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# *Crown Point Telephone Corporation*

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**Jaclyn A. Brilling**
**Secretary**
**State of New York**
**Public Service Commission**
**Three Empire State Plaza**
**Albany, NY 12223**

December 08, 2005

Re: Stray Voltage Request for Response

Dear Secretary Brilling:

In its October 3, 2005 Order, the Commission ordered all facilities-based telephone companies to respond to four specific questions regarding stray voltage in their outside plant. Crown Point Telephone Corporation has no payphones and so respectfully submits responses to only three of the four questions.

We have enclosed four copies of the following, as requested: Our responses to the applicable questions, NEC guidelines, NESC guidelines, NYSTA Occupational Health and Safety Manual as well as a self-addressed, stamped envelope. ***Crown Point Telephone Corporation requests that one of the copies be time-stamped and returned to us in the envelope provided.*** Sew 12/9/05

If you have any questions or concerns regarding this submission, please contact me at the address or phone number above. Thank you.

Sincerely,

Shana Knapp Macey
Shana Knapp Macey
Vice President/Treasurer

Encl.

*(1) All facilities-based telephone companies, including payphone providers, must submit an original and three copies of a statement of the current state of compliance of their telephone facilities which are generally accessible to the public (e.g., outside plant) with the National Electric Safety Code and the National Electric Code. The statement should describe currently deployed plant that was installed prior to the adoption of a policy which required adherence to electric codes.*

**Crown Point Telephone Corporation possesses, and uses as a guideline for installation, copies of applicable NEC and NESC Handbooks. Crown Point Telephone Corporation has made every reasonable effort to ensure that outside plant installed prior to the adherence of these codes is now safe with the proper electrical protection. Crown Point Telephone Corporation installation procedures follow guidelines given "NYSTA Environmental Health and Safety Manual.**

*(2) All facilities-based telephone companies, including payphone providers, must submit an original and three copies of comments on why adherence to the NESC and the NEC should not be mandated for them.*

**Crown Point Telephone Corporation has been safely providing the installation and maintenance of outside plant and telephone equipment for over one hundred years. We agree with the importance of compliance with the NEC and NESC but feel that our individual compliance with these standards is solely our responsibility, and should not be that of the Commission's. Crown Point Telephone Corporation does not believe that it is appropriate for the Commission to mandate this compliance. With the telephone network having a low voltage output we believe that the Commission should not concern itself with "mandating" compliance. NRIC Best Practices, common sense and appropriate employee training, all of which Crown Point Telephone Corporation subscribes to, should ensure compliance with any applicable codes.**

*(3) All facilities-based telephone companies, including payphone providers, and cable companies, must file an original and three copies of their policies and procedures that address protocols for dealing with instances of stray voltage.*

**Crown Point Telephone Corporation adheres to the electrical power safety section of OSHA 1910.268 (Telecommunications). These safety sections are compiled in our "NYSTA Environmental Health and Safety Manual" which we follow as part of our procedures for maintaining compliance (included with submittal).**

- Chain hoist will not be used to secure poles during transportation. The appropriate pole binder shall be in place.

### Grinding Wheels

Goggles or face shield must be used when operating a grinding wheel. All bench and stand grinders shall be provided with safety guards which cover the spindle ends, nut and flange projections. Machines will be securely anchored to prevent movement, or designed in such a manner that in normal operation they will not move.

An adjustable work rest of rigid construction shall be used to support the work on offhand grinding machines. Work rests shall be kept adjusted closely to the wheel with a maximum clearance of 1/8 inch.

### Welding

- Welder's clothing must be kept free of excessive oil, grease and other flammable substances
- All oxygen & acetylene hoses shall be repaired with proper clamps and connections
- It shall be the responsibility of each welder to insure they are properly shielded before striking the arc
- Have portable fire extinguisher near when welding, cutting, or soldering
- Any defective welding leads or grounds cables shall be properly repaired
- Welder is responsible for examining area for possible fire hazards
- Torches shall be lighted only with friction type lighter



- Acetylene line gauge pressure shall not exceed 15 PSI
- All welding hoses shall be coiled and hung in a safe manner when welding is completed
- All spent welding electrodes shall be properly disposed of
- All empty oxygen bottles, hoses, torches, or oxygen related equipment shall be kept away from all petroleum products
- When not is use, gauges should be protected or removed and caps replaced
- Screens shall be in place when arc welding is being performed
- Good housekeeping shall be practiced
- All welders will wear eye protection with suitable filter lenses when welding, cutting, chipping, grinding or any other activity which might cause eye injury
- Only trained employees shall use welding equipment

# 3. ELECTRICAL POWER SAFETY

### Voltage Tester

**C-9970 Voltage Detector**

The C-9970 Voltage Detector is the standard tool for checking for the presence of hazardous high voltages. It is intended for use in testing various conductive objects such as:

- power ground wires
- street light fixtures
- metal frameworks
- newly driven ground rods
- any vertical ground wire attached to pole
- metallic conduit
- mobile homes
- pedestals
- metal siding on homes
- all down guys
- all telephone strand
- machinery
- similar potentially hazardous items

Before first time use of the C-9970 Voltage Detector, the technician should completely read the entire manufacturer's handbook to ensure proper training.

The C-9970 uses electronics and high voltage mechanical design to indicate the presence of dangerously high AC and.DC voltages, regardless of current potential. It does this by comparing the voltage difference between the user's body and the object being tested to an internal safety reference. If the voltage difference exceeds this reference, the voltage detector indicates danger. Its range is 50 to 20,000 volts AC at 60 Hz. and 6 to 2000volts DC. The test set indicates the presence of a hazardous voltage by means of a red flashing LED. It does not indicate actual voltage.

When the test set indicates the presence of a potentially hazardous voltage, the technician should contact their supervisor **immediately**. The supervisor will determine if the voltage is hazardous and take the appropriate steps to eliminate the hazard.



The capacitance between the user's hand and the handle of the voltage detector is part of the measuring circuit and can effect the sensitivity of the voltage detector. The use of high voltage electrical safety gloves should be avoided where possible, since gloves reduce the sensitivity of the detector and may cause erroneous indications. Where voltages may exceed 20,000volts AC, gloves are required when using the voltage detector.

If, under gloved conditions, the detector indicates a safe condition, perform a second test without gloves. Follow the indications of this second test. If, however, the detector indicates a high voltage under gloved conditions, **DO NOT RETEST WITHOUT GLOVES, MOVE AWAY AND CONTACT YOUR SUPERVISOR.**

**Self Check**

Self check is a test that **must** be performed before **each** use of the Voltage Detector. To perform the self check:

- Ensure the entire housing is clean and dry. Dirt and moisture reduce the insulating properties of the plastic surface.
- Examine the housing for cracks. If there are cracks or other obvious defects, **do not use the detector**.
- Grasp the handle with your bare hand. Using the thumb, depress the trigger and observe the green indicator. If it does not light or is very dim, check the internal battery and replace if necessary. If the green indicator still does not light, **do not use the voltage detector**.

- With the trigger depressed, touch both the probe tip and the "check contact" (smaller of the two metal contact points on the sides of the front of the detector). The red indicator should flash and the green indicator should go out. If they do not, **do not use the voltage detector.**
- **Note:** It may be necessary to wet the fingers touching the probe tip and "check contact" in order to start the red flashing light. This is acceptable and does not indicate a malfunction.
- After passing self check, the voltage detector may be used to perform a voltage check on the object(s) in question.

AC Hazardous Voltage Testing

No grounding is required for AC hazardous voltage testing.

Always perform self check before each test.

Remember that the detector is designed to detect voltages at 60 Hz.: it may require a higher voltage to trigger a hazard indication at different frequencies.

Refer to the operator's handbook for the procedure for AC Voltage Testing.

**Aerial Applications**

Since the capacitance between the detector and the user's body is part of the measuring circuit, voltages induced into the user's body can impact the readings. Such induced voltages can be introduced when the user is isolated from ground while working



aloft near power transmission lines. This can cause the voltage detector to indicate danger where none exists.
Refer to the operator's handbook for details on testing in this environment.

**DC Hazardous Voltage Testing**

When testing for DC voltages, a connection **must** be established between the ground terminal of the voltage detector and a **KNOWN EARTH GROUND.**
Refer to the operator's handbook for details of the DC Voltage Test procedures.

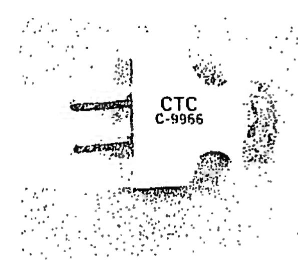
**Additional Equipment**

Your C-9970 Voltage Detector comes in a kit that should also contain two additional pieces of equipment (see photo):
C-9972 (left) Temporary Bond
C-9967 (right) Ground Cord

The use of these items is explained in the operator's handbook.

**Periodic Performance Tests**

The voltage detector must be checked periodically to assure that it is working properly and that it retains its protective properties.




__**Self Check**__

Should be performed prior to every use of the voltage detector.
See the section above for details on performing this check.

**Test Plug Threshold Sensitivity Check**

This test verifies the sensitivity of the voltage detector. The test plug (C-9966, see photo below) provides the proper reference voltage. This test:

- Should be performed at least weekly.
- Verifies proper sensitivity.
- May be performed whenever the insulation is in doubt.
- Should be performed whenever the detector suffers severe mechanical stress (is dropped, etc.).

Refer to the operator's handbook for details on performing the Threshold Sensitivity Test. You may also ask your Safety Manager for a copy of the instructions in the form of the poster on the following page.



## Threshold Test for C-9970 Voltage Detector

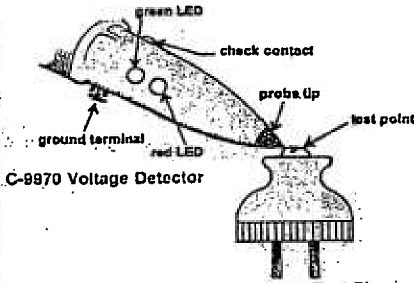
**How to Perform the Threshold Test**

Grasp the voltage detector with your bare hand. With your thumb, press the trigger and observe the green LED indicator. If it doesn't light or is very dim, check the internal battery (replace if necessary). If the green LED indicator still doesn't light, DO NOT USE THE VOLTAGE DETECTOR. If the green LED indicator lights, proceed.

With the trigger pressed, touch detector's probe tip to the plug's test point. The red LED indicator should flash and the green go dark. If they don't, DO NOT USE THE VOLTAGE DETECTOR, turn it in for repair and secure a replacement.

Perform this test WEEKLY.

Reference Frontier Safety Manual.




**C-9970 Voltage Detector Test Plug**

The test plug is used to verify the lowest (threshold) voltage at which the voltage detector indicates danger. It is an AC operated plug which provides a suitable current-limited reference voltage to verify proper operation of the voltage detector. It plugs into a standard ground-referenced power outlet, consumes less than 30 milliwatts, and may be left in an outlet indefinitely if desired. It may be touched without electrical shock, even while energized.

Daily: before each use. "Self Check."

Weekly: test plug threshold (sensitivity) test.

Yearly: inspection, verification, & certification, then label is affixed.

CUT OUT THIS AREA AND FIT POSTER AROUND POWER OUTLET.

Note C-9970 Voltage Tester has replaced the 188 Voltage Tester. Both Voltage Testers are identical in color and operate the same. See pages 31-35 in the ~~Frontier~~ Safety Manual.

**Yearly Inspection, Verification and Certification**

Annual testing is required. Do not use your C-9970 Voltage Detector if the certification has expired.

## AERIAL POLE TESTING

- All poles will be visually checked and tested before any pole is worked on.
- Probe And Sound Test The Pole
- Caution MUST be taken when removing anything from a pole, especially the last attachment or wire.

- Report to your supervisor and engineering of any dangerous condition. (i.e., shell and ground , structural damage, electrical hazards.
- The method for marking the unsafe condition is with burnt orange paint marking a large X on the cable side of the pole or danger tag made out with follow-up procedure.
- You must be familiar with ropes and knots that are common to pole conditions. Before starting any joint pole work, the electric utility must be notified. Electric wires should be guarded before work starts.
- Ladders must be lashed securely to support while working aloft. Keep 60 inches clearance for voltages over 750 volts.

**Testing Cable Suspension Strand**

Before attaching a splicing platform to cable suspension strand, it shall be tested as follows to make sure it has sufficient strength to support the weight of the platform and the employee, except that where the strand crosses above power lines or major railroad tracks, an inspection should be made.

One of the following methods or its equivalent shall be used:

- Throw 3/8 inch rope (or larger) over the strand. On joint lines, pass the rope over the strand using tree pruner handles or a wire-raising tool. If two employees are present, both shall grip the double rope and slowly transfer their entire weight to the rope. The feet should not be more than about 12 inches above the ground.



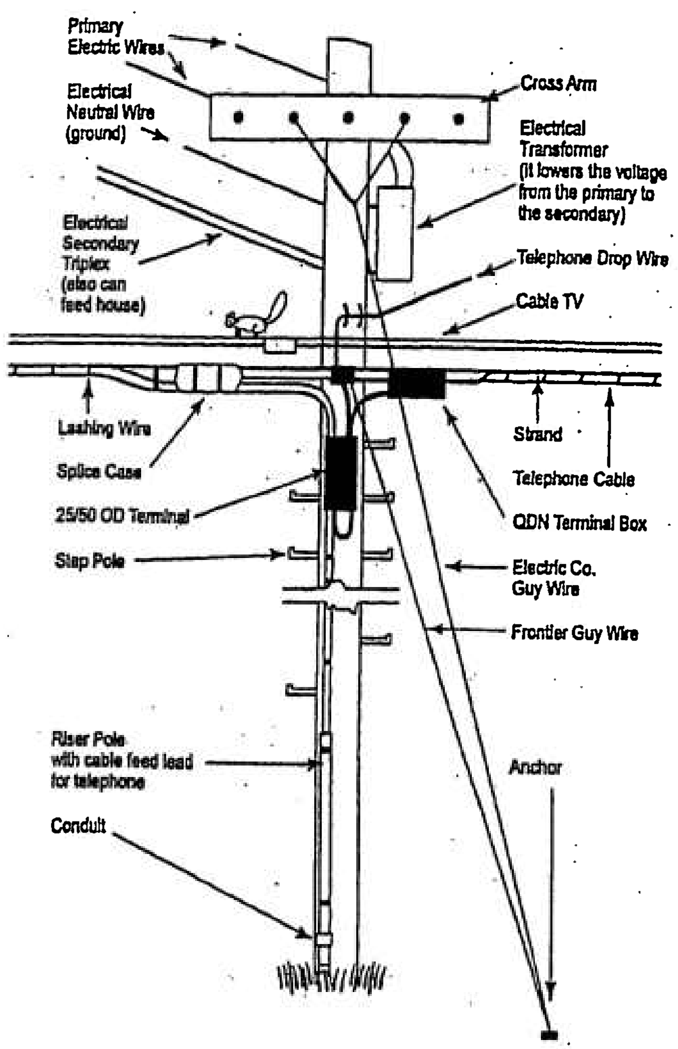
- If only one employee is present, one end of the rope shall be tied to the bumper of the truck or other equally secure anchorage; the employee shall then grasp the other end of the rope and attempt to raise himself about a foot above the ground.

**Inspection of Strand**

Where the strand passes over electric power lines or major railroad tracks, it shall not be tested, but shall be inspected from a convenient working position at both poles supporting the span in question. If any of the following conditions exist, such strand shall not be used to support any splicing platform, scaffold, or cable car.

Look for:

- Corrosion so that no galvanizing can be seen.
- One or more wires of the strand are broken.
- Any worn spots.
- Burn marks such as those caused by contact with electric power wires.
- Notify supervisor if unsafe conditions exist.




## Outside Work Platforms and Scaffolds

Safety straps and body belts shall be used while working on elevated work platforms such as aerial splicing platforms, pole platforms, ladder platforms, and terminal balconies, unless railings are provided.



## Other Elevated Locations

Safety straps and body belts shall be worn to protect employees working at elevated positions on poles, towers, or similar structures.

## Methods of Testing Wood Poles

All employees in the work area must wear the appropriate insulating rubber gloves with leather protectors at all times. All parts of the body other than protected hands will be kept free from contact with the pole or tools used in the handling of the pole during the period that the pole might contact electric wires.

One of the following methods or its equivalent shall be used:

- **Probe and Sounding Test**: Rap the pole sharply with a hammer weighing about 3 pounds, beginning near the ground line and continuing to a height of about 6 feet, going completely around the pole. The hammer will produce a clear sound and rebound sharply when striking sound wood. Decay pockets will be indicated by a dull sound and the hammer rebound is less pronounced. In this case, the pole shall be considered unsafe. Also, prod the pole as near the ground line as possible using a pole prod or a screwdriver with 5 inch or longer blade. If substantial decay is encountered, the pole shall be considered unsafe.
- Apply a horizontal force to the pole and attempt to rock back and forth in a direction across the line. Caution must be exercised to avoid causing power lines to swing together. The force may be applied either by pushing with a pike pole or

pulling with a rope. If the pole cracks during the test, it shall be considered unsafe.

- Unsafe poles or structures: Poles or structures found to be unsafe by test or observation shall not be climbed until made safe by guying, bracing, or other adequate means. Poles found unsafe to climb shall, until they are made safe, be tagged in a conspicuous place to alert and warn all employees of the unsafe condition.

**Lockout/Tagout**

The lockout/tagout (loto) standard applies to the telecommunications industry and covers the servicing and maintenance of machines and equipment in which the unexpected startup or release of stored energy could result in death or injury to employees.

Lockout and tagout of the energy isolating devices will be required whenever performing maintenance or service work on machines or equipment.

**Required LOTO:**

- Whenever there is a potential for injury by unexpected start-up of equipment or release of any stored energy, including pressurized lines.
- Whenever an employee must remove a guard or other safety device.
- Whenever an employee must place any part of their body where it could be caught by moving machinery.
- Whenever anyone is working "away from" any energy isolating device which could result in an



injury if this energy isolating device was accidentally and or unexpectedly released.

**Exceptions to LOTO**

- Cord and plug type of equipment (if operator has control of cord)
- "Copy machines" have interlocks that do not allow the copier to operate when removing paper jams.
- During hot tap operations that involve transmission and distribution systems for telecommunications power systems, gas, steam, water; when continuity of service is essential, and shutdown of the system is impractical; and employees are provided with an alternative type of protection that is equally effective.

**Examples of stored energy where LOTO might apply:**

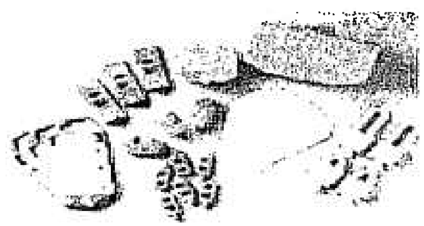
- Central office power areas
- Electrical power distribution panels
- Stand-by generators
- Lasers

**Procedures**

1. Preparation: Locate all energy sources that need to be isolated.
2. Employee Notification: Notify all affected employees that LOTO is going to be utilized and the reason for lockout. (tailgate meeting)

3. Equipment Isolation: Operate the switch, valve, stopper or other device so that the equipment is isolated from energy source(s).
4. For Electrical Energy: locate correct electrical disconnect switch or circuit breaker and turn to the off position. Check with voltmeter to assure it is de-energized.
5. For Mechanical Energy: such as springs, elevated machine members, rotating flywheels, must be dissipated or restrained by methods such as repositioning or blocking.
6. For Flammable, Pneumatic, Hydraulic, Thermal, or Chemical where such energy is contained in lines on pipes: valves must be closed or lines disconnected, or isolating "blanks" or stoppers installed.
7. LASTLY TAG all energy isolating devices that are controlling the unexpected release of energy, attach locks to these devices.

**Approved LOTO Devices:** Specific Tags and Locks will be available to all authorized employees.



- Tags will be standardized
- Each tag will list the name of the person or Supervisor requesting the tagout. (Name of the person the Tag is protecting)



- Locks shall be used in combination with the tag.
- The employee being protected must maintain the lock key. Supervisor may maintain a duplicate key BUT cannot utilize it without following Lock removal procedures.
- When individual Locks are issued they will specifically identify lock's owner.
- Making duplicate keys for these individual Locks is strictly prohibited.
- Designated Tags and Locks shall NOT be used for any other purpose than LOTO.
- Multiple Lock adapters will be available for all jobs requiring more than one safety LOCK to be placed on an energy isolating device.
- Tags will be used in all LOTO situations.

**Application of LOTO devices:**

- When practical and feasible each person shall place their Lock and Tag on the locking device. A single lock may not be used to represent more than one employee unless procedures have been established that will provide "at least as effective" protection to all employees working on that particular equipment.
- When it is NOT practical and feasible for each employee to place their own Lock and Tag on the energy isolating device, the Supervisor shall have the Tagout in his/her name. Supervisor must also authorize removal.
- If a Supervisor has his/her name on the Tag and they are replaced by another Supervisor on this job, new tags shall be hung with new Supervisor's name written on this new Tag. If an

individual Lock was used it should also be changed at this time.

**Restoring Locked Equipment: (by installer)**

1. Notify personnel in start-up area.
2. Clear all tools and repair equipment.
3. Remove Locking and Tag devices.
4. Restore isolating devices to normal operating position.
5. Notify operating personnel of operation status.

**Emergency Removal of Locks By Others Than Installer:**

1. Attempt to reach person who's name is on the Tag to find out job status.
2. Notify Supervisor.
3. Supervisor will inspect equipment or line to be placed in operation.
    - Review work.
    - Repairs complete?
    - Guards installed?
    - Tools clear from machinery?
4. Notify personnel in the area of start up and follow unlocking procedures.

**Responsibilities:**

**Employees**-understands the purpose of LOTO, the hazards of unexpected energizing of equipment, can perform LOTO procedures and the importance of NOT attempting to remove a LOTO device without following ALL STEPS.



**Supervisors**-Knowledge and Enforcement of LOTO procedures. Recognition when re-training is needed and make arrangements for and participates in development of specific job procedures needing LOTO.

**Safety Manager**-Develops LOTO procedure and identity's LOTO devices. Inspections to insure compliance and initial and re-training of employees including records of training. Procurement and supply of LOTO devices.

**If Someone Is Shocked**

1. Don't touch anyone in contact with a power source – you could be killed or seriously injured! Instead, turn off power at the control panel/power source. Then call for help and tell them it's an electrical injury.
2. If the victim is not breathing, begin CPR. If the victim is not revived right away, continue CPR until someone trained in CPR relieves you, or until medical personnel has arrived.

**Electrical Fires**

- If you smell smoke or see a flame, unplug equipment involved or turn power off at the main control panel.
- If the fire is small, use a multipurpose fire extinguisher to put it out. **__Never__ use water on an electrical fire.**
- If you have any doubt that you can put the fire out, sound alarm, leave immediately and take everyone with you.
- Call fire department. Be sure to give your name, location, inform them that it is an electrical fire,

and give any other information you feel important.

**Uninterruptible Power Supply (UPS)**

UPS systems can present both electrical hazards and possible noise exposures. Noise is generally generated not by the UPS itself, but by air movement due to ventilation requirements. Noise should be evaluated and documented. Administrative controls for electrical hazards must also be evaluated. Most often you will have three systems providing power to the UPS (Power company, batteries, and emergency generator). All must be controlled prior to service work. (See Lockout/Tagout Section).

**Batteries**

Battery rooms require employee protection be available due to the sulfuric acid in the batteries. Sealed or unsealed batteries do change the potential for exposure, but not the requirements for personal protective equipment. Each type contains sulfuric acid and therefore possibly exposes the employee.

This requires chemical resistant personal protective equipment of:

- Eyewash (Where sealed batteries are used, substitution of a water rinse or neutralizing packs is acceptable. Other facilities require drenching or flushing facility)
- Face shield
- Apron
- Gloves
- Shoes or boots.



Each battery room must contain chemical neutralizer for the acid in the event of a spill and proper room ventilation.

# 4. MATERIAL HANDLING

**Compressed Gas**

Compressed gas cylinders are dangerous when improperly stored or handled incorrectly. Always assume that a cylinder is pressurized. Handle it carefully. Never throw, bang, tilt, drag, slide, roll, or drop a cylinder from a truck bed or other raised surface. Two or more people are required to manually lifting of any cylinder. Because of their shape, smooth surface, and weight, gas cylinders are difficult to move by hand. A truck or an approved cylinder handcart must always be used to move a cylinder. Never use cylinders, even empty ones, rollers for moving materials, as work supports, or other purposes.

If damaged, a cylinder can cause severe injuries, including lung damage from inhalation of toxic contents and physical trauma from explosion. A pressurized gas cylinder can become a dangerous projectile if its valve is broken or damaged.

When a cylinder is not in use, either a pressure regulator must be connected or the safety cap must be in place. In all cases it is extremely important that the valve be kept closed. The cap protects the cylinder valve (do not lift cylinders by their caps). Notify the regional/company safety person, giving details and cylinder serial number, if you believe that a foreign substance may have entered the cylinder or valve. All Oxygen/Acetylene rigs must use flash arrestors.

Cylinders containing compressed gases should not be subjected to a temperature above 125 degrees F. Flames, sparks, molten metal, or slag must never come in contact with any part of a compressed gas cylinder, pressure apparatus, hoses, or any part of the system. Do not place cylinders where they might become part of an electric circuit. When cylinders are used in conjunction with electric welding, ensure that the cylinders cannot be accidentally grounded and burned by the electric welding arc.

Cylinders must not be subjected to artificially low temperatures. Many ferrous metals become extremely brittle at low temperatures. The loss of ductility and thermal stress at low temperature may cause a steel cylinder to rupture. Never attempt to repair, alter, or tamper with cylinders, valves, or safety relief devices.

Compressed gases cylinders must be stored in an upright position with the cap or regulator installed and chained to a cart or a permanent structure. Fuel gas storage must be separated from oxygen storage by either 20 feet or a half-hour firewall 5 feet high. Transportation of all fuel cylinders must be in vertical racks that would prevent inadvertent damage or overturn. It is imperative that an acetylene cylinder never be tilted beyond a 30 degree angle, tilting at greater than 30 degrees could result in an explosion.



Compressed gases (over 150 psig) are usually stored in steel cylinders manufactured according to DOT specifications. When the DOT was formed in 1969, it acquired responsibility for cylinder specifications, formerly issued by the ICC (Interstate Commerce Commission).

DOT regulations require the following markings on all cylinders:

- Type of cylinder and pressure rating
- Serial number
- Inspection date:
  example: DOT 3AA 2065 973487 6/90

DOT 3AA indicates DOT specification 3AA, which is a seamless alloy-steel cylinder of definite prescribed steel, not over 1000-lb. water capacity, with at least 150-psi service pressure; 2065 is the service pressure at 70 degrees F. and the maximum refill pressure; 973487 is the manufacturer's serial number; and 6/90 is the date of the initial qualifying test.

Old cylinders (made before 1970) will have "ICC" in the markings, whereas cylinders manufactured after 1970 will be marked "DOT." The other identification markings are unchanged.

**Inspections**

All compressed gas cylinders, hoses, tubing, and manifolds must be inspected frequently to ensure that they are free of defects that could cause a failure. Cylinders must be removed from service if

| Organization/Telephone Number/Web Address |
| --- |
| American National Standards Institute (ANSI)<br>(212) 642-4900<br>www.ansi.org |
| American Society of Civil Engineers (ASCE)<br>www.asce.org<br>(800) 548-2723 or (703) 295-6300 |
| American Society for Testing and Materials (ASTM)<br>(610) 832-9585<br>www.astm.org |
| Institute of Electrical and Electronic Engineers (IEEE)<br>(800) 678-4333<br>www.ieee.org |
| National Fire Protection Association (NFPA)<br>(800) 344-3555<br>www.nfpa.org |

**Fig.03-1.** Organization phone numbers and web site addresses (Sec. 03).

## Section 09

# Grounding Methods for Electric Supply and Communications Facilities

### 090. PURPOSE

The purpose of Sec. 09 is to provide practical methods of grounding. Grounding is one of the ways to protect people from hazardous voltages. Grounding also allows protective devices to operate during a fault condition. The basic theory behind grounding is to keep the voltage of a grounded part (e.g., equipment case, neutral conductor, etc.) as close as possible to the potential of the earth so that a voltage difference does not exist between a person and a grounded metal object. The Code states in this rule that grounding is used as one of the means of safe-guarding employees and the public from injury. Other means include, but are not limited to, guarding, clearance heights, short circuit protection, etc.

### 091. SCOPE

The scope of Sec. 09 is to provide the *methods* of protective grounding for supply and communication conductors and equipment. The *requirements* for grounding are listed in the other parts of the Code (i.e., the grounding rules in Part 1, "Electric Supply Stations," Part 2, "Overhead Lines," Part 3, "Underground Lines," and Part 4, "Work Rules"). The scope of Sec. 09 does not include the grounded return of electric railways or lightning protection not associated with supply and communication wires, for example, lightning protection installed on a commercial building.

## 092. POINT OF CONNECTION OF GROUNDING CONDUCTOR

**092A. Direct Current Systems That Are to Be Grounded.** This rule has basic connection requirements for direct-current (DC) systems. For 750 V and less, the grounding conductor connection must be made only at the supply station. For three-wire DC circuits, the connection must be made to the neutral. For DC systems over 750 V, the grounding conductor connection must be made at both the supply and load points. The connection must be made to the neutral of the system. The ground or grounding electrode can be external or remote from each of the stations. This permits separating the electrode from areas with ground currents that can cause electrolytic damage. The Code permits one of the two stations to have its grounding connection made through a surge arrester as long as the other station has the neutral effectively grounded. An exception is provided for the 750 V and greater category for back-to-back DC converter stations that are adjacent to each other. For this condition the neutral of the system should be connected to ground at one point only.

**092B. Alternating-Current Systems That Are to Be Grounded**

**092B1. 750 V and Below.** The point of grounding connection on alternating-current (AC) grounding connection on wye-connected, three-phase, four-wire, and single-phase, three-wire systems operated at 750 V and below is shown in Fig. 092-1.

On other one-, two-, or three-phase systems feeding lighting circuits, a grounding connection must be made to a common circuit conductor. Common examples include a 120/240-V, three-phase, four-wire center tap delta service, a 120/208-V, single-phase, three-wire service fed from a 120/208-V, three-phase, four-wire service, or a 120-V, single-phase, two-wire service fed from a 120/240-V, single-phase, three-wire service.

Wye and delta circuits that are not grounded or do not use a common (neutral) conductor for grounding cannot be used to serve lighting loads. See Fig. 092-2.

Grounding connections must be made at the source and line side of a service as shown in Fig. 092-3.

**092B2. Over 750 V.** Nonshielded conductors (e.g., bare neutral conductors) must be grounded as shown in Fig. 092-4.

The wording in Rule 092B2a requires unigrounding at the source (substation transformer) and permits, but does not require, multigrounding along the line. However, various rules in Part 2, "Overhead Lines," and Part 3, "Underground Lines," will require systems to be effectively grounded. Effectively grounded systems typically need to be multigrounded to provide sufficiently low ground impedance. Multigrounded systems are discussed in Rule 096C.

Shielded conductors on riser poles must be grounded as shown in Fig. 092-5.

Shielded cables without an insulating jacket must be grounded as shown in Fig. 092-6.



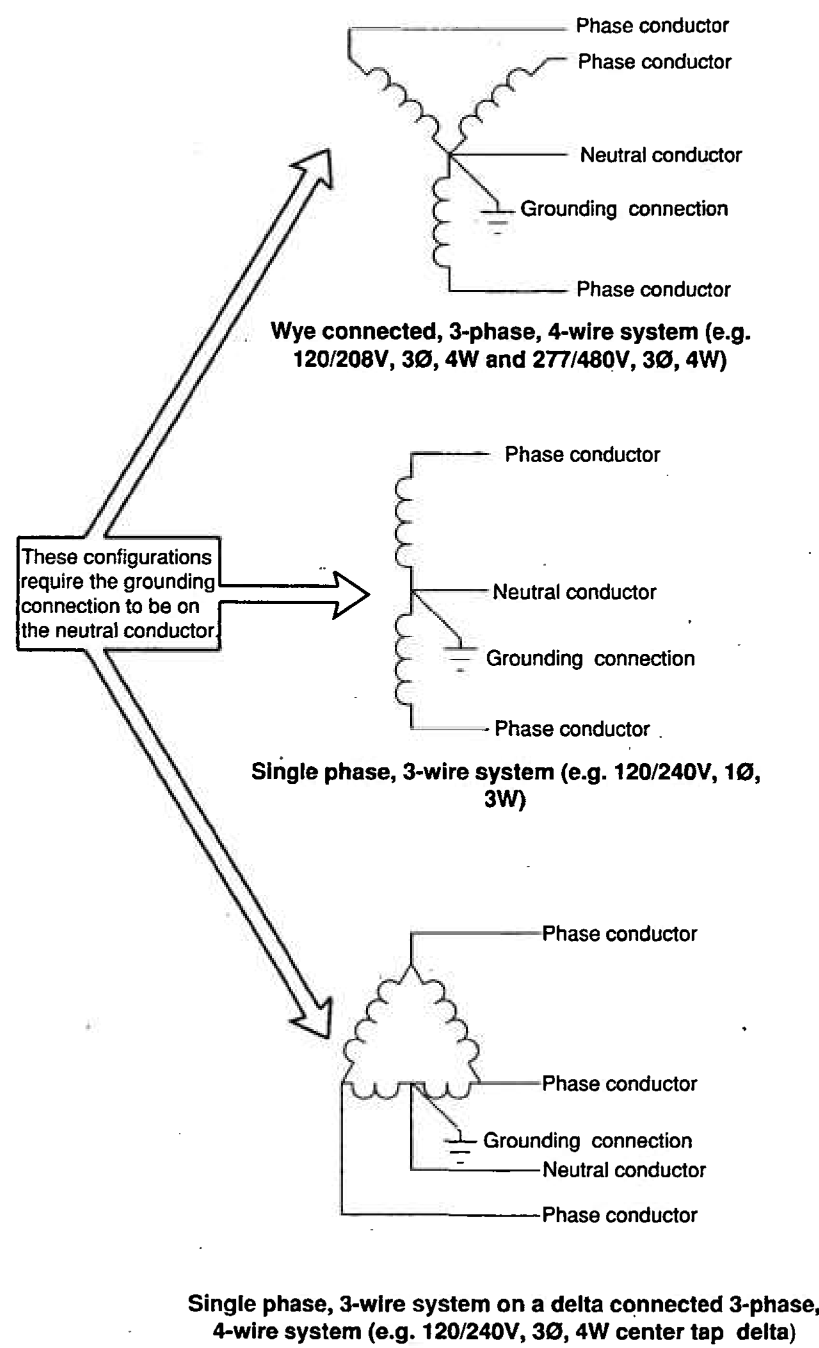



**Fig. 092-1.** Grounding connection on wye-connected three-phase, four-wire and single-phase, three-wire systems (Rule 092B1).

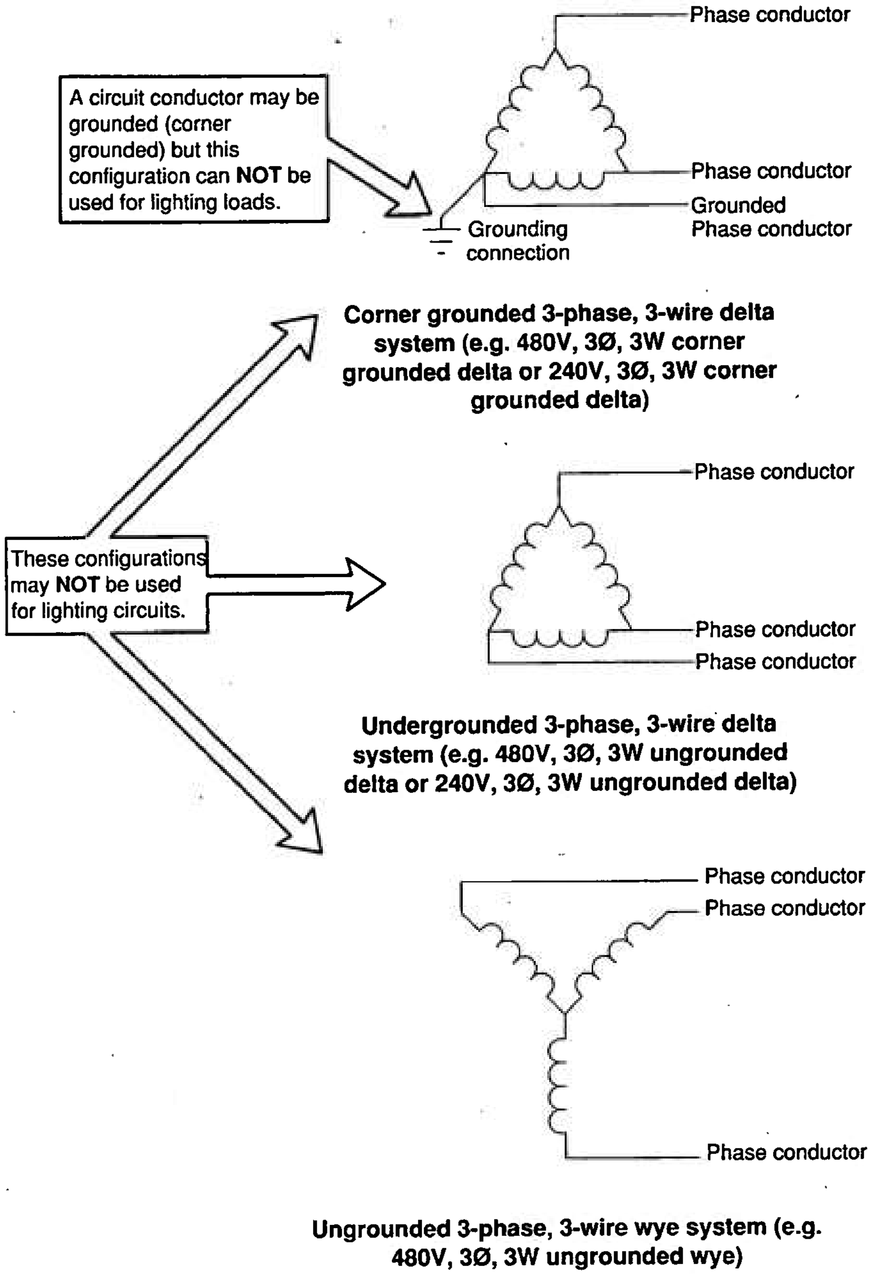



**Fig. 092-2.** Wye and delta systems not to be used for lighting loads (Rule 092B1).



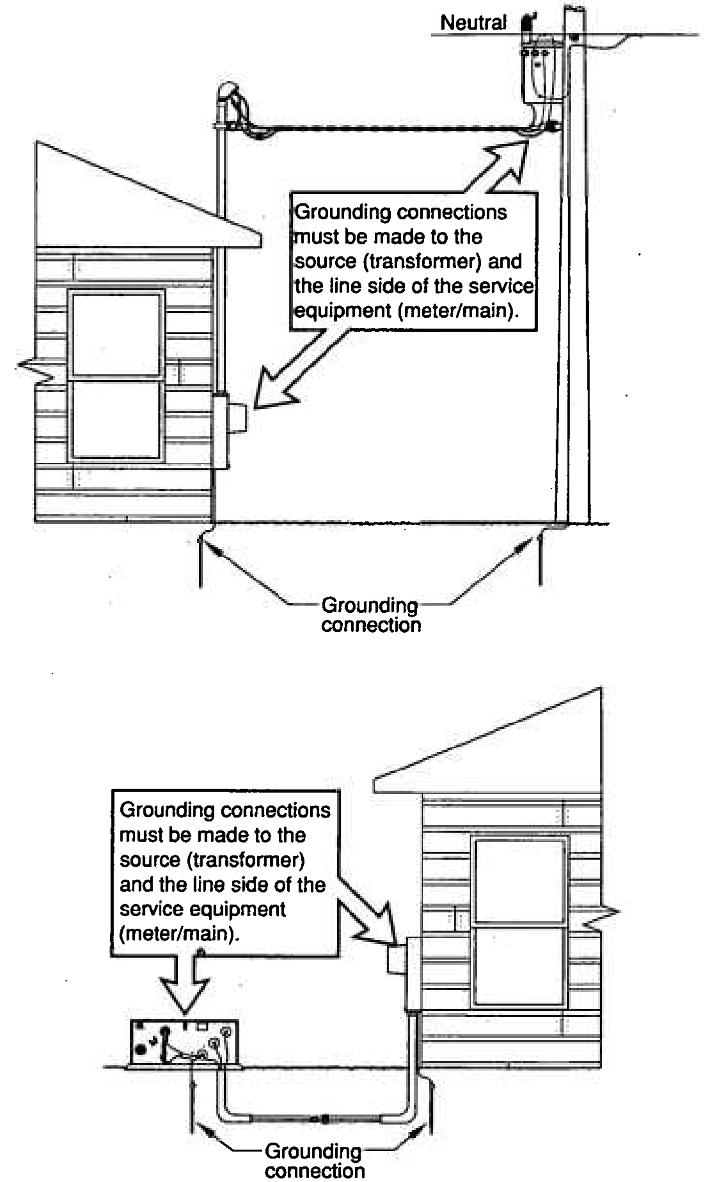



**Fig. 092-3.** Grounding connections at source and line side of a service (Rule 092B1).

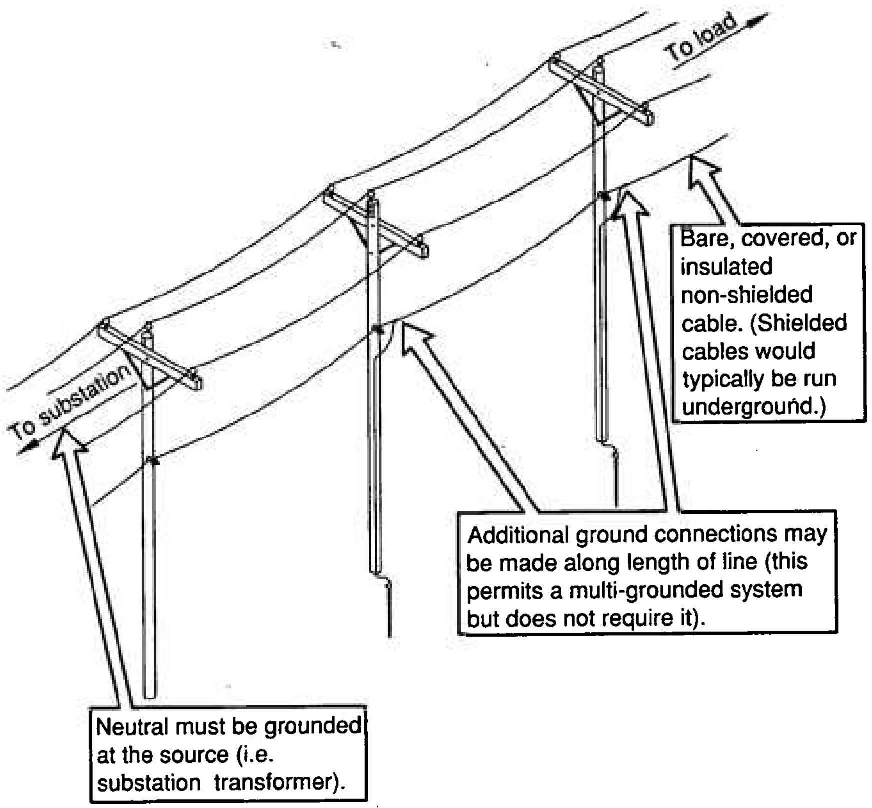



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**Fig. 092-4.** Grounding connections for nonshielded cables over 750 V (Rule 092B2a).

Shielded cables with an insulating jacket must be grounded as shown in Fig. 092-7.

Shielded cable without an insulating jacket that is buried in direct contact with the earth has an advantage of being grounded all along its length. However, direct-buried shielded cable without an insulating jacket is susceptible to corrosion. The insulating jacket can prevent corrosion of the shield or concentric neutral, but grounding is not as effective. Shielded cables with an insulating jacket may need to have a section of jacket removed and a ground attachment made to meet the multigrounding requirements of Rule 096C. The same applies to both bare and jacketed concentric neutral cables installed in conduit.

**092B3. Separate Grounding Conductor.** If a separate grounding conductor is used on an AC system to be grounded as an adjunct (joined addition) to a cable run underground, there are several conditions that apply. The separate grounding conductor must be connected directly or through the neutral to items that must be grounded. The conductor must be located as shown in Fig. 092-8.

Adjunct (joined addition) grounding conductors are typically used with shielded supply cables. If the shield on the supply cable is not a sufficient size to carry neutral current or fault current, an adjunct grounding cable can



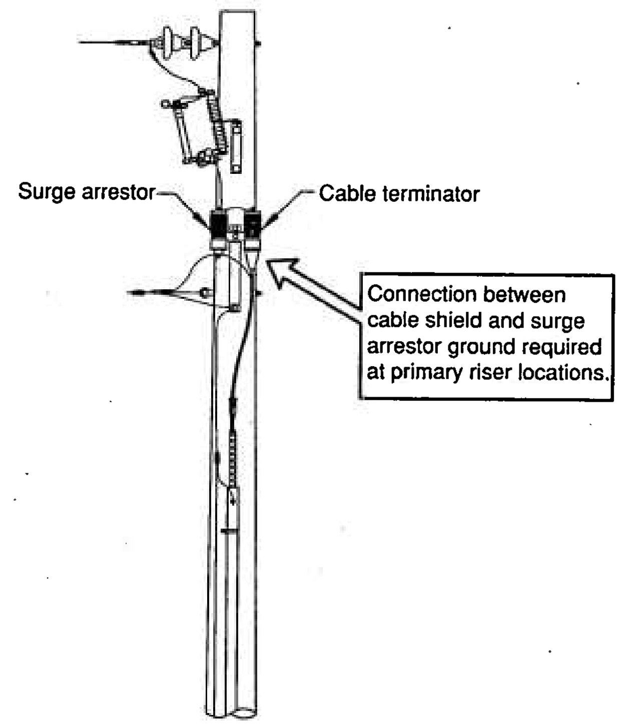


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**Fig. 092-5.** Surge arrester cable—shielding interconnection (Rule 092B2b(1)).

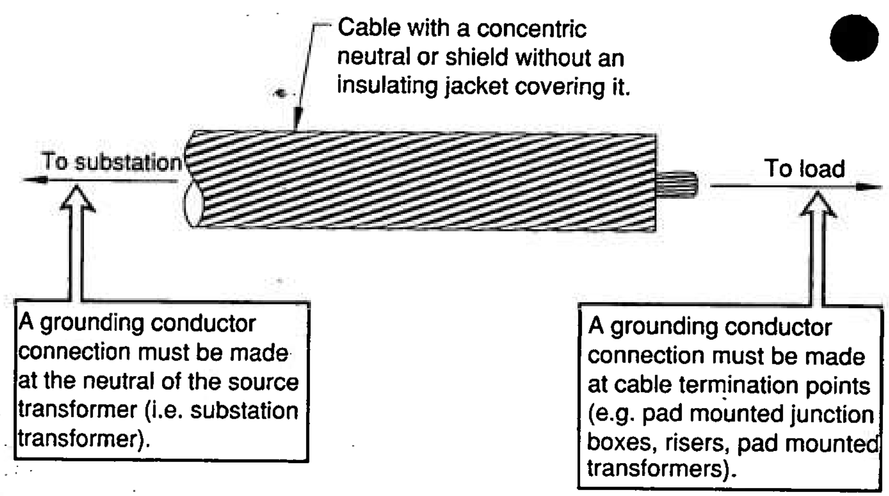


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**Fig. 092-6.** Grounding points for a shielded cable without an insulating jacket (Rule 092B2b(2)).

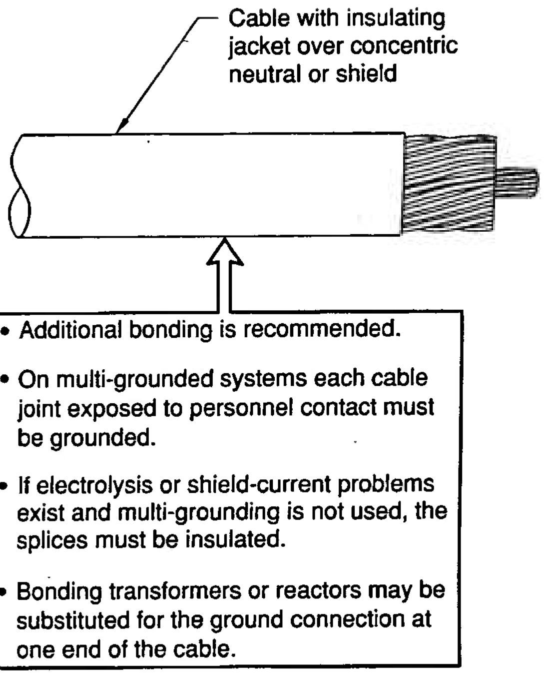


**Fig. 092-7.** Grounding points for a shielded cable with an insulating jacket (Rule 092B2b(3)).

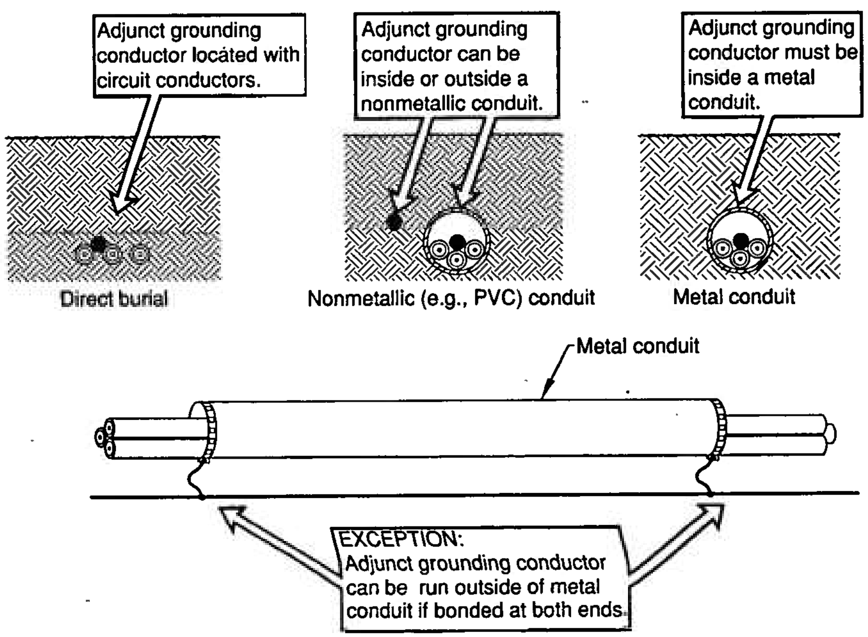


**Fig. 092-8.** Separate (adjunct) grounding conductor (Rule 092B3).



be used. An adjunct grounding conductor should not be used to replace a corroded concentric neutral conductor in a direct-buried cable. Rule 350B requires that a direct-buried cable operating above 600 V have a continuous metallic shield, sheath, or concentric neutral. The adjunct grounding conductor can be used to supplement the concentric neutral but not replace it if it has corroded away.

**092C. Messenger Wires and Guys**

**092C1. Messenger Wires.** The point of connection of the grounding conductor to messenger wires that are required to be grounded by other parts of the code is shown in Fig. 092-9.

Communications messenger wires on joint-use poles are required to be grounded in Part 2, "Overhead Lines," to meet certain clearance and grade of construction requirements. The messenger must meet certain ampacity and strength criteria defined in Rules 093C1, 093C2, and 093C5. The four grounds per mile rule appears here for the first time in the Code. It is discussed in detail in Rule 096C.

**092C2. Guys.** The point of connection of the grounding conductor to guys that are required to be grounded by other parts of the code is shown in Fig. 092-10.

Guys must be either grounded or insulated per Rule 215C2 and Rule 279A2. If they are grounded, they must be grounded using the methods in this rule.

**092C3. Common Grounding of Messengers and Guys on the Same Supporting Structure.** When messengers and guys are on the same supporting structure and they are required to be grounded by other parts of the Code, they must be bonded together and grounded by the connection methods listed in this rule. The methods listed are a combination of the messenger and guy connection requirements. When a messenger and guy are on a common crossing structure, they must be bonded together at that structure and grounded. For structures other than crossing structures, the common grounding of messengers and guys must be done at least four (or eight) times in each mile but not at any specific structure. Common bonding and grounding of a messenger and guy at a common crossing structure are shown in Fig. 092-11.

**092D. Current in Grounding Conductor.** This rule recognizes that multi-grounded systems, for example, a 12.47/7.2-kV, three-phase, four-wire circuit that has four or more grounds per mile may develop objectionable current flow on the grounding conductor. This rule provides methods to alleviate the objectionable current flow.

Objectionable current flow may exist due to stray earth currents or other reasons. Fault currents and lightning discharge currents are not considered objectionable current flows when applying this rule.

**092E. Fences.** When fences are required to be grounded by other parts of this Code, they must be connected to a grounding conductor as shown in Fig. 092-12.

This rule provides both specific requirements for fence grounding (Rules 092E1 through 092E6) and general requirements by noting IEEE Standard 80, which is the industry standard for substation grounding information. An example of substation fence grounding is shown in Fig. 092-13.

Fence mesh strands are only required to be bonded if the fence posts are nonconducting. For conducting (metal) fence posts, the fence mesh must be

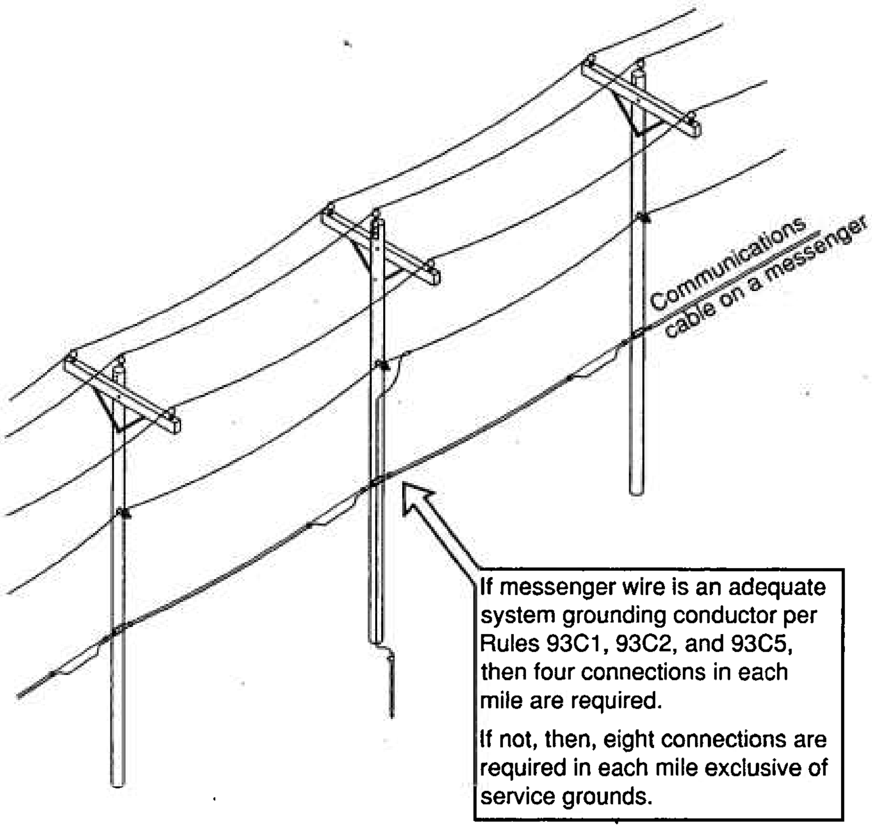


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**Fig. 092-9.** Grounding of messenger wires (Rule 092C1).

under tension and electrically connected to the post for the mesh to be grounded. In the example shown in Fig. 092-13, the grounding conductor feed up to the barbwire strands is woven through the chain-link mesh for added grounding continuity.

## 093. GROUNDING CONDUCTOR AND MEANS OF CONNECTION

**093A. Composition of Grounding Conductors.** Grounding conductors can be copper or other metals or combinations of metals that will not corrode during their expected service life under the existing conditions. Surge arrester connections must be short, straight, and free from sharp bends. Metallic electrical equipment cases or the structural metal frame of a building can also be used as a grounding conductor. Many utilities use copper for the entire length of the grounding conductor. Some utilities use aluminum or ACSR. Typically, the alu-



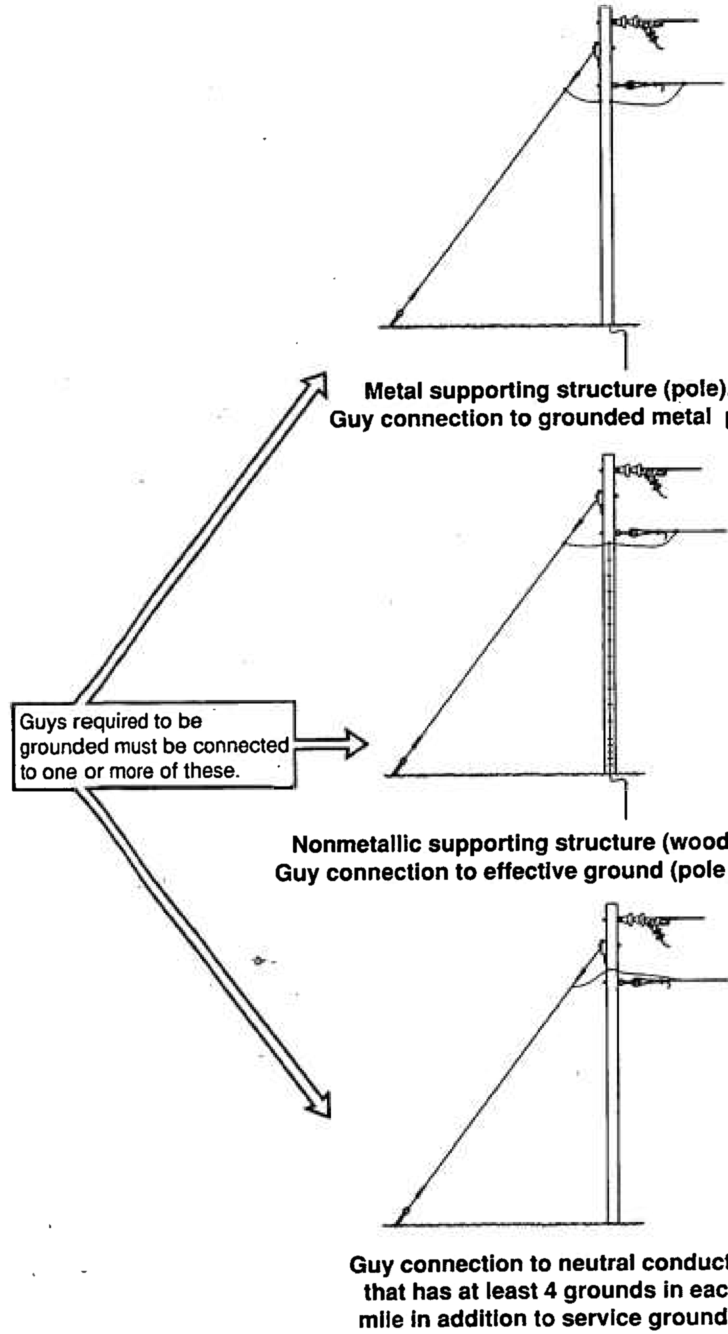


**Fig. 092-10.** Grounding of guys (Rule 092C2).

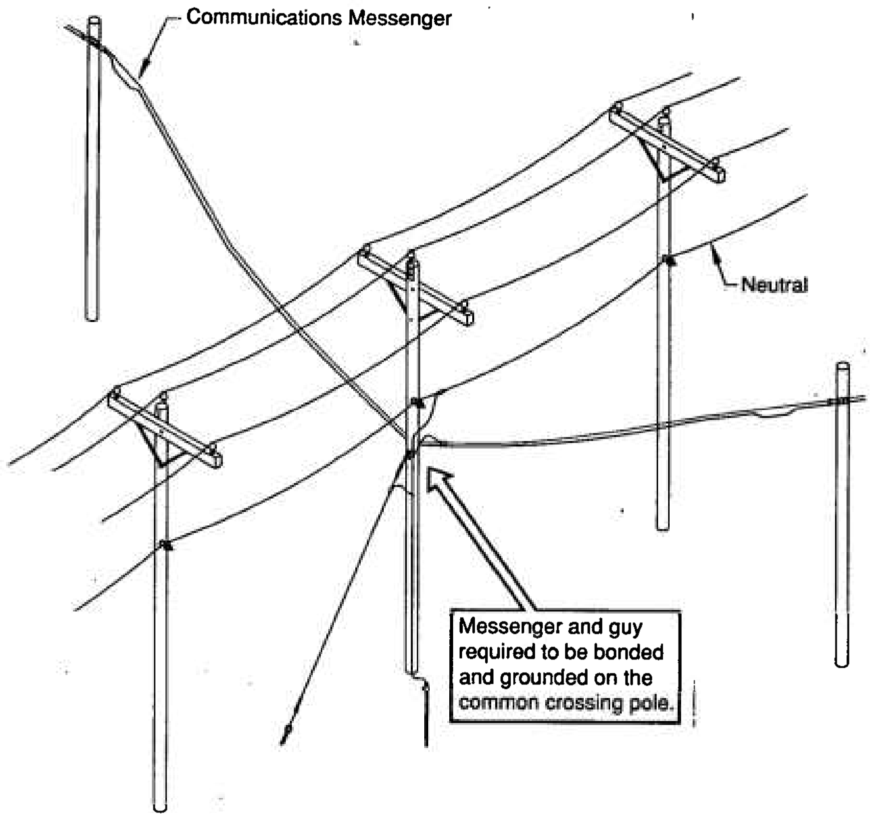


**Fig. 092-11.** Common grounding of messenger and guy on a crossing structure (Rule 092C3b).

minum or ACSR is used above grade, spliced to copper, which then runs below grade. Some utilities utilize copper-coated steel. Copper substitutes have become popular due to copper theft.

Never should the grounding conductor have a switching device unless all the conductors to the equipment are disconnected at the same time. Other exceptions include high-voltage DC systems, testing under competent supervision, and surge arrester operation. This rule provides an important note stating that the normally grounded base of the surge arrester may be at line potential (fully energized) following the operation of the disconnector.

**093B. Connection of Grounding Conductors.** The connection between the grounding conductor (pole ground) and grounded conductor (neutral) must be made considering the metals involved and exposure to the environment. The connector must not corrode and must be rated for the type of metals it is connecting. Dissimilar metals connected together with an improper connector will set up a battery action which will accelerate corrosion. Soldering is not acceptable except on lead sheath cable, as fault currents will produce enough heat to melt the solder. Suitable connection methods are shown in Fig. 093-1



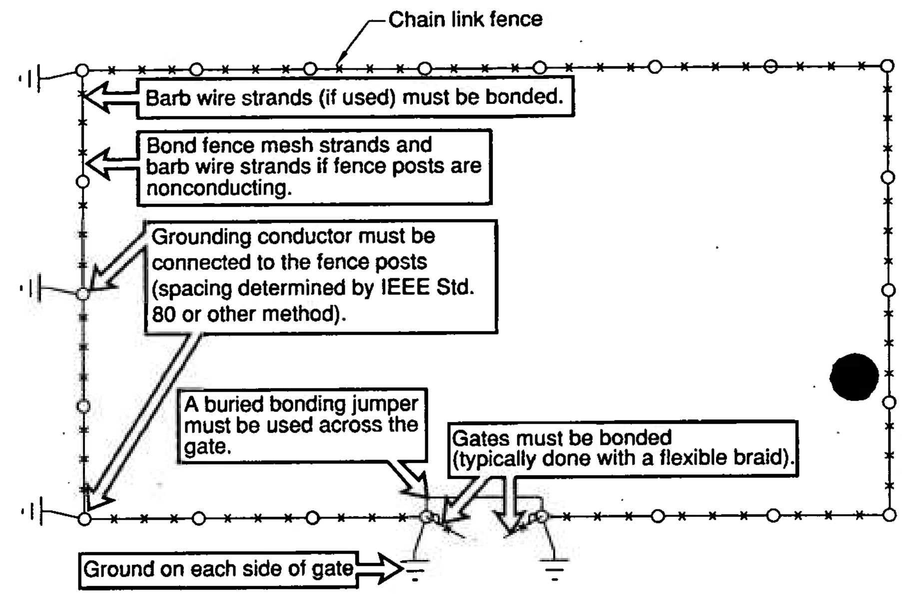


**Fig. 092-12.** Fence grounding (Rule 092E).

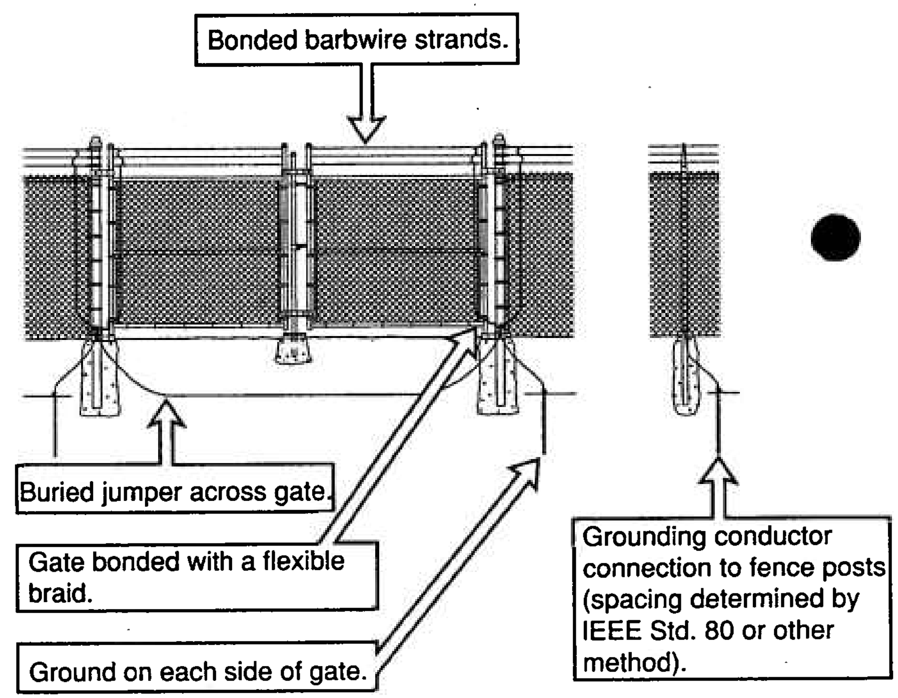


**Fig. 092-13.** Example of fence grounding (Rule 092E).

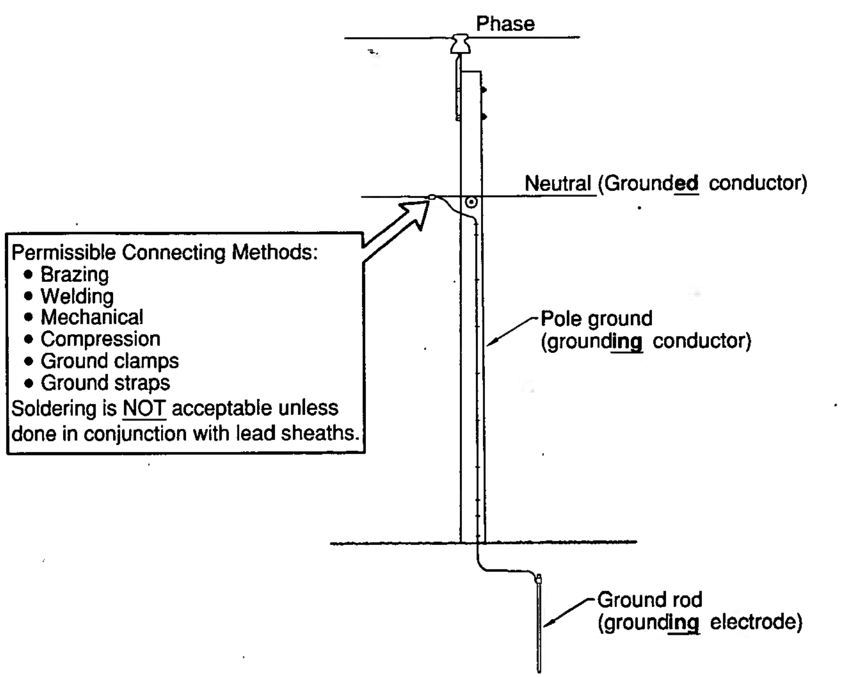


**Fig. 093-1.** Connection of grounding conductor to grounded conductor (Rule 093B).

**093C. Ampacity and Strength.** This rule lists short-time ampacity requirements for bare and insulated grounding conductors. A bare conductor can carry a larger fault current than an insulated conductor of the same size because melting or damaging the bare conductor is the limiting factor. The insulated grounding conductor has the additional constraint of not damaging the insulation. See Fig. 093-2.

Short-time ampacity of both bare and insulated conductors can be obtained from conductor manufacturers. The charts used to obtain this information are typically referred to as short-circuit withstand charts.

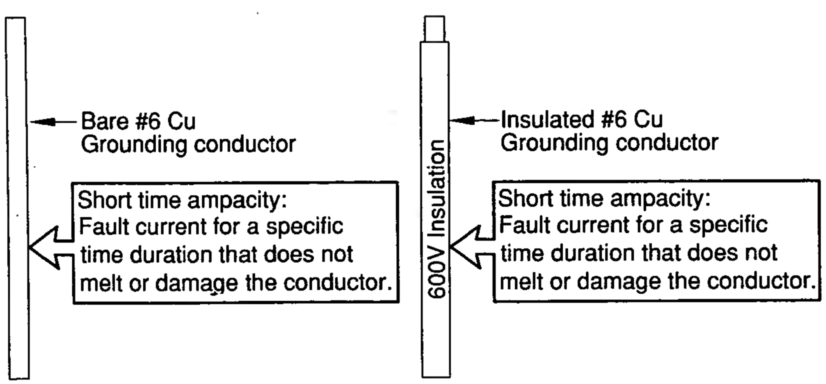


**Fig. 093-2.** Short-time ampacity of bare and insulated grounding conductors (Rule 093C).



Short-time ampacity for a single-grounded system is shown in Fig. 093-3.

Short-time ampacity for a multigrounded AC system is shown in Fig. 093-4.

Rule 093C2 references Rule 093C8, which also specifies ampacity limits based on the ampacity of phase conductors and grounding electrode resistance. The one-fifth ampacity requirement applies to the normal operating current, not to the short-time fault ampacity. An example of pole ground sizing is shown in Fig. 093-5.

In addition to checking the pole ground to the primary neutral, the service transformer neutral should also be considered. A bare AWG No. 6 copper pole ground connected to the neutral of a large secondary service may not have the required one-fifth ampacity of the secondary neutral. Large secondary services require careful application of Rules 093C2 and 093C8.

In addition to single-grounded and multigrounded system requirements, Rule 093C requires AWG No. 12 copper or larger conductors to ground instrument transformers and AWG No. 6 copper or AWG No. 4 aluminum or larger conductors to ground primary surge arresters. The primary surge arrester rule has an exception permitting use of copper-clad or aluminum-clad steel wires.

Grounding conductors for equipment, messenger wires, and guys must have a short-time ampacity based on the available fault current and operating time of the circuit protective device. If the circuit does not have an overcurrent or fault protection device (e.g., fuse, recloser, relay, controlled circuit breaker, etc.), then the design and operating conditions of the circuit must be analyzed and the grounding conductor cannot be smaller than AWG No. 8 copper. If a

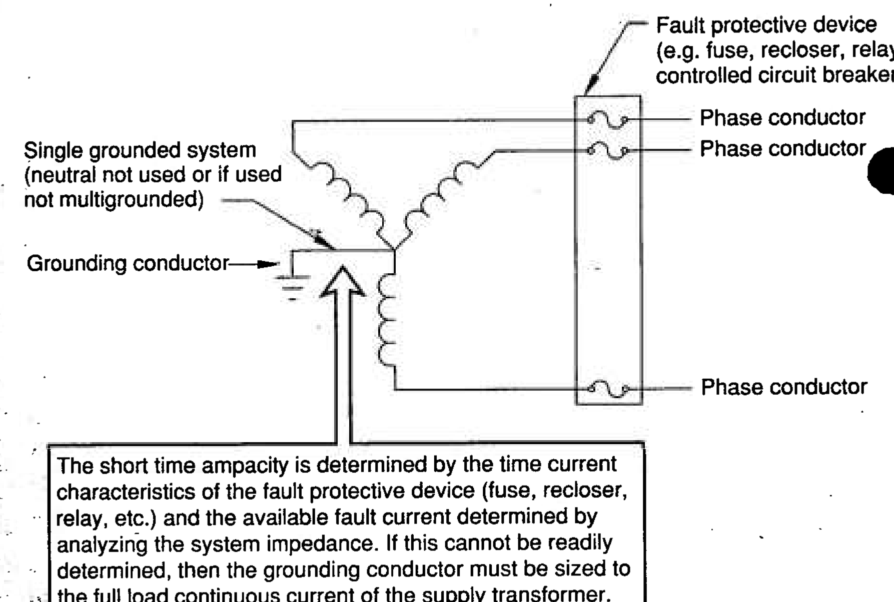


**Fig. 093-3.** System grounding conductor for single-grounded systems (Rule 093C1).

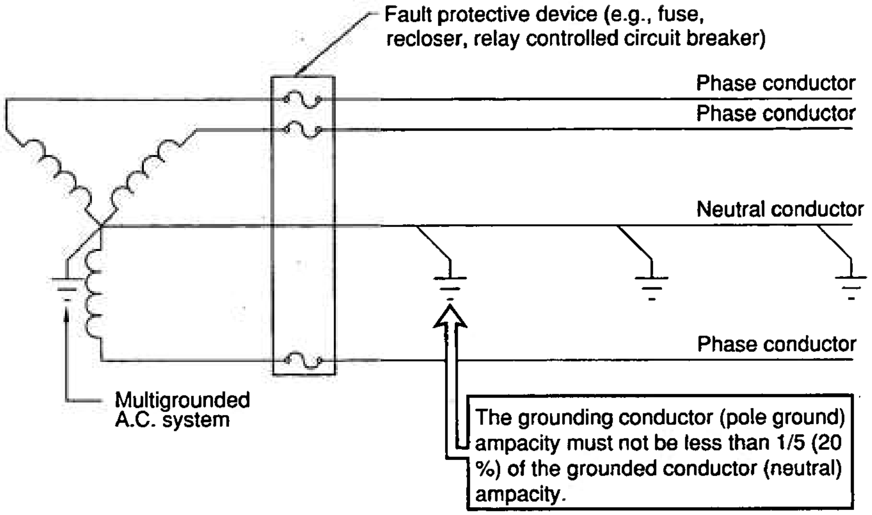


**Fig. 093-4.** System grounding conductors for multigrounded alternating current systems (Rule 093C2).

conductor enclosure (i.e., rigid steel conduit) is connected to a metal equipment enclosure with suitable lugs, bushings, etc., the metallic conduit and metallic equipment path can be used as an equipment-grounding conductor. When grounding conductors are used, they shall be connected to a suitable lug, terminal, or other device without disruption.

The ampacity and strength of the grounding conductor used for grounding fences must also have adequate short-time ampacities or must be Stl WG No. 5 or larger.

Bonding of equipment frames and enclosures must consist of a metallic path back to the grounded terminal of the local supply. If the supply is remote, metallic parts within reach must be bonded and connected to ground.

Rule 093C8 specifies an ampacity limit such that no grounding conductor needs to have an ampacity greater than either:

- The phase conductor that would supply the ground fault, or
- The maximum current in the grounding conductor calculated by dividing the supply voltage by the electrode resistance

Consider an example related to Rule 093C8b. Assuming a 7200-V phase to ground circuit and assuming a 25-Ω ground rod resistance, 7200 V divided by 25 Ω = 288 A. For a 120/240-V secondary, 120 V to ground divided by a 25-Ω ground rod resistance would be 4.8A. Rule 093C8 may limit the size of the ground wire specified in other parts of Rule 093C based on required ampacity. Secondary services may have large grounded (neutral) conductors; however, the grounding (pole ground) conductor size may be limited by applying Rule 093C8. In this example, the assumption of a 25-Ω ground rod resistance is just that, an assumption. Ground rod resistance will vary by



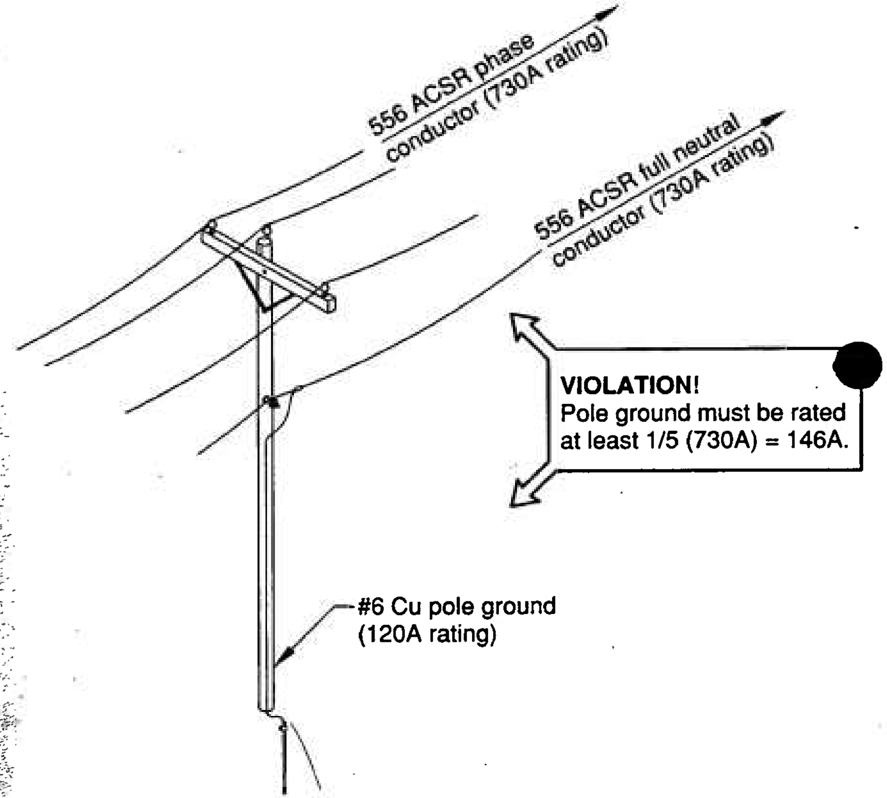


**Fig. 093-5.** Example of pole ground ampacity (Rule 093C2).

type of soil, moisture in the soil, length of rod, etc. Field measurements must be taken to determine actual ground rod resistance.

The mechanical strength of grounding conductors must be suitable to the conditions they are exposed to (i.e., lawn mowers, weed eaters, car bumpers, etc.). Unguarded grounding conductors must have a tensile strength equal to or greater than AWG No. 8 soft-drawn copper except for conductors noted in Rule 093C3 (i.e., AWG No. 12 copper for instrument transformers).

**093D. Guarding and Protection.** Guards over grounding conductors are only required for single-grounded systems that are exposed to the public. If the grounding electrode is on a single-grounded system that is not exposed to the public (i.e., in a fenced substation), it does not have to be guarded. Grounding electrodes on multigrounded systems are not required to be guarded even if they are exposed to mechanical damages. A multigrounded system requires at least four grounds per mile, and Rule 214 requires inspection of overhead lines. These two requirements provide a method to assure safe grounding on multigrounded systems; therefore, guards on multigrounded systems are not required. Even if guards are not

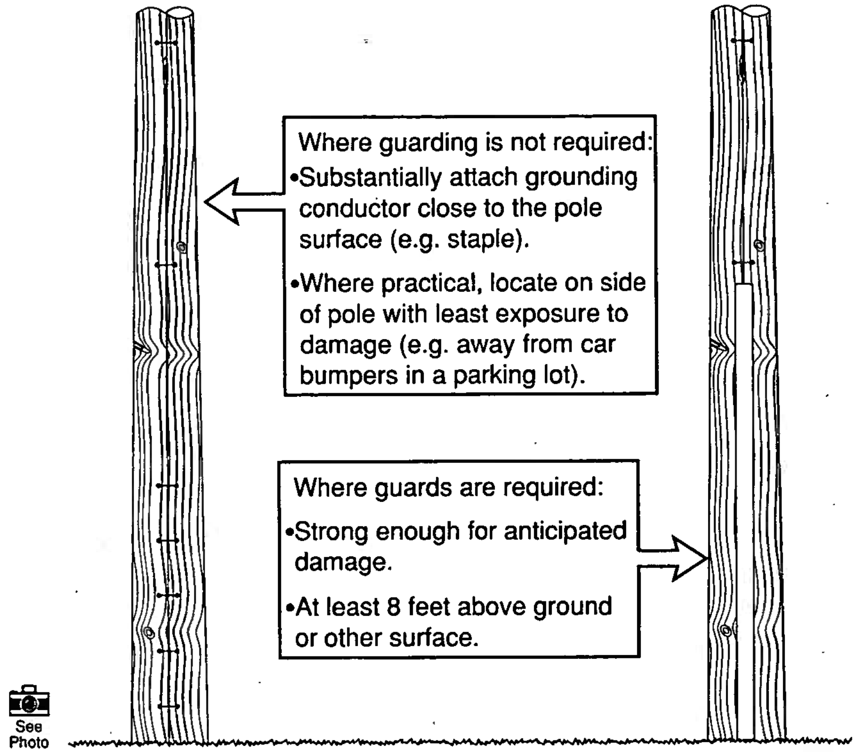


**Fig. 093-6.** Requirements for grounding conductors with or without guards (Rules 093D2 and 093D3).

required, they can be installed. If guards are not required but they are installed, they should be installed in a manner as if they were required.

Rules 239D and 360A also provide guarding requirements for various conductors. If guarding of the grounding conductor is required, guards must be suitable for the damage to which they will be exposed. If guarding of the grounding conductor is not required, a typical installation method is stapling the grounding conductor to a wood pole. The requirements for grounding conductors with or without guards are outlined in Fig. 093-6.

Rule 093D4 recognizes that an inductive choke is created when a conductor is run through a metallic raceway. This can create hazardous voltage during lightning strike or fault conditions. The Code requires a nonmetallic guard (e.g., conduit) to avoid this condition. The strength of nonmetallic materials (i.e., plastics) has increased to the point where they can be used for protection without cracking or breaking. A U-shaped metallic raceway is acceptable, as it does not completely enclose the grounding conductor. If a metallic guard similar to a steel pipe or rigid metal conduit is used, it must be bonded to the grounding conductor at both ends, as shown in Fig. 093-7.

**093E. Underground.** Grounding conductors laid underground require slack due to the earth's settling. Direct-buried joints or splices must be made with



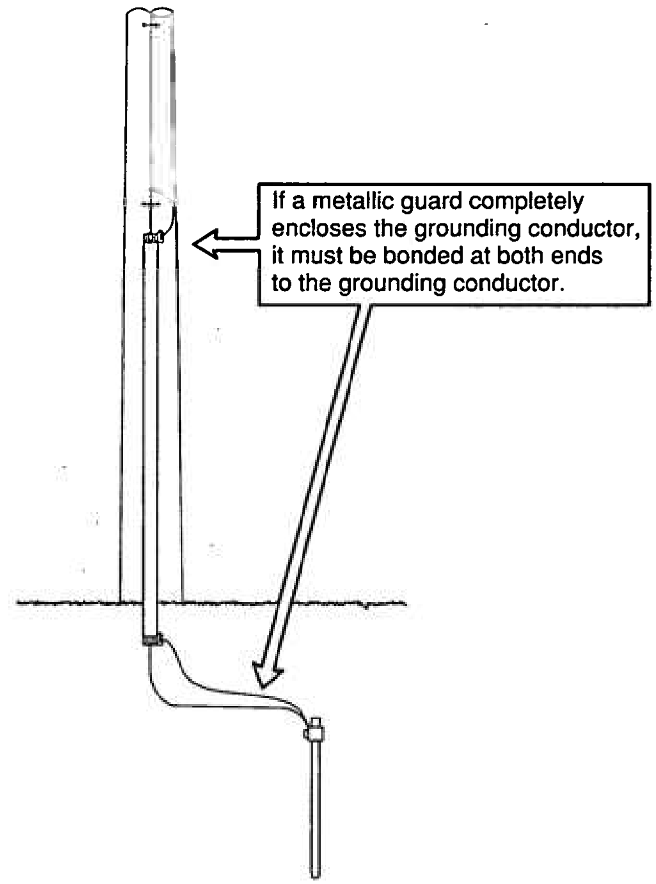


**Fig. 093-7.** Requirements for a metallic guard that completely encloses the grounding conductor (Rule 93D4).

corrosion resistance in mind. Corrosion must be kept to a minimum. A cable insulation shield (e.g., concentric neutral, metallic foil, braid, etc.) must be connected to other grounded equipment in underground enclosures. Looped magnetic elements must not be positioned between the grounding conductor and the phase conductors.

The metals used for grounding in earth, concrete, or masonry must not corrode. This rule specifically notes that aluminum is not generally acceptable when used underground. An example of an aluminum ground wire that transitions to copper for underground burial is shown in Fig. 093-8.

**093F. Common Grounding Conductor for Circuits, Metal Raceways, and Equipment.** This rule allows one common grounding conductor for both the supply system (neutral) and equipment (e.g., a recloser) where the ampacity of the grounding conductor is adequate for both. Ampacity for the system grounding conductor and equipment grounding conductor is discussed in Rule 093C. An

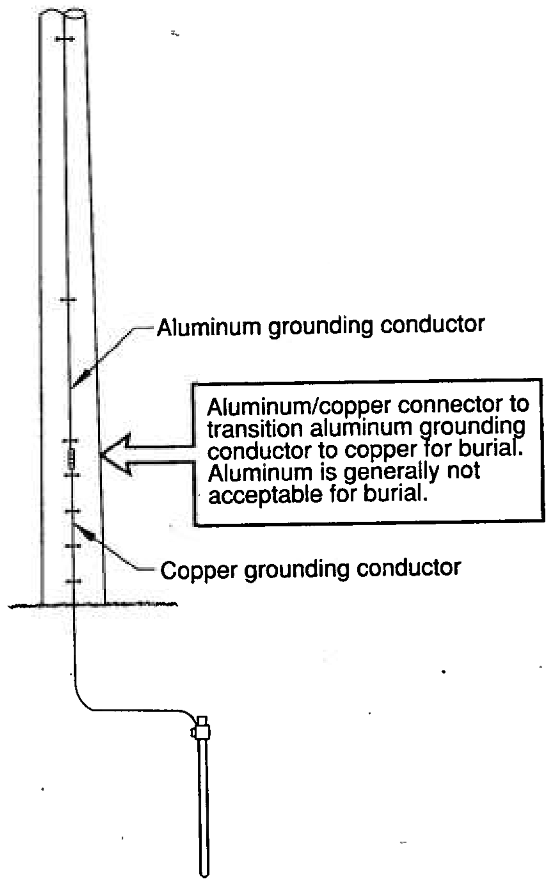


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**Fig. 093-8.** Example of aluminum grounding conductor transitioning to copper for burial (Rule 093E5).

example of one common grounding conductor for the circuit and equipment is shown in Fig. 093-9.

## 094. GROUNDING ELECTRODES

Grounding electrodes can be existing electrodes or made electrodes. Existing electrodes are existing conductive items buried in the earth for a purpose other than grounding but can also serve as a grounding electrode. Most utilities use made electrodes, which are purposely constructed and buried to serve as grounding electrodes. Requirements for existing electrodes are outlined in Figs. 094-1 through 094-3.



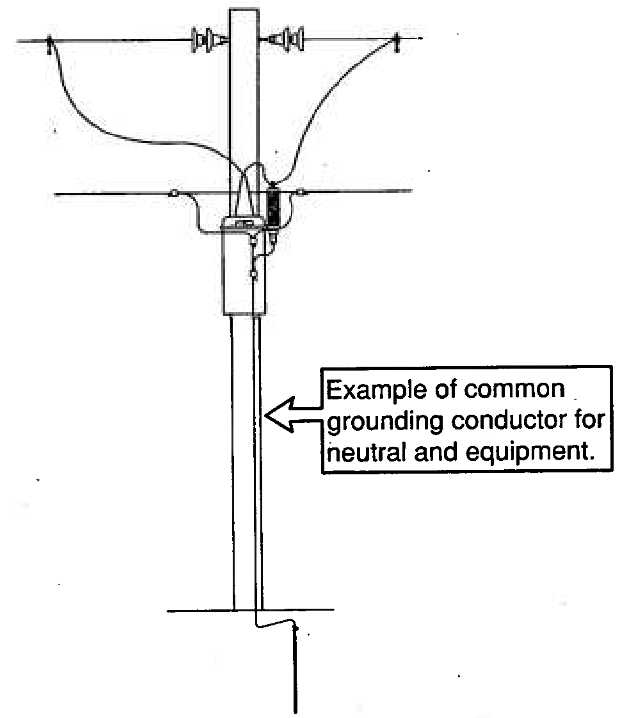



**Fig. 093-9.** Example of common grounding conductor for neutral and equipment (Rule 093F).

Made electrodes must penetrate the moisture level and be below the frost line. They must be metal or combined metals that do not corrode and they must not be painted, enameled, or covered in any way with an insulating material. The driven ground rod is the most commonly used made electrode. Requirements for made electrodes are outlined in Figs. 094-4 through 094-11.

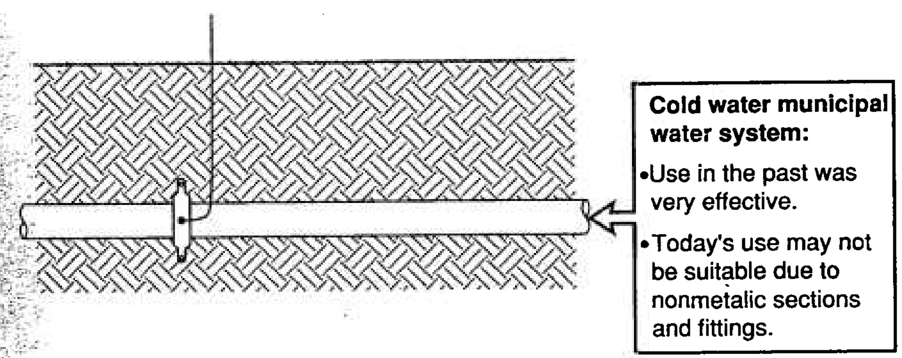



**Fig. 094-1.** Existing electrode—metallic water piping system (Rule 094A1).

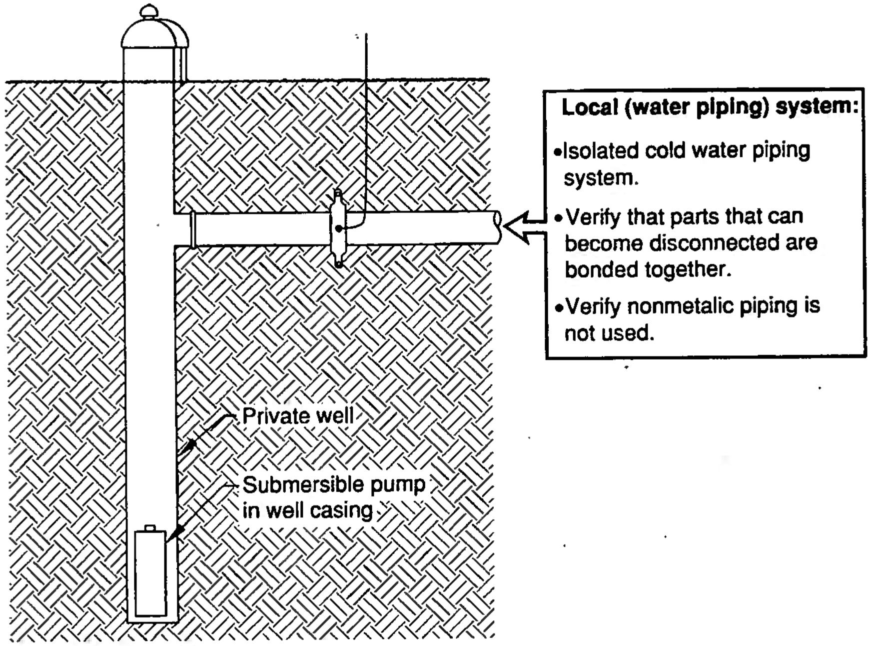



**Fig. 094-2.** Existing electrode—local (water piping) system (Rule 094A2).

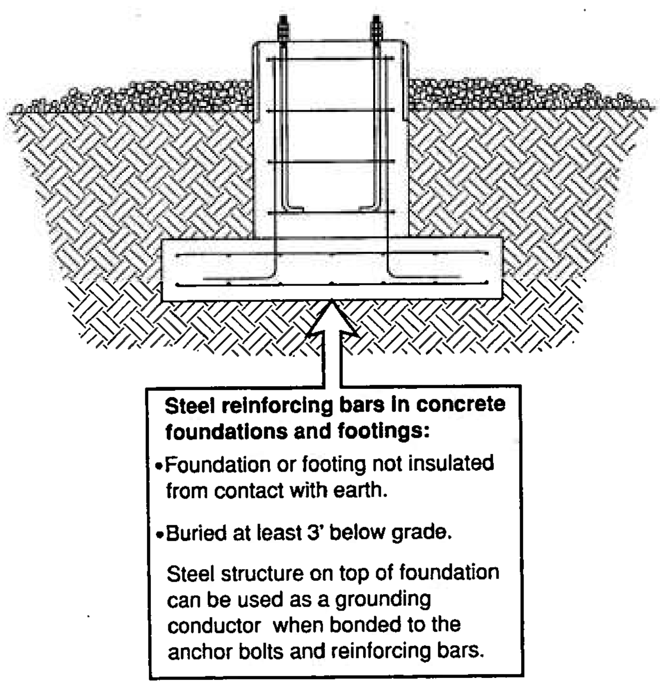



**Fig. 094-3.** Existing electrode—steel reinforcing bars in concrete foundations and footings (Rule 094A3).



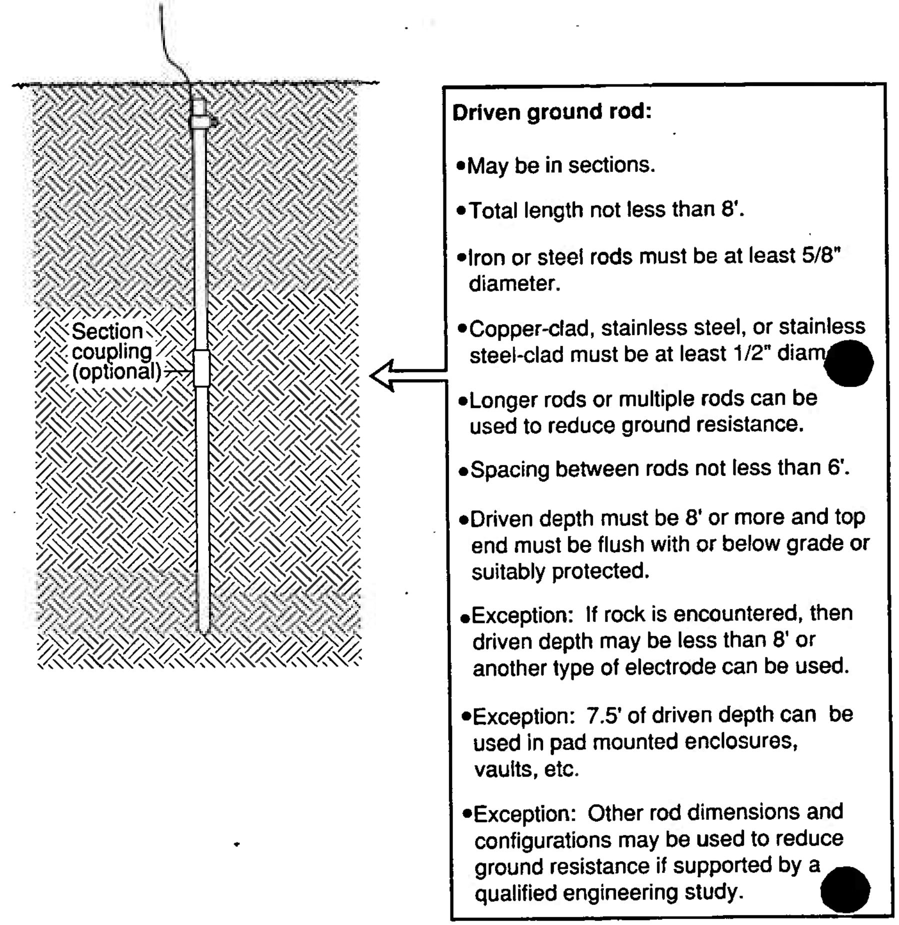



**Fig. 094-4.** Made electrodes—driven ground rods (Rule 094B2).

## 095. METHOD OF CONNECTION TO ELECTRODE

The connection to the grounding electrode must be permanent (except for removal due to inspection or maintenance) and be mechanically sound, corrosion-resistant, and have the required ampacity for the fault current to which it will be subjected. Suitable connection methods are shown in Fig. 095-1.

The Code also has specific rules for connecting to steel framed and non-steel-framed structures. The connection to water piping systems is also outlined. When water piping is used as the grounding electrode, bonds must be made around meters or other removable fittings.

The Code (in Sec. 094, "Grounding Electrodes") does not list gas piping as an acceptable electrode. Made electrodes or grounded structures should be separated from high-pressure (150 lb/in² or greater) pipelines containing flammable liquids

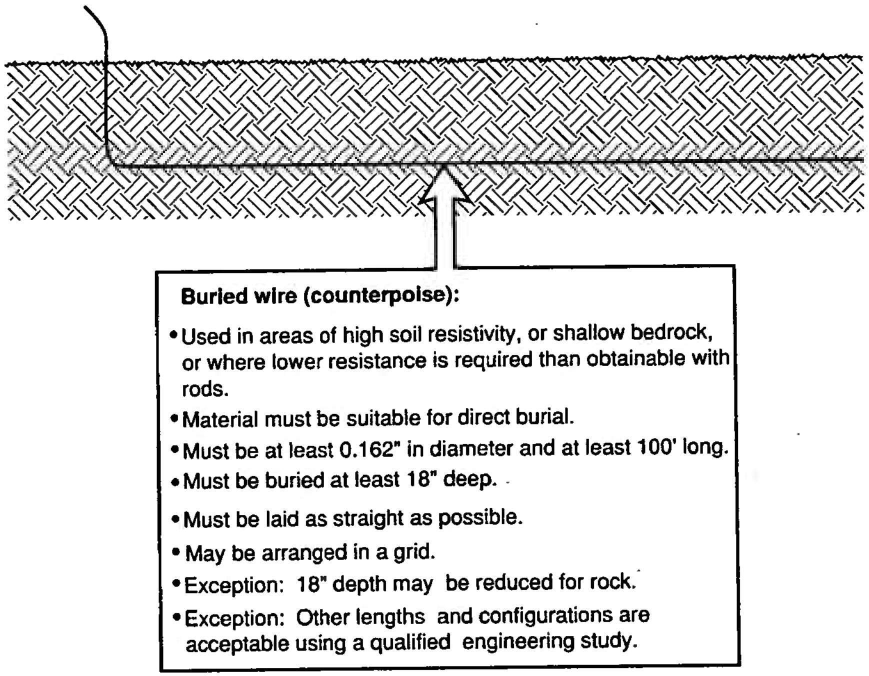



**Fig. 094-5.** Made electrodes—buried wire (counterpoise) (Rule 094B3a).

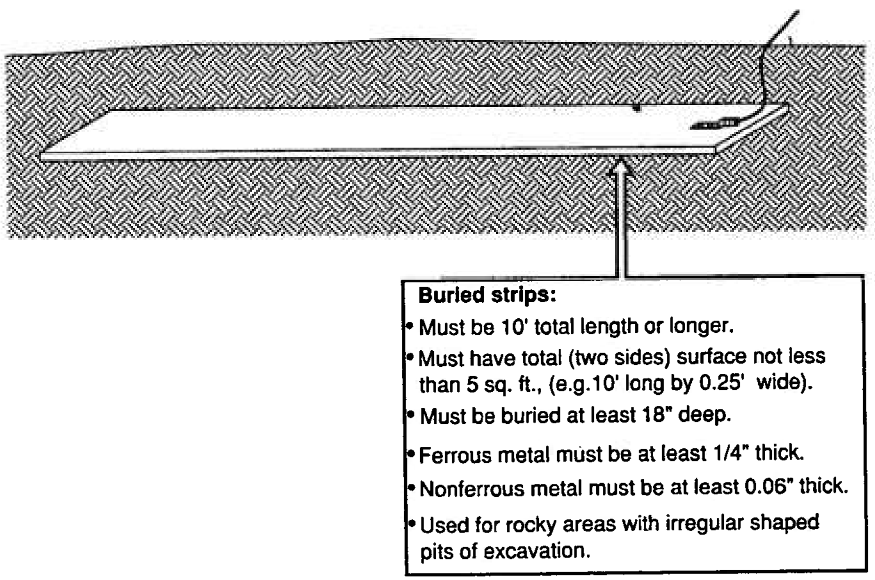



**Fig. 094-6.** Made electrodes—buried strips (Rule 094B3b).



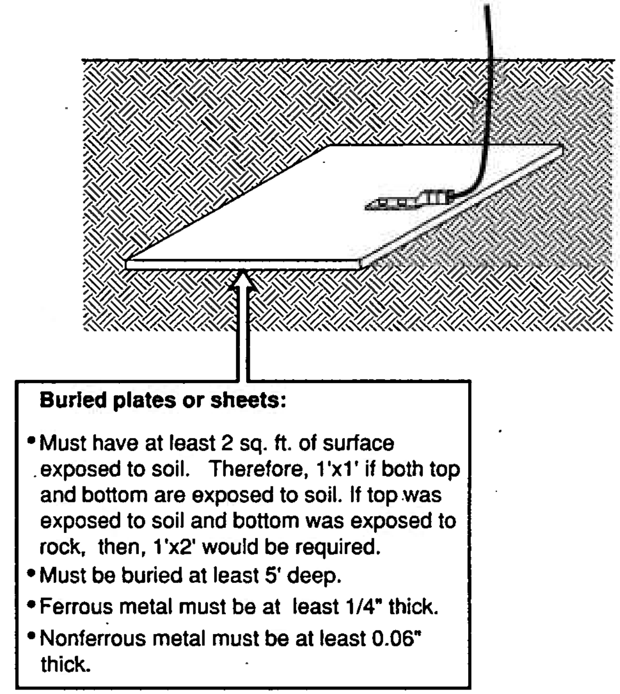



**Fig. 094-7.** Made electrodes—buried plates or sheets (Rule 094B3c).

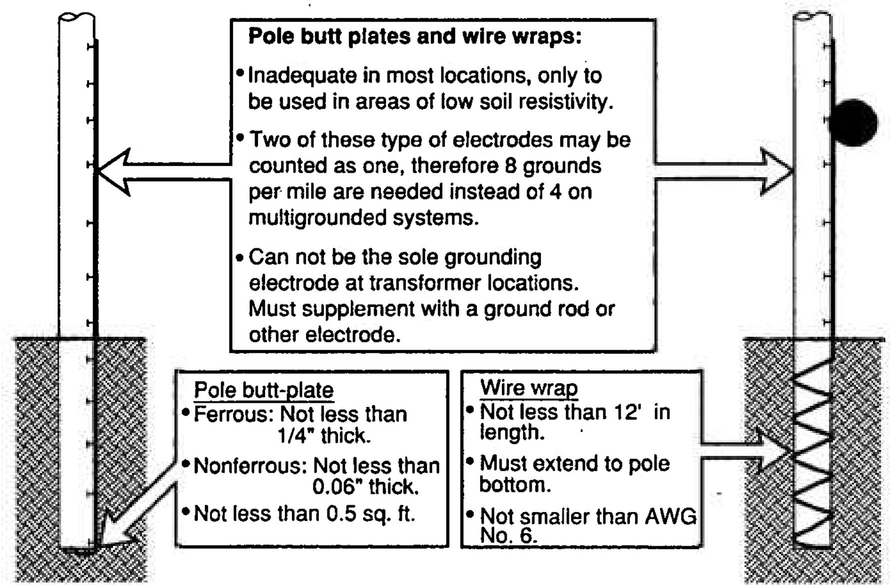



**Fig. 094-8.** Made electrodes—butt plates and wire wraps (Rule 094B4).

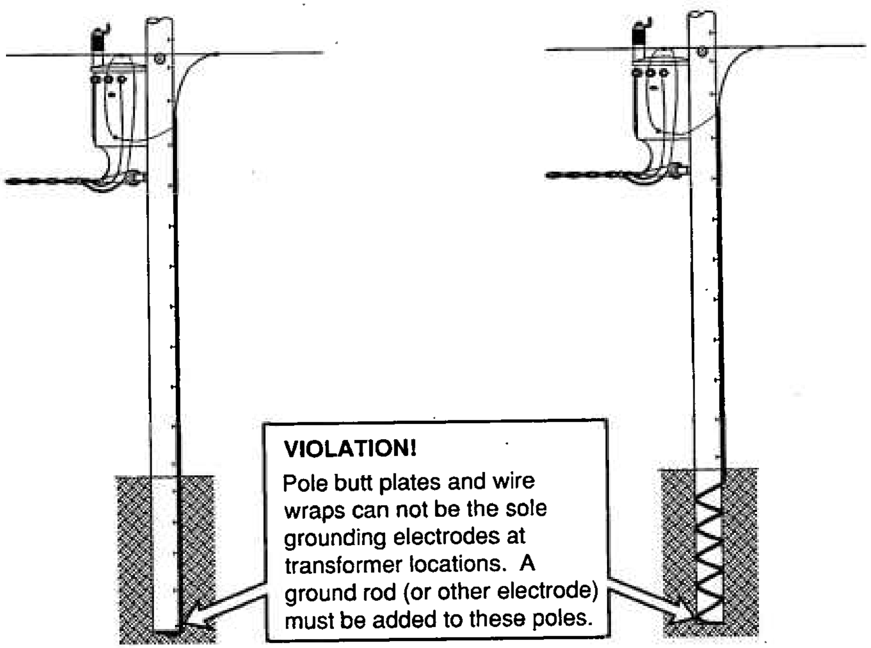



**Fig. 094-9.** Made electrodes—butt plates and wire wraps at transformer locations (Rule 094B4a).

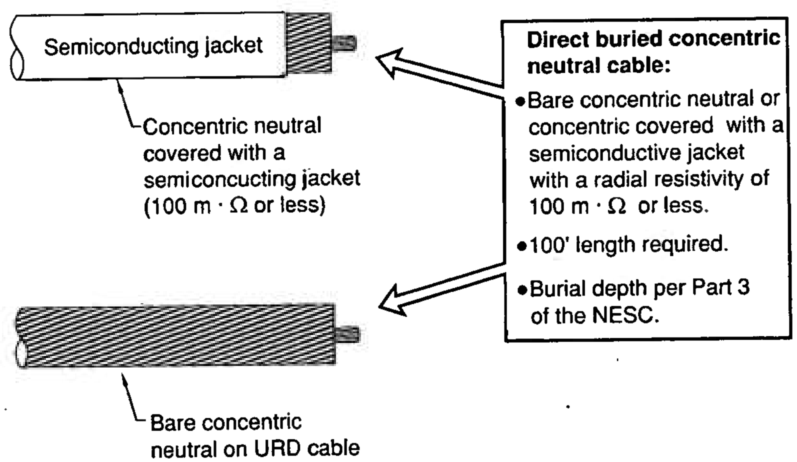



**Fig. 094-10.** Made electrodes—direct-buried concentric neutral cable (Rule 094B5).

or gases by a distance of 10 ft or more. No distances are specified for separating grounding electrodes from low-pressure gas lines. High-pressure pipelines are used as transmission facilities. Low-pressure pipelines are most commonly used



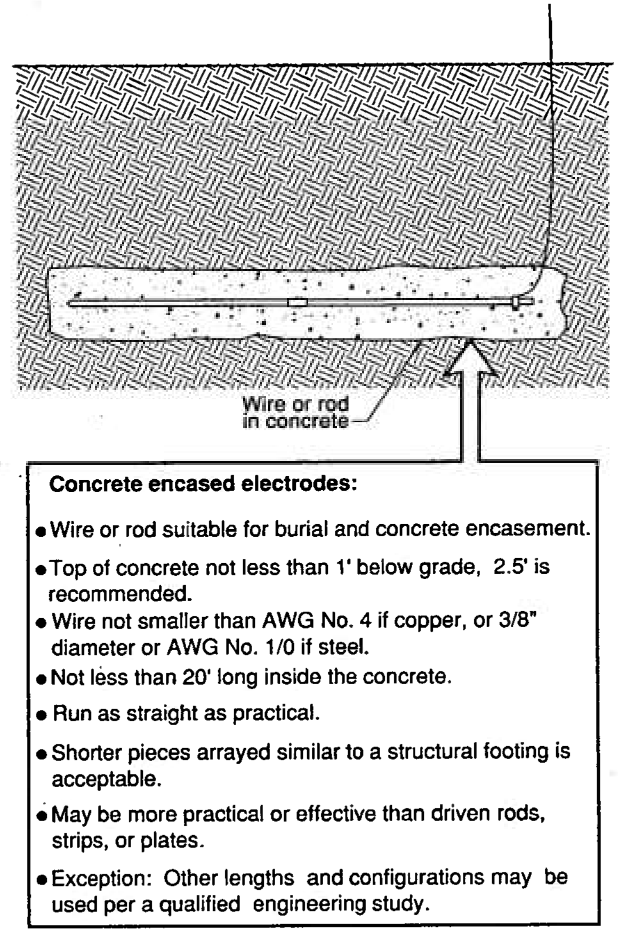


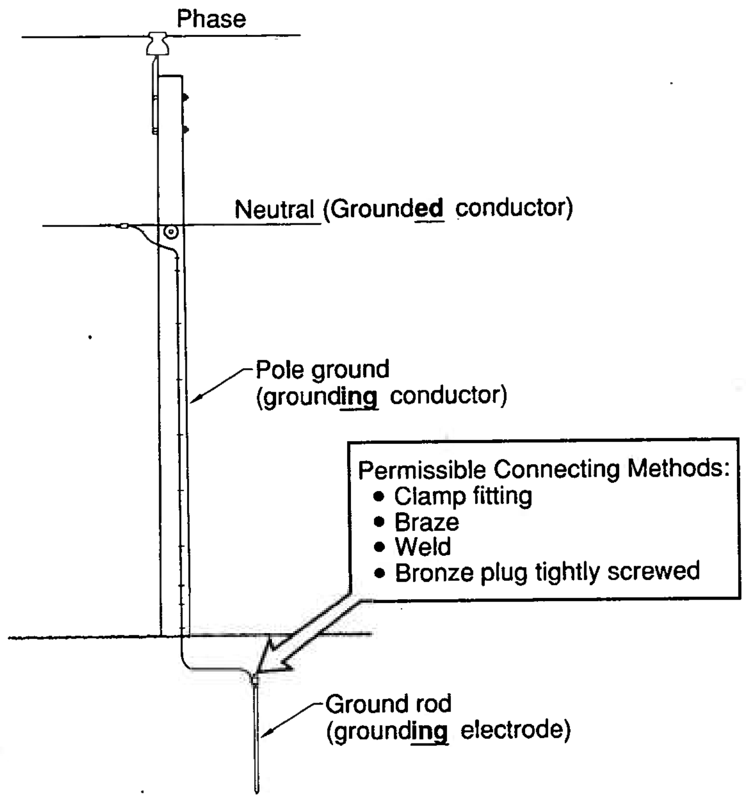

**Fig. 094-11.** Made electrodes—concrete-encased electrodes (Rule 094B6).

to supply natural gas to homes. The requirements for separating grounding electrodes from high-pressure pipelines are shown in Fig. 095-2.

Rule 095C requires that the connection to the grounding electrode be free from rust, enamel, or scale. This can be done by cleaning or using fittings that penetrate such coatings.

## 096. GROUND RESISTANCE REQUIREMENTS

The main intent of Rule 96 is to assure a grounding resistance low enough to permit prompt operation of circuit protective devices (e.g., fuses, reclosers, relay-controlled circuit breakers).




See Photo

**Fig. 095-1.** Connection of grounding conductor to grounding electrode (Rule 095A).

**096A. Supply Stations.** Supply stations normally require extensive grounding systems consisting of a ground grid or mat combined with grounding electrodes. They are designed to limit touch, step, mesh, and transferred potentials. The Code notes IEEE Standard 80 as a reference for substation grounding.

**096B. Single-Grounded (Unigrounded or Delta) Systems.** Single-grounded systems, typically grounded wye transmission systems that do not carry a neutral and are grounded only at the source transformer, must have a ground resistance not exceeding 25 Ω. This rule states that if a single electrode exceeds 25 Ω, then two electrodes in parallel must be used. The Code does not specifically comment on what happens if the second electrode does not bring the ground resistance below 25 Ω; however, the main idea of this rule is to have a ground resistance low enough to permit prompt operation of circuit protective devices.

**096C. Multigrounded Systems.** Multigrounded systems are the most common type of distribution system. A typical 12.47/7.2-kV, three-phase, four-wire grounded-wye distribution system is multigrounded. For a system to be multigrounded, the following must occur:



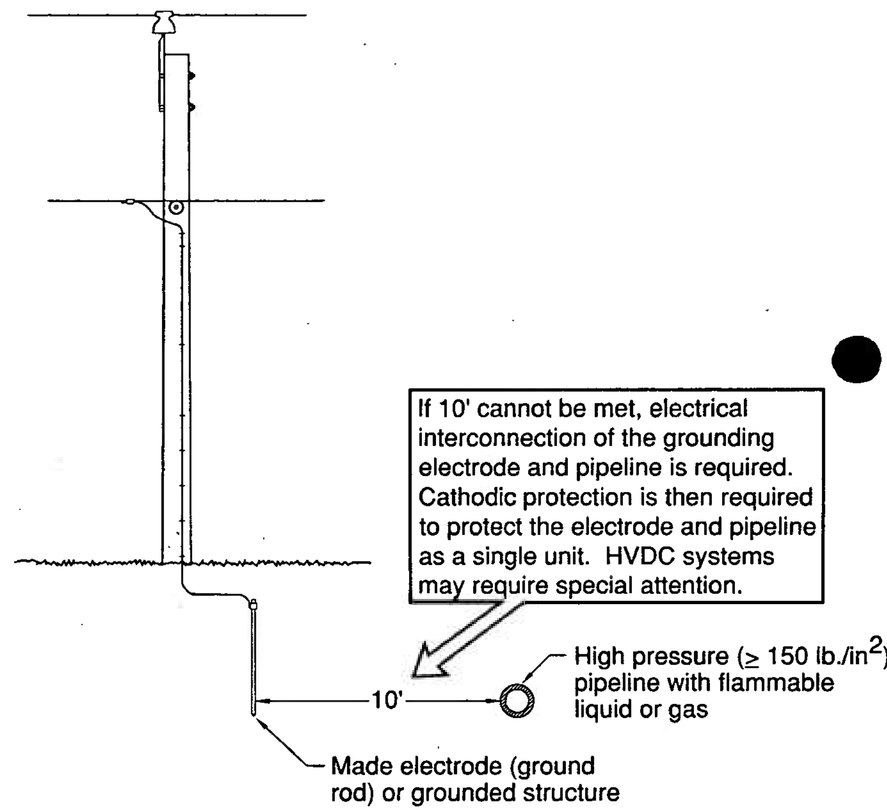



**Fig. 095-2.** Grounding electrode separation from high-pressure pipelines (Rule 095B2).

- The circuit must have a neutral of sufficient size and ampacity.
- The neutral must be connected to a grounding electrode at each transformer location.
- The neutral must be connected to a grounding electrode not less than four times in each mile of the entire line. The grounds at transformers can be counted in the four grounds in each mile, but the grounds at individual services (i.e., meters) cannot be counted.

The intent of a multigrounded system is to always carry a neutral and to have four grounds in each mile of the entire line. To check the four grounds in each mile, a "one-mile window" can be used. Examples are shown in Fig. 096-1.

The Code does not specify a ground resistance for multigrounded systems. The Code notes that multigrounded systems are dependent on the multiplicity of grounding electrodes, not the ground resistance of any individual electrode.

For underground installations where the supply cable has an insulating jacket over the concentric neutral or the supply cable is in conduit, the cable must be terminated and grounded four times in every mile. If an express

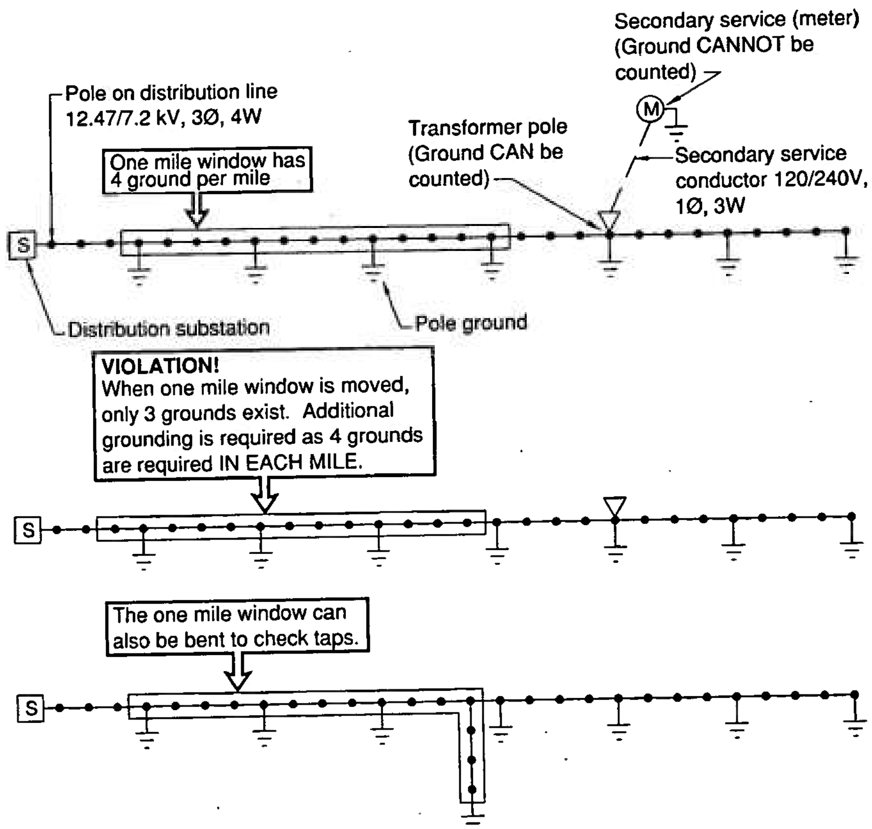



**Fig. 096-1.** Example of checking "four grounds in each mile" (Rule 096C).

direct-buried underground feeder is constructed with an insulating jacket but without frequent termination points, the cable jacket must be stripped back and a suitable grounding electrode must be connected four times in each mile. If a supply cable has a semiconducting jacket, the cable can be treated similar to a bare concentric neutral cable and the jacket does not need to be stripped back for grounding. The semiconducting jacket must not exceed 100 mΩ radial resistivity. Use of semiconducting jacketed cable is not very common due to the fact that these cables are higher in cost than insulated jacketed cable.

Rule 096 provides an exception to the four grounds in every mile for underwater crossings. Grounding on each side of the underwater crossing should be given special attention to make up for any lack of grounding in the underwater portion of the cable.



## 097. SEPARATION OF GROUNDING CONDUCTORS

Rule 097A requires that separate grounding conductors be run to separate grounding electrodes for primary surge arresters over 750 V, secondary circuits under 750 V, and shield wires. But Rule 097B allows a single grounding conductor and single grounding electrode if a ground connection exists at each surge arrester location and the primary neutral or shield wire and secondary neutral are connected together. When the primary and secondary neutrals are connected, Rule 097C requires the common neutral to be multigrounded (see Rule 096C). Rule 097A is typically applied in conjunction with Rule 097D1. An example of this application is a delta-delta transformer bank fed from an ungrounded primary system as shown in Fig. 097-1.

Rules 097B and 097C are typically applied to grounded-wye–grounded-wye three-phase systems and grounded-wye single-phase systems fed from a multigrounded primary system as shown in Fig. 097-2.

On multigrounded systems the primary and secondary neutrals should be interconnected. The NESC uses the word "should" in this case, not "shall," as there are times when separation of primary and secondary neutrals on a multigrounded system is applicable. The most common reason for separating primary and secondary neutrals on a multigrounded system is to minimize

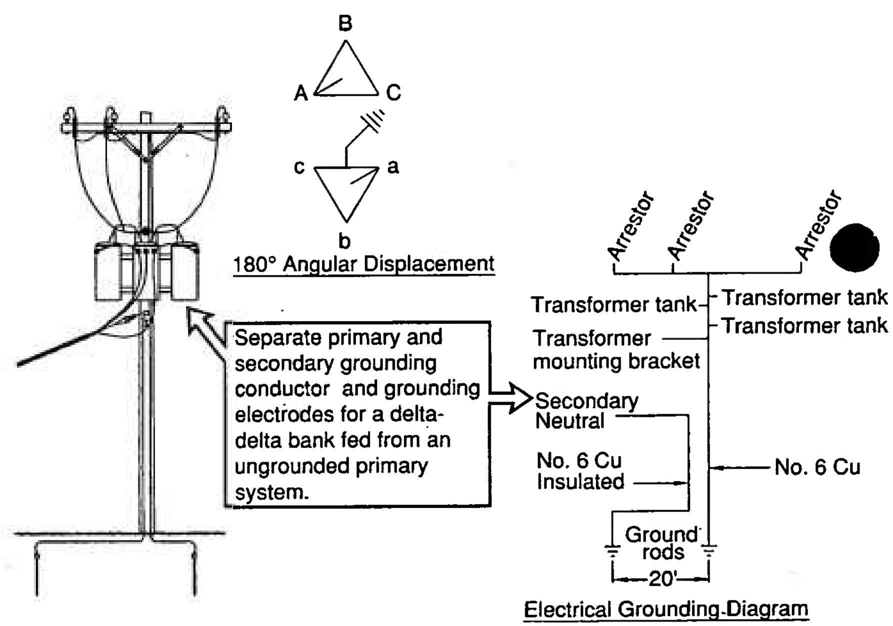



**Fig. 097-1.** Example of separate primary and secondary grounding (Rules 097A and 097D1)

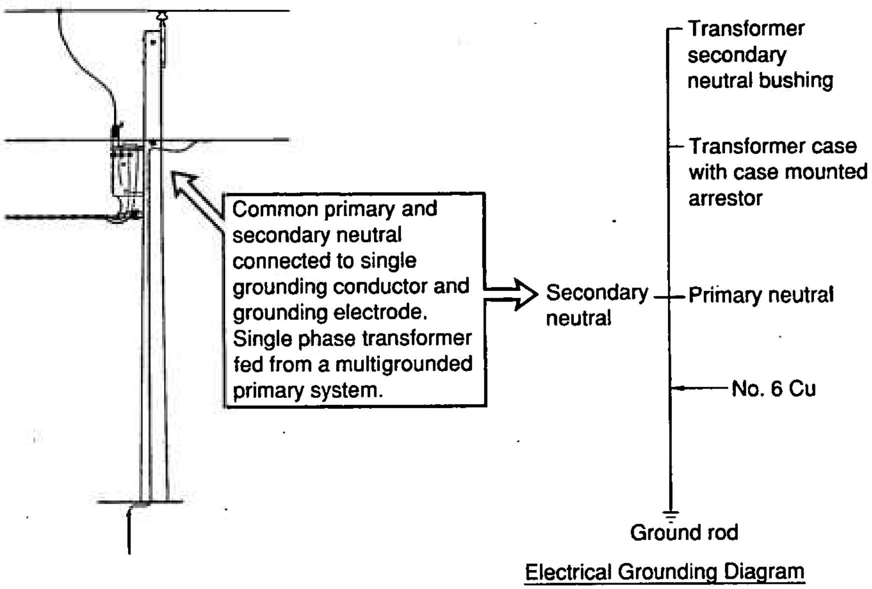



**Fig. 097-2.** Example of a common neutral with single grounding (Rules 097B and 097C).

stray voltage on the secondary neutral imposed by the primary neutral. The requirements separating primary and secondary neutrals for stray voltage or other valid reasons are outlined in Fig. 097-3.

If a made electrode is used to ground surge arresters on an ungrounded system exceeding 15 kV phase to phase, the NESC requires that the ground rod(s) be at least 20 ft from buried communication cables.

Rule 097G focuses on grounding requirements for joint-use poles. If separate grounding conductors (pole grounds) are run to the supply neutral and the communications messenger, a bond between the pole grounds should be added. If a single grounding conductor (pole ground) is used on the joint-use pole, it should be connected to both the supply neutral and the communications messenger. Most utilities use a single-pole ground for grounding both power and communications. The single-pole ground method will require a review for special cases like the delta-delta transformation or for stray voltage applications discussed in this rule.

## 098. NUMBER 098 NOT USED IN THIS EDITION.

## 099. ADDITIONAL REQUIREMENTS FOR COMMUNICATION APPARATUS

This rule outlines how to ground communication apparatus when grounding is required in other parts of the Code. This rule references Note 2 of Rule



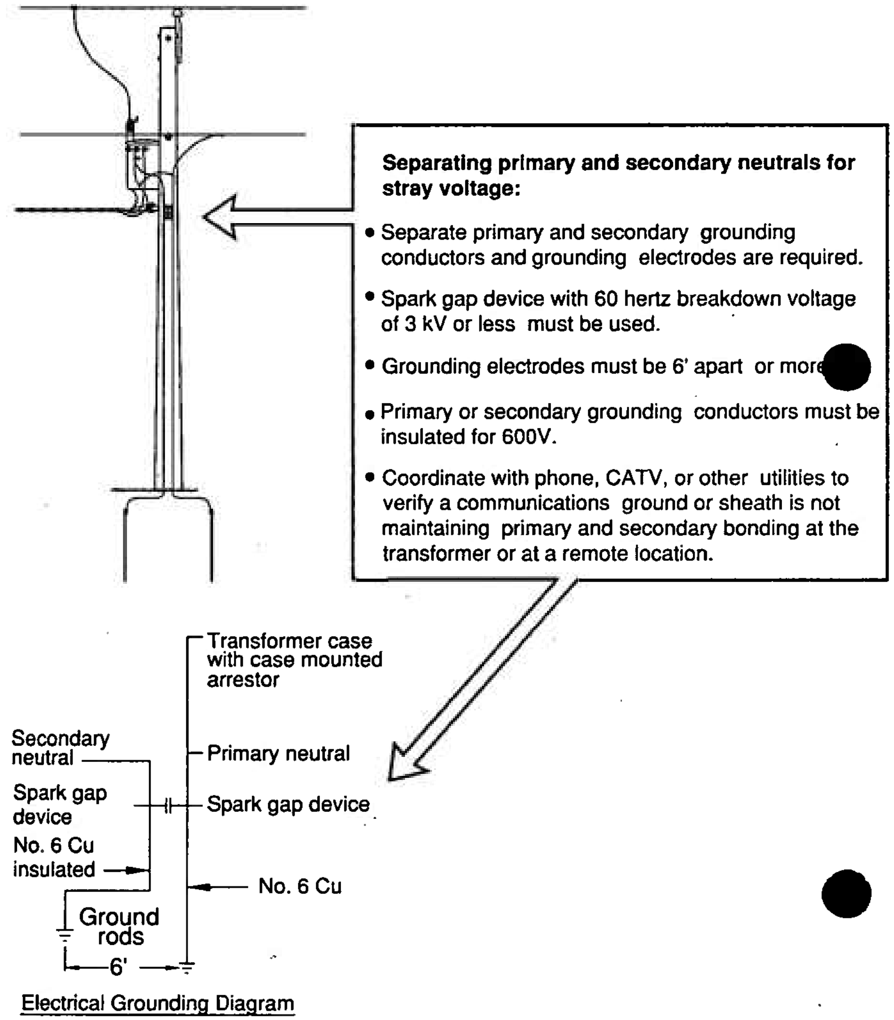



**Fig. 097-3.** Separating primary and secondary neutrals for stray voltage (Rule 097D2).

097D2, which discusses cooperation between supply and communications employees to isolate primary and secondary neutrals (typically for resolving stray-voltage problems).

A communications grounding conductor shall preferably be made of copper or other material that will not corrode and shall not be less than AWG No. 14. The communications grounding conductor must be connected as shown in Fig. 099-1.

A separate communications ground rod is not required per Rule 099A. If a communications ground rod is used because a supply service does not exist, the communications ground rod may be smaller in diameter and length per the

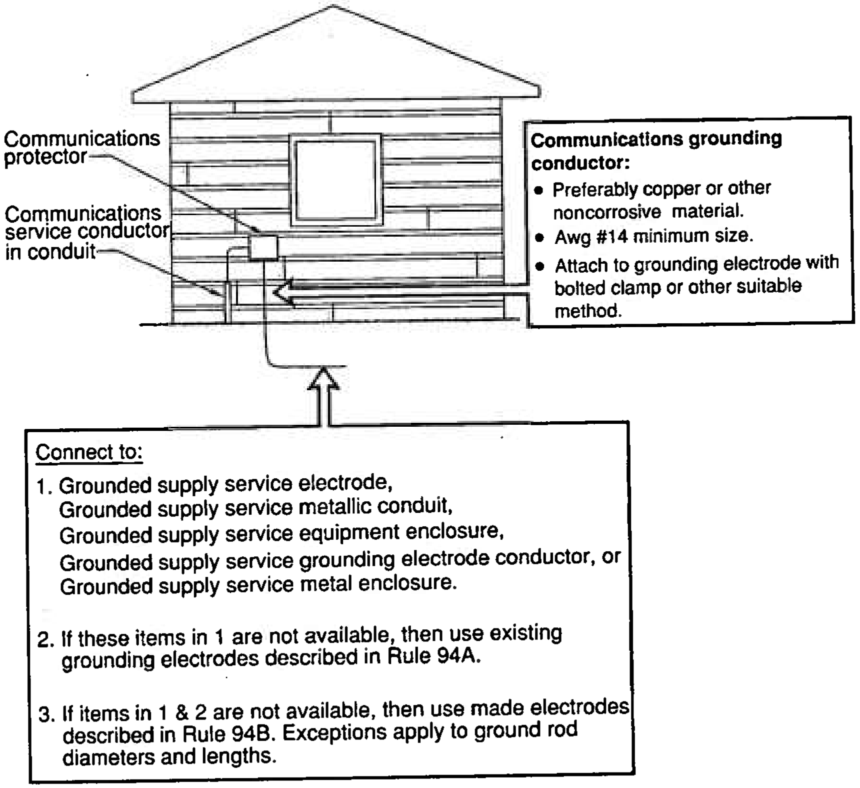



**Fig. 099-1.** Additional requirements for communications grounding (Rules 099A and 099B).

exception to Rule 099A3. However, if a supply service does exist and a communications ground rod is used to supplement the supply grounding system, the exception to Rule 099A3 permitting smaller rods does not apply. Rule 099A does not prohibit a supplemental communications ground rod, but only if the supply service does not exist can the smaller communications-size ground rod be used. If a standard-size ground rod (per Rule 094B2) is used for communications grounding to supplement the supply ground rod, an AWG No. 6 copper or equivalent jumper must bond the two ground rods together as shown in Fig. 099-2.



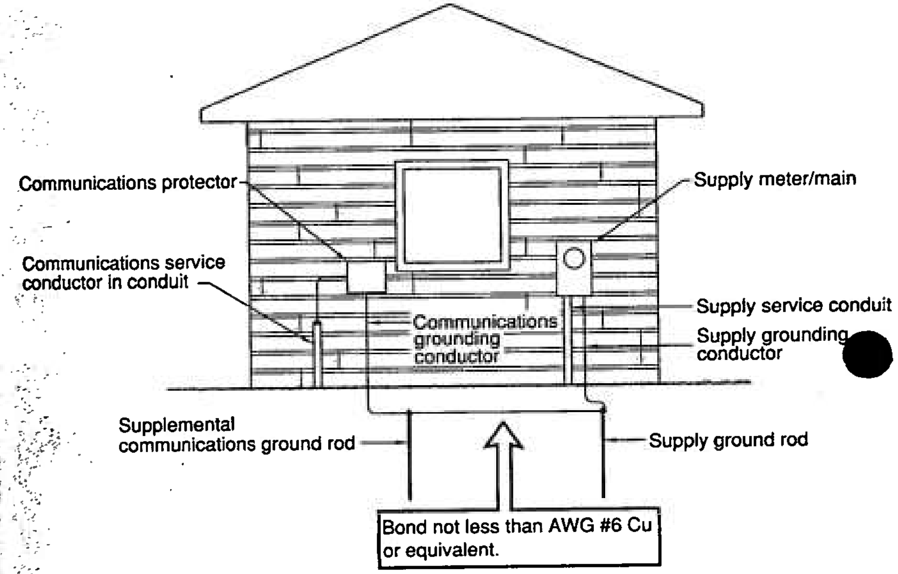



**Fig. 099-2.** Bonding of communications and supply electrodes (Rule 099C).

# ARTICLE 800
# Communications Circuits

## Summary of Changes

- Reorganized and renumbered as part of an effort to achieve parallel structure among Articles 770, 800, 820, and 830.
- **800.2:** Definitions for *air duct, communications circuit integrity (CI) cable,* and *communications equipment* added.
- **800.24:** Removed requirement that the cable must be supported by a structural component. Clarification added that this section applies to ceilings regardless of which side of the ceiling is supporting the cable. Revised to apply the requirement of 300.11 to Article 800 cables.
- **800.100A(4):** FPN added to clarify the requirement of a 20 ft maximum grounding conductor in one- and two-family dwellings.
- **800.100(D):** Revised to remove permission to bond together all separate electrodes.
- **Table 800.113:** Deleted multipurpose cable Types MPP, MPR, MPG, and MP.
- **Figure 800.154:** Revised to delete multipurpose cable Types MPP, MPR, MPG, and MP.
- **800.179:** Revised to delete multipurpose cable Types MPP, MPR, MPG, and MP.
- **800.179(H):** Revised to permit a 2-hour fire-rated communications circuit integrity cable.

## Contents







FPN: Rules that are followed by a reference in brackets contain text that has been extracted from NFPA 97–2003, *Standard Glossary of Terms Relating to Chimneys, Vents, and Heat-Producing Appliances.* Only editorial changes were made to the extracted text to make it consistent with this *Code.*

## I. General

### 800.1 Scope

This article covers telephone, telegraph (except radio), outside wiring for fire alarm and burglar alarm, and similar central station systems; and telephone systems not connected to a central station system but using similar types of equipment, methods of installation, and maintenance.

Section 90.3, Code Arrangement, states that Chapter 8, which comprises Articles 800, 810, 820, and 830, covers communications systems and is not subject to the requirements of Chapters 1–7 except where a requirement from these chapters is specifically referenced in Chapter 8. For instance, 800.44(A)(3) references 225.14(D), 800.90(C) references Article 500, and 800.3(D) references 300.22(C).

Although information technology equipment systems are often used for or with communications systems, Article 800 does not cover wiring of this equipment. Instead, Article 645 provides requirements for wiring contained solely within an information technology equipment (computer) room. (See 645.4 for a description of the type of information technology equipment room to which Article 645 applies.) Article 725 provides requirements for wiring that extends beyond a computer room and also covers wiring of local area networks within buildings. Article 760 covers wiring requirements for fire alarm systems.

In some cases, telephone system wiring is also used for data transmission; this use is covered by Article 800. Telephone company central offices are exempt from the requirements of Article 800 by 90.2(B)(4). The format of Article 800 is similar to that of Articles 725, 760, 770, and 820.

Article 830 covers network-powered broadband communications systems.

FPN No. 1: For further information for fire alarm, sprinkler waterflow, and sprinkler supervisory systems, see Article 760.

FPN No. 2: For installation requirements of optical fiber cables, see Article 770.

FPN No. 3: For installation requirements for network-powered broadband communications circuits, see Article 830.

### 800.2 Definitions

See Article 100. For purposes of this article, the following additional definitions apply.

**Abandoned Communications Cable.** Installed communications cable that is not terminated at both ends at a connector or other equipment and not identified for future use with a tag.

The term *abandoned communications cable* applies to 800.154, which requires removal of accessible abandoned communications cable. Abandoned cable increases fire loading unnecessarily, and, where installed in plenums, it can affect airflow. Similar requirements can be found in Articles 640, 645, 725, 760, 770, 820, and 830.

**Air Duct.** A conduit or passageway for conveying air to or from heating, cooling, air conditioning, or ventilating equipment, but not including the plenum. [NFPA 97:1.2.6]

The definition of *air duct* was added to the 2005 *Code* to provide a term to distinguish between electrical ducts and ducts that form part of an environmental air distribution system.

**Block.** A square or portion of a city, town, or village enclosed by streets and including the alleys so enclosed, but not any street.

**Cable.** A factory assembly of two or more conductors having an overall covering.

**Cable Sheath.** A covering over the conductor assembly that may include one or more metallic members, strength members, or jackets.

**Communications Circuit Integrity (CI) Cable.** Cable used in communications systems to ensure continued operation of critical circuits during a specified time under fire conditions.

The definition of *communications circuit integrity (CI) cable* was added to the 2005 *Code* to define a term used in 800.179(H). CI cables are used to maintain communications throughout the entire time of an emergency. Such cable is intended to ensure the survivability of certain critical communications circuits during a fire in a building.

**Communications Equipment.** The electronic equipment that performs the telecommunications operations for the transmission of audio, video, and data, and including power equipment (e.g., dc converters, inverters and batteries) and technical support equipment (e.g., computers).

The definition of *communications equipment* was added to the 2005 *Code* to clearly define what associated equipment is considered part of the communications equipment. The definition clearly indicates that the power supplies and computers are considered part of the communications equipment and thus are subject to requirements that apply to communications equipment. The telephone switch shown in Exhibit 800.1 also is considered part of telecommunications equipment and so is subject to the same requirements. The definition correlates with NFPA 76, *Recommended Practice for the Fire Protection of Telecommunications Facilities.*

**Exhibit 800.1** A private automatic branch exchange, one part of telecommunications equipment.

**Exposed.** A circuit that is in such a position that, in case of failure of supports and insulation, contact with another circuit may result.

FPN: See Article 100 for two other definitions of *Exposed.*

**Point of Entrance.** Within a building, the point at which the wire or cable emerges from an external wall, from a concrete floor slab, or from a rigid metal conduit or an intermediate metal conduit grounded to an electrode in accordance with 800.100(B).

**Premises.** The land and buildings of a user located on the user side of the utility-user network point of demarcation.

**Wire.** A factory assembly of one or more insulated conductors without an overall covering.

See Article 100 for the definitions of *conductor, equipment,* and *raceway.*

## 800.3 Other Articles

**(A) Hybrid Power and Communications Cables** The provisions of 780.6 shall apply for listed hybrid power and communications cables in closed-loop and programmed power distribution.

See 800.179(J) for listing requirements and applications of hybrid power and communications cable in one- and two-family residences for other than closed-loop and programmed power distribution.

FPN: See 800.179(J) for hybrid power and communications cable in other applications.

**(B) Hazardous (Classified) Locations** Communications circuits and equipment installed in a location that is classified in accordance with Article 500 shall comply with the applicable requirements of Chapter 5.

Paragraph 800.3(B) alerts users that communications circuits installed in locations classified in accordance with Article 500 must conform to the applicable requirements of Chapter 5.

**(C) Spread of Fire or Products of Combustion** Section 300.21 shall apply. The accessible portion of abandoned communications cables shall not be permitted to remain.

Section 800.3(C) was revised for the 2005 *Code* for use with the definition of *abandoned communications cable* in 800.2. Section 800.3(C) requires the removal of accessible abandoned communications cable. Abandoned cable increases fire loading unnecessarily, and, where installed in plenums, it can affect airflow. Similar requirements can be found in Articles 640, 645, 725, 760, 770, 820, and 830. (See the definition of *abandoned communications cable* in 800.2.)





**(D) Equipment in Other Space Used for Environmental Air** Section 300.22(C) shall apply.

## 800.18 Installation of Equipment

Equipment electrically connected to a telecommunications network shall be listed in accordance with 800.170. Installation of equipment shall also comply with 110.3(B).

UL 1863, *Communication Circuit Accessories,* and UL 60950, *Safety of Information Technology Equipment, Part 1: General Requirements,* are two safety standards that contain requirements for determining whether equipment connected to a telecommunications network is suitable for the intended purpose. Listed equipment that is connected to the telecommunications network and evaluated according to other U.S. safety standards is also subject to telecommunications requirements appropriate for the equipment. Examples of this equipment include information technology equipment, audio-video equipment, and signaling equipment connected to a central station. The appropriate requirements contained within the applicable safety standard are extracted from UL 1863, UL 60950, or both.

...Except for test equipment, all permanently installed electrical components of the communications network are subject to the listing requirements of 800.170.

*Exception: This listing requirement shall not apply to test equipment that is intended for temporary connection to a telecommunications network by qualified persons during the course of installation, maintenance, or repair of telecommunications equipment or systems.*

## 800.21 Access to Electrical Equipment Behind Panels Designed to Allow Access

Access to electrical equipment shall not be denied by an accumulation of wires and cables that prevents removal of panels, including suspended ceiling panels.

An excess accumulation of wires and cables can limit access to equipment by preventing the removal of access panels. (See Exhibit 800.2.)

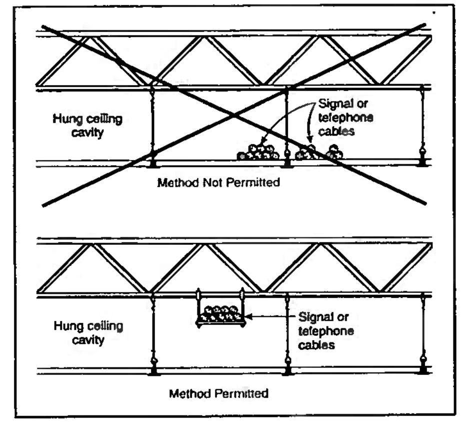



**Exhibit 800.2** Installations of conductors and cables, which can prevent access to equipment or cables. Correct and incorrect methods are shown.

## 800.24 Mechanical Execution of Work

Communications circuits and equipment shall be installed in a neat and workmanlike manner. Cables installed exposed on the surface of ceilings and sidewalls shall be supported by the building structure in such a manner that the cable will not be damaged by normal building use. Such cables shall be secured by straps, staples, hangers, or similar fittings designed and installed so as not to damage the cable. The installation shall also conform with 300.4(D) and 300.11.

Section 800.24 provides definitive requirements for workmanship. Cable must be attached to or supported by the structure by straps, clamps, hangers, and the like. The installation method must not damage the cable. In addition, the location of the cable must be carefully evaluated to ensure that activities and processes within the building do not damage the cable. In the 2005 *Code*, there was a change to this section to permit attachment to baseboards and non-load bearing walls, which are not structural components. The equipment illustrated in Exhibit 800.3 is used by installers of telecommunications systems to organize cables and make connections in a neat and workmanlike manner.

FPN: Accepted industry practices are described in ANSI/NECA/BICSI 568-2001, *Standard for Installing Commercial Building Telecommunications Cabling,* and other ANSI-approved installation standards.

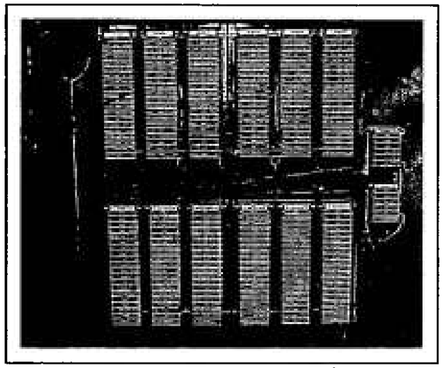


Exhibit 800.3 An example of punch blocks used on a private automatic branch exchange.

## II. Wires and Cables Outside and Entering Buildings

### 800.44 Overhead Communications Wires and Cables

Overhead communications wires and cables entering buildings shall comply with 800.44(A) and 800.44(B).

**(A) On Poles and In-Span** Where communications wires and cables and electric light or power conductors are supported by the same pole or run parallel to each other in-span, the conditions described in 800.44(A)(1) through (A)(4) shall be met.

**(1) Relative Location** Where practicable, the communications wires and cables shall be located below the electric light or power conductors.

**(2) Attachment to Crossarms** Communications wires and cables shall not be attached to a cross-arm that carries electric light or power conductors.

**(3) Climbing Space** The climbing space through communications wires and cables shall comply with the requirements of 225.14(D).

**(4) Clearance** Supply service drops of 0–750 volts running above and parallel to communications service drops shall have a minimum separation of 300 mm (12 in.) at any point in the span, including the point of and at their attachment to the building, provided the nongrounded conductors are insulated and that a clearance of not less than 1.0 m (40 in.) is maintained between the two services at the pole.

**(B) Above Roofs** Communications wires and cables shall have a vertical clearance of not less than 2.5 m (8 ft) from all points of roofs above which they pass.

*Exception No. 1: Auxiliary buildings, such as garages and the like.*

*Exception No. 2: A reduction in clearance above only the overhanging portion of the roof to not less than 450 mm (18 in.) shall be permitted if (a) not more than 1.2 m (4 ft) of communications service-drop conductors pass above the roof overhang and (b) they are terminated at a through- or above-the-roof raceway or approved support.*

*Exception No. 3: Where the roof has a slope of not less than 100 mm in 300 mm (4 in. in 12 in.), a reduction in clearance to not less than 900 mm (3 ft) shall be permitted.*

FPN: For additional information regarding overhead wires and cables, see ANSI C2-2002, *National Electric Safety Code*, Part 2, Safety Rules for Overhead Lines.

### 800.47 Underground Circuits Entering Buildings

Underground communications wires and cables entering buildings shall comply with 800.47(A) and 800.47(B).

**(A) With Electric Light or Power Conductors** Underground communications wires and cables in a raceway, handhole enclosure, or manhole containing electric light, power, Class 1, or non–power-limited fire alarm circuit conductors shall be in a section separated from such conductors by means of brick, concrete, or tile partitions or by means of a suitable barrier.

**(B) Underground Block Distribution** Where the entire street circuit is run underground and the circuit within the block is placed so as to be free from the likelihood of accidental contact with electric light or power circuits of over 300 volts to ground, the insulation requirements of 800.50(A) and 800.50(C) shall not apply, insulating supports shall not be required for the conductors, and bushings shall not be required where the conductors enter the building.

### 800.50 Circuits Requiring Primary Protectors

Circuits that require primary protectors as provided in 800.90 shall comply with 800.50(A), (B), and (C).

**(A) Insulation, Wires, and Cables** Communications wires and cables without a metallic shield, running from the last outdoor support to the primary protector, shall be listed.

**(B) On Buildings** Communications wires and cables in accordance with 800.50(A) shall be separated at least 100 mm (4 in.) from electric light or power conductors not in a raceway or cable or be permanently separated from conductors of the other system by a continuous and firmly fixed nonconductor in addition to the insulation on the wires, such as porcelain tubes or flexible tubing. Communications wires and cables in accordance with 800.50(A) exposed to accidental contact with electric light and power conductors operating at over 300 volts to ground and attached to buildings shall be separated from woodwork by being supported on glass, porcelain, or other insulating material.

*Exception: Separation from woodwork shall not be required where fuses are omitted as provided for in 800.90(A)(1), or where conductors are used to extend circuits to a building from a cable having a grounded metal sheath.*

**(C) Entering Buildings** Where a primary protector is installed inside the building, the communications wires and cables shall enter the building either through a noncombustible, nonabsorbent insulating bushing or through a metal raceway. The insulating bushing shall not be required where the entering communications wires and cables (1) are in metal-sheathed cable, (2) pass through masonry, (3) meet the requirements of 800.50(A) and fuses are omitted as provided in 800.90(A)(1), or (A)(4) meet the requirements of 800.50(A) and are used to extend circuits to a building from a cable having a grounded metallic sheath. Raceways or bushings shall slope upward from the outside or, where this cannot be done, drip loops shall be formed in the communications wires and cables immediately before they enter the building.

Raceways shall be equipped with an approved service head. More than one communications wire and cable shall be permitted to enter through a single raceway or bushing. Conduits or other metal raceways located ahead of the primary protector shall be grounded.

### 800.53 Lightning Conductors

Where practicable, a separation of at least 1.8 m (6 ft) shall be maintained between communications wires and cables on buildings and lightning conductors.

## III. Protection

### 800.90 Protective Devices

**(A) Application** A listed primary protector shall be provided on each circuit run partly or entirely in aerial wire or aerial cable not confined within a block. Also, a listed primary protector shall be provided on each circuit, aerial or underground, located within the block containing the building served so as to be exposed to accidental contact with electric light or power conductors operating at over 300 volts to ground. In addition, where there exists a lightning exposure, each interbuilding circuit on a premises shall be protected by a listed primary protector at each end of the interbuilding circuit. Installation of primary protectors shall also comply with 110.3(B).

Telephone utility companies ordinarily provide primary protectors where telephone lines are exposed to lightning. Installers of private networks that include interbuilding cable should also install primary protectors where cables are exposed to lightning. Generally, cable is considered to be exposed to lightning unless one or more of the conditions in FPN No. 2 exist. A primary protector is required at each end of an interbuilding communications circuit where lightning exposure exists.

FPN No. 1: On a circuit not exposed to accidental contact with power conductors, providing a listed primary protector in accordance with this article helps protect against other hazards, such as lightning and above-normal voltages induced by fault currents on power circuits in proximity to the communications circuit.

FPN No. 2: Interbuilding circuits are considered to have a lightning exposure unless one or more of the following conditions exist:

(1) Circuits in large metropolitan areas where buildings are close together and sufficiently high to intercept lightning.
(2) Interbuilding cable runs of 42 m (140 ft) or less, directly buried or in underground conduit, where a continuous metallic cable shield or a continuous metallic conduit containing the cable is bonded to each building grounding electrode system.
(3) Areas having an average of five or fewer thunderstorm days per year and earth resistivity of less than 100 ohm-meters. Such areas are found along the Pacific coast.

**(1) Fuseless Primary Protectors** Fuseless-type primary protectors shall be permitted under any of the conditions given in (A)(1)(a) through (A)(1)(e).

(a) Where conductors enter a building through a cable with grounded metallic sheath member(s) and where the conductors in the cable safely fuse on all currents greater than the current-carrying capacity of the primary protector and of the primary protector grounding conductor

(b) Where insulated conductors in accordance with 800.50(A) are used to extend circuits to a building from a cable with an effectively grounded metallic sheath member(s) and where the conductors in the cable or cable stub, or the connections between the insulated conductors and the exposed plant, safely fuse on all currents greater than the current-carrying capacity of the primary protector, or the associated insulated conductors and of the primary protector grounding conductor

(c) Where insulated conductors in accordance with 800.50(A) or 800.50(B) are used to extend circuits to a building from other than a cable with metallic sheath member(s), where (1) the primary protector is listed as being suitable for this purpose for application with circuits extending from other than a cable with metallic sheath members, and (2) the connections of the insulated conductors to the exposed plant or the conductors of the exposed plant safely fuse on all currents greater than the current-carrying capacity of the primary protector, or associated insulated conductors and of the primary protector grounding conductor

(d) Where insulated conductors in accordance with 800.50(A) are used to extend circuits aerially to a building from an unexposed buried or underground circuit

(e) Where insulated conductors in accordance with 800.50(A) are used to extend circuits to a building from cable with an effectively grounded metallic sheath member(s), and where (1) the combination of the primary protector and insulated conductors is listed as being suitable for this purpose for application with circuits extending from a cable with an effectively grounded metallic sheath member(s), and (2) the insulated conductors safely fuse on all currents greater than the current-carrying capacity of the primary protector and of the primary protector grounding conductor

The term *effectively grounded* (listed as *Grounded, Effectively*) is defined in Article 100.

**(2) Fused Primary Protectors** Where the requirements listed under 800.90(A)(1)(a) through (A)(1)(e) are not met, fused-type primary protectors shall be used. Fused-type primary protectors shall consist of an arrester connected between each line conductor and ground, a fuse in series with each line conductor, and an appropriate mounting arrangement. Primary protector terminals shall be marked to indicate line, instrument, and ground, as applicable.

**(B) Location** The primary protector shall be located in, on, or immediately adjacent to the structure or building served and as close as practicable to the point of entrance.

FPN: See 800.2 for the definition of *point of entrance*.

Exhibit 800.4 shows an example of a primary protector unit typically installed in commercial buildings. Exhibit 800.5 shows an example of applications of listed communications and multipurpose cable.

For purposes of this section, primary protectors located at mobile home service equipment located in sight from and not more than 9.0 m (30 ft) from the exterior wall of the mobile home it serves, or at a mobile home disconnecting means grounded in accordance with 250.32 and located in sight from and not more than 9.0 m (30 ft) from the exterior wall of the mobile home it serves, shall be considered to meet the requirements of this section.

FPN: Selecting a primary protector location to achieve the shortest practicable primary protector grounding conductor helps limit potential differences between communications circuits and other metallic systems.

**(C) Hazardous (Classified) Locations** The primary protector shall not be located in any hazardous (classified) location as defined in Article 500 or in the vicinity of easily ignitible material.

*Exception: As permitted in 501.150, 502.150, and 503.150.*

**(D) Secondary Protectors** Where a secondary protector is installed in series with the indoor communications wire and cable between the primary protector and the equipment, it shall be listed for the purpose in accordance with 800.170(B).

FPN: Secondary protectors on exposed circuits are not intended for use without primary protectors.

### 800.93 Cable Grounding

The metallic sheath of communications cables entering buildings shall be grounded as close as practicable to the point of entrance or shall be interrupted as close to the point of entrance as practicable by an insulating joint or equivalent device.

FPN: See 800.2 for the definition of *point of entrance*.

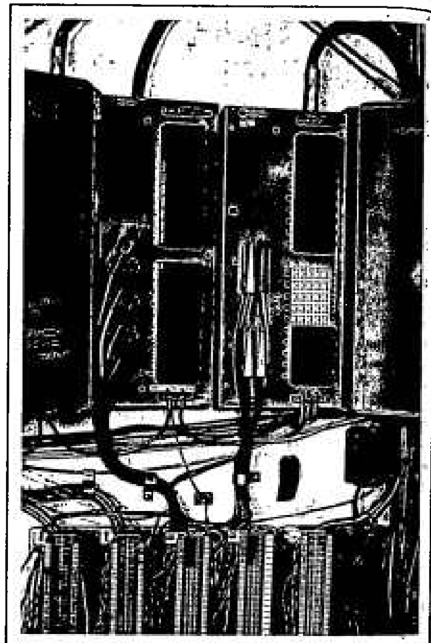


Exhibit 800.4 A primary protector unit typically installed in commercial buildings. This unit is the interface to the outside plant cable.





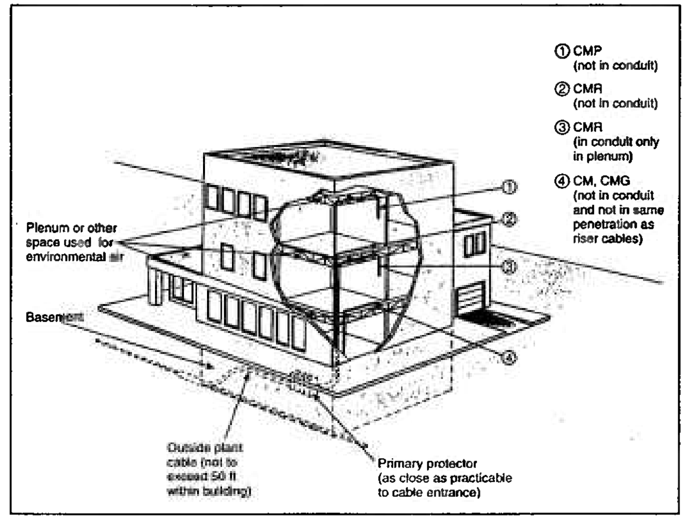



Exhibit 800.5 An example of applications of listed communications cables.

## IV. Grounding Methods

### 800.100 Cable and Primary Protector Grounding

The metallic member(s) of the cable sheath, where required to be grounded by 800.93, and primary protectors shall be grounded as specified in 800.100(A) through 800.100(D).

**(A) Grounding Conductor.**

**(1) Insulation** The grounding conductor shall be insulated and shall be listed as suitable for the purpose.

**(2) Material** The grounding conductor shall be copper or other corrosion-resistant conductive material, stranded or solid.

**(3) Size** The grounding conductor shall not be smaller than 14 AWG.

**(4) Length** The primary protector grounding conductor shall be as short as practicable. In one- and two-family dwellings, the primary protector grounding conductor shall be as short as practicable, not to exceed 6.0 m (20 ft) in length.

For one- and two-family dwellings, 800.100(A)(4) restricts the length of the primary protector grounding conductor to 20 ft. This restricted conductor length reduces the impedance of the grounding conductor, resulting in a lower potential difference between the communications system conductors and equipment and the electrical conductors and equipment in the building. The low impedance bonding connection will reduce the fire hazard and shock hazard to persons in the event that electric utility power lines come in contact with communications conductors. Section 800.100(D) requires bonding of communications and power grounding electrodes at the same building or structure.

See the commentary following 250.52(A)(1) for information on water pipes as grounding electrodes.

FPN: Similar grounding conductor length limitations applied at apartment buildings and commercial buildings help to reduce voltages that may be developed between the building's power and communications systems during lightning events.

When the 20-ft limitation was instituted in the 2002 *Code*, the predominant application was in one- and two-family dwellings; apartment and commercial buildings were specifically not addressed. In the 2005 *Code*, some guidance is provided for apartment and commercial buildings, without being overly restrictive because of intersystem bonding situations that may exist at these facilities. The FPN to 800.100(A)(4) provides guidance for the treatment of the cable and primary protector grounding conductor length at apartment and commercial buildings that is consistent with the 20-ft rule for one- and two-family dwellings. However, a specific length is not specified in the *Code* because such a length limitation may not be practical in some installations.

*Exception: In one- and two-family dwellings where it is not practicable to achieve an overall maximum primary protector grounding conductor length of 6.0 m (20 ft), a separate communications ground rod meeting the minimum dimensional criteria of 800.100(B)(2)(2) shall be driven, the primary protector shall be grounded to the communications ground rod in accordance with 800.100(C), and the communications ground rod shall be bonded to the power grounding electrode system in accordance with 800.100(D).*

**(5) Run in Straight Line** The grounding conductor shall be run to the grounding electrode in as straight a line as practicable.

**(6) Physical Damage** Where necessary, the grounding conductor shall be guarded from physical damage. Where the grounding conductor is run in a metal raceway, both ends of the raceway shall be bonded to the grounding conductor or the same terminal or electrode to which the grounding conductor is connected.

**(B) Electrode** The grounding conductor shall be connected in accordance with 800.100(B)(1) and (B)(2).

**(1) In Buildings or Structures with Grounding Means** To the nearest accessible location on the following:

(1) The building or structure grounding electrode system as covered in 250.50
(2) The grounded interior metal water piping system, within 1.5 m (5 ft) from its point of entrance to the building, as covered in 250.52
(3) The power service accessible means external to enclosures as covered in 250.94
(4) The metallic power service raceway
(5) The service equipment enclosure
(6) The grounding electrode conductor or the grounding electrode conductor metal enclosure
(7) The grounding conductor or the grounding electrode of a building or structure disconnecting means that is grounded to an electrode as covered in 250.32

For purposes of this section, the mobile home service equipment or the mobile home disconnecting means, as described in 800.90(B), shall be considered accessible.

**(2) In Buildings or Structures Without Grounding Means** If the building or structure served has no grounding means, as described in 800.100(B)(1), the grounding conductor shall be connected to either of the following:

(1) To any one of the individual electrodes described in 250.52(A)(1), (A)(2), (A)(3), or (A)(4)
(2) If the building or structure served has no grounding means, as described in 800.100(B)(1) or (B)(2)(1), to an effectively grounded metal structure or to a ground rod or pipe not less than 1.5 m (5 ft) in length and 12.7 mm (½ in.) in diameter, driven, where practicable, into permanently damp earth and separated from lightning conductors as covered in 800.53 and at least 1.8 m (6 ft) from electrodes of other systems. Steam or hot water pipes or air terminal conductors (lightning-rod conductors) shall not be employed as electrodes for protectors.

**(C) Electrode Connection** Connections to grounding electrodes shall comply with 250.70.

**(D) Bonding of Electrodes** A bonding jumper not smaller than 6 AWG copper or equivalent shall be connected between the communications grounding electrode and power grounding electrode system at the building or structure served where separate electrodes are used.

*Exception: At mobile homes as covered in 800.106.*

FPN No. 1: See 250.60 for use of air terminals (lightning rods).

FPN No. 2: Bonding together of all separate electrodes limits potential differences between them and between their associated wiring systems.

### 800.106 Primary Protector Grounding and Bonding at Mobile Homes

**(A) Grounding** Where there is no mobile home service equipment located in sight from, and not more than 9.0 m (30 ft) from, the exterior wall of the mobile home it serves, or there is no mobile home disconnecting means grounded in accordance with 250.32 and located within sight from and not more than 9.0 m (30 ft) from, the exterior wall of the mobile home it serves, the primary protector ground shall be in accordance with 800.100(B)(2).

**(B) Bonding** The primary protector grounding terminal or grounding electrode shall be bonded to the metal frame or available grounding terminal of the mobile home with a copper grounding conductor not smaller than 12 AWG under either of the following conditions:

(1) Where there is no mobile home service equipment or disconnecting means as in 800.106(A)
(2) Where the mobile home is supplied by cord and plug

## V. Communications Wires and Cables Within Buildings

Data circuits between computers are classified as Class 2 circuits. In a typical office environment consisting of a group of computers connected to a local area network, data wiring is as prevalent as telephone wiring. One common way to minimize the amount of cabling is to run the telephone and data circuits in the same cable, as illustrated in Exhibit 800.6. Section 725.56(D) requires that either a communications cable or a multipurpose cable be used for this purpose.





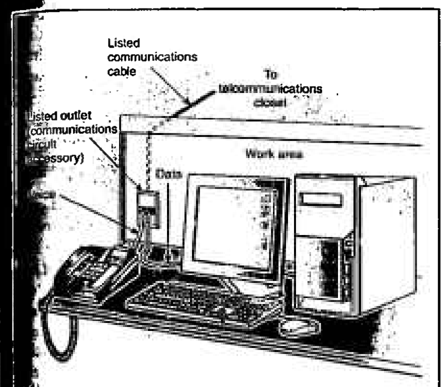



Exhibit 800.6 An example of telephone and data circuits in the same cable.

### 800.110 Raceways for Communications Wires and Cables

Where communications wires and cables are installed in a raceway, the raceway shall be either of a type permitted in Chapter 3 and installed in accordance with Chapter 3 or a listed nonmetallic raceway complying with 800.182, and installed in accordance with 362.24 through 362.56, where the requirements applicable to electrical nonmetallic tubing apply.

*Exception: Conduit fill restrictions shall not apply.*

### 800.113 Installation and Marking of Communications Wires and Cables

Listed communications wires and cables and listed multipurpose cables shall be installed as wiring within buildings. Communications cables and undercarpet communications wires shall be marked in accordance with Table 800.113. The cable voltage rating shall not be marked on the cable or on the undercarpet communications wire.

FPN: Voltage markings on cables may be misinterpreted to suggest that the cables may be suitable for Class 1, electric light, and power applications.

**Table 800.113 Cable Markings**

| Cable Marking | Type | Reference |
|---|---|---|
| CMP | Communications plenum cable | 800.179(A) and 800.154(A) |
| CMR | Communications riser cable | 800.179(B) and 800.154(B) |
| CMG | Communications general-purpose cable | 800.179(C) and 800.154(D) and (E)(1) |
| CM | Communications general-purpose cable | 800.179(D) and 800.154(D) and (E)(1) |
| CMX | Communications cable, limited use | 800.179(E) and 800.154(E)(2), (3), (4), and (5) |
| CMUC | Undercarpet communications wire and cable | 800.179(F) and 800.154(E)(6) |

FPN No. 1: Cable types are listed in descending order of fire resistance rating.

FPN No. 2: See the referenced sections for permitted uses.

*Exception No. 1: Voltage markings shall be permitted where the cable has multiple listings and voltage marking is required for one or more of the listings.*

*Exception No. 2: Listing and marking shall not be required where the length of the cable within the building, measured from its point of entrance, does not exceed 15 m (50 ft) and the cable enters the building from the outside and is terminated in an enclosure or on a listed primary protector.*

FPN No. 1 to Exception No. 2: Splice cases or terminal boxes, both metallic and plastic types, are typically used as enclosures for splicing or terminating telephone cables.

FPN No. 2 to Exception No. 2: This exception limits the length of unlisted outside plant cable to 15 m (50 ft), while 800.90(B) requires that the primary protector be located as close as practicable to the point at which the cable enters the building. Therefore, in installations requiring a primary protector, the outside plant cable may not be permitted to extend 15 m (50 ft) into the building if it is practicable to place the primary protector closer than 15 m (50 ft) to the entrance point.

### 800.133 Installation of Communications Wires, Cables, and Equipment

Communications wires and cables from the protector to the equipment or, where no protector is required, communications wires and cables attached to the outside or inside of the building shall comply with 800.133(A) through 800.133(D).

Section 800.133 includes non-power-limited fire alarm circuits covered by Article 760 and network-powered broadband communications circuits covered by Article 830.

**(A) Separation from Other Conductors**

**(1) In Raceways, Boxes, and Cables**

(a) Other Power-Limited Circuits. Communications cables shall be permitted in the same raceway or enclosure with cables of any of the following:

(1) Class 2 and Class 3 remote-control, signaling, and power-limited circuits in compliance with Article 725
(2) Power-limited fire alarm systems in compliance with Article 760
(3) Nonconductive and conductive optical fiber cables in compliance with Article 770
(4) Community antenna television and radio distribution systems in compliance with Article 820
(5) Low-power network-powered broadband communications circuits in compliance with Article 830

(b) Class 2 and Class 3 Circuits. Class 1 circuits shall not be run in the same cable with communications circuits. Class 2 and Class 3 circuit conductors shall be permitted in the same cable with communications circuits, in which case the Class 2 and Class 3 circuits shall be classified as communications circuits and shall meet the requirements of this article. The cables shall be listed as communications cables or multipurpose cables.

*Exception: Cables constructed of individually listed Class 2, Class 3, and communications cables under a common jacket shall not be required to be classified as communications cable. The fire-resistance rating of the composite cable shall be determined by the performance of the composite cable.*

(c) Electric Light, Power, Class 1, Non–Power-Limited Fire Alarm, and Medium Power Network-Powered Broadband Communications Circuits in Raceways, Compartments, and Boxes. Communications conductors shall not be placed in any raceway, compartment, outlet box, junction box, or similar fitting with conductors of electric light, power, Class 1, non–power-limited fire alarm, or medium power network-powered broadband communications circuits.

*Exception No. 1: Where all of the conductors of electric light, power, Class 1, non–power-limited fire alarm, and medium power network-powered broadband communications circuits are separated from all of the conductors of communications circuits by a permanent barrier or listed divider.*

This exception recognizes the use of a listed field-installed divider to separate the communications circuits from the power circuits.

*Exception No. 2: Power conductors in outlet boxes, junction boxes, or similar fittings or compartments where such conductors are introduced solely for power supply to communications equipment. The power circuit conductors shall be routed within the enclosure to maintain a minimum of 6 mm (0.25 in.) separation from the communications circuit conductors.*

*Exception No. 3: As permitted by 620.36.*

**(2) Other Applications** Communications wires and cables shall be separated at least 50 mm (2 in.) from conductors of any electric light, power, Class 1, non–power-limited fire alarm, or medium power network-powered broadband communications circuits.

*Exception No. 1: Where either (1) all of the conductors of the electric light, power, Class 1, non–power-limited fire alarm, and medium power network-powered broadband communications circuits are in a raceway or in metal-sheathed, metal-clad, nonmetallic-sheathed, Type AC, or Type UF cables, or (2) all of the conductors of communications circuits are encased in raceway.*

*Exception No. 2: Where the communications wires and cables are permanently separated from the conductors of electric light, power, Class 1, non–power-limited fire alarm, and medium power network-powered broadband communications circuits by a continuous and firmly fixed nonconductor, such as porcelain tubes or flexible tubing, in addition to the insulation on the wire.*

**(B) Cable Trays** Types CMP, CMR, CMG, and CM communications cables shall be permitted to be installed in cable trays. Communications raceways, as described in 800.179, shall be permitted to be installed in cable trays.

Exhibit 800.7 shows overhead ladder–type cable tray that contains communications cables.

**(C) Support of Conductors** Raceways shall be used for their intended purpose. Communications cables or wires shall not be strapped, taped, or attached by any means to the exterior of any conduit or raceway as a means of support.

See 800.21 and 800.24, which require that communications cable be supported by the building structure in such a manner that it will not be damaged by ordinary building use.

*Exception: Overhead (aerial) spans of communications cables or wires shall be permitted to be attached to the exterior of a raceway-type mast intended for the attachment and support of such conductors.*

In some instances, the only way to achieve the proper clearance above roadways, driveways, or structures is by use of a mast. The exception to 800.133(C) permits overhead spans of communications cable to be attached to the exterior of a raceway-type mast only if the mast is installed to support communications cable. Section 230.28 prohibits the attachment of communications cable to a service mast.

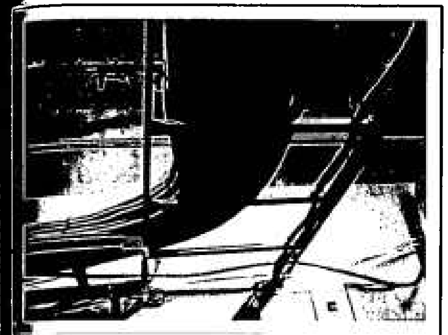


Exhibit 800.7 Overhead ladder–type cable tray containing communications cables.

**(D) Wiring in Ducts for Dust, Loose Stock, or Vapor Removal** Section 300.22(A) shall apply.

## 800.154 Applications of Listed Communications Wires and Cables and Communications Raceways

Communications wires and cables shall comply with the requirements of 800.154(A) through 800.154(F) or where cable substitutions are made in accordance with 800.154(G).

Note that the length of unlisted outside-plant cable permitted in a building depends on the location of the primary protector, in accordance with 800.90(B) and 800.113(C). Exception.

Section 800.154(A) covers listed plenum communications raceways. These raceways provide limited mechanical protection and ease of installation, but they are limited to Type CMP plenum-rated cable if installed in ducts and plenums.

Section 800.154(B) covers riser raceways. Riser raceways provide limited mechanical protection and ease of installation, but they are limited to Type CMP plenum-rated cable or Type CMR riser-rated cable if installed in risers. Table 800.154 lists the permitted uses of field applications for various cable types.

**(A) Plenum** Cables installed in ducts, plenums, and other spaces used for environmental air shall be Type CMP. Abandoned cables shall not be permitted to remain. Types CMP, CMR, CMG, CM, and CMX and communications wire installed in compliance with 300.22 shall be permitted. Listed plenum communications raceways shall be permitted to be installed in ducts and plenums as described in 300.22(B) and in other spaces used for environmental air as described in 300.22(C). Only Type CMP cable shall be permitted to be installed in raceways.

FPN: See 8.14.1 of NFPA 13-2002, *Installation of Sprinkler Systems*, for requirements for sprinklers in concealed spaces containing exposed combustibles.

**(B) Riser** Cables installed in risers shall comply with 800.154(B)(1), (B)(2), or (B)(3).

**(1) Cables in Vertical Runs** Cables installed in vertical runs and penetrating more than one floor, or cables installed in vertical runs in a shaft, shall be Type CMR. Floor penetrations requiring Type CMR shall contain only cables suitable for riser or plenum use. Abandoned cables shall not be permitted to remain. Listed riser communications raceways shall be permitted to be installed in vertical riser runs in a shaft from floor to floor. Only Type CMR and CMP cables shall be permitted to be installed in these raceways.

**(2) Metal Raceways or Fireproof Shafts** Listed communications cables shall be encased in a metal raceway or located in a fireproof shaft having firestops at each floor.

**(3) One- and Two-Family Dwellings** Type CM and CMX cable shall be permitted in one- and two-family dwellings.

FPN: See 800.3(C) for firestop requirements for floor penetrations.

**(C) Distributing Frames and Cross-Connect Arrays** Listed communications wire and Types CMP, CMR, CMG, and CM communications cables shall be used in distributing frames and cross-connect arrays.

**(D) Cable Trays** Types CMP, CMR, CMG, and CM communications cables shall be permitted to be installed in cable trays.

**(E) Other Wiring Within Buildings** Cables installed in building locations other than the locations covered in 800.154(A) through 800.154(D) shall be in accordance with 800.154(E)(1) through (E)(6).

**(1) General** Cables shall be Type CMG or Type CM. Listed communications general-purpose raceways shall be permitted. Only Types CMG, CM, CMR, or CMP cables shall be permitted to be installed in general-purpose communications raceways.

**(2) In Raceways** Listed communications wires that are enclosed in a raceway of a type included in Chapter 3 shall be permitted.

**(3) Nonconcealed Spaces** Type CMX communications cable shall be permitted to be installed in nonconcealed spaces where the exposed length of cable does not exceed 3 m (10 ft).

**(4) One- and Two-Family Dwellings** Type CMX communications cable less than 6 mm (0.25 in.) in diameter shall be permitted to be installed in one- and two-family dwellings.

**(5) Multi-Family Dwellings** Type CMX communications cable less than 6 mm (0.25 in.) in diameter shall be permitted to be installed in nonconcealed spaces in multi-family dwellings.

**(6) Under Carpets** Type CMUC undercarpet communications wires and cables shall be permitted to be installed under carpet.

**(F) Hybrid Power and Communications Cable** Hybrid power and communications cable listed in accordance with 800.179(I) shall be permitted to be installed in one- and two-family dwellings.

**(G) Cable Substitutions** The uses and permitted substitutions for communications cables listed in Table 800.154 shall be considered suitable for the purpose and shall be permitted.

**Table 800.154 Cable Substitutions**

| Cable Type | Use | References | Permitted Substitutions |
|---|---|---|---|
| CMR | Communications riser cable | 800.154(B) | CMP |
| CMG, CM | Communications general-purpose cable | 800.154(E)(1) | CMP, CMR |
| CMX | Communications cable, limited use | 800.154(E) | CMP, CMR, CMG, CM |

FPN: See Figure 800.154, Cable Substitution Hierarchy.

FPN: For information on Types CMP, CMR, CMG, CM, and CMX cables, see 800.179.

## VI. Listing Requirements

### 800.170 Equipment

Communications equipment shall be listed as being suitable for electrical connection to a telecommunications network.

FPN: One way to determine applicable requirements is to refer to UL 1950-1993, *Standard for Safety of Information Technology Equipment, Including Electrical Business Equipment*, third edition; UL 1459-1995, *Standard for Safety, Telephone Equipment*, third edition; or UL 1863-1995, *Standard for Safety, Communications Circuit Accessories*, second edition. For information on listing requirements for communications raceways, see UL 2024-1995, *Standard for Optical Fiber Raceways*.

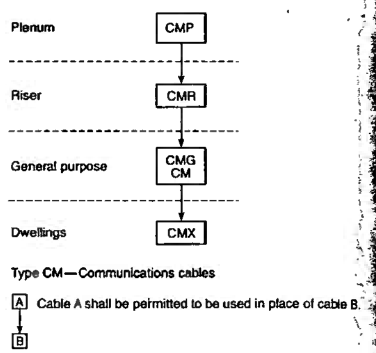



**Figure 800.154 Cable Substitution Hierarchy.**

**(A) Primary Protectors** The primary protector shall consist of an arrester connected between each line conductor and ground in an appropriate mounting. Primary protector terminals shall be marked to indicate line and ground as applicable.

FPN: One way to determine applicable requirements for a listed primary protector is to refer to ANSI/UL 497-1995, *Standard for Protectors for Paired Conductor, Communications Circuits.*

**(B) Secondary Protectors** The secondary protector shall be listed as suitable to provide means to safely limit currents to less than the current-carrying capacity of listed indoor communications wire and cable, listed telephone set line cords, and listed communications terminal equipment having ports for external wire line communications circuits. Any overvoltage protection, arresters, or grounding connection shall be connected on the equipment terminals side of the secondary protector current-limiting means.

FPN: One way to determine applicable requirements for a listed secondary protector is to refer to UL 497A-1996, *Standard for Secondary Protectors for Communications Circuits.*

### 800.173 Drop Wire and Cable

Communications wires and cables without a metallic shield, running from the last outdoor support to the primary protector, shall be listed as being suitable for the purpose and shall have current-carrying capacity as specified in 800.90(A)(1)(b) or (A)(1)(c).

### 800.179 Communications Wires and Cables

Communications wires and cables shall have a voltage rating of not less than 300 volts and shall be listed in accordance with 800.179(A) through 800.179(J). Conductors in communications cables, other than in a coaxial cable, shall be copper.

Section 800.179 requires a rating of 300 volts for the following reasons:

1. To coordinate with protector installation requirements (i.e., protectors are not required within a block unless the cable is exposed to over 300 volts)
2. To recognize the fact that primary protectors are designed to allow voltages below 300 to pass
3. To accommodate the voltages ordinarily found on a telephone line (48 volts dc plus ringing voltage up to 130 volts rms)
4. To permit communications cable to substitute for 300-volt power-limited fire-protective signaling cable

FPN: See 800.170 for listing requirement for equipment.

**(A) Type CMP** Type CMP communications plenum cable shall be listed as being suitable for use in ducts, plenums, and other spaces used for environmental air and shall also be listed as having adequate fire-resistant and low smoke-producing characteristics.

See the commentary following 725.82(A), FPN, for information on a test method for wires and cables to be installed without raceways in plenums and other spaces used for environmental air.

FPN: One method of defining a cable that is low smoke-producing cable and fire-resistant cable is that the cable exhibits a maximum peak optical density of 0.5 or less, an average optical density of 0.15 or less, and a maximum flame spread distance of 1.52 m (5 ft) or less when tested in accordance with NFPA 262-2002, *Standard Method of Test for Flame Travel and Smoke of Wires and Cables for Use in Air-Handling Spaces.*

**(B) Type CMR** Type CMR communications riser cable shall be listed as being suitable for use in a vertical run in a shaft or from floor to floor and shall also be listed as having fire-resistant characteristics capable of preventing the carrying of fire from floor to floor.

See the commentary following 725.82(B), FPN, for information on a test for defining fire-resistant characteristics capable of preventing fire spread from floor to floor.

FPN: One method of defining fire-resistant characteristics capable of preventing the carrying of fire from floor to floor is that the cables pass the requirements of ANSI/UL 1666-2002, *Standard Test for Flame Propagation Height of Electrical and Optical-Fiber Cable Installed Vertically in Shafts.*

**(C) Type CMG** Type CMG general-purpose communications cable shall be listed as being suitable for general-purpose communications use, with the exception of risers and plenums, and shall also be listed as being resistant to the spread of fire.

See the commentary following 725.82(C), FPN, for information on the UL vertical tray flame test.

FPN: One method of defining *resistant to the spread of fire* is for the damage (char length) not to exceed 1.5 m (4 ft 11 in.) when performing the vertical flame test for cables in cable trays, as described in CSA C22.2 No. 0.3-M-1985, *Test Methods for Electrical Wires and Cables.*

**(D) Type CM** Type CM communications cable shall be listed as being suitable for general-purpose communications use, with the exception of risers and plenums, and shall also be listed as being resistant to the spread of fire.

See the commentary following 725.82(D), FPN, for information on test methods for determining whether cable is resistant to the spread of fire.

FPN: One method of defining *resistant to the spread of fire* is that the cables do not spread fire to the top of the tray in the vertical-tray flame test in ANSI/UL 1581-1991, *Reference Standard for Electrical Wires, Cables and Flexible Cords*. Another method of defining *resistant to the spread of fire* is for the damage (char length) not to exceed 1.5 m (4 ft 11 in.) when performing the vertical flame test for cables in cable trays, as described in CSA C22.2 No. 0.3-M-1985, *Test Method for Electrical Wires and Cables.*

**(E) Type CMX** Type CMX limited-use communications cable shall be listed as being suitable for use in dwellings and for use in raceway and shall also be listed as being resistant to flame spread.

FPN: One method of determining that cable is resistant to flame spread is by testing the cable to the VW-1 (vertical-wire) flame test in ANSI/UL 1581-1991, *Reference Standard for Electrical Wires, Cables and Flexible Cords.*

**(F) Type CMUC Undercarpet Wire and Cable** Type CMUC undercarpet communications wire and cable shall be listed as being suitable for undercarpet use and shall also be listed as being resistant to flame spread.

FPN: One method of determining that cable is resistant to flame spread is by testing the cable to the VW-1 (vertical-wire) flame test in ANSI/UL 1581-1991, *Reference Standard for Electrical Wires, Cables and Flexible Cords.*

**(G) Multipurpose (MP) Cables** Until July 1, 2003, cables that meet the requirements for Types CMP, CMR, CMG, and CM and also satisfy the requirements of 760.82(B) for multiconductor cables and 760.82(H) for coaxial cables shall be permitted to be listed and marked as multipurpose cable Types MPP, MPR, MPG, and MP, respectively.

The deletion of stranding requirements for fire alarm cable resulted in an increased number of copper communications cables, such as Types MPP, MPR, MPG, and MP, that qualify for listing as multipurpose cable.

**(H) Communications Circuit Integrity (CI) Cable** Cables suitable for use in communications systems to ensure survivability of critical circuits during a specified time under fire conditions shall be listed as circuit integrity (CI) cable. Cables identified in 800.90(A), (B), (C), (D), and (E) that meet the requirements for circuit integrity shall have the additional classification using the suffix "CI."

FPN: One method of defining circuit integrity (CI) cable is by establishing a minimum 2-hour fire resistance rating for the cable when tested in accordance with UL 2196-1995, *Standard for Tests of Fire Resistive Cables.*

**(I) Communications Wires** Communications wires, such as distributing frame wire and jumper wire, shall be listed as being resistant to the spread of fire.

FPN: One method of defining *resistant to the spread of fire* is that the cables do not spread fire to the top of the tray in the vertical-tray flame test in ANSI/UL 1581-1991, *Reference Standard for Electrical Wires, Cables and Flexible Cords.* Another method of defining *resistant to the spread of fire* is for the damage (char length) not to exceed 1.5 m (4 ft 11 in.) when performing the vertical flame test for cables in cable trays, as described in CSA C22.2 No. 0.3-M-1985, *Test Methods for Electrical Wires and Cables.*

**(J) Hybrid Power and Communications Cable** Listed hybrid power and communications cable shall be permitted where the power cable is a listed Type NM or NM-B conforming to the provisions of Article 334, and the communications cable is a listed Type CM, the jackets on the listed NM or NM-B and listed CM cables are rated for 600 volts minimum, and the hybrid cable is listed as being resistant to the spread of fire.

FPN: One method of defining *resistant to the spread of fire* is that the cables do not spread fire to the top of the tray in the vertical-tray flame test in ANSI/UL 1581-1991, *Reference Standard for Electrical Wires, Cables and Flexible Cords.* Another method of defining *resistant to the spread of fire* is for the damage (char length) not to exceed 1.5 m (4 ft 11 in.) when performing the vertical flame test for cables in cable trays, as described in CSA C22.2 No. 0.3-M-1985, *Test Methods for Electrical Wires and Cables.*

### 800.182 Communications Raceways

Communications raceways shall be listed in accordance with 800.182(A) through 800.182(C).

**(A) Plenum Communications Raceways** Plenum communications raceways listed as plenum optical fiber raceways shall be permitted for use in ducts, plenums, and other spaces used for environmental air and shall also be listed as having adequate fire-resistant and low smoke-producing characteristics.

FPN: One method of defining that an optical fiber raceway is a low smoke producing raceway and a fire-resistant raceway is that the raceway exhibits a maximum peak optical density of 0.5 or less, an average optical density of 0.15 or less, and a maximum flame spread distance of 1.52 m (5 ft) or less when tested in accordance with the plenum test in UL 2024, *Standard for Optical Fiber Cable Raceway.*

**(B) Riser Communications Raceways** Riser communications raceways shall be listed as having adequate fire-resistant characteristics capable of preventing the carrying of fire from floor to floor.

FPN: One method of defining fire-resistant characteristics capable of preventing the carrying of fire from floor to floor is that the raceways pass the requirements of the test for Flame Propagation (riser) in UL 2024, *Standard for Optical Fiber Cable Raceway.*

**(C) General-Purpose Communications Raceways** General-purpose communications raceways shall be listed as being resistant to the spread of fire.

The communications raceways covered in 800.182(A) through (C) are listed raceways used in plenum, riser, or general-purpose applications. This listing includes raceways and fittings for the installation of communications cable in accordance with Article 800. These raceways are not suitable for installation of wires, cords, or cabling with or without communications members.

A raceway marked "plenum" is suitable for use in ducts, plenums, or other spaces used for environmental air in accordance with 800.154(A) when used to enclose communications cable marked CMP. This raceway exhibits a maximum peak optical density of 0.5, a maximum average optical density of 0.15, and a maximum flame-spread distance of 5 ft when tested in accordance with UL 2024, *Standard for Optical-Fiber Cable Raceway.* This raceway is identified by a marking on its surface or on a marker tape indicating "plenum." A raceway marked "plenum" is also suitable for installation in risers when used to enclose communications cable marked CMP or CMR; for general-purpose use when used to enclose communications cable marked CMP, CMR, CMG, or CM; and for dwellings when used to enclose communications cable marked CMP, CMR, CMG, CM, or CMX.

A raceway marked "riser" is suitable for installation in risers in accordance with 800.154(B) when used to enclose communications cable marked CMP or CMR. This raceway has fire-resistant characteristics capable of preventing the carrying of fire from floor to floor, and it meets the test requirements of UL 2024, *Standard for Optical-Fiber Cable Raceway.* This raceway is identified by a marking on its surface or on a marker tape indicating "riser." A raceway marked "riser" is also suitable for general-purpose use when used to enclose communications cable marked CMP, CMR, CMG, or CM, and for dwellings when used to enclose communications cable marked CMP, CMR, CMG, CM, or CMX.

A raceway marked "general purpose" is suitable for installation in general-purpose areas in accordance with 800.154(D) when used to enclose communications cable marked CMP, CMR, CMG, or CM, and for dwellings when used to enclose communications cable marked CMP, CMR, CMG, CM, or CMX.

Pliable raceway is raceway that can be bent by hand without the use of tools. The smallest radius of the curve of the inner edge of any bend to which the raceway can be bent without cracking either on the outer surface or internally is not less than 2½ times the outside diameter of the raceway.

FPN: One method of defining *resistance to the spread of fire* is that the raceways pass the requirements of the Vertical-Tray Flame Test (General Use) in UL 2024, *Standard for Optical Fiber Cable Raceway.*

# ARTICLE 810
# Radio and Television Equipment

Contents



## I. General

### 810.1 Scope

This article covers antenna systems for radio and television receiving equipment, amateur radio transmitting and receiving equipment, and certain features of transmitter safety. This article covers antennas such as multi-element, vertical rod, and dish, and also covers the wiring and cabling that

**(G) Fire Alarm Circuit Integrity (CI) Cable or Electrical Circuit Protective System** Cables used for survivability of critical circuits shall be listed as circuit integrity (CI) cable. Cables specified in 760.82(D), (E), (F), and (H) and used for circuit integrity shall have the additional classification using the suffix "-CI." Cables that are part of a listed electrical circuit protective system shall be considered to meet the requirements of survivability.

FPN No. 1: Fire alarm circuit integrity (CI) cable and electrical circuit protective systems may be used for fire alarm circuits to comply with the survivability requirements of *NFPA 72®-2002, National Fire Alarm Code®*, 6.9.4.3 and 6.9.4.6, that the circuit maintain its electrical function during fire conditions for a defined period of time.

FPN No. 2: One method of defining circuit integrity (CI) cable is by establishing a minimum 2-hour fire resistance rating for the cable when tested in accordance with UL 2196-1995, *Standard for Tests of Fire Resistive Cables.*

There are provisions in *NFPA 72, National Fire Alarm Code*, that require continued operation of the fire alarm system, including circuit wiring, under severe conditions such as attack by fire. To provide this integrity, *NFPA 72* recognizes the use of 2-hour fire-rated cable assemblies. FPN No. 2 to 760.82(G) refers to cables tested in accordance with UL 2196, *Standard for Tests for Fire Resistive Cables*, as an example of the type of wiring method that would qualify as circuit integrity (CI) cable. For one such example of CI cable, see Exhibit 760.5.

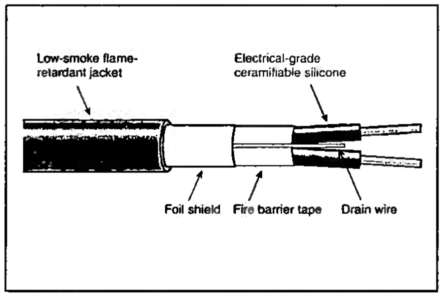



**Exhibit 760.5** Circuit integrity cable. (Redrawn courtesy of Rockbestos-Suprenant Cable Corp.)

**(H) Coaxial Cables** Coaxial cables shall be permitted to use 30 percent conductivity copper-covered steel center conductor wire and shall be listed as Type FPLP, FPLR, or FPL cable.

**(I) Cable Marking** The cable shall be marked in accordance with Table 760.82(I). The voltage rating shall not be marked on the cable. Cables that are listed for circuit integrity shall be identified with the suffix CI as defined in 760.82(G).

FPN: Voltage ratings on cables may be misinterpreted to suggest that the cables may be suitable for Class 1, electric light, and power applications.

*Exception: Voltage markings shall be permitted where the cable has multiple listings and voltage marking is required for one or more of the listings.*

**Table 760.82(I) Cable Markings**

| Cable Marking | Type |
|---|---|
| FPLP | Power-limited fire alarm plenum cable |
| FPLR | Power-limited fire alarm riser cable |
| FPL | Power-limited fire alarm cable |

Note: Cables identified in 760.82(D), (E), and (F) as meeting the requirements for circuit integrity shall have the additional classification using the suffix "CI" (for example, FPLP-CI, FPLR-CI, and FPL-CI).

FPN: Cable types are listed in descending order of fire-resistance rating.

**(J) Insulated Continuous Line-Type Fire Detectors** Insulated continuous line-type fire detectors shall be rated in accordance with 760.82(C), listed as being resistant to the spread of fire in accordance with 760.82(D) through 760.82(F), marked in accordance with 760.82(I), and the jacket compound shall have a high degree of abrasion resistance.

# ARTICLE 770
# Optical Fiber Cables and Raceways

## Summary of Changes

- General restructuring of Article 770 to make it consistent with Articles 800, 820, and 830.
- **770.12:** Completely revised wording of 770.6 of 2002 *NEC* to become 770.12. Section 770.12(C) accepts listed optical fiber raceways as innerduct.
- **770.12(D):** Revised to require firestopping of unlisted outside plant innerduct at the point of entrance to a building or structure.
- **770.113, Exception No. 2:** Revised to specifically identify the types of Chapter 3 raceways permitted to be used with unlisted nonconductive optical fiber cables entering a building from the outside.
- **770.133(A):** Revised to permit Type ITC cable to be mixed with nonconductive optical fiber cables in the same raceway or cable tray.





Contents



# I. General

## 770.1 Scope

The provisions of this article apply to the installation of optical fiber cables and raceways. This article does not cover the construction of optical fiber cables and raceways.

Article 770 permits the orderly development and use of optical fiber technology in conjunction with electrical conductors for communications, signaling, and control circuits in lieu of metallic conductors. The most common optical fiber cable used in buildings is nonconductive. (See Exhibit 770.1.)

Because they are not affected by electrical noise, optical fiber cables may be desirable in some circumstances to transmit data or other communications where electrical noise is a problem. Optical fiber cables may be nonconductive, or they may contain electrical conductors. See Exhibits 770.1 and 770.2.

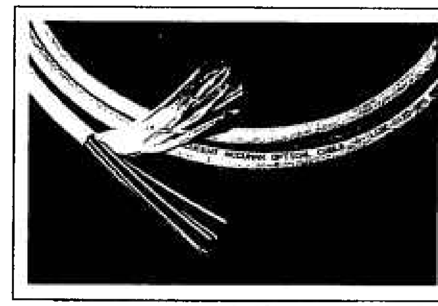


**Exhibit 770.1** An example of a nonconductive optical fiber cable.

## 770.2 Definitions

**Abandoned Optical Fiber Cable.** Installed optical fiber cable that is not terminated at equipment other than a connector and not identified for future use with a tag.

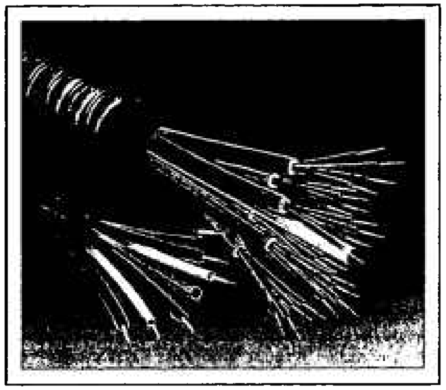


**Exhibit 770.2** An example of a composite optical fiber cable. This cable also meets the requirements of Article 330 and is referred to as Type MC cable. (Courtesy of AFC Cable Systems, Inc.)

The definition of *abandoned optical fiber cable* is for use with 770.3(A), which requires removal of accessible abandoned optical fiber cable. Abandoned cable increases fire loading unnecessarily, and, where installed in plenums, it can affect airflow. Similar requirements can be found in Articles 640, 645, 725, 760, 800, 820, and 830.

**Exposed.** The circuit is in such a position that, in case of failure of supports and insulation, contact with another circuit may result.

FPN: See Article 100 for two other definitions of *Exposed.*

**Optical Fiber Raceway.** A raceway designed for enclosing and routing listed optical fiber cables.

**Point of Entrance.** The point at which the cable emerges from an external wall, from a concrete floor slab, or from a rigid metal conduit or an intermediate metal conduit grounded to an electrode in accordance with 800.100(B).

### 770.3 Other Articles

Circuits and equipment shall comply with 770.3(A) and 770.3(B). Only those sections of Article 300 referenced in this article shall apply to optical fiber cables and raceways.

**(A) Spread of Fire or Products of Combustion** The requirements of 300.21 for electrical installations shall also apply to installations of optical fiber cables and raceways. The accessible portion of abandoned optical fiber cables shall be removed.

**(B) Ducts, Plenums, and Other Air-Handling Spaces** The requirements of 300.22 for electric wiring shall apply to installations of optical fiber cables and raceways where they are installed in ducts or plenums or other spaces used for environmental air.

*Exception: As permitted in 770.154(A).*

See the commentary following 300.22(B) and (C) for more information on wiring systems installed in ducts, plenums, or other spaces used for environmental air.

### 770.6 Optical Fiber Cables

Optical fiber cables transmit light for control, signaling, and communications through an optical fiber.

### 770.9 Types

Optical fiber cables can be grouped into three types.

**(A) Nonconductive** These cables contain no metallic members and no other electrically conductive materials.

**(B) Conductive** These cables contain non-current-carrying conductive members such as metallic strength members, metallic vapor barriers, and metallic armor or sheath.

**(C) Composite** These cables contain optical fibers and current-carrying electrical conductors, and shall be permitted to contain non–current-carrying conductive members such as metallic strength members and metallic vapor barriers. Composite optical fiber cables shall be classified as electrical cables in accordance with the type of electrical conductors.

### 770.12 Raceways for Optical Fiber Cables

Installations of raceways shall comply with 770.12(A) through 770.12(D).

**(A) Listed Chapter 3 Raceways** Listed optical fiber cable shall be permitted to be installed in any type of listed raceway permitted in Chapter 3 where that listed raceway is installed in accordance with Chapter 3. Where optical fiber cables are installed within raceway without current-carrying conductors, the raceway fill tables of Chapter 3 and Chapter 9 shall not apply. Where nonconductive optical fiber cables are installed with electric conductors in a raceway, the raceway fill tables of Chapter 3 and Chapter 9 shall apply.

Conduit fill requirements apply where the optical fiber is installed in a raceway with electrical conductors.

**(B) Optical Fiber Raceways** Listed optical fiber cable shall be permitted to be installed in listed plenum optical fiber raceway, listed riser optical fiber raceway, or listed general-purpose optical fiber raceway installed in accordance with 770.154 and 362.24 through 362.56, where the requirements applicable to electrical nonmetallic tubing shall apply.

**(C) Innerduct** Listed plenum optical fiber raceway, listed riser optical fiber raceway, or listed general-purpose optical fiber raceway installed in accordance with 770.154 shall be permitted to be installed as innerduct in any type of listed raceway permitted in Chapter 3.

**(D) Entering Buildings** Unlisted underground or outside plant construction plastic innerduct entering the building from the outside shall be terminated and firestopped at the point of entrance.

### 770.21 Access to Electrical Equipment Behind Panels Designed to Allow Access

Access to electrical equipment shall not be denied by an accumulation of cables that prevents removal of panels, including suspended ceiling panels.

See the commentary following 725.7 for information on safe access to electrical equipment behind panels.

### 770.24 Mechanical Execution of Work

Optical fiber cables shall be installed in a neat and workmanlike manner. Cables installed exposed on the surface of ceilings and sidewalls shall be supported by the building structure in such a manner that the cable will not be damaged by normal building use. Such cables shall be secured by straps, staples, hangers, or similar fittings designed and installed so as not to damage the cable. The installation shall also conform with 300.4(D) and 300.11.

FPN: Accepted industry practices are described in ANSI/NECA/BICSI 568-2001, *Standard for Installing Commercial Building Telecommunications Cabling*, and other ANSI-approved installation standards.

Section 770.24 makes it clear that the *Code* requires optical fiber cables to be installed in a neat and workmanlike manner. New for the 2002 *Code*, this section provides definitive requirements for workmanship. Cable must be attached to or supported by the structure by straps, clamps, hangers, or the like. The installation method must not damage the cable. In addition, the location of the cable should be carefully evaluated to ensure that activities and processes within the building do not cause damage to the cable. The reference to 300.4(D) calls attention to the hazard to which cables are exposed where they are installed on framing members. Such cables are required to be installed in a manner that protects them from nail or screw penetration.

## II. Protection

### 770.93 Grounding of Entrance Cables

Where exposed to contact with electric light or power conductors, the non–current-carrying metallic members of optical fiber cables entering buildings shall be grounded as close to the point of entrance as practicable or shall be interrupted as close to the point of entrance as practicable by an insulating joint or equivalent device.

## III. Cables Within Buildings

### 770.113 Installation and Marking of Listed Optical Fiber Cables

Listed optical fiber cables shall be installed as wiring within buildings. Optical fiber cables shall be marked in accordance with Table 770.113.

**Table 770.113 Cable Markings**

| Cable Marking | Type | Reference |
|---|---|---|
| OFNP | Nonconductive optical fiber plenum cable | 770.179(A) and 770.154 |
| OFCP | Conductive optical fiber plenum cable | 770.179(A) and 770.154(A) |
| OFNR | Nonconductive optical fiber riser cable | 770.179(B) and 770.154(B) |
| OFCR | Conductive optical fiber riser cable | 770.179(B) and 770.154(B) |
| OFNG | Nonconductive optical fiber general-purpose cable | 770.179(C) and 770.154(C) |
| OFCG | Conductive optical fiber general-purpose cable | 770.179(C) and 770.154(C) |
| OFN | Nonconductive optical fiber general-purpose cable | 770.179(D) and 770.154(C) |
| OFC | Conductive optical fiber general-purpose cable | 770.179(D) and 770.154(C) |

FPN No. 1: Cables types are listed in descending order of fire resistance rating. Within each fire resistance rating, nonconductive cable is listed first because it may substitute for the conductive cable.

FPN No. 2: See the referenced sections for requirements and permitted uses.

*Exception No. 1: Optical fiber cables shall not be required to be listed and marked where the length of the cable within the building, measured from its point of entrance, does not exceed 15 m (50 ft) and the cable enters the building from the outside and is terminated in an enclosure.*

FPN: Splice cases or terminal boxes, both metallic and plastic types, typically are used as enclosures for splicing or terminating optical fiber cables.

*Exception No. 2: Nonconductive optical fiber cables shall not be required to be listed and marked where the cable* *enters the building from the outside and is run in raceway systems installed in compliance with any of the following articles in Chapter 3: Article 342, Intermediate Metal Conduit: Type IMC; Article 344, Rigid Metal Conduit: Type RMC; Article 352, Rigid Nonmetallic Conduit: Type RNC; and Article 358, Electrical Metallic Tubing: Type EMT.*

### 770.133 Installation of Optical Fibers and Electrical Conductors

**(A) With Conductors for Electric Light, Power, Class 1, Non-Power-Limited Fire Alarm, or Medium Power Network-Powered Broadband Communications Circuits** Optical fibers shall be permitted within the same composite cable for electric light, power, Class 1, non–power-limited fire alarm, or medium power network-powered broadband communications circuits operating at 600 volts or less only where the functions of the optical fibers and the electrical conductors are associated.

Nonconductive optical fiber cables shall be permitted to occupy the same cable tray or raceway with conductors for electric light, power, Class 1, non–power-limited fire alarm, Type ITC, or medium power network-powered broadband communications circuits, operating at 600 volts or less. Conductive optical fiber cables shall not be permitted to occupy the same cable tray or raceway with conductors for electric light, power, Class 1, non–power-limited fire alarm, Type ITC, or medium power network-powered broadband communications circuits.

Composite optical fiber cables containing only current-carrying conductors for electric light, power, Class 1 circuits rated 600 volts or less shall be permitted to occupy the same cabinet, cable tray, outlet box, panel, raceway, or other termination enclosure with conductors for electric light, power, or Class 1 circuits operating at 600 volts or less.

Nonconductive optical fiber cables shall not be permitted to occupy the same cabinet, outlet box, panel, or similar enclosure housing the electrical terminations of an electric light, power, Class 1, non–power-limited fire alarm, or medium power network-powered broadband communications circuit.

*Exception No. 1: Occupancy of the same cabinet, outlet box, panel, or similar enclosure shall be permitted where nonconductive optical fiber cable is functionally associated with the electric light, power, Class 1, non–power-limited fire alarm, or medium power network-powered broadband communications circuit.*

*Exception No. 2: Occupancy of the same cabinet, outlet box, panel, or similar enclosure shall be permitted where nonconductive optical fiber cables are installed in factory- or field-assembled control centers.*

*Exception No. 3: In industrial establishments only, where conditions of maintenance and supervision ensure that only qualified persons service the installation, nonconductive optical fiber cables shall be permitted with circuits exceeding 600 volts.*

*Exception No. 4: In industrial establishments only, where conditions of maintenance and supervision ensure that only qualified persons service the installation, composite optical fiber cables shall be permitted to contain current-carrying conductors operating over 600 volts.*

**(B) With Other Conductors** Optical fibers shall be permitted in the same cable, and conductive and nonconductive optical fiber cables shall be permitted in the same cable tray, enclosure, or raceway with conductors of any of the following:

(1) Class 2 and Class 3 remote-control, signaling, and power-limited circuits in compliance with Article 725
(2) Power-limited fire alarm systems in compliance with Article 760
(3) Communications circuits in compliance with Article 800
(4) Community antenna television and radio distribution systems in compliance with Article 820
(5) Low-power network-powered broadband communications circuits in compliance with Article 830

**(C) Grounding** Non–current-carrying conductive members of optical fiber cables shall be grounded in accordance with Article 250.

### 770.154 Applications of Listed Optical Fiber Cables and Raceways

Nonconductive and conductive optical fiber cables shall comply with any of the requirements given in 770.154(A) through 770.154(E) or where cable substitutions are made as shown in 770.154(F).

It should be noted that 770.3(A) requires the removal of accessible abandoned optical fiber cable. Abandoned cable increases fire loading unnecessarily, and, where installed in plenums, it can affect airflow. Similar requirements can be found in Articles 640, 645, 725, 760, 800, 820, and 830. See the definition of *abandoned communications cable* in 800.2.

**(A) Plenums** Cables installed in ducts, plenums, and other spaces used for environmental air shall be Type OFNP or OFCP. Abandoned cables shall not be permitted to remain. Types OFNR, OFCR, OFNG, OFN, OFCG, and OFC cables installed in compliance with 300.22 shall be permitted. Listed plenum optical fiber raceways shall be permitted to be installed in ducts and plenums as described in 300.22(B) and in other spaces used for environmental air as described in 300.22(C). Only type OFNP and OFCP cables shall be permitted to be installed in these raceways.

FPN: See 8.14.1 of NFPA 13 (2002), *Installation of Sprinkler Systems*, for requirements for sprinklers in concealed spaces containing exposed combustibles.

**(B) Riser** Cables installed in risers shall be as described in any of the following:

(1) Cables installed in vertical runs and penetrating more than one floor, or cables installed in vertical runs in a shaft, shall be Type OFNR or OFCR. Floor penetrations requiring Type OFNR or OFCR shall contain only cables suitable for riser or plenum use. Abandoned cables shall not be permitted to remain. Listed riser optical fiber raceways shall be permitted to be installed in vertical riser runs in a shaft from floor to floor. Only Type OFNP, OFCP, OFNR, and OFCR cables shall be permitted to be installed in these raceways.
(2) Type OFNG, OFN, OFCG, and OFC cables shall be permitted to be encased in a metal raceway or located in a fireproof shaft having firestops at each floor.
(3) Type OFNG, OFN, OFCG, and OFC cables shall be permitted in one- and two-family dwellings.

FPN: See 300.21 for firestop requirements for floor penetrations.

**(C) Other Wiring Within Buildings** Cables installed in building locations other than the locations covered in 770.154(A) and 770.154(B) shall be Type OFNG, OFN, OFCG, or OFC. Such cables shall be permitted to be installed in listed general-purpose optical fiber raceways.

**(D) Hazardous (Classified) Locations** Cables installed in hazardous (classified) locations shall be any type indicated in Table 770.154.

**Table 770.154 Cable Substitutions**

| Cable Type | Permitted Substitutions |
|---|---|
| OFNP | None |
| OFCP | OFNP |
| OFNR | OFNP |
| OFCR | OFNP, OFCP, OFNR |
| OFNG, OFN | OFNP, OFNR |
| OFCG, OFC | OFNP,OFCP,OFNR,OFCR, OFNG, OFN |

**(E) Cable Trays** Optical fiber cables of the types listed in Table 770.113 shall be permitted to be installed in cable trays.

FPN: It is not the intent to require that these optical fiber cables be listed specifically for use in cable trays.

**(F) Cable Substitutions** The substitutions for optical fiber cables listed in Table 770.154 shall be permitted.

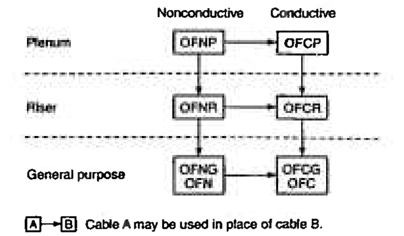



**Figure 770.154 Cable Substitution Hierarchy.**

## IV. Listing Requirements

### 770.179 Optical Fiber Cables

Optical fiber cables shall be listed in accordance with 770.179(A) through 770.179(D).

**(A) Types OFNP and OFCP** Types OFNP and OFCP nonconductive and conductive optical fiber plenum cables shall be listed as being suitable for use in ducts, plenums, and other space used for environmental air and shall also be listed as having adequate fire resistant and low smoke producing characteristics.

FPN: One method of defining a cable that is low smoke producing cable and fire-resistant cable is that the cable exhibits a maximum peak optical density of 0.5 or less, an average optical density of 0.15 or less, and a maximum flame spread distance of 1.52 m (5 ft) or less when tested in accordance with NFPA 262–2002, *Standard Method of Test for Flame Travel and Smoke of Wires and Cables for Use in Air-Handling Spaces.*

For further information on the fire test method for optical fiber plenum cables, see the commentary following 725.82(A), FPN.

**(B) Types OFNR and OFCR** Types OFNR and OFCR nonconductive and conductive optical fiber riser cables shall be listed as being suitable for use in a vertical run in a shaft or from floor to floor and shall also be listed as having the fire-resistant characteristics capable of preventing the carrying of fire from floor to floor.

FPN: One method of defining fire-resistant characteristics capable of preventing the carrying of fire from floor to floor is that the cables pass the requirements of ANSI/UL 1666-2002, *Standard Test for Flame Propagation*

*Height of Electrical and Optical-Fiber Cable Installed Vertically in Shafts.*

For further information on the fire test method for optical fiber riser cables, see the commentary following 725.82(B), FPN.

**(C) Types OFNG and OFCG** Types OFNG and OFCG nonconductive and conductive general-purpose optical fiber cables shall be listed as being suitable for general-purpose use, with the exception of risers and plenums, and shall also be listed as being resistant to the spread of fire.

FPN: One method of defining *resistance to the spread of fire* is for the damage (char length) not to exceed 1.5 m (4 ft 11 in.) when performing the vertical flame test for cables in cable trays, as described in CSA C22.2 No. 0.3-M-1985, *Test Methods for Electrical Wires and Cables.*

For further information on the fire test method for optical fiber cables used as other wiring within buildings, see the commentary following 725.82(C), FPN.

**(D) Types OFN and OFC** Types OFN and OFC nonconductive and conductive optical fiber cables shall be listed as being suitable for general-purpose use, with the exception of risers, plenums, and other spaces used for environmental air, and shall also be listed as being resistant to the spread of fire.

FPN: One method of defining *resistant to the spread of fire* is that the cables do not spread fire to the top of the tray in the vertical-tray flame test in ANSI/UL 1581-1991, *Reference Standard for Electrical Wires, Cables, and Flexible Cords.*

Another method of defining *resistant to the spread of fire* is for the damage (char length) not to exceed 1.5 m (4 ft 11 in.) when performing the vertical flame test for cables in cable trays, as described in CSA C22.2 No. 0.3-M-1985, *Test Methods for Electrical Wires and Cables.*

## 770.182 Optical Fiber Raceways

Optical fiber raceways shall be listed in accordance with 770.182(A) through 770.182(C).

The optical fiber raceways covered in 770.182 are listed raceways used in plenum, riser, or general-purpose applications. This listing includes raceways and fittings for installations of nonconductive optical fiber cables in accordance with Article 770. These raceways are not suitable for installation of current-carrying conductors, cords, or cables. Nor are these raceways suitable for installations of hybrid cables that contain optical fiber members and current-carrying conductors.

### Plenum Raceway

A raceway marked "plenum" is suitable for use in ducts, plenums, or other spaces used for environmental air in accordance with 770.154(A) where used to enclose optical fiber cables marked OFNP. This plenum raceway exhibits a maximum peak optical density of 0.5, a maximum average optical density of 0.15, and a maximum flame-spread distance of 5 ft when tested in accordance with the plenum test in UL 2024, *Standard for Optical Fiber Cable Raceway*. This raceway is identified by a marking on the surface of the raceway or on a marker tape indicating "plenum." A raceway marked "plenum" is also suitable for installation in risers where used to enclose optical fiber cables marked OFNP or OFNR and for general-purpose use where used to enclose optical fiber cables marked OFNP, OFNR, OFNG, or OFN.

### Riser Raceway

A raceway marked "riser" is suitable for installation in risers in accordance with 770.154(B) where used to enclose optical fiber cable marked OFNP or OFNR. This raceway has fire-resistant characteristics capable of preventing the carrying of fire from floor to floor. Riser raceway meets the flame propagation test requirements in UL 2024, *Standard for Optical Fiber Cable Raceway.* This raceway is identified by a marking on the surface of the raceway or on a marker tape indicating "riser." A raceway marked "riser" is also suitable for general-purpose use when used to enclose optical fiber cable marked OFNP, OFNR, OFNG, or OFN.

### General-Purpose Raceway

A raceway marked "general purpose" is suitable for installation in general-purpose areas in accordance with 770.154(C) where used to enclose optical fiber cable marked OFNP, OFNR, OFNG, or OFN. General-purpose raceway has fire-resistant characteristics that are capable of preventing the spread of fire as determined by the Vertical-Tray Flame Test in UL 2024, *Standard for Optical Fiber Raceway.*

Pliable raceway is raceway that can be bent by hand without the use of tools. The smallest radius of the curve of the inner edge of any bend to which the raceway may be bent without cracking either on the outer surface or internally is not less than 2½ times the outside diameter of the raceway.

**(A) Plenum Optical Fiber Raceway** Plenum optical fiber raceways shall be listed as having adequate fire-resistant and low smoke-producing characteristics.

FPN: One method of defining that an optical fiber raceway is a low smoke producing raceway and a fire-resistant raceway is that the raceway exhibits a maximum peak optical density of 0.5 or less, an average optical density of 0.15 or less, and a maximum flame spread distance of 1.52 m (5 ft) or less when tested in accordance with the plenum test in UL 2024, *Standard for Optical Fiber Cable Raceway.*

**(B) Riser Optical Fiber Raceway** Riser optical fiber raceways shall be listed as having fire-resistant characteristics capable of preventing the carrying of fire from floor to floor.

FPN: One method of defining fire-resistant characteristics capable of preventing the carrying of fire from floor to floor is that the raceways pass the requirements of the test for Flame Propagation (riser) in UL 2024, *Standard for Optical Fiber Cable Raceway.*

**(C) General-Purpose Optical Fiber Cable Raceway** General-purpose optical fiber cable raceway shall be listed as being resistant to the spread of fire.

FPN: One method of defining resistance to the spread of fire is that the raceways pass the requirements of the Vertical-Tray Flame Test (General Use) in UL 2024, *Standard for Optical Fiber Cable Raceway.*





# ARTICLE 780
# Closed-Loop and Programmed Power Distribution

Contents



## 780.1 Scope

The provisions of this article apply to premise power distribution systems jointly controlled by a signaling between the energy controlling equipment and utilization equipment.

Article 780 provides requirements for the "smart house" concept, which involves universal cable terminating in universal outlets.

Buildings wired by conventional methods require separate sets of conductors for different systems. In a smart house, however, multiple conductors for 120-volt ac power, 24-volt dc UPS, telephone, remote-control, and signaling, as well as coaxial cable, are combined in a single construction known as *hybrid cabling.*

Hybrid cabling serves multipurpose receptacle outlets known as *convenience centers*, which are capable of supplying different types of energy and signals to specific appliances or equipment.

A smart house uses an energy safety technique called *closed-loop control* to reduce shock hazard. In conventional wiring, receptacles are energized at all times under normal operating conditions. In the closed-loop configuration, receptacles are not energized until the insertion of an attachment plug generates a characteristic electrical identification.

Exhibit 780.1 illustrates a typical smart house installation. Present smart house technology uses 120/240-volts ac, with 24-volts dc UPS, to maintain system electronics in the event of a transient or utility power outage.

## 780.2 General

**(A) Other Articles** Except as modified by the requirements of this article, all other applicable articles of this *Code* shall apply.

**(B) Component Parts** All equipment and conductors shall be listed and identified.

## 780.3 Control

The control equipment and all power switching devices operated by the control equipment shall be listed and identified. The system shall operate in accordance with 780.3(A) through 780.3(D).

**(A) Characteristic Electrical Identification Required** Outlets shall not be energized unless the utilization equipment first exhibits a characteristic electrical identification.

Receptacles are energized with 120-volt ac power only when electronic circuitry in the convenience center receives this characteristic identification.

**(B) Conditions for De-Energization** Outlets shall be de-energized when any of the following conditions occur:

(1) A nominal-operation acknowledgment signal is not being received from the utilization equipment connected to the outlet.
(2) A ground-fault condition exists.

Convenience center receptacles are de-energized when the characteristic electrical identification ceases (when the attachment plug is withdrawn). In addition, appliances with secondary transformer voltage ratio, effectively protects the secondary conductors.

## IX. Overcurrent Protection Over 600 Volts, Nominal

### 240.100 Feeders and Branch Circuits

**(A) Location and Type of Protection** Feeder and branch-circuit conductors shall have overcurrent protection in each ungrounded conductor located at the point where the conductor receives its supply or at an alternative location in the circuit when designed under engineering supervision that includes but is not limited to considering the appropriate fault studies and time–current coordination analysis of the protective devices and the conductor damage curves. The overcurrent protection shall be permitted to be provided by either 240.100(A)(1) or (A)(2).

**(1) Overcurrent Relays and Current Transformers** Circuit breakers used for overcurrent protection of 3-phase circuits shall have a minimum of three overcurrent relay elements operated from three current transformers. The separate overcurrent relay elements (or protective functions) shall be permitted to be part of a single electronic protective relay unit.

On 3-phase, 3-wire circuits, an overcurrent relay element in the residual circuit of the current transformers shall be permitted to replace one of the phase relay elements.

An overcurrent relay element, operated from a current transformer that links all phases of a 3-phase, 3-wire circuit, shall be permitted to replace the residual relay element and one of the phase-conductor current transformers. Where the neutral is not regrounded on the load side of the circuit as permitted in 250.184(B), the current transformer shall be permitted to link all 3-phase conductors and the grounded circuit conductor (neutral).

**(2) Fuses** A fuse shall be connected in series with each ungrounded conductor.

**(B) Protective Devices** The protective device(s) shall be capable of detecting and interrupting all values of current that can occur at their location in excess of their trip-setting or melting point.

**(C) Conductor Protection** The operating time of the protective device, the available short-circuit current, and the conductor used shall be coordinated to prevent damaging or dangerous temperatures in conductors or conductor insulation under short-circuit conditions.

### 240.101 Additional Requirements for Feeders

**(A) Rating or Setting of Overcurrent Protective Devices** The continuous ampere rating of a fuse shall not exceed three times the ampacity of the conductors. The long-time trip element setting of a breaker or the minimum trip setting of an electronically actuated fuse shall not exceed six times the ampacity of the conductor. For fire pumps, conductors shall be permitted to be protected for overcurrent in accordance with 695.4(B).

**(B) Feeder Taps** Conductors tapped to a feeder shall be permitted to be protected by the feeder overcurrent device where that overcurrent device also protects the tap conductor.

# ARTICLE 250 Grounding and Bonding

## Summary of Changes

- **250.2:** Revised definition of *effective ground-fault current path* to include its function of facilitating the operation of overcurrent devices or ground-fault detectors.
- **Table 250.3:** Added reference to Article 392 grounding requirements for cable trays.
- **250.4(A)(5):** Revised to include facilitating the operation of overcurrent devices or ground-fault detectors as part of the performance requirements for the *effective ground-fault current path.*
- **250.8:** Revised to prohibit use of sheet metal screws as a means to attach connection devices for grounding conductors.
- **250.20(E):** Added new requirement to correlate 250.20 with 250.36 and 250.186.
- **250.21:** Revised to require ground detectors on ungrounded ac systems unless the voltage to ground is less than 120 volts.
- **250.24(B):** Added requirement from 250.28 covering purpose of the main bonding jumper at service equipment.
- **250.28:** Added the term *system bonding jumper* throughout this section for application with separately derived systems.
- **250.30:** Reorganized this requirement to improve usability and integrated the new term *system bonding jumper* where applicable. Revised requirement for sizing the *common grounding electrode conductor* to require a minimum 3/0 AWG copper or 250 kcmil aluminum conductor.
- **250.32:** Revised the title of the requirement to better convey the type of supply to a building or structure that is covered by these rules. Added new provision in the exception to 250.32(A) permitting multiwire circuits to be considered as a single branch circuit.
- **250.50:** Revised to require the use of a concrete-encased electrode if a building has a footing or a foundation. Exception added to exempt existing buildings or structures where access to concrete-encased electrode requires damaging the concrete.
- **250.52(A)(2):** Deleted the phrase *effectively grounded* and provided a list of conditions under which the metal frame of a building can be used as a grounding electrode.
- **250.64(B):** Revised to delete the word *severe* from the protection requirement for 4 AWG or larger grounding electrode conductors that are subject to physical damage.
- **250.64(C):** Revised to permit the use of a copper or aluminum busbar as a connection point for grounding electrode conductors or bonding jumpers.
- **250.64(D):** Revised to clarify requirements for sizing the grounding electrode conductor and the grounding electrode "taps" used in multiple service disconnecting means arrangements.
- **250.64(E):** Revised to limit the bonding requirement to ferrous metal enclosures and to indicate that nonferrous metal enclosures are not required to be electrically continuous.
- **250.68(A):** Added an exception exempting grounding electrode connections to structural metal encapsulated with fire-proofing material from having to be accessible.
- **250.84(B):** Revised requirement to apply only to metal raceways that contain metal sheathed or armored cable.
- **250.92(B)(4):** Revised to require that bonding fitting used at services be listed.
- **250.100:** Revised to require specific bonding methods for raceways, enclosures, and equipment installed in hazardous (classified) locations regardless of the presence of a supplementary equipment grounding conductor in the raceways or enclosures.
- **250.104(D):** Relocated requirements for bonding water piping and structural metal to separately derived systems from 250.104(A)(4) of 2002 *Code*.
- **250.118(5)d and 250.118(6)e:** Revised to indicate that only where the flexible metal or liquidtight flexible metal conduit requires the ability to flex or move after the initial installation is a "wire type" equipment grounding conductor required.
- **250.118(14):** Added surface metal raceways listed for grounding as a permitted type of equipment grounding conductor.
- **250.122(E):** Revised to require sizing equipment grounding conductor per Table 250.122 for cords and fixture wire with circuit conductors larger than 10 AWG.
- **250.122(G):** Added new requirement for sizing wire-type equipment grounding conductors run with feeder tap conductors.
- **250.126:** Revised to permit other grounding symbols.
- **250.146(A):** Revised to permit a listed self-grounding contact yoke or device that complies with 250.146(B). Added rule to require that at least one of the insulating mounting screw retention washers be removed from receptacles that are not the listed self-grounding type.
- **250.184:** Revised section to contain specific rules for single-point grounded neutral systems. Clarified that both single-point or multigrounded neutral systems are permitted by this requirement. Added specific installation requirements for each grounding option.

## Contents

# I. General

## 250.1 Scope

This article covers general requirements for grounding and bonding of electrical installations, and specific requirements in (1) through (6).

The complete revision of Article 250 is one of the most significant changes to occur in the recent history of the *Code*. Undertaken during the 1999 *Code* revision cycle, the task of reorganizing the large amount of subject matter contained in this article for the purpose of creating a more logical approach to the subject of grounding and bonding was a collective effort of the NEC Usability Task Group, Code-Making Panel 5, and *NEC* users who submitted proposals and comments. To better organize the existing requirements, similar rules that previously appeared in different parts of Article 250 were relocated and grouped in the same part of the article. In addition, many of the exceptions were converted into positive code language. The overall new approach to the layout provides a more user-friendly Article 250. As an aid to the users of the *Code*, the commentary for Annex F provides two cross-reference lists. Exhibit F.1 references the 1996, 1999, 2002, and 2005 sections to the 1996 Article 250 topics, and Exhibit F.2 references the 2002, 1999, and 1996 sections to the 2005 Article 250 topics. For the 2005 *Code*, the title of Article 250 has been changed to *Grounding and Bonding* to reinforce that grounding and bonding are two separate concepts but are not mutually exclusive and in fact are directly interrelated through the requirements of Article 250.

(1) Systems, circuits, and equipment required, permitted, or not permitted to be grounded
(2) Circuit conductor to be grounded on grounded systems
(3) Location of grounding connections
(4) Types and sizes of grounding and bonding conductors and electrodes
(5) Methods of grounding and bonding
(6) Conditions under which guards, isolation, or insulation may be substituted for grounding

## 250.2 Definitions

**Effective Ground-Fault Current Path.** An intentionally constructed, permanent, low-impedance electrically conductive path designed and intended to carry current under ground-fault conditions from the point of a ground fault on a wiring system to the electrical supply source and that facilitates the operation of the overcurrent protective device or ground fault detectors on high-impedance grounded systems.

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

**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.

FPN: Examples of ground-fault current paths could consist of 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.





Section 250.2 was new for the 2002 *Code*. Following a common numbering sequence throughout the *NEC*, definitions that are specific to an article and not generally used elsewhere now appear in X.2 of their respective articles. For examples of article-related definitions, see 240.2, 280.2, 285.2, 517.2, and 680.2.

One of the keys to proper application of the Article 250 requirements is understanding the definitions of terms used throughout the *Code* that relate to bonding and grounding. Some of the most basic and widely used terms are *bonding, grounded, grounded conductor, equipment grounding conductor,* and *grounding electrode conductor.* These terms are defined in Article 100.

## 250.3 Application of Other Articles

In other articles applying to particular cases of installation of conductors and equipment, requirements are identified in Table 250.3 that are in addition to, or modifications of, those of this article.

## 250.4 General Requirements for Grounding and Bonding

The following general requirements identify what grounding and bonding of electrical systems are required to accomplish. The prescriptive methods contained in Article 250 shall be followed to comply with the performance requirements of this section.

Section 250.4 provides the performance requirements for grounding and bonding of electrical systems and equipment. Performance-based requirements provide an overall objective without stating the specifics for accomplishing that objective. The first paragraph of 250.4 indicates that the performance objectives stated in 250.4(A) for grounded systems and in 250.4(B) for ungrounded systems are accomplished by complying with the prescriptive requirements found in the rest of Article 250.

The requirements of 250.4 do not provide a specific rule for the sizing or connection of grounding conductors; rather, it states overall performance considerations for grounding conductors and applies to both grounded and ungrounded systems. Sections 250.4(A)(5) for grounded systems and 250.4(B)(4) for ungrounded systems contain fault current path objectives that were stated in 250.51 of the 1996 and earlier editions of the *Code*.

### (A) Grounded Systems

**(1) Electrical System Grounding** Electrical systems that are grounded shall be connected to earth in a manner that will limit the voltage imposed by lightning, line surges, or unintentional contact with higher-voltage lines and that will stabilize the voltage to earth during normal operation.

**(2) Grounding of Electrical Equipment** Non–current-carrying conductive materials enclosing electrical conductors or equipment, or forming part of such equipment, shall be connected to earth so as to limit the voltage to ground on these materials.

**(3) Bonding of Electrical Equipment** Non–current-carrying conductive materials enclosing electrical conductors or equipment, or forming part of such equipment, shall be connected together and to the electrical supply source in a manner that establishes an effective ground-fault current path.

**(4) Bonding of Electrically Conductive Materials and Other Equipment** Electrically conductive materials that are likely to become energized shall be connected together and to the electrical supply source in a manner that establishes an effective ground-fault current path.

**(5) Effective Ground-Fault Current Path** Electrical equipment and wiring and other electrically conductive material likely to become energized shall be installed in a manner that creates a permanent, low-impedance circuit facilitating the operation of the overcurrent device or ground detector for high-impedance grounded systems. It shall 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. The earth shall not be considered as an effective ground-fault current path.

This section was revised for the 2005 *Code* to recognize that the performance objective for the effective ground-fault current path is not always to facilitate operation of an overcurrent protective device. In the case of a high-impedance grounded system installed in accordance with 250.36, the performance objective is to ensure operation of the required ground detector to provide annunciation of a ground-fault condition.

### (B) Ungrounded Systems

**(1) Grounding Electrical Equipment** Non–current-carrying conductive materials enclosing electrical conductors or equipment, or forming part of such equipment, shall be connected to earth in a manner that will limit the voltage imposed by lightning or unintentional contact with higher-voltage lines and limit the voltage to ground on these materials.

**(2) Bonding of Electrical Equipment** Non–current-carrying conductive materials enclosing electrical conductors or equipment, or forming part of such equipment, shall be connected together and to the supply system grounded equipment in a manner that creates a permanent, low-imped-

**Table 250.3 Additional Grounding Requirements**

| Conductor/Equipment | Article | Section |
|---|---|---|
| Agricultural buildings | | 547.9 and 547.10 |
| Audio signal processing, amplification, and reproduction equipment | | 640.7 |
| Branch circuits | | 210.5, 210.6, 406.3 |
| Cablebus | | 370.9 |
| Cable trays | 392 | 392.3(C), 392.7 |
| Capacitors | | 460.10, 460.27 |
| Circuits and equipment operating at less than 50 volts | 720 | |
| Closed-loop and programmed power distribution | | 780.3 |
| Communications circuits | 800 | |
| Community antenna television and radio distribution systems | | 820.93, 820.100, 820.103 |
| Conductors for general wiring | 310 | |
| Cranes and hoists | 610 | |
| Electrically driven or controlled irrigation machines | | 675.11(C), 675.12, 675.13, 675.14, 675.15 |
| Electric signs and outline lighting | 600 | |
| Electrolytic cells | 668 | |
| Elevators, dumbwaiters, escalators, moving walks, wheelchair lifts, and stairway chair lifts | 620 | |
| Fire alarm systems | | 760.9 |
| Fixed electric heating equipment for pipelines and vessels | | 427.29, 427.48 |
| Fixed outdoor electric deicing and snow-melting equipment | | 426.27 |
| Flexible cords and cables | | 400.22, 400.23 |
| Floating buildings | | 553.8, 553.10, 553.11 |
| Grounding-type receptacles, adapters, cord connectors, and attachment plugs | | 406.9 |
| Hazardous (classified) locations | 500–517 | |
| Health care facilities | 517 | |
| Induction and dielectric heating equipment | 665 | |
| Industrial machinery | 670 | |
| Information technology equipment | | 645.15 |
| Intrinsically safe systems | | 504.50 |
| Luminaires (lighting fixtures) and lighting equipment | | 410.17, 410.18, 410.20, 410.21, 410.105(B) |
| Luminaires (fixtures), lampholders, and lamps | 410 | |
| Marinas and boatyards | | 555.15 |
| Mobile homes and mobile home park | 550 | |
| Motion picture and television studios and similar locations | | 530.20, 530.64(B) |
| Motors, motor circuits, and controllers | 430 | |
| Outlet, device, pull, and junction boxes; conduit bodies; and fittings | | 314.4, 314.25 |
| Over 600 volts, nominal, underground wiring methods | | 300.50(B) |
| Panelboards | | 408.40 |
| Pipe organs | 650 | |
| Radio and television equipment | 810 | |
| Receptacles and cord connectors | | 406.3 |
| Recreational vehicles and recreational vehicle parks | 551 | |
| Services | 230 | |
| Solar photovoltaic systems | | 690.41, 690.42, 690.43, 690.45, 690.47 |
| Swimming pools, fountains, and similar installations | 680 | |
| Switchboards and panelboards | | 408.3(D) |
| Switches | | 404.12 |
| Theaters, audience areas of motion picture and television studios, and similar locations | | 520.81 |
| Transformers and transformer vaults | | 450.10 |
| Use and identification of grounded conductors | 200 | |
| X-ray equipment | 660 | 517.78 |





ance path for ground-fault current that is capable of carrying the maximum fault current likely to be imposed on it.

**(3) Bonding of Electrically Conductive Materials and Other Equipment** Electrically conductive materials that are likely to become energized shall be connected together and to the supply system grounded equipment in a manner that creates a permanent, low-impedance path for ground-fault current that is capable of carrying the maximum fault current likely to be imposed on it.

**(4) Path for Fault Current** Electrical equipment, wiring, and other electrically conductive material likely to become energized shall be installed in a manner that creates a permanent, low-impedance circuit from any point on the wiring system to the electrical supply source to facilitate the operation of overcurrent devices should a second fault occur on the wiring system. The earth shall not be considered as an effective fault-current path.

FPN No. 1: A second fault that occurs through the equipment enclosures and bonding is considered a ground fault.

FPN No. 2: See Figure 250.4 for information on the organization of Article 250.

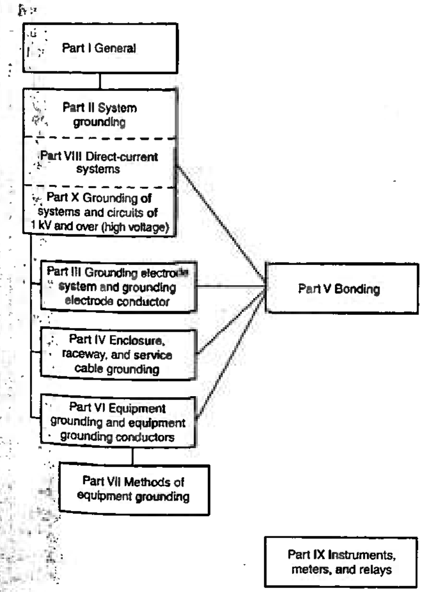



**Figure 250.4 Grounding**

Grounding can be divided into two areas: system grounding and equipment grounding. These two areas are kept separate except at the point where they receive their source of power, such as at the service equipment or at a separately derived system.

Grounding is the intentional connection of a current-carrying conductor to ground or something that serves in place of ground. In most instances, this connection is made at the supply source, such as a transformer, and at the main service disconnecting means of the premises using the energy.

There are three basic reasons for grounding:

1. To limit the voltages caused by lightning or by accidental contact of the supply conductors with conductors of higher voltage
2. To stabilize the voltage under normal operating conditions (which maintains the voltage at one level relative to ground, so that any equipment connected to the system will be subject only to that potential difference)
3. To facilitate the operation of overcurrent devices, such as fuses, circuit breakers, or relays, under ground-fault conditions

Exhibit 250.1 shows a typical grounding system for a single-phase, 3-wire service supplied from a utility transformer. Inside the service disconnecting means, the grounded conductor of the system is intentionally connected to a grounding electrode via the grounding electrode conductor. Bonding the equipment grounding bus to the grounded or neutral bus via the main bonding jumper within the service disconnecting means provides a ground reference for exposed, non–current-carrying parts of the electrical system and a circuit through the grounded service conductor back to the utility transformer (source of supply) for ground-fault cur-

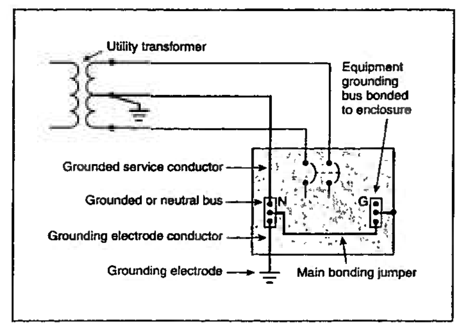



**Exhibit 250.1** A typical grounding system for a single-phase, 3-wire service.

rent. At the utility transformer, oftentimes, an additional connection from the grounded conductor to a separate grounding electrode is made.

### 250.6 Objectionable Current over Grounding Conductors

**(A) Arrangement to Prevent Objectionable Current** The grounding of electrical systems, circuit conductors, surge arresters, and conductive non–current-carrying materials and equipment shall be installed and arranged in a manner that will prevent objectionable current over the grounding conductors or grounding paths.

**(B) Alterations to Stop Objectionable Current** If the use of multiple grounding connections results in objectionable current, one or more of the following alterations shall be permitted to be made, provided that the requirements of 250.4(A)(5) or (B)(4) are met:

(1) Discontinue one or more but not all of such grounding connections.
(2) Change the locations of the grounding connections.
(3) Interrupt the continuity of the conductor or conductive path interconnecting the grounding connections.
(4) Take other suitable remedial and approved action.

An increase in the use of electronic controls and computer equipment, which are sensitive to stray currents, has caused installation designers to look for ways to isolate electronic equipment from the effects of such stray circulating currents. Circulating currents on equipment grounding conductors, metal raceways, and building steel develop potential differences between ground and the neutral of electronic equipment.

A solution often recommended by inexperienced individuals is to isolate the electronic equipment from all other power equipment by disconnecting it from the power equipment ground. In this ill-conceived corrective action, the equipment grounding means is removed or nonmetallic spacers are installed in the metallic raceway system. The electronic equipment is then grounded to an earth ground isolated from the common power system ground. Isolating equipment in this manner creates a potential difference that is a shock hazard. The error is compounded because such isolation does not establish a low-impedance ground-fault return path to the power source, which is necessary to actuate the overcurrent protection device. Section 250.6(B) is not intended to allow disconnection of all power grounding connections to the electronic equipment. See also the commentary following 250.6(D).

**(C) Temporary Currents Not Classified as Objectionable Currents** Temporary currents resulting from accidental conditions, such as ground-fault currents, that occur only while the grounding conductors are performing their intended protective functions shall not be classified as objectionable current for the purposes specified in 250.6(A) and (B).

**(D) Limitations to Permissible Alterations** The provisions of this section shall not be considered as permitting electronic equipment from being operated on ac systems or branch circuits that are not grounded as required by this article. Currents that introduce noise or data errors in electronic equipment shall not be considered the objectionable currents addressed in this section.

Section 250.6(D) indicates that currents that result in noise or data errors in electronic equipment are not considered to be the objectionable currents referred to in 250.6, which limits the alterations permitted by 250.6(C). See 250.96 and 250.146(D) for requirements that provide safe bonding and grounding methods to minimize noise and data errors.

**(E) Isolation of Objectionable Direct-Current Ground Currents** Where isolation of objectionable dc ground currents from cathodic protection systems is required, a listed ac coupling/dc isolating device shall be permitted in the equipment grounding path to provide an effective return path for ac ground-fault current while blocking dc current.

The dc ground current on grounding conductors as a result of a cathodic protection system may be considered objectionable. Because of the required grounding and bonding connections associated with metal piping systems, it is inevitable that where cathodic protection for the piping system is provided, dc current will be present on grounding and bonding conductors.

Section 250.6(E) allows the use of a listed ac coupling/dc isolating device. This device prevents the dc current on grounding and bonding conductors and allows the ground-fault return path to function properly. To be listed for this function, these devices are evaluated by the product testing organizations for proper performance under ground-fault conditions.

### 250.8 Connection of Grounding and Bonding Equipment

Grounding conductors and bonding jumpers shall be connected by exothermic welding, listed pressure connectors, listed clamps, or other listed means. Connection devices or fittings that depend solely on solder shall not be used. Sheet metal screws shall not be used to connect grounding conductors or connection devices to enclosures.



Section 250.8 prohibits the use of sheet metal screws as a means for directly attaching equipment grounding conductors to equipment or as a means for attaching connection devices for equipment grounding conductors to equipment. Connection means that are listed, that are part of listed equipment, or that are exothermically welded are required to ensure a permanent and low-resistance connection. Exhibit 250.2 and Exhibit 250.3 illustrate two methods of attaching an equipment bonding jumper to a grounded metal box.

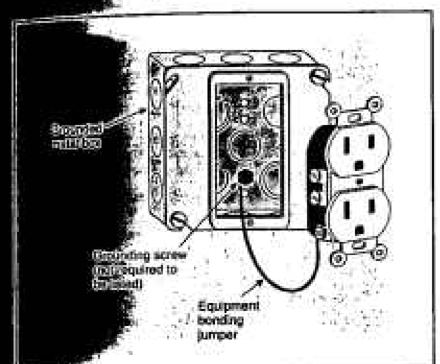



Exhibit 250.2 Use of a grounding screw to attach equipment bonding jumper to a metal box.

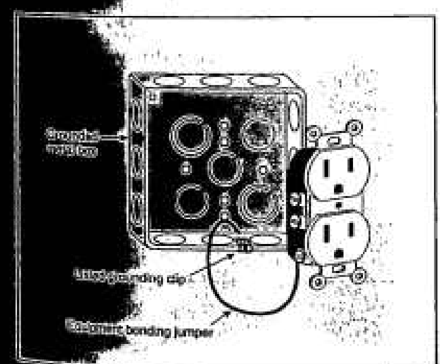



Exhibit 250.3 Use of a listed grounding clip to attach a grounding conductor to a metal box.



### 250.10 Protection of Ground Clamps and Fittings

Ground clamps or other fittings shall be approved for general use without protection or shall be protected from physical damage as indicated in (1) or (2) as follows:

(1) In installations where they are not likely to be damaged
(2) Where enclosed in metal, wood, or equivalent protective covering

### 250.12 Clean Surfaces

Nonconductive coatings (such as paint, lacquer, and enamel) on equipment to be grounded shall be removed from threads and other contact surfaces to ensure good electrical continuity or be connected by means of fittings designed so as to make such removal unnecessary.

## II. System Grounding

### 250.20 Alternating-Current Systems to Be Grounded

Alternating-current systems shall be grounded as provided for in 250.20(A), (B), (C), or (D). Other systems shall be permitted to be grounded. If such systems are grounded, they shall comply with the applicable provisions of this article.

FPN: An example of a system permitted to be grounded is a corner-grounded delta transformer connection. See 250.26(4) for conductor to be grounded.

**(A) Alternating-Current Systems of Less Than 50 Volts** Alternating-current systems of less than 50 volts shall be grounded under any of the following conditions:

(1) Where supplied by transformers, if the transformer supply system exceeds 150 volts to ground
(2) Where supplied by transformers, if the transformer supply system is ungrounded
(3) Where installed as overhead conductors outside of buildings

**(B) Alternating-Current Systems of 50 Volts to 1000 Volts** Alternating-current systems of 50 volts to 1000 volts that supply premises wiring and premises wiring systems shall be grounded under any of the following conditions:

(1) Where the system can be grounded so that the maximum voltage to ground on the ungrounded conductors does not exceed 150 volts

Exhibit 250.4 illustrates the grounding requirements of 250.20(B)(1) as applied to a 120-volt, single-phase, 2-wire system and to a 120/240-volt, single-phase, 3-wire system.

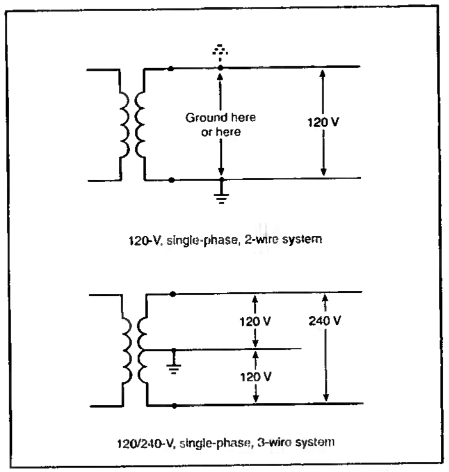



**Exhibit 250.4** Typical systems required to be grounded in accordance with 250.20(B)(1). The conductor to be grounded is in accordance with 250.26.

The selection of which conductor is to be grounded is covered by 250.26.

(2) Where the system is 3-phase, 4-wire, wye connected in which the neutral is used as a circuit conductor
(3) Where the system is 3-phase, 4-wire, delta connected in which the midpoint of one phase winding is used as a circuit conductor

Exhibit 250.5 illustrates which conductor is required to be grounded for all wye systems if the neutral is used as a circuit conductor. Where the midpoint of one phase of a 3-phase, 4-wire delta system is used as a circuit conductor, it must be grounded and the high-leg conductor must be identified. See 250.20(B)(2) and 250.20(B)(3), as well as 250.26.

**(C) Alternating-Current Systems of 1 kV and Over** Alternating-current systems supplying mobile or portable equipment shall be grounded as specified in 250.188. Where supplying other than mobile or portable equipment, such systems shall be permitted to be grounded.

**(D) Separately Derived Systems** Separately derived systems, as covered in 250.20(A) or (B), shall be grounded as specified in 250.30.

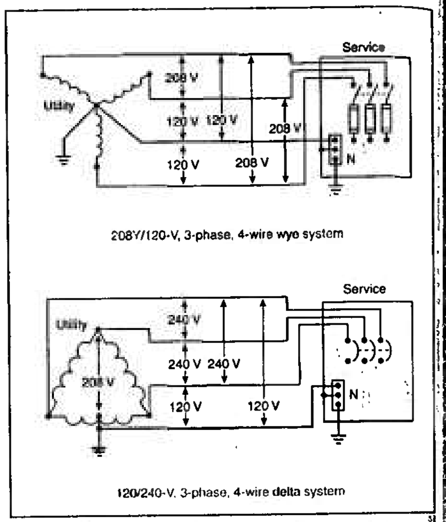



**Exhibit 250.5** Typical systems required to be grounded by 250.20(B)(2) and 250.20(B)(3). The conductor to be grounded is in accordance with 250.26.

Two of the most common sources of separately derived systems in premises wiring are transformers and generators. An autotransformer or step-down transformer that is part of electrical equipment and that does not supply premises wiring is not the source of a separately derived system. See the definition of *premises wiring* in Article 100.

FPN No. 1: An alternate ac power source such as an on-site generator is not a separately derived system if the neutral is solidly interconnected to a service-supplied system neutral.

Exhibit 250.6 and Exhibit 250.7 depict a 208Y/120-volt, 3-phase, 4-wire electrical service supplying a service disconnecting means to a building. The system is fed through a transfer switch connected to a generator intended to provide power for an emergency or standby system.

In Exhibit 250.6, the neutral conductor from the generator to the load is not disconnected by the transfer switch. There is 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. Under these conditions, it is necessary to run an equipment grounding conductor from the service equipment to the 3-pole transfer switch and from the 3-pole transfer switch to the generator. This can be in the form of any of the items listed in 250.118.





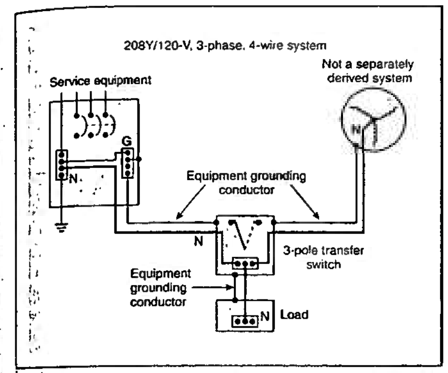



**Exhibit 250.6** A 208Y/120-volt, 3-phase, 4-wire system that has a direct electrical connection of the grounded circuit conductor (neutral) to the generator and is therefore not considered a separately derived system.

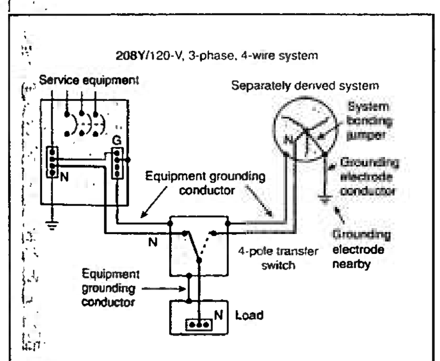



**Exhibit 250.7** A 208Y/120-volt, 3-phase, 4-wire system that does not have a direct electrical connection of the grounded circuit conductor (neutral) to the generator and is therefore considered a separately derived system.

In Exhibit 250.7, 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) and 250.20(D). 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 should be located as close to the generator as practicable, according to 250.30(A)(4). If the generator is in a building, the preferred grounding electrode is required to be one of the following, depending on which grounding electrode is closest to the generator location: (1) effectively grounded structural metal member or (2) the first 5 ft of water pipe into a building where the piping is effectively grounded. (The exception to 250.52(A)(1) permits the grounding connection to the water piping beyond the first 5 ft.) For buildings or structures in which the preferred electrodes are not available, the choice can be made from any of the grounding electrodes specified in 250.52(A)(3) through 250.52(A)(7).

FPN No. 2: For systems that are not separately derived and are not required to be grounded as specified in 250.30, see 445.13 for minimum size of conductors that must carry fault current.

**(E) Impedance Grounded Neutral Systems** Impedance grounded neutral systems shall be grounded in accordance with 250.36 or 250.186.

### 250.21 Alternating-Current Systems of 50 Volts to 1000 Volts Not Required to Be Grounded

The following ac systems of 50 volts to 1000 volts shall be permitted to be grounded but shall not be required to be grounded:

(1) Electric systems used exclusively to supply industrial electric furnaces for melting, refining, tempering, and the like
(2) Separately derived systems used exclusively for rectifiers that supply only adjustable-speed industrial drives
(3) Separately derived systems supplied by transformers that have a primary voltage rating less than 1000 volts, provided that all the following conditions are met:
   a. The system is used exclusively for control circuits.
   b. The conditions of maintenance and supervision ensure that only qualified persons service the installation.

c. Continuity of control power is required.
d. Ground detectors are installed on the control system.

(4) Other systems that are not required to be grounded in accordance with the requirements of 250.20(B).

Where an alternating-current system is not grounded as permitted in 250.21(1) through (4), ground detectors shall be installed on the system.

*Exception: Systems of less than 120 volts to ground as permitted by this Code shall not be required to have ground detectors.*

New for the 2005 *Code*, ungrounded electrical systems as permitted in 250.21 are required to be provided with ground detectors. In the 2002 and previous editions, the installation of ground detectors was required only for some very specific applications of ungrounded systems (and in impedance grounded neutral systems), but there was only a recommendation that they be installed on all ungrounded electrical systems. The exception to this requirement permits the operation of specific-purpose ungrounded systems without ground detectors where the voltage to ground is less than 120 volts. For further information on what is considered to be the voltage to ground in an ungrounded system, see the definition of *voltage to ground* in Article 100.

Ungrounded electrical systems are permitted by the *NEC* for the specific functions described in 250.21(1), (2), and (3) and for general power distribution systems in accordance with 250.21(4). Delta-connected, 3-phase, 3-wire, 240-volt and 480-volt systems are examples of common electrical distribution systems that are permitted but are not required to have a circuit conductor that is intentionally grounded. The operational advantage in using an ungrounded electrical system is continuity of operation, which in some processes might create a safer condition than would be achieved by the automatic and unplanned opening of the supply circuit.

Unlike solidly grounded systems, in which the first line-to-ground fault causes the overcurrent protective device to automatically open the circuit, the same line-to-ground fault in an ungrounded system does not result in the operation of the overcurrent device — it simply results in the faulted circuit conductor becoming a grounded conductor until a repair of the damaged conductor insulation can be performed. However, this latent ground-fault condition will remain undetected unless ground detectors are installed in the ungrounded system or until another insulation failure on a different ungrounded conductor results in a line-to-line-to-ground fault, with the potential for more extensive damage to electrical equipment.

Ground detectors are used to provide a visual indication, an audible signal, or both, to alert system operators and maintainers of a ground-fault condition in the electrical system. With notification of the ground-fault condition, rather than automatic interruption of the circuit, the operators of the process supplied by the ungrounded system can then take the necessary steps to effect an orderly shutdown, determine where the ground fault is located in the system, and safely perform the necessary repair.

It should be noted that ungrounded systems are simply systems without an intentionally grounded circuit conductor that is part of normal circuit operation, as is the case in 120/240-volt, single-phase, 3-wire; 208Y/120-volt, 3-phase, 4-wire; and 480Y/277-volt, 3-phase, 4-wire systems in which there is a grounded conductor that is used as a circuit conductor. The fact that a system operates without a grounded conductor does not exempt that system from complying with all of the applicable requirements in Article 250 for establishing a grounding electrode system and for equipment grounding. These protective features are required for grounded and ungrounded electrical distribution systems.

## 250.22 Circuits Not to Be Grounded

The following circuits shall not be grounded:

(1) Circuits for electric cranes operating over combustible fibers in Class III locations, as provided in 503.155
(2) Circuits in health care facilities as provided in 517.61 and 517.160
(3) Circuits for equipment within electrolytic cell working zone as provided in Article 668
(4) Secondary circuits of lighting systems as provided in 411.5(A)

## 250.24 Grounding Service-Supplied Alternating-Current Systems

**(A) System Grounding Connections** A premises wiring system supplied by a grounded ac service shall have a grounding electrode conductor connected to the grounded service conductor, at each service, in accordance with 250.24(A)(1) through (A)(5).

**(1) General** The connection shall be made at any accessible point from the load end of the service drop or service lateral to and including the terminal or bus to which the grounded service conductor is connected at the service disconnecting means.

The grounded conductor of an ac service is connected to a grounding electrode system to limit the voltage to ground imposed on the system by lightning, line surges, and (unintentional) high-voltage crossovers. Another reason for requiring this connection is to stabilize the voltage to ground during normal operation, including short circuits. These performance requirements are stated in 250.4(A) and 250.4(B).

The actual connection of the grounded service conductor to the grounded electrode conductor is permitted to be made at various locations, according to 250.24(A)(1). Allowing various locations for the connection to be made continues to meet the overall objectives for grounding while allowing the installer a variety of practical solutions. Exhibit 250.8 illustrates three possible connection point solutions to where the grounded conductor of the service could be connected to the grounding electrode conductor.

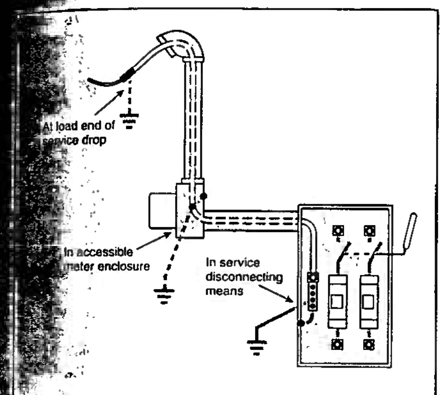



Exhibit 250.8 An ac service supplied from an overhead distribution system illustrating three accessible connection points where the grounded service conductor is connected to the grounding electrode conductor according to 250.24(A)(1).

FPN: See definitions of *Service Drop* and *Service Lateral* in Article 100.

**(2) Outdoor Transformer** Where the transformer supplying the service is located outside the building, at least one additional grounding connection shall be made from the grounded service conductor to a grounding electrode, either at the transformer or elsewhere outside the building.

See Exhibit 250.9 for an illustration of an outdoor distribution system transformer connected to an additional grounding electrode.

*Exception: The additional grounding connection shall not be made on high-impedance grounded neutral systems. The system shall meet the requirements of 250.36.*

**(3) Dual Fed Services** For services that are dual fed (double ended) in a common enclosure or grouped together in separate enclosures and employing a secondary tie, a single grounding electrode connection to the tie point of the grounded conductor(s) from each power source shall be permitted.

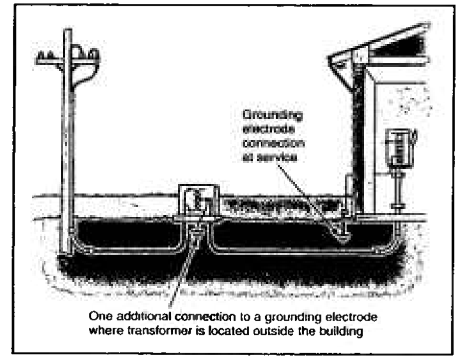



Exhibit 250.9 A 3-wire, 120/240-volt ac, single-phase, secondary distribution system in which grounding connections are required on the secondary side of the transformer according to 250.24(A)(2) and the supply side of the service disconnecting means according to 250.24(A)(1).

**(4) Main Bonding Jumper as Wire or Busbar** Where the main bonding jumper specified in 250.28 is a wire or busbar and is installed from the grounded conductor terminal bar or bus to the equipment grounding terminal bar or bus in the service equipment, the grounding electrode conductor shall be permitted to be connected to the equipment grounding terminal, bar, or bus to which the main bonding jumper is connected.

**(5) Load-Side Grounding Connections** A grounding connection shall not be made to any grounded conductor on the load side of the service disconnecting means except as otherwise permitted in this article.

FPN: See 250.30(A) for separately derived systems, 250.32 for connections at separate buildings or structures, and 250.142 for use of the grounded circuit conductor for grounding equipment.

The power for ac premises wiring systems is either separately derived, in accordance with 250.20(D), or supplied by the service. See the definition of *service* in Article 100. Section 250.30 covers grounding requirements for separately derived ac systems. Section 250.24(A) covers system grounding requirements for service-supplied ac systems.

According to 250.24, a premises wiring system supplied by an ac service that is required to be grounded must have a grounding electrode conductor at each service connected to the grounding electrodes that meets the requirements in Part III of Article 250. Note that the grounding electrode requirements for a separately derived system are specified in 250.30(A)(3) and 250.30(A)(4).

The grounding electrode conductor connection to the grounded conductor is specific. The *Code* requires that the connection be made to the grounded service conductor and describes where this connection is permitted. Where the transformer supplying a service is located outside of a building or structure, a grounding connection must be made at the transformer secondary or at another outdoor location under the conditions specified in 250.24(A)(2). In addition, the conductor that is grounded at the transformer is required to be grounded again at the building or structure, according to 250.24(A)(1).

Section 250.24(A)(5) prohibits regrounding of the grounded conductor on the load side of the service disconnecting means. This requirement is also in concert with 250.142(B).

**(B) Main Bonding Jumper** For a grounded system, an unspliced main bonding jumper shall be used to connect the equipment grounding conductor(s) and the service-disconnect enclosure to the grounded conductor within the enclosure for each service disconnect in accordance with 250.28.

Where the service equipment of a grounded system consists of multiple disconnecting means, a main bonding jumper for each separate service disconnecting means is required to connect the grounded service conductor, the equipment grounding conductor, and the service equipment enclosure. See Exhibit 250.10 and Exhibit 250.11, which accompany the commentary following 250.24(C), Exception.

*Exception No. 1: Where more than one service disconnecting means is located in an assembly listed for use as service equipment, an unspliced main bonding jumper shall bond the grounded conductor(s) to the assembly enclosure.*

Where multiple service disconnecting means are part of an assembly listed as service equipment, all grounded service conductors are required to be run to and bonded to the assembly. However, only one section of the assembly is required to have the main bonding jumper connection. See Exhibit 250.12, which accompanies the commentary following 250.28(D).

*Exception No. 2: Impedance grounded neutral systems shall be permitted to be connected as provided in 250.36 and 250.186.*

**(C) Grounded Conductor Brought to Service Equip-ment** Where an ac system operating at less than 1000 volt[s] is grounded at any point, the grounded conductor(s) sha[ll] be run to each service disconnecting means and shall b[e] bonded to each disconnecting means enclosure. Th[e] grounded conductor(s) shall be installed in accordance wit[h] 250.24(C)(1) through (C)(3).

*Exception: Where more than one service disconnectin[g] means are located in an assembly listed for use as servic[e] equipment, it shall be permitted to run the grounded conduc-tor(s) to the assembly, and the conductor(s) shall be bonde[d] to the assembly enclosure.*

If the utility service that supplies premises wiring is grounded, the grounded conductor, whether or not it is use[d] to supply a load, must be run to the service equipment, b[e] bonded to the equipment, and be connected to a groundin[g] electrode system. Exhibit 250.10 shows an example of th[e] main rule in 250.24(C), which requires the grounded servi[ce] conductor to be brought in and bonded to each service di[s]connecting means enclosure. This requirement is based o[n] the grounded conductor being used to complete the groun[d-]fault current path between the service equipment and th[e] utility source. The grounded service conductor's other fun[c-]

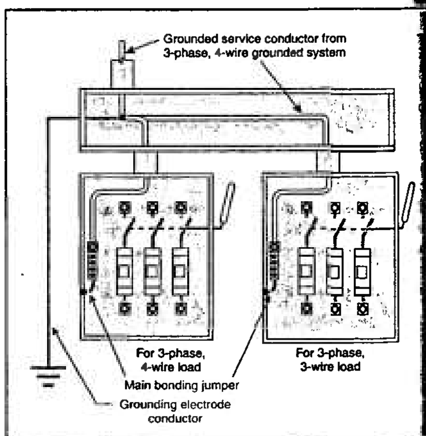



**Exhibit 250.10** A grounded system in which the grounded se[r]vice conductor is brought into a 3-phase, 4-wire service equip[-]ment enclosure and to the 3-phase, 3-wire service equipmen[t] enclosure, where it is bonded to each service disconnecting means.





... circuit conductor for normal loads, is covered in ... and 220.61.

The exception to 250.24(C) permits a single connection of the grounded service conductor to a listed service assembly (such as a switchboard) that contains more than one service disconnecting means, as shown in Exhibit 250.11.

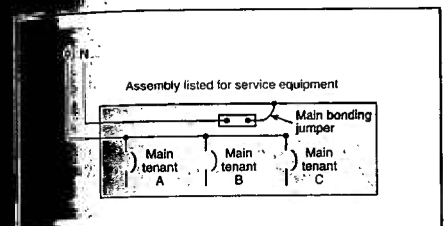



**Exhibit 250.11** One connection of the grounded service conductor to a listed service assembly containing multiple service disconnecting means, in accordance with 250.24(C), Exception.

**(1) Routing and Sizing** This conductor shall be routed with the phase conductors and shall not be smaller than the required grounding electrode conductor specified in Table 250.66 but shall not be required to be larger than the largest ungrounded service-entrance phase conductor. In addition, for service-entrance phase conductors larger than 1100 kcmil copper or 1750 kcmil aluminum, the grounded conductor shall not be smaller than 12½ percent of the area of the largest service-entrance phase conductor. The grounded conductor of a 3-phase, 3-wire delta service shall have an ampacity not less than that of the ungrounded conductors.

**(2) Parallel Conductors** Where the service-entrance phase conductors are installed in parallel, the size of the grounded conductor shall be based on the total circular mil area of the parallel conductors as indicated in this section. Where installed in two or more raceways, the size of the grounded conductor in each raceway shall be based on the size of the ungrounded service-entrance conductor in the raceway but not smaller than 1/0 AWG.

FPN: See 310.4 for grounded conductors connected in parallel.

For a multiple raceway or cable service installation, the minimum size for the grounded conductor in each raceway or cable where conductors are in parallel cannot be less than 1/0 AWG. Although the cumulative size of the parallel ... conductors may be larger than is required by 25... (C)(1), the minimum 1/0 AWG per raceway or cable correlates with the requirements for parallel conductors contained in 310.4.

**(3) High Impedance** The grounded conductor on a high-impedance grounded neutral system shall be grounded in accordance with 250.36.

**(D) Grounding Electrode Conductor** A grounding electrode conductor shall be used to connect the equipment grounding conductors, the service-equipment enclosures, and, where the system is grounded, the grounded service conductor to the grounding electrode(s) required by Part III of this article.

High-impedance grounded neutral system connections shall be made as covered in 250.36.

FPN: See 250.24(A) for ac system grounding connections.

**(E) Ungrounded System Grounding Connections** A premises wiring system that is supplied by an ac service that is ungrounded shall have, at each service, a grounding electrode conductor connected to the grounding electrode(s) required by Part III of this article. The grounding electrode conductor shall be connected to a metal enclosure of the service conductors at any accessible point from the load end of the service drop or service lateral to the service disconnecting means.

## 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 common 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

Section 250.26 works in conjunction with 250.20(B). Once the requirements of 250.20(B) establish that a system is required to be grounded, the requirements of 250.26 identify the conductor in the system that is required to be grounded. In addition to covering systems where it is mandatory to ground the system, this requirement also identifies which conductor is to be grounded in systems that are permitted to be grounded, such as a corner-grounded delta system.

## 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 term *system bonding jumper* is new for the 2005 *Code*. This new term distinguishes the system bonding jumper installed in the disconnecting means enclosure supplied from a separately derived system from the main bonding jumper installed only in a service disconnecting means enclosure. See the commentary following the Article 100 definition of *bonding jumper, system*.

**(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.

The requirement in 250.28(B) specifies that where a screw is used for the main or system bonding jumper, the screw must have a green color that is visible when it is 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 attached in the manner specified by the applicable provisions of 250.8.

**(D) Size** Main bonding jumpers and system bonding jumpers shall not be smaller than the sizes shown in Table 250.66. Where the supply conductors are larger than 1100 kcmil copper or 1750 kcmil aluminum, the bonding jumper shall have an area that is not less than 12½ percent of the area of the largest phase conductor except that, where the phase conductors and the bonding jumper are of different materials (copper or aluminum), the minimum size of the bonding jumper shall be based on the assumed use of phase conductors of the same material as the bonding jumper and with an ampacity equivalent to that of the installed phase conductors.

The minimum size for the main bonding jumper on the supply side of a service and for the system bonding jumper on the supply side of a separately derived system is determined through the use of a table and a calculation that establishes a proportional relationship between the size of the largest ungrounded supply conductor and the minimum conductor size (cross-sectional area) necessary to create an effective ground-fault current return path for short-time high-current conditions.

In a grounded system, the primary function of the main bonding jumper and of the system bonding jumpers is to create the link for ground-fault current between the equipment grounding conductors and the grounded conductor. Table 250.66, Grounding Electrode Conductor for Alternating-Current Systems, has a number of functions in Article 250 in addition to its use for sizing the grounding electrode conductor. It is used in several sections of Article 250 for sizing various supply-side conductors of the grounding and bonding system. Section 250.28(D) refers to Table 250.66 for directly sizing main and system bonding jumpers where the ungrounded conductors do not exceed 1100-kcmil copper or 1750-kcmil aluminum.

Unlike the function of the grounding electrode conductor, which carries current to the ground or to the conducting body that serves as 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. Therefore, where the largest ungrounded supply conductor exceeds the parameters of Table 250.66, it is necessary to maintain a proportional relationship between the ungrounded conductor and the main or system bonding jumper. Grounding electrode conductors are not required to be larger than 3/0 AWG copper or 250-kcmil aluminum conductors, but to establish the minimum size for the main or system bonding jumper for ungrounded conductors exceeding 1100-kcmil copper or 1750-kcmil aluminum, its circular mil area cannot be less than 12½ percent of the circular mil area of the largest ungrounded conductor (for conductors in parallel, the total area of the largest phase set). It should be noted that where a main or system bonding jumper is provided as part of listed equipment, such as is the case with many panelboards and switchboards listed for use as service equipment, it is not necessary to replicate this bonding jumper with another one sized in accordance with 250.28(D).

To apply the bonding jumper requirements, each line-side service equipment enclosure is treated separately, as depicted in Exhibit 250.12. 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 250.66, 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 250.66 using the 500-kcmil ungrounded service conductors.

In addition to the main bonding jumpers for the two disconnecting means enclosures, other conductors shown in Exhibit 250.12 are 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. It should be noted that there are conditions where the grounding electrode conductor is permitted to sized smaller than what is required in the table: see 250.66.

Next, the grounded conductor run to each enclosure in





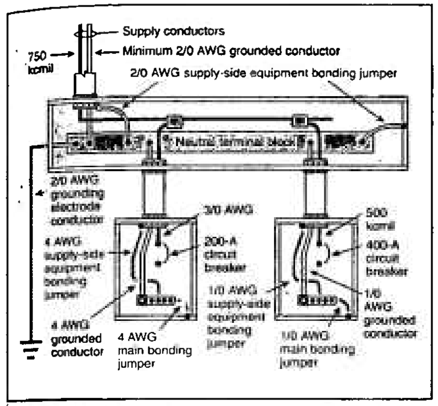



**Exhibit 250.12** An example of the bonding requirements for service equipment.

accordance with 250.24(B) is sized using Table 250.66 as the minimum size permitted. For the grounded conductor, the reference to Table 250.66 is found in 250.24(C)(1). For each enclosure, the minimum size grounded conductor is established based on the largest ungrounded conductor serving that enclosure. The grounded 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 250.66.

Finally, supply-side equipment bonding jumpers are used for the three bonding metal conduits containing service conductors and the metal wireway located above the two service equipment enclosures. These bonding jumpers are also sized from Table 250.66 via a reference from 250.102(C). 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 the wireway itself, the bonding jumper is sized from Table 250.66 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 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 equipment bonding jumpers, respectively.

There are instances, particularly with large capacity services or separately derived systems, where the main or system bonding jumper is required to be larger than the grounding electrode conductor. Section 250.28(D) requires that where the service-entrance conductors are larger than 1100-kcmil copper or 1750-kcmil aluminum, the bonding jumper is to have a cross-sectional area of not less than 12½ percent of the cross-sectional area of the largest phase conductor. For example, if 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 × 500 kcmil = 2000 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.

## 250.30 Grounding Separately Derived Alternating-Current Systems

**(A) Grounded Systems** A separately derived ac system that is grounded shall comply with 250.30(A)(1) through (A)(8). A grounding connection shall not be made to any grounded circuit conductor on the load side of the point of grounding of the separately derived system except as otherwise permitted in this article.

FPN: 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 250.186.*

Section 250.30(A) provides the requirements for bonding and grounding the separately derived systems described in 250.20(D). A *separately derived system* is defined in Article 100 as a premises wiring system in which power is derived from a battery, a solar photovoltaic system, a generator, a transformer, or converter windings. It has no direct electrical connection, including a solidly connected grounded circuit conductor, to supply conductors originating in another system.

The requirements of 250.30 are commonly applied to 480-volt transformers that transform a 480-volt supply to a 208Y/120-volt system for lighting and appliance loads. These requirements provide for a low-impedance path to ground so that line-to-ground faults on circuits supplied by the transformer result in a sufficient amount of current to operate the overcurrent devices. These requirements also apply to generators or systems that are derived from converter windings, although these systems do not have the same wide use as separately derived systems that are derived from transformers.

**(1) System Bonding Jumper** An unspliced system bonding jumper in compliance with 250.28(A) through (D) that is sized based on the derived phase conductors shall be used to connect the equipment grounding conductors of the separately derived system to the grounded conductor. 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.

Where a separately derived system provides a grounded conductor, a system bonding jumper must be installed to connect the equipment grounding conductors to the grounded conductor. Equipment grounding conductors are connected to the grounding electrode system by the grounding electrode conductor. The system bonding jumper is sized according to 250.28(D) and may be located at any point between the source terminals (transformer, generator, etc.) and the first disconnecting means or overcurrent device. See the commentary following 250.28(D) for further information on sizing the system bonding jumper.

*Exception No. 1: For separately derived systems that are dual fed (double ended) in a common enclosure or grouped together in separate enclosures and employing a secondary tie, 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: A system bonding jumper at both the source and the first disconnecting means shall be permitted where doing so does not establish a parallel path for the grounded conductor. Where 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 phase conductors and shall not be smaller than 14 AWG copper or 12 AWG aluminum.*

Section 250.30(A)(1) requires the system bonding jumper to be not smaller than the sizes given in Table 250.66, that is, not smaller than 8 AWG copper. Exception No. 3 to 250.30(A)(1) permits a system bonding jumper for a Class 1, Class 2, or Class 3 circuit to be not smaller than 14 AWG copper or 12 AWG aluminum.

**(2) Equipment Bonding Jumper Size** Where a bonding jumper of the wire type 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 250.102(C), based on the size of the derived phase conductors.

**(3) 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 phase conductors and shall be used to connect the grounded conductor of the derived system to the grounding electrode as specified in 250.30(A)(7). This connection shall be made at the same point on the separately derived system where the system bonding jumper is installed.

*Exception No. 1: Where 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: Where a separately derived system originates in listed equipment suitable 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 the grounding electrode conductor is of sufficient size for the separately derived system. Where the equipment ground 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 (transformer, generator, etc.) and the first





disconnecting means or overcurrent device. The location of the grounding electrode conductor connection to the grounded conductor must be at the same point as where the bonding jumper is connected to the grounded conductor. By establishing a common point of connection, normal neutral current will be carried only on the system grounded conductor. Metal raceways, piping systems, and structural steel must not provide a parallel circuit for neutral current. Exhibits 250.13 and 250.14 illustrate examples of grounding electrode connections for separately derived systems.

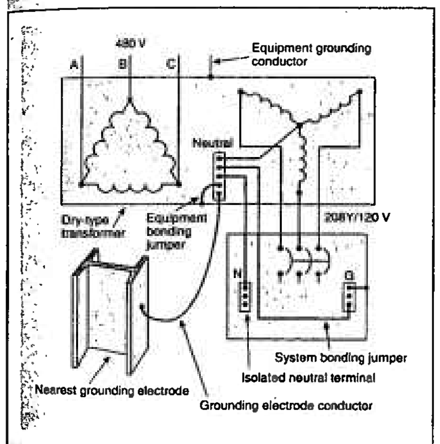



**Exhibit 250.13** A grounding arrangement for a separately derived system in which the grounding electrode conductor connection is made at the transformer.

**(4) Grounding Electrode Conductor, Multiple Separately Derived Systems** Where more than one separately derived system is installed, it shall be permissible to connect a tap from each separately derived system to a common grounding electrode conductor. Each tap conductor shall connect the grounded conductor of the separately derived system to the common grounding electrode conductor. The grounding electrode conductors and taps shall comply with 250.30(A)(4)(a) through (A)(4)(c).

*Exception No. 1: Where 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.*

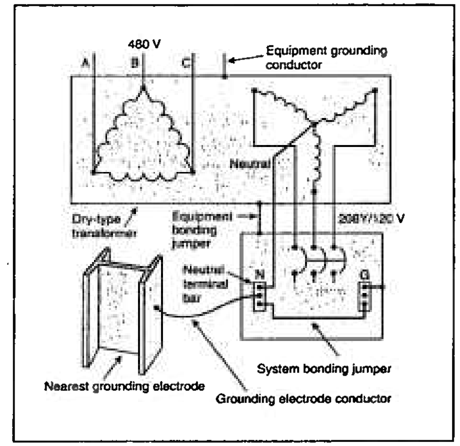



**Exhibit 250.14** A grounding arrangement for a separately derived system in which the grounding electrode conductor connection is made at the first disconnecting means.

*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 Size. The common grounding electrode conductor 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 phase conductors of the separately derived system it serves.

*Exception: Where a separately derived system originates in listed equipment suitable 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 the grounding electrode conductor is o[illegible]fficient size for the separately derived system. Where th[illegible]nt ground bus internal to the equipment is not sn[illegible] required grounding electrode conductor fo[illegible] derived system, the grounding electrode c[illegible] separately derived system shall be perr[illegible] the bus.*

(3) 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 listed connector.
(2) Listed connections to aluminum or copper busbars not less than 6 mm × 50 mm (¼ in. × 2 in.). Where aluminum busbars are used, the installation shall comply with 250.64(A).
(3) By 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.

A common grounding electrode conductor serving several separately derived systems is permitted instead of installing separate individual grounding electrode conductors from each separately derived system to the grounding electrode system. 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 sizing requirement for the common grounding electrode conductor was revised for the 2005 *Code*. So that the grounding electrode conductor always has sufficient size to accommodate the multiple separately derived systems that it serves, the minimum size for this conductor is now 3/0 AWG copper or 250-kcmil aluminum. Note that this new 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)(4)(a), and the sizing requirement for the individual taps to the common grounding electrode conductor is specified in 250.30(A)(4)(b). The rules covering the method of connection of the tap conductor to the common grounding electrode conductor are specified in 250.30(A)(4)(c). The following example, together with Exhibit 250.15, illustrates this new permitted installation method.

### Example

A large post-and-beam loft-type building is being renovated for use as an office building. The building is being furnished with four 45-kVA, 480 to 120/208-volt, 3-phase, 4-wire, wye-connected transformers. Each transformer secondary supplies an adjacent 150-ampere main circuit breaker panelboard using 1/0 AWG, Type THHN copper conductors. The transformers are strategically placed throughout the building to facilitate efficient distribution. Because the building contains no effectively grounded structural steel, each transformer secondary must be grounded to the water service electrode within the first 5 ft of entry into the building. A common grounding electrode conductor has been selected as the method to connect all the transformers to the grounding electrode system.

What is the minimum-size common grounding electrode conductor that must be used to connect the four transformers to the grounding electrode system? What is the minimum-size grounding electrode conductor to connect each of the four transformers to the common grounding electrode conductor?

Solution

STEP 1. Determine the minimum size for the common grounding electrode conductor. In accordance with 250.30(A)(4)(a), the minimum size required is 3/0 copper or 250-kcmil aluminum. No calculation is necessary, and the common grounding electrode conductor does not have to be sized larger than specified by this requirement. Additional transformers installed in the building can be connected to this common grounding electrode conductor, and no increase in its size is required.

STEP 2. Determine the size of each individual grounding electrode tap conductor for each of the separately derived systems. According to Table 250.66, a 1/0 AWG copper derived phase conductor requires a conductor not smaller than 6 AWG copper for each transformer grounding electrode tap conductor. This individual grounding electrode conductor will be used as the permitted tap conductor and will run from the conductor to be grounded of each separately derived system to a connection point located on the common grounding electrode conductor. This conductor is labeled "Conductor B" in Exhibit 250.15.

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

(6) Bonding Structural steel and metal piping shall be bonded in accordance with 250.104(D).

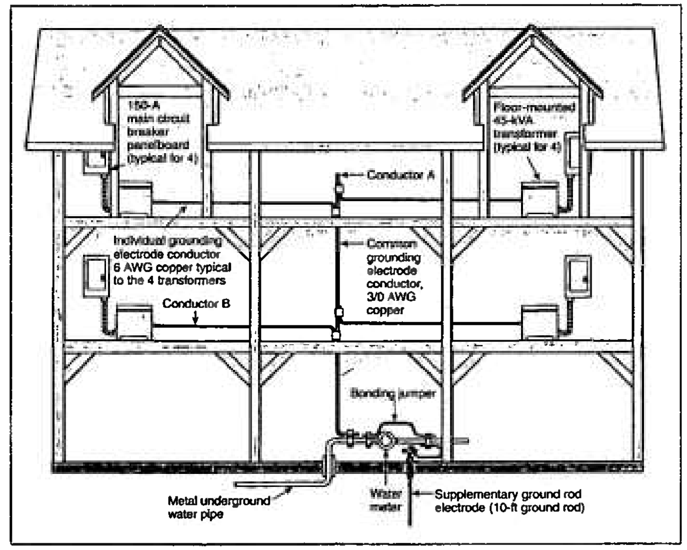
(7) Grounding Electrode The grounding electrode shall be as near as practicable to and preferably in the same area as the grounding electrode conductor connection to the system. The grounding electrode shall be the nearest one of the following:

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





Exhibit 250.15 The grounding arrangement for multiple separately derived systems using taps from a common grounding electrode conductor, according to 250.30(A)(4)(a) and 250.30(A)(4)(b).




(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 where the electrodes specified by 250.30(A)(7) are not available.*

*Exception No. 2 to (1) and (2): Where 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.*

FPN: See 250.104(D) for bonding requirements of interior metal water piping in the area served by separately derived systems.

Section 250.30(A)(7) requires that the grounding electrode be as near as is practicable to the grounding conductor connection to the system to minimize the impedance to ground. If an effectively grounded structural metal member of the building structure or an effectively grounded metal water pipe is available nearby, 250.30(A)(7) requires that it be used as the grounding electrode. For example, where a transformer is installed on the fiftieth floor, the grounding electrode conductor is not required to be run to the service grounding electrode system. However, where an effectively grounded metal water pipe is used as an electrode for a separately derived system, 250.52(A) specifies that only the first 5 ft of water piping entering the building can be used as a grounding electrode. Therefore, the grounding electrode conductor connection to the metal water piping must be made at some point on this first 5 ft of piping.

Concern over the use of nonmetallic piping or fittings is the basis for the "within 5 ft" requirement. Where the piping system is located in an industrial or commercial building and is serviced only by qualified persons and the entire length that will be used as an electrode is exposed, the connection may be made at any point on the piping system.

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)(7) is available. However, 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)(7), but it must be grounded in accordance with the manufacturer's instructions.

Exhibit 250.13 and Exhibit 250.14 are typical wiring diagrams for dry-type transformers supplied from a 480-volt, 3-phase feeder to derive a 208Y/120-volt or 480Y/277-volt secondary. As indicated in 250.30(A)(1), the bonding jumper connection is required to be sized according to 250.28(D). In Exhibit 250.13, this connection is made at the source of the separately derived system, in the transformer enclosure. In Exhibit 250.14, the bonding jumper connection is made at the first disconnecting means. 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 from the secondary grounded circuit conductor is sized according to Table 250.66.

**(8) Grounded Conductor** Where a grounded conductor is installed and the system bonding jumper is not located at the source of the separately derived system, 250.30(A)(8)(a), (A)(8)(b), and (A)(8)(c) shall apply.

(a) Routing and Sizing. This conductor shall be routed with the derived phase conductors and shall not be smaller than the required grounding electrode conductor specified in Table 250.66 but shall not be required to be larger than the largest ungrounded derived phase conductor. In addition, for phase conductors larger than 1100 kcmil copper or 1750 kcmil aluminum, the grounded conductor shall not be smaller than 12½percent of the area of the largest derived phase conductor. The grounded conductor of a 3-phase, 3-wire delta system shall have an ampacity not less than that of the ungrounded conductors.

(b) Parallel Conductors. Where the derived phase conductors are installed in parallel, the size of the grounded conductor shall be based on the total circular mil area of the parallel conductors, as indicated in this section. Where installed in two or more raceways, the size of the grounded conductor in each raceway shall be based on the size of the ungrounded conductors in the raceway but not smaller than 1/0 AWG.

FPN: See 310.4 for grounded conductors connected in parallel.

(c) Impedance Grounded System. The grounded conductor of an impedance grounded neutral system shall be installed in accordance with 250.36 or 250.186.

**(B) Ungrounded Systems** The equipment of an ungrounded separately derived system shall be grounded as specified in 250.30(B)(1) and (B)(2).

**(1) Grounding Electrode Conductor** A grounding electrode conductor, sized in accordance with 250.66 for the derived phase conductors, shall be used to connect the metal enclosures of the derived system to the grounding electrode, as specified in 250.30(B)(2). This connection shall be made at any point on the separately derived system from the source to the first system disconnecting means.

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 equipment grounding conductors 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)(7).

## 250.32 Buildings or Structures Supplied by 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 or grounding electrode system installed in accordance with 250.50. The grounding electrode conductor(s) shall be connected in accordance with 250.32(B) or (C). Where there is no existing grounding electrode, the grounding electrode(s) required in 250.50 shall be installed.

Where a building or structure is supplied by a feeder, 250.32(A) requires that a grounding electrode system be established at each building or structure supplied, unless one already exists. The equipment grounding bus must be bonded to the grounding electrode system, and the disconnecting means enclosure, building steel, and interior metal water piping are also required to be bonded to the grounding electrode system. All exposed non–current-carrying metal parts of electrical equipment are required to be grounded through equipment grounding conductor connections to the equipment grounding bus at the building disconnecting means. The connection of the grounded (neutral) conductor to the grounding electrode system, as shown in Exhibit 250.16, is permitted only where it can be ensured that such a connection does not establish a parallel circuit path for normal neutral current on equipment grounding conductors, metal shields of cables not intended to be used as a current-carrying conductor, metal piping systems, or other metal structures that are continuous between buildings.





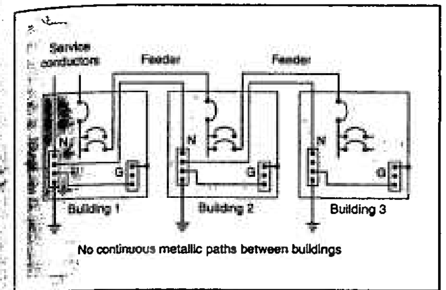



**Exhibit 250.16** Example of grounding electrode systems required at feeder-supplied Building 2 and Building 3, in accordance with 250.32(A).

*Exception: A grounding electrode shall not be required where only a single branch circuit supplies the building or structure and the branch circuit includes an equipment grounding conductor for grounding the conductive non–current-carrying parts of equipment. For the purpose of this section, a multiwire branch circuit shall be considered as a single branch circuit.*

Where a building is supplied by a single branch circuit (2-wire or multiwire) and is installed in or has a wire-type equipment grounding conductor, as covered in 250.118, it is not required to establish a grounding electrode system or connect to an existing one. Where the installation occurs at other than a dwelling unit, the disconnecting means at the remote building is required to be suitable for service equipment in accordance with 225.36. See Exhibit 250.17 for an example of this provision.

**(B) Grounded Systems** For a grounded system at the separate building or structure, the connection to the grounding electrode and grounding or bonding of equipment, structures, or frames required to be grounded or bonded shall comply with either 250.32(B)(1) or (B)(2).

**(1) Equipment Grounding Conductor** An equipment grounding conductor as described in 250.118 shall be run with the supply conductors and connected to the building or structure disconnecting means and to the grounding electrode(s). The equipment grounding conductor shall be used for grounding or bonding of equipment, structures, or frames required to be grounded or bonded. The equipment grounding conductor shall be sized in accordance with 250.122. Any installed grounded conductor shall not be connected to the equipment grounding conductor or to the grounding electrode(s).

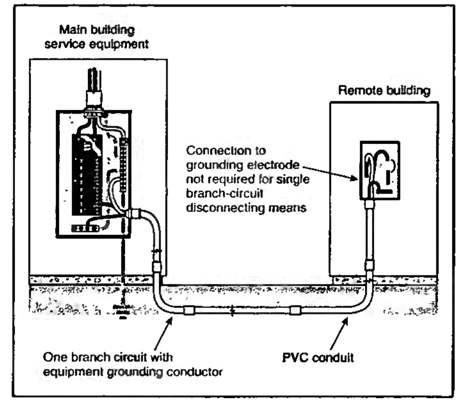



**Exhibit 250.17** An installation where a connection from the single branch-circuit disconnecting means enclosure to a grounding electrode system is not required at the remote building because an equipment grounding conductor is installed with the circuit conductors.

Where a feeder supplies a building and an equipment grounding conductor is run with or encloses the feeder, the grounded conductor (neutral) is not permitted to be connected to the equipment grounding conductor or to the grounding electrode system, as illustrated in Exhibit 250.18.

**(2) Grounded Conductor** Where (1) an equipment grounding conductor is not run with the supply to the building or structure, (2) there are no continuous metallic paths bonded to the grounding system in each building or structure involved, and (3) ground-fault protection of equipment has not been installed on the supply side of the feeder(s), the grounded conductor run with the supply to the building or structure shall be connected to the building or structure disconnecting means and to the grounding electrode(s) and shall be used for grounding or bonding of equipment, structures, or frames required to be grounded or bonded. The size of the grounded conductor shall not be smaller than the larger of either of the following:

(1) That required by 220.61
(2) That required by 250.122

Similar to the provisions of 250.30(A)(3), the requirement in 250.32(B)(2) eliminates the creation of parallel paths for normal neutral current on grounding conductors, metal raceways, metal piping, and other metal structures. In the

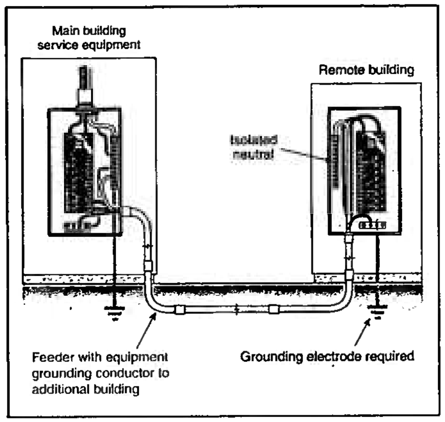



Exhibit 250.18 An installation in which connection between the grounded conductor (neutral) and equipment grounding terminal bar is not allowed. A connection from the equipment grounding terminal bus to the grounding electrode is required.

1999 and previous editions of the *Code*, the grounding electrode conductor and equipment grounding conductors were permitted to be connected to the grounded conductor at a separate building or structure. This multiple-location grounding arrangement could provide parallel paths for neutral current along the electrical system and along other continuous metallic piping and mechanical systems as well. Connection of the grounded conductor to a grounding electrode system at a separate building or structure is permitted only if these parallel paths are not created and if there is no common ground-fault protection of equipment provided at the service where the feeder or branch circuit originates.

Where the grounded conductor is used as part of the ground-fault current return circuit, it is required to be sized no less than that required by 250.122 for equipment grounding conductors, but it also has to be sized to carry the maximum unbalanced load, as specified in 220.61.

Like the grounded service conductor, a branch-circuit or feeder grounded conductor used in the application permitted by 250.32(B)(2) is a circuit conductor for normal neutral current and is also the circuit conductor used to create an effective ground-fault current return path. Therefore, it is necessary to size the grounded conductor in this application based on which of those two functions requires the larger conductor. Of course there is no prohibition on installing a full-size grounded (neutral) conductor, thus ensuring compliance with both 250.122 and 220.61.

**(C) Ungrounded Systems** The grounding electrode(s) shall be connected to the building or structure disconnecting means.

**(D) Disconnecting Means Located in Separate Building or Structure on the Same Premises** Where one or more disconnecting means supply one or more additional buildings or structures under single management, and where these disconnecting means are located remote from those buildings or structures in accordance with the provisions of 225.32, Exception Nos. 1 and 2, all of the following conditions shall be met:

(1) The connection of the grounded conductor to the grounding electrode at a separate building or structure shall not be made.
(2) An equipment grounding conductor for grounding any non–current-carrying equipment, interior metal piping systems, and building or structural metal frames is run with the circuit conductors to a separate building or structure and bonded to existing grounding electrode(s) required in Part III of this article, or, where there are no existing electrodes, the grounding electrode(s) required in Part III of this article shall be installed where a separate building or structure is supplied by more than one branch circuit.
(3) Bonding the equipment grounding conductor to the grounding electrode at a separate building or structure shall be made in a junction box, panelboard, or similar enclosure located immediately inside or outside the separate building or structure.

Exhibit 250.19 illustrates an installation in which the disconnect for Building 2 is located in Building 1. Section 250.32(D) applies to separate buildings or structures that do not have a disconnect, as permitted by Exception No. 1 and Exception No. 2 to 225.32. The feeder conductors must terminate in a panelboard, junction box, or similar enclosure that is located immediate to the point the supply conductors enter the building or structure inside or outside the building.

An equipment grounding conductor must be run with the feeder conductors, the grounded conductor must not be bonded to the enclosure or equipment grounding bus, and the equipment grounding bus must be connected to a new or existing grounding electrode system at the second building. All non–current-carrying metal parts of equipment, building steel, and interior metal piping systems must be connected to the grounding electrode system.

**(E) Grounding Electrode Conductor** The size of the grounding electrode conductor to the grounding electrode(s) shall not be smaller than given in 250.66, based on the largest ungrounded supply conductor. The installation shall comply with Part III of this article.

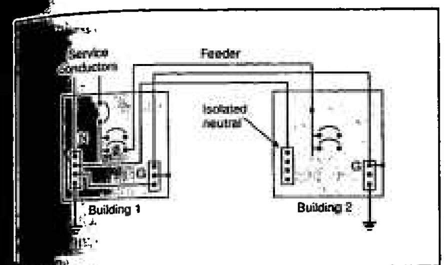



Exhibit 250.19 Grounding and bonding requirements for a separate building under single management with the disconnect remotely located from the building.

A grounding electrode system is connected to the grounded conductor and/or the equipment enclosures by the grounding electrode conductor (see definition in Article 100) according to 250.24 for services, to 250.30 for separately derived systems, and to 250.32 for two or more buildings supplied from a common service. Each of these sections directs the user to the same general requirements; that is, the grounding electrode conductor must comply with Part III of Article 250. A revision to the 2002 *Code* clarified that where a feeder or branch circuit supplies a building or structure, the conductor used to connect the equipment grounding conductor and, as permitted by 250.32(B)(2), the grounded conductor to the grounding electrode system is a grounding electrode conductor and must be sized in accordance with 250.66.

## 250.34 Portable and Vehicle-Mounted Generators

**(A) Portable Generators** The frame of a portable generator shall not be required to be connected to a grounding electrode as defined in 250.52 for a system supplied by the generator under the following conditions:

(1) The generator supplies only equipment mounted on the generator, cord-and-plug-connected equipment through receptacles mounted on the generator, or both, and
(2) The non–current-carrying metal parts of equipment and the equipment grounding conductor terminals of the receptacles are bonded to the generator frame.

*Portable* describes equipment that is easily carried by personnel from one location to another. *Mobile* describes equipment, such as vehicle-mounted generators, that is capable of being moved on wheels or rollers.

The frame of a portable generator is not required to be connected to earth (ground rod, water pipe, etc.) if the generator has receptacles mounted on the generator panel and the receptacles have equipment grounding terminals bonded to the generator frame.

**(B) Vehicle-Mounted Generators** The frame of a vehicle shall not be required to be connected to a grounding electrode as defined in 250.52 for a system supplied by a generator located on this vehicle under the following conditions:

(1) The frame of the generator is bonded to the vehicle frame, and
(2) The generator supplies only equipment located on the vehicle or cord-and-plug-connected equipment through receptacles mounted on the vehicle, or both equipment located on the vehicle and cord-and-plug-connected equipment through receptacles mounted on the vehicle or on the generator, and
(3) The non–current-carrying metal parts of equipment and the equipment grounding conductor terminals of the receptacles are bonded to the generator frame.

Vehicle-mounted generators that provide a neutral conductor and are installed as separately derived systems supplying equipment and receptacles on the vehicle are required to have the neutral conductor bonded to the generator frame and to the vehicle frame. The non-current-carrying parts of the equipment must be bonded to the generator frame.

**(C) Grounded Conductor Bonding** A system conductor that is required to be grounded by 250.26 shall be bonded to the generator frame where the generator is a component of a separately derived system.

FPN: For grounding portable generators supplying fixed wiring systems, see 250.20(D).

Portable and vehicle-mounted generators that are installed as separately derived systems and that provide a neutral conductor (such as 3-phase, 4-wire wye connected; single-phase 240/120 volt; or 3-phase, 4-wire delta connected) are required to have the neutral conductor bonded to the generator frame.

## 250.36 High-Impedance Grounded Neutral Systems

High-impedance grounded neutral systems in which a grounding impedance, usually a resistor, limits the ground-fault current to a low value shall be permitted for 3-phase ac systems of 480 volts to 1000 volts where all the following conditions are met:

(1) The conditions of maintenance and supervision ensure that only qualified persons service the installation.
(2) Continuity of power is required.
(3) Ground detectors are installed on the system.
(4) Line-to-neutral loads are not served.

Section 250.36 covers high-impedance grounded neutral systems of 480 to 1000 volts. Systems rated over 1000 volts are covered in 250.186. For information on the differences between solidly grounded systems and high-impedance grounded neutral systems, see "Grounding for Emergency and Standby Power Systems," by Robert B. West, *IEEE Transactions on Industry Applications*, Vol. IA-15, No. 2, March/April 1979.

As the schematic diagram in Exhibit 250.20 shows, a high-impedance grounded neutral system is designed to minimize the amount of fault current during a ground fault. The grounding impedance is usually selected to limit fault current to a value that is slightly greater than or equal to the capacitive charging current. This system is used where continuity of power is required. Therefore, a ground fault results in an alarm condition rather than in the tripping of a circuit breaker, which allows a safe and orderly shutdown of a process in which a non-orderly shutdown can introduce additional or increased hazards.

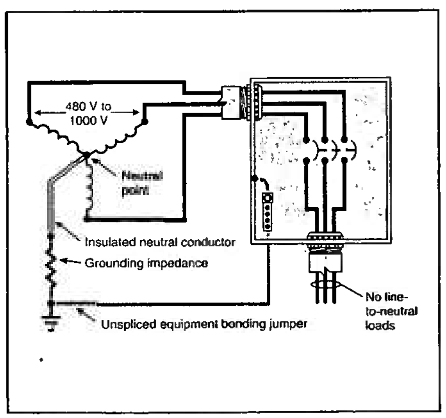



**Exhibit 250.20** Schematic diagram of a high-impedance grounded neutral system.

High-impedance grounded neutral systems shall comply with the provisions of 250.36(A) through (G).

**(A) Grounding Impedance Location** The grounding impedance shall be installed between the grounding electrode conductor and the system neutral. Where a neutral is not available, the grounding impedance shall be installed between the grounding electrode conductor and the neutral derived from a grounding transformer.

**(B) Neutral Conductor** The neutral conductor from the neutral point of the transformer or generator to its connection point to the grounding impedance shall be fully insulated.

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

The current through the neutral conductor is limited by the grounding impedance. Therefore, the neutral conductor is not required to be sized to carry high-fault current. The neutral conductor cannot be smaller than 8 AWG copper or 6 AWG aluminum.

**(C) System Neutral Connection** The system neutral conductor shall not be connected to ground except through the grounding impedance.

FPN: 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 142-1991, *Recommended Practice for Grounding of Industrial and Commercial Power Systems.*

Additional information can be found in "Charging Current Data for Guesswork-Free Design of High-Resistance Grounded Systems," by D. S. Baker, *IEEE Transactions on Industry Applications*, Vol. IA-15, No. 2, March/April 1979, and "High-Resistance Grounding," by Baldwin Bridger, Jr., *IEEE Transactions on Industry Applications*, Vol. IA-19, No. 1, January/February 1983.

**(D) Neutral 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. 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 Location** The grounding electrode conductor shall be attached at any point from the grounded side of the grounding impedance to the equipment grounding connection at the service equipment or first system disconnecting means.

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

(1) Where 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) Where 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)(6) 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)(7) shall be installed and used.

Section 250.50 introduces the important concept of a "grounding electrode system," in which all electrodes are bonded together, as illustrated in Exhibit 250.21. Rather than total reliance on a single grounding electrode to perform its function over the life of the electrical installation, the *NEC* encourages the formation of a system of electrodes "that are present at each building or structure served." There is no doubt that building a system of electrodes adds a level of reliability and helps ensure system performance over a long period of time.

This section was revised for the 2005 *Code* to clearly require the inclusion of a concrete-encased electrode, described in 250.52(A)(3), in the grounding electrode system for buildings or structures having a concrete footing or foundation with not less than 20 ft of surface area in direct contact with the earth. This requirement applies to all buildings and structures with a foundation and/or footing having 20 ft or more of ½ in. or greater electrically conductive reinforcing steel or 20 ft or more of bare copper not smaller than 4 AWG. However, an exception does exempt existing buildings and structures where access to the concrete-encased electrode would involve some type of demolition or similar activity that would disturb the existing construction. Because the installation of the footings and foundation is one of the first elements of a construction project and in most cases has long been completed by the time the electric service is installed, this revised text necessitates an awareness and coordinated effort on the part of designers and the construction trades in making sure that the concrete-encased electrode is incorporated into the grounding electrode system.

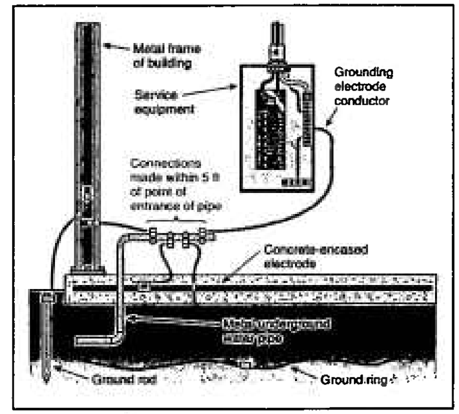



**Exhibit 250.21** A grounding electrode system that uses the metal frame of a building, a ground ring, a concrete-encased electrode, a metal underground water pipe, and a ground rod.

*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.*

### 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 effectively 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 conductors. Interior metal water piping located more than 1.52 m (5 ft) from the point of entrance to the building shall not be used as a part of the grounding electrode system or as a conductor to interconnect electrodes that are part of the grounding electrode system.

*Exception: In industrial and commercial buildings or structures where 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 part of the grounding electrode system or as a conductor to interconnect electrodes that are part of the grounding electrode system, provided that the entire length, other than short sections passing perpendicular through walls, floors, or ceilings, of the interior metal water pipe that is being used for the conductor is exposed.*

The effectiveness of underground water piping as a grounding electrode for electrical systems has long been recognized, but 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).

The National Institute of Standards and Technology (NIST) has monitored the electrolysis of metal systems, because current at a grounding electrode on dc systems can cause displacement of metal. The results of this monitoring have shown that problems are minimal.

The last sentence of 250.52(A)(1) prohibits the use of that portion of the interior metal water piping system that extends more than 5 ft beyond the point of entrance into the building to interconnect grounding electrodes and the grounding electrode conductor, because there are concerns over the use of nonmetallic piping or fittings causing an interruption in the interior electrical continuity of the metal water piping. The exception to 250.52(A)(1), however, permits this practice, provided there is qualified maintenance and the entire length of the water piping used as an electrode is exposed. This 5-ft limit also applies to the replacement of nongrounding receptacles with grounding-type or branch-circuit extensions in accordance with 250.130(C). See the commentary following 250.130(C) and the illustration that accompanies that commentary, Exhibit 250.49.

**(2) Metal Frame of the Building or Structure** The metal frame of the building or structure, where any of the following methods are used to make an earth connection:

(1) 3.0 m (10 ft) or more of a single structural metal member in direct contact with the earth or encased in concrete that is in direct contact with the earth
(2) The structural metal frame is bonded to one or more of the grounding electrodes as defined in 250.52(A)(1), (A)(3), or (A)(4)
(3) The structural metal frame is bonded to one or more of the grounding electrodes as defined in 250.52(A)(5) or (A)(6) that comply with 250.56, or
(4) Other approved means of establishing a connection to earth.

The 2005 *NEC* revision to 250.52(A)(2) provides four means by which the metal frame of a building or structure can be judged suitable for use as a grounding electrode. This revision defines what is considered to be effectively grounded as applied to the metal frame of a building. The metal frame of the building can be considered an electrode through 10 ft of direct contact with the earth or through connection to one of the electrode types described in 250.52(A)(1), 250.52(A)(3), or 250.52(A)(4) or through connection to rod or plate type electrodes that comply with the requirements of 250.56. If building steel is grounded through a connection to an underground metal water pipe, replacement of the water pipe with nonmetallic piping will result in the building steel no longer being "effectively grounded."

**(3) Concrete-Encased Electrode** An electrode encased by at least 50 mm (2 in.) of concrete, located within and near the bottom of a concrete foundation or footing that is in direct contact with the earth, consisting of at least 6.0 m (20 ft) of 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, or consisting of at least 6.0 m (20 ft) of bare copper conductor not smaller than 4 AWG. Reinforcing bars shall be permitted to be bonded together by the usual steel tie wires or other effective means.

Exhibit 250.22 shows an example of a concrete-encased electrode.

**(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 2.5 m (8 ft) in length and shall consist of the following materials.

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





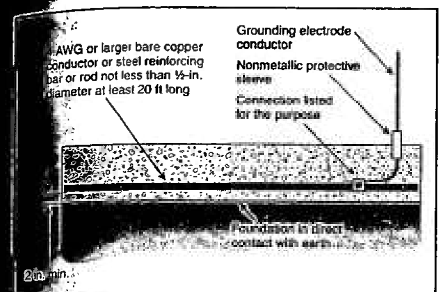


Exhibit 250.22 A concrete-encased electrode.

(b) Electrodes of rods of iron or steel shall be at least 15.87 mm (⅝ in.) in diameter. Stainless steel rods less than 16 mm (⅝ in.) in diameter, nonferrous rods, or their equivalent shall be listed and shall not be less than 13 mm (½ in.) in diameter.

**(6) Plate Electrodes** Each plate electrode shall expose not less than 0.186 $m^2$ (2 $ft^2$) of surface to exterior soil. Electrodes of iron or steel plates shall be at least 6.4 mm (¼ in.) in thickness. Electrodes of nonferrous metal shall be at least 1.5 mm (0.06 in.) in thickness.

**(7) 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 effectively bonded to a metal water pipe.

**(B) Electrodes Not Permitted for Grounding** The following shall not be used as grounding electrodes:

(1) Metal underground gas piping system
(2) Aluminum electrodes

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

## 250.53 Grounding Electrode System Installation

FPN: See 547.9 and 547.10 for special grounding and bonding requirements for agricultural buildings.

**(A) Rod, Pipe, and Plate Electrodes** Where 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.

**(B) Electrode Spacing** Where more than one of the electrodes of the type specified in 250.52(A)(5) or (A)(6) are used, each electrode of one grounding system (including that used for air terminals) 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 effectively 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** Where 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)(7). Where the supplemental electrode is a rod, pipe, or plate type, it shall comply with 250.56. The supplemental electrode shall be permitted to be bonded to the grounding electrode conductor, the grounded service-entrance conductor, the nonflexible grounded service raceway, or any grounded service enclosure.

*Exception: The supplemental electrode shall be permitted to be bonded to the interior metal water piping at any convenient point as covered in 250.52(A)(1), Exception.*

Section 250.53(D)(2) specifically requires that rod, pipe, or plate electrodes used to supplement metal water piping be installed in accordance with 250.56. This requirement clarifies that the supplemental electrode system must be installed as if it were the sole grounding electrode for the system. If 25 ohms or less of earth resistance cannot be achieved with one rod, pipe, or plate, another electrode (other than the metal piping that is being supplemented) must be provided. One of the permitted methods of bonding a supplemental grounding electrode conductor to the primary electrode system is to connect it to the service enclosure.

The requirement to supplement the metal water pipe is based on the practice of using a plastic pipe for replacement when the original metal water pipe fails. This type of replacement 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 250.52(A)(6) 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 for ground rod or pipe or for plate electrodes between the service equipment and the electrodes 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.

All rod and pipe electrodes must have at least 8 ft of length in contact with the soil, regardless of rock bottom. Where rock bottom is encountered, the electrodes must either be driven at not more than a 45-degree angle or buried in a 2½-ft-deep trench. It should be noted that driving the rod at an angle is permitted only if it is not possible to drive the rod vertically to obtain at least 8 ft of earth contact. Burying the ground rod is permitted only if it is not possible to drive the rod vertically or at an angle.

Ground clamps used on buried electrodes must be listed for direct earth burial. Ground clamps installed aboveground must be protected where subject to physical damage. Exhibit 250.23 illustrates these requirements.

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

## 250.54 Supplementary Grounding Electrodes

Supplementary 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 250.56, 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).

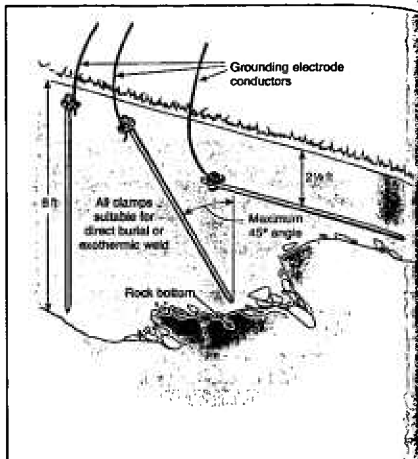



**Exhibit 250.23** Installation requirements for rod and pipe electrodes as specified by 250.53(G).

Grounding electrodes, such as ground rods, that are connected to equipment are not permitted to be used in lieu of the equipment grounding conductor, but they may be used for supplementary protection 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. Sections 250.4(A)(5) and 250.4(B)(4) also specify that the earth not be used as the sole equipment grounding conductor or effective (ground) fault current path. Supplementary grounding electrodes are not required to be incorporated into the grounding electrode system for the service or other source of electric supply.

## 250.56 Resistance of Rod, Pipe, and Plate Electrodes

A single electrode consisting of a rod, pipe, or plate that does not have a resistance to ground of 25 ohms or less shall be augmented by one additional electrode of any of the types specified by 250.52(A)(2) through (A)(7). Where 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.

FPN: The paralleling efficiency of rods longer than 2.5 m (8 ft) is improved by spacing greater than 1.8 m (6 ft).

A supplemental rod, pipe, or plate electrode must be spaced at least 6 ft from any other rod, pipe, and plate electrode. See Exhibit 250.24.

The resistance to ground of a driven grounding electrode can be measured by a ground tester used in the manner shown in Exhibit 250.25.

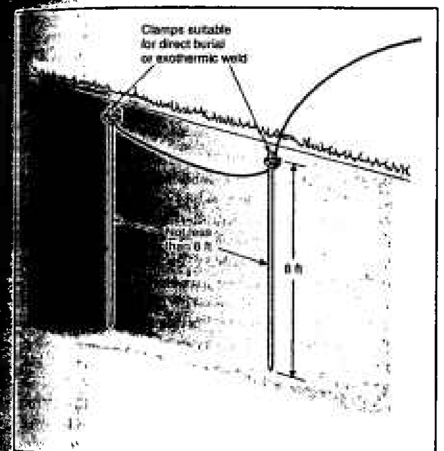



**Exhibit 250.24** The 6-ft spacing between electrodes required by 250.53(B) and 250.56.

## 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 effectively bonded together shall be considered as a single grounding electrode system in this sense.

## 250.60 Use of Air Terminals

Air terminal conductors and driven pipes, rods, or plate electrodes used for grounding air terminals 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.

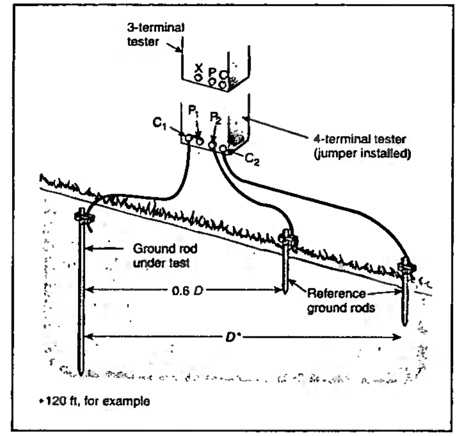



**Exhibit 250.25** The resistance to ground of a ground rod being measured by a ground tester.

FPN No. 1: See 250.106 for spacing from air terminals. See 800.100(D), 810.21(J), and 820.100(D) for bonding of electrodes.

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

## 250.62 Grounding Electrode Conductor Material

The grounding electrode conductor shall be of copper, aluminum, or copper-clad aluminum. The material selected shall be resistant to any corrosive condition existing at the installation or shall be suitably protected against corrosion. The conductor shall be solid or stranded, insulated, covered, or bare.

## 250.64 Grounding Electrode Conductor Installation

Grounding electrode conductors shall be installed as specified in 250.64(A) through (F).

**(A) Aluminum or Copper-Clad Aluminum Conductors** Bare aluminum or copper-clad aluminum grounding conductors shall not be used where in direct contact with masonry or the earth or where subject to corrosive conditions. Where used outside, aluminum or copper-clad aluminum grounding conductors shall not be terminated within 450 mm (18 in.) of the earth.

**(B) Securing and Protection Against Physical Damage** Where exposed, a grounding electrode conductor or its enclosure shall be securely fastened to the surface on which it is carried. A 4 AWG or larger copper or aluminum grounding electrode conductor shall be protected where exposed to physical damage. A 6 AWG grounding electrode conductor that is free from exposure to physical damage shall be permitted to be run along the surface of the building construction without metal covering or protection where it is securely fastened to the construction; otherwise, it shall be in rigid metal conduit, intermediate metal conduit, rigid nonmetallic conduit, electrical metallic tubing, or cable armor. Grounding electrode conductors smaller than 6 AWG shall be in rigid metal conduit, intermediate metal conduit, rigid nonmetallic conduit, electrical metallic tubing, or cable armor.

See 250.64(E) for additional information on situations in which raceways enclose the grounding electrode conductor. Also see the commentary following 250.92(A)(3) and the illustration that accompanies that commentary, Exhibit 250.32, for installation requirements for metal raceways used to install and physically protect the grounding electrode conductor(s).

**(C) Continuous** Grounding electrode conductor(s) shall be installed in one continuous length without a splice or joint except as permitted in (1) through (4):

(1) Splicing shall be permitted only by irreversible compression-type connectors listed as grounding and bonding equipment or by the exothermic welding process.
(2) Sections of busbars shall be permitted to be connected together to form a grounding electrode conductor.
(3) Bonding jumper(s) from grounding electrode(s) and grounding electrode conductor(s) shall be permitted to be connected to an aluminum or copper busbar not less than 6 mm × 50 mm (¼ in. × 2 in.). The busbar shall be securely fastened and shall be installed in an accessible location. Connections shall be made by a listed connector or by the exothermic welding process.
(4) Where aluminum busbars are used, the installation shall comply with 250.64(A).

Although an infrequent occurrence, there are conditions under which it may be necessary to splice the grounding electrode conductor, such as in the case of a remodeling project within a building or the replacement of existing electrical equipment. Section 250.64(C) permits splicing a wire-type grounding electrode conductor with irreversible compression-type fittings specifically listed as grounding equipment or by exothermic welding. These methods create connections that are equated to have the same permanency as an unspliced conductor. This section also recognizes the normal bolted connections between sections of busbar that are joined to form the grounding electrode conductor.

A new method for connecting sections of the grounding electrode conductor is recognized in the 2005 *Code*. A securely fastened section of copper or aluminum busbar, not less than ¼ in. thick by 2 in. wide (the length can be whatever is necessary to make the connections), is permitted as a connection point for multiple grounding electrode conductors or for bonding jumpers that are used to bond multiple grounding electrodes together. The connection of the wire to the busbar must be via an exothermic weld or by a listed connector that is attached to the busbar using the typical bolted connection.

**(D) Grounding Electrode Conductor Taps** Where a service consists of more than a single enclosure as permitted in 230.71(A), it shall be permitted to connect taps to the common grounding electrode conductor. Each such tap conductor shall extend to the inside of each such enclosure. The common grounding electrode conductor shall be sized in accordance with 250.66, based on the sum of the circular mil area of the largest ungrounded service entrance conductors. Where more than one set of service entrance conductors as permitted by 230.40, Exception No. 2 connect directly to a service drop or lateral, the common grounding electrode conductor shall be sized in accordance with Table 250.66 Note 1. The tap conductors shall be permitted to be sized in accordance with the grounding electrode conductors specified in 250.66 for the largest conductor serving the respective enclosures. The 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.

Grounding electrode (tap) conductors must be sized using Table 250.66 and are based on the size of the largest phase conductor serving each service disconnecting means enclosure. The main grounding electrode conductor from which the taps are made is sized from Table 250.66 based on the sum of the cross-sectional areas of the largest ungrounded service-entrance conductors or equivalent cross-sectional area for parallel conductors that supply the multiple service disconnecting means. As illustrated in Exhibit 250.26, the tap method eliminates the difficulties found in looping grounding electrode conductors from one enclosure to another. The 2 AWG grounding electrode conductor (based on the 350-kcmil ungrounded conductor) shown in Exhibit 250.26 is required to be installed without a splice or joint, except as permitted in 250.64(C), and the 8 AWG and 4 AWG taps are sized from Table 250.66 based on the size of the ungrounded conductor serving the respective service disconnecting means.





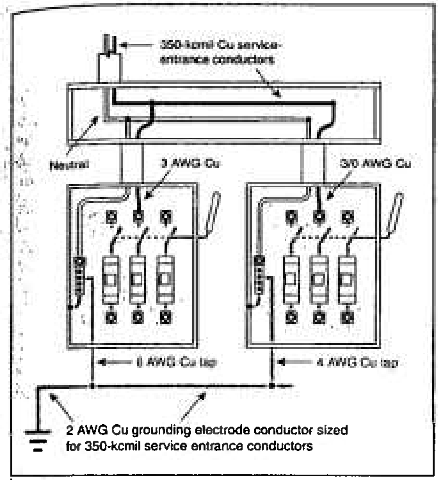



Exhibit 250.26 The tap method of connecting grounding electrode conductors from one enclosure to another.

**(E) Enclosures for Grounding Electrode Conductors** Ferrous metal enclosures for grounding electrode conductors shall be 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. Nonferrous metal enclosures shall not be required to be electrically continuous. Ferrous metal enclosures that are not physically continuous from cabinets or equipment to the grounding electrode shall be made electrically continuous by bonding each end of the raceway or enclosure to the grounding electrode conductor. Bonding shall apply at each end and to all intervening ferrous raceways, boxes, and enclosures between the service equipment and the grounding electrode. The bonding jumper for a grounding electrode conductor raceway or cable armor shall be the same size as, or larger than, the required enclosed grounding electrode conductor. Where a raceway is used as protection for a grounding electrode conductor, the installation shall comply with the requirements of the appropriate raceway article.

Bonding jumpers installed to ensure the electrical continuity of ferrous metal enclosures must be sized in accordance with 250.102(C). Exhibit 250.32, which appears in the commentary following 250.92(A)(3), shows the bonding of a ferrous metal raceway to a grounding electrode conductor at both ends to ensure that the raceway and conductor are in parallel.

**(F) To Electrode(s)** A grounding electrode conductor shall be permitted to be run to any convenient grounding electrode available in the grounding electrode system, or to one or more grounding electrode(s) individually, or to the aluminum or copper busbar as permitted in 250.64(C). The grounding electrode conductor shall be sized for the largest grounding electrode conductor required among all the electrodes connected to it.

Exhibit 250.27 shows an example of a grounding electrode system. The single grounding electrode conductor is permitted to run "to any convenient grounding electrode available," and the other electrodes are connected together using bonding jumpers sized in accordance with 250.66. For the 2005 *Code*, a permitted alternative to running the grounding

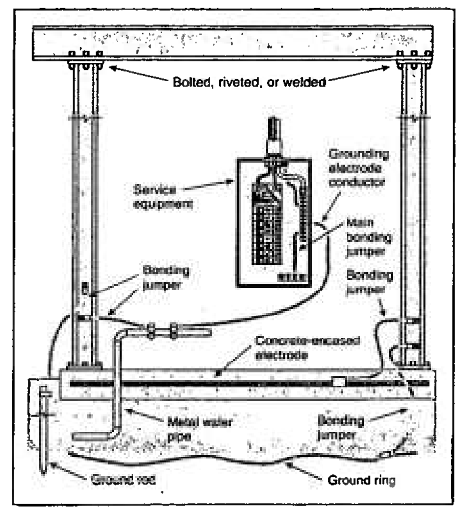



Exhibit 250.27 An example of running the grounding electrode conductor to any convenient electrode available as well as bonding electrodes together to form the grounding electrode system required by 250.50.

electrode conductor to an electrode is to run it to a busbar used as a connection point for bonding jumpers from multiple electrodes that form the grounding electrode system. See the commentary on 250.64(C) for more information on this method.

### 250.66 Size of Alternating-Current Grounding Electrode Conductor

The size of the grounding electrode conductor 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).

FPN: See 250.24(C) for size of ac system conductor brought to service equipment.

**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. Where multiple sets of service-entrance conductors are used as permitted in 230.40, Exception No. 2, 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).

Example

Apply the sizing requirements in Table 250.66 to Exhibit 250.28 to determine the size of the grounding electrode conductor.

Solution

STEP 1. Using Table 8 in Chapter 9, calculate the total circular mil area of both grounded service conductors.

3 AWG = 52,620 circular mils
3/0 AWG = 167,800 mills
Total area = 220,420 circular mils

From Table 8, the next larger standard size is 250 kcmil.

STEP 2. Use Table 250.66 to size the grounding electrode conductor. According to the fourth row, "Over 3/0 through 350," the size should be 2 AWG copper or 1/0 AWG aluminum.

Note that the taps to the grounding electrode conductor from each service disconnecting means enclosure in Exhibit 250.28 are sized from Table 250.66 based on the size of the service-entrance conductors supplying the enclosures.

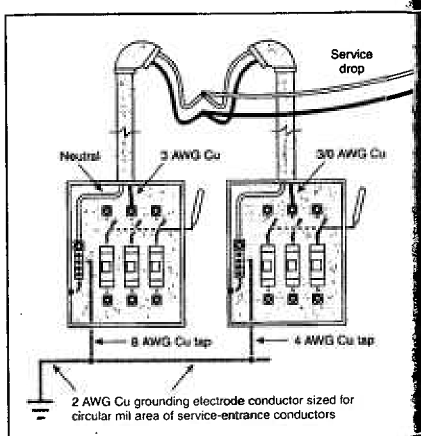



**Exhibit 250.28** A grounding electrode conductor with multiple sets of service conductors, sized according to Table 250.66, Note 1.

**(A) Connections to Rod, Pipe, or Plate Electrodes** Where the grounding electrode conductor is connected to rod, pipe, or plate electrodes as permitted in 250.52(A)(5) or (A)(6), that portion of the conductor that is the sole connection to the grounding electrode 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 concrete-encased electrode as permitted in 250.52(A)(3), that portion of the conductor that is the sole connection to the grounding electrode 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.

As illustrated in Exhibit 250.29, where a grounding electrode conductor is run from the service equipment or separately derived system to a water pipe or structural metal building member and from that point to one of the electrodes mentioned in 250.66(A), that portion of the grounding electrode between the service equipment or separately derived system and the water pipe or structural metal building member must be a full-size conductor, per Table 250.66. If the grounding electrode conductor from the service equipment was run, for example, to the ground rod first and then to the water pipe, the conductor to the ground rod would also have to be full size, per Table 250.66. Note that Exhibit 250.29 is not intended to show the physical routing and connection of the bonding jumpers. The sizes for the bonding jumpers to the ground rod and the concrete-encased electrode shown in Exhibit 250.29 are the maximum sizes required by the *Code*. The use of bonding jumpers or grounding electrode conductors larger than required by 250.66 is certainly not prohibited.

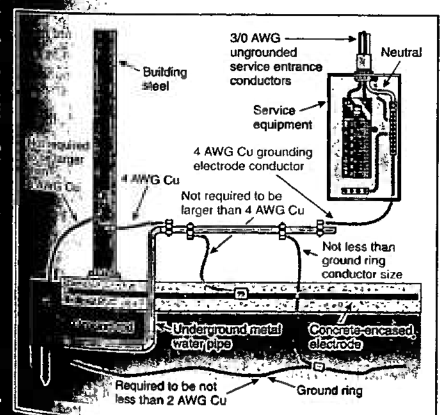



**Exhibit 250.29** Grounding electrode conductor and bonding jumpers sized in accordance with 250.66 for a service supplied by 3/0 AWG ungrounded conductors.

### 250.68 Grounding Electrode Conductor and Bonding Jumper Connection to Grounding Electrodes

**(A) Accessibility** The connection of 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: An exothermic or irreversible compression connection to fire-proofed structural metal 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, terminations are not required 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, either by a marking on the connector or by a tag attached to the connector. See Exhibit 250.22 and Exhibit 250.24 for illustrations of encased and buried electrodes. For the 2005 *Code*, an exception has been added to permit connections to fireproofed structural steel to be encapsulated by the fireproofing material. Because these connections are not required to be accessible for inspection, the method of connection to the structural member must be either an exothermic weld or an irreversible compression connector. This new exception 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 a permanent and effective grounding path. Where necessary to ensure the grounding path for a metal piping system used as a grounding electrode, effective bonding shall be provided around insulated joints and around any equipment likely to be disconnected for repairs or replacement. Bonding conductors shall be of sufficient length to permit removal of such equipment while retaining the integrity of the bond.

Examples of equipment likely to be disconnected for repairs or replacement are water meters and water filter systems.

### 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 telecommunications 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 is used and terminates, for example, on a galvanized water pipe, the clamp must be of a material that is compatible with steel, to prevent galvanic corrosion. The same type of compatibility requirement applies to ground clamps on copper water pipe.

Exhibit 250.30 shows a listed 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 shows a listed U-bolt ground clamp. These clamps are available for all pipe sizes and all grounding

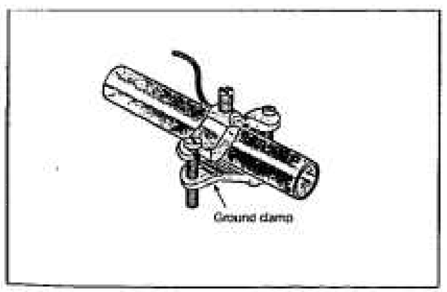



**Exhibit 250.30** An application of a listed ground clamp.

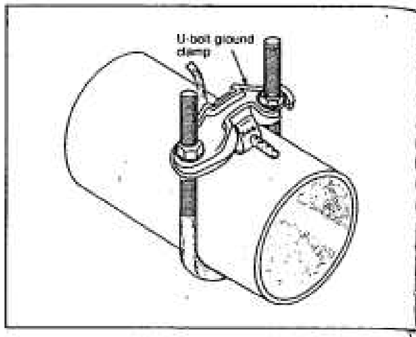



**Exhibit 250.31** An application of a listed U-bolt ground clamp.

electrode conductor sizes. Where grounding electrode conductors are run in conduit, conduit hubs may be bolted to the threaded portion of the U-bolt.

## IV. Enclosure, Raceway, and Service Cable Grounding

### 250.80 Service Raceways and Enclosures

Metal enclosures and raceways for service conductors and equipment shall be grounded.

*Exception: A metal elbow that is installed in an underground installation of rigid nonmetallic conduit 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 grounded.*

The exception to 250.80 recognizes that metal sweep elbows are often installed in underground installations of rigid nonmetallic conduit. The metal elbows are installed because nonmetallic elbows can be damaged by friction from the pulling ropes used during conductor installation. The elbows are isolated from physical contact by burying the entire elbow at a depth not less than 18 in. below grade.

### 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 bonded to the grounded underground system shall not be required to be grounded at the building or structure. The sheath or armor shall be permitted to be insulated from the interior metal raceway conduit or piping.

**(B) Underground Service Raceway Containing Cable** An underground metal service raceway that contains a metal-





sheathed or armored cable bonded to the grounded underground system shall not be required to be grounded 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 grounded.

Section 250.86 requires grounding, bonding, and ensured electrