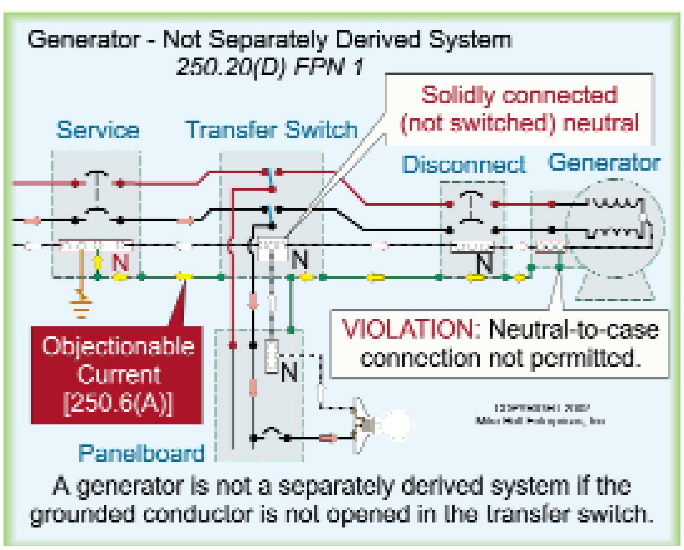


Figure 250–72

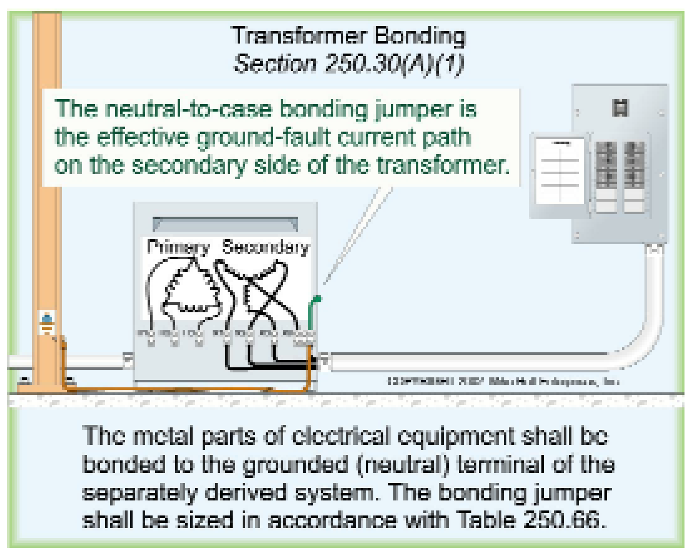


Figure 250–74

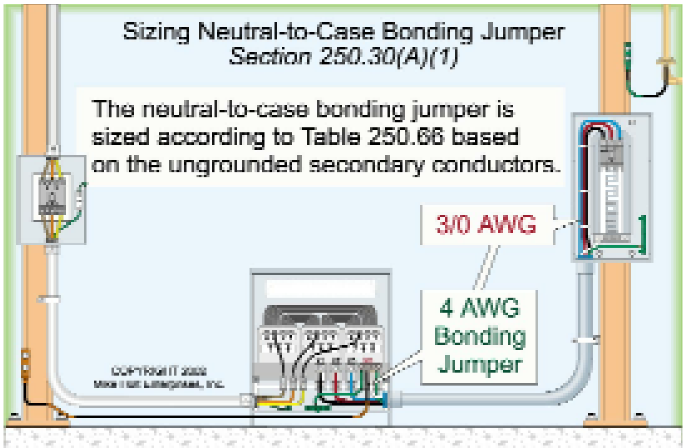


Figure 250–75

grounded (neutral) terminal of the separately derived system, then a ground fault cannot be cleared and the metal parts of electrical equipment, as well as metal piping and structural steel, will remain energized providing the potential for electric shock as well as fires. Figure 250-76

AUTHOR'S COMMENT: The neutral-to-case bonding jumper establishes the effective ground-fault current path for the equipment grounding (bonding) conductor on the secondary and the separately derived system (secondary). To protect against a primary ground fault, the primary circuit conductors shall contain an effective ground-fault current path. Figure 250-77

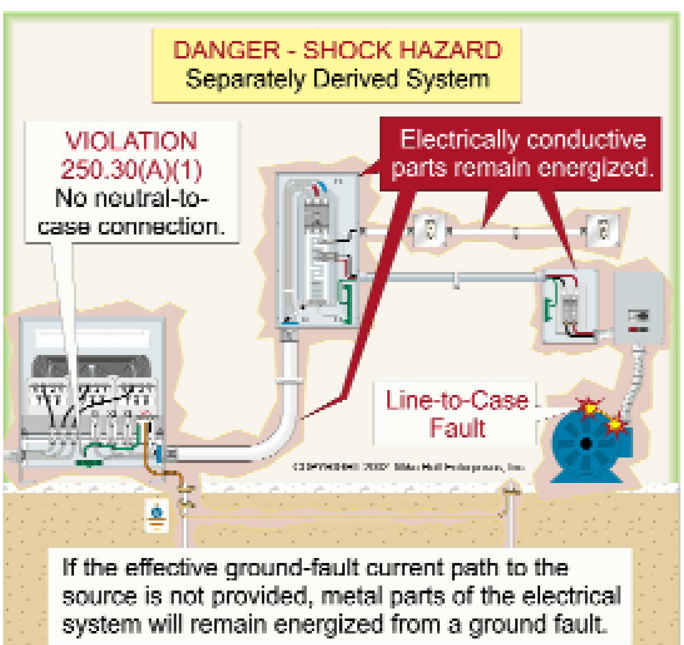


Figure 250–76

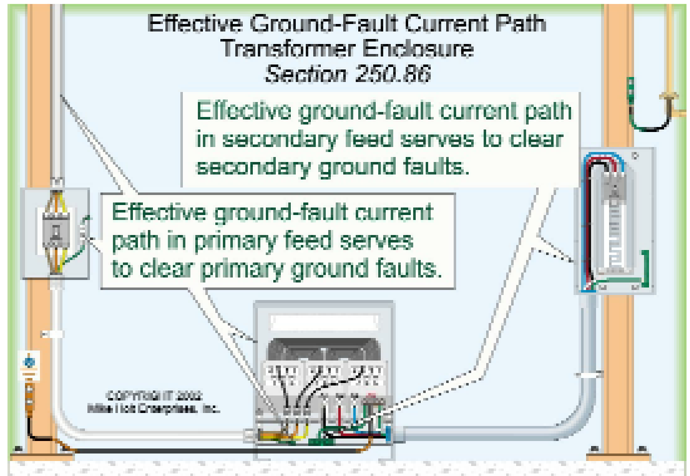


Figure 250–77

The point of connection for the separately derived system neutral-to-case bond shall be made at the same location where the separately derived grounding electrode conductor terminates in accordance with 250.30(A)(2)(a). Figure 250-78

The neutral-to-case bond can be made at the source of a separately derived system or at the first system disconnecting means, but not at both locations. Figure 250-79

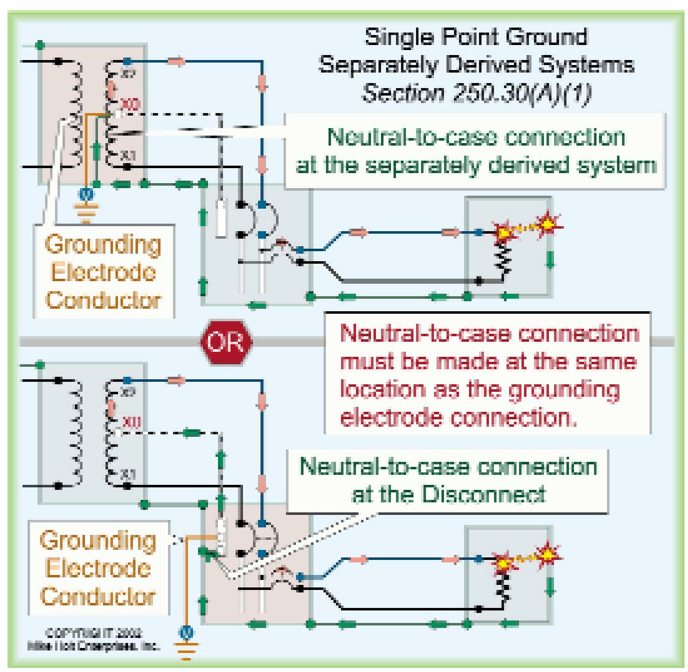


Figure 250–78

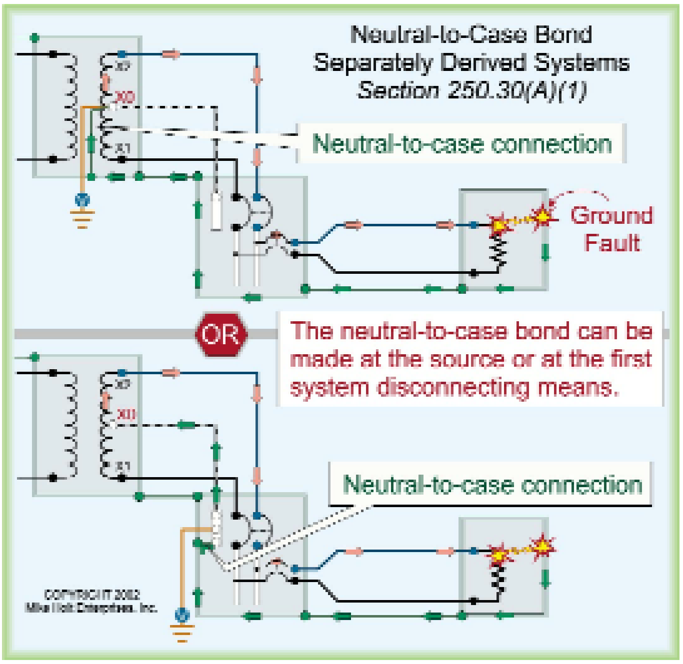


Figure 250–79

CAUTION: The neutral-to-case bond for a separately derived system cannot be made at more than one location, because doing so results in a parallel path(s) for neutral current. Multiple neutral current return paths to the grounded (neutral) terminal of the power supply can create dangerous objectionable current flow on grounding and bonding paths in violation of 250.6 and 250.142(A). Figure 250-80

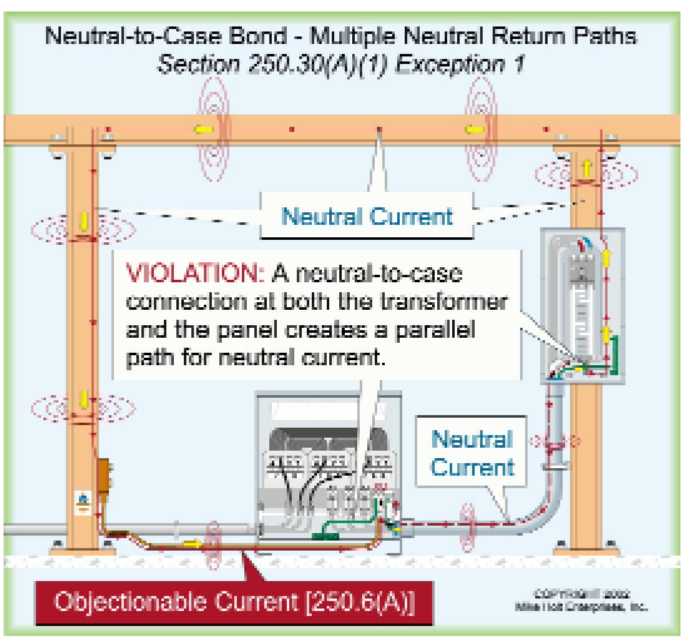


Figure 250–80

Exception No. 2: The bonding jumper for a system rated not more than 1,000 VA shall not be smaller than the derived phase conductors, and shall not be smaller than 14 AWG copper.

(2) Grounding. To stabilize the line-to-earth voltage during normal operation, a grounding electrode conductor shall ground the separately derived system grounded (neutral) conductor to a suitable grounding electrode.

(a) Single Separately Derived System. The grounding electrode conductor for a single separately derived system shall be sized in accordance with 250.66, based on the area of the largest separately derived ungrounded conductor. This conductor shall ground the grounded (neutral) conductor of the separately derived system to a suitable grounding electrode as specified in 250.30(A)(4). Figure 250-81

AUTHOR'S COMMENT: The grounding electrode conductor connection shall terminate directly to the grounded (neutral) terminal, not to the separately derived system enclosure.

To prevent objectionable current from flowing on grounding and bonding conductors, the grounding electrode conductor shall terminate at the same point on the separately derived system where the

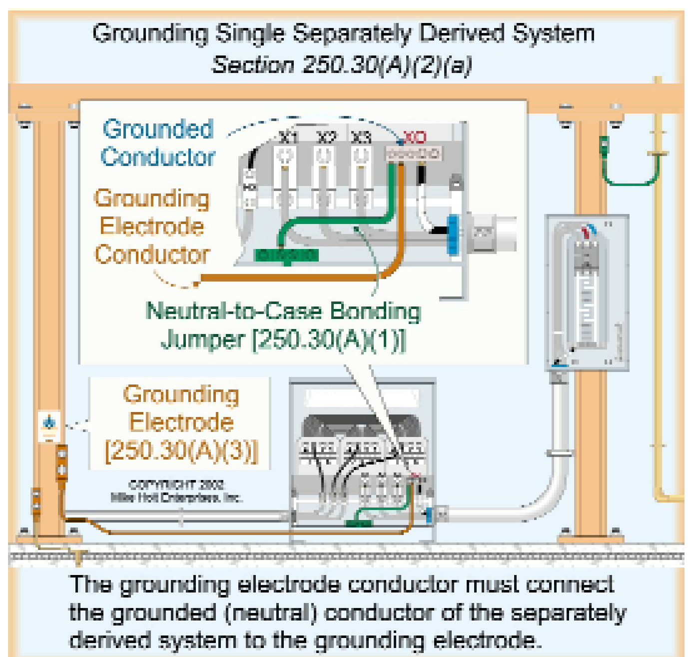


Figure 250–81

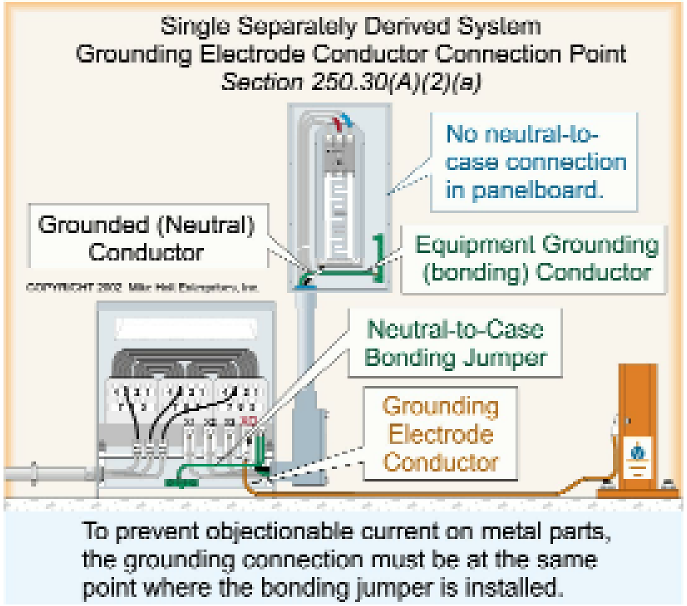


Figure 250–82

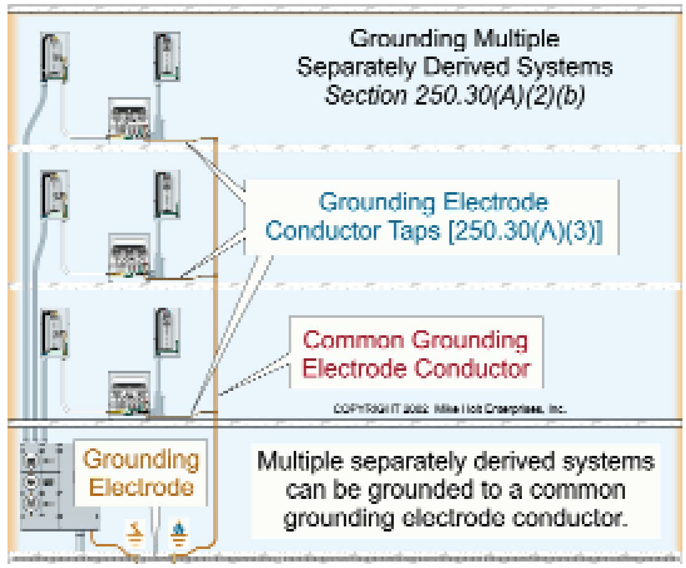


Figure 250–83

neutral-to-case bonding jumper is installed. Figure 250-82

Exception: A grounding electrode conductor is not required for a system rated not more than 1,000 VA. However, the system shall be bonded in accordance with 250.30(A)(1) Ex. 2.

(b) Multiple Separately Derived Systems. Where multiple separately derived systems are grounded to a common grounding electrode conductor as provided in 250.30(A)(3), the common grounding electrode conductor shall be sized in accordance with Table 250.66 based on the total circular mil area of the separately derived ungrounded conductors from all of the separately derived systems. Figure 250-83

(3) Grounding Electrode Taps. A grounding electrode tap from a separately derived system to a common grounding electrode conductor shall be permitted to ground the grounded (neutral) terminal of the separately derived system to a common grounding electrode conductor.

(a) Tap Conductor Size. Each grounding electrode tap conductor shall be sized in accordance with 250.66, based on the size of the largest separately derived ungrounded conductor of the separately derived system.

(b) Connections. All grounding electrode tap connections shall be made at an accessible location by a listed irreversible compression connector, listed connections to copper busbars, or by exothermic welding. Grounding electrode tap conductors shall be grounded to the common grounding electrode conductor as specified in 250.30(A)(2)(b) in such a manner that the common grounding electrode conductor is not spliced.

(c) Installation. The common grounding electrode conductor and the grounding electrode taps to each separately derived system shall be:

- Copper where within 18 in. of earth [250.64(A)].
- Securely fastened to the surface on which it is carried and adequately protected if exposed to physical damage [250.64(B)].
- Installed in one continuous length without a splice or joint, unless spliced by irreversible compression-type connectors listed for the purpose or by the exothermic welding process [250.64(C)].
- Metal enclosures (such as a raceway) enclosing a common grounding electrode conductor shall be made electrically continuous from the point of attachment to cabinets or equipment to the grounding electrode and shall be securely fastened to the ground clamp or fitting [250.64(E)].

(4) Grounding Electrode Conductor. The grounding electrode conductor shall terminate to a suitable grounding electrode that is located as close as practicable and preferably in the same area as the grounding electrode conductor termination to the grounded (neutral) conductor. The grounding electrode shall be the nearest one of the following:

(1) Effectively grounded metal member of the structure.

(2) Effectively grounded metal water pipe, within 5 ft from the point of entrance into the building.

Exception: For industrial and commercial buildings where conditions of maintenance and supervision ensure that only qualified persons service the installation, the grounding electrode conductor can terminate on the metal water-pipe system at any point, if the entire length of the interior metal water pipe that is being used for the grounding electrode is exposed.

(3) Where none of the grounding electrodes as listed in (1) or (2) above are available, one of the following grounding electrodes shall be used:

- A concrete-encased grounding electrode encased by at least 2 in. of concrete, located within and near the bottom of a concrete foundation or footing that is in direct contact with earth, consisting of at least 20 ft of one or more bare or zinc galvanized or other electrically conductive coated steel reinforcing bars or rods of not less than $^1/_2$ in. in diameter, or consisting of at least 20 ft of bare copper conductor not smaller than 4 AWG [250.52(A)(3)].
- A ground ring encircling the building or structure, buried at least 30 in., consisting of at least 20 ft of bare copper conductor not smaller than 2 AWG [250.52(A)(4) and 250.53(F)].
- A ground rod having not less than 8 ft of contact with the soil [250.52(A)(5) and 250.53(G)].
- A buried ground plate electrode with not less than 2 sq ft of exposed surface area [250.52(A)(6)].
- Other metal underground systems or structures, such as piping systems and underground tanks [250.52(A)(7)].

FPN: Interior metal water piping in the area served by a separately derived system shall be bonded to the grounded (neutral) conductor at the separately derived system in accordance with the requirements contained in 250.104(A)(4).

(5) Equipment Bonding Jumper Size. Where an equipment bonding jumper is run with the derived phase conductors from the source of a separately derived system to the first disconnecting means, it shall be sized in accordance with Table 250.66, based on the total area of the largest separately derived ungrounded conductors.

(6) Grounded (neutral) Conductor. Where the neutral-to-case bond is made at the first system disconnecting means, instead of at the source of the separately derived system, the following requirements shall apply: Figure 250-84

(a) Routing and Sizing. Because the grounded (neutral) conductor is to serve as the effective ground-fault current path, the grounded (neutral) conductor shall be routed with the secondary conductors, and it shall be sized no smaller than specified in Table 250.66, based on the largest derived ungrounded conductor.

(b) Parallel Conductors. If the secondary conductors are installed in parallel, the grounded (neutral) secondary conductor in each raceway shall be sized based on the area of the largest derived ungrounded conductors in the raceway.

AUTHOR'S COMMENT: When the neutral-to-case bonding jumper is located in the first system disconnecting means, the grounding electrode conductor shall terminate at the same location to prevent objectionable current from flowing on grounding and bonding paths [250.30(A)(2)(a)].

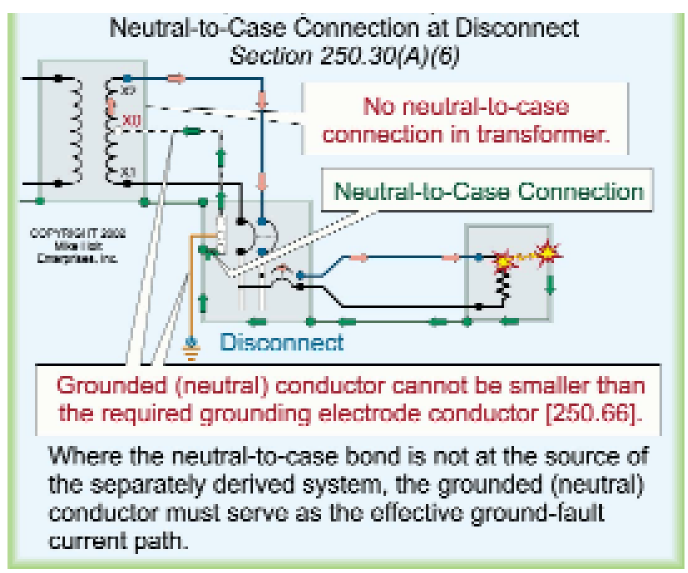


Figure 250–84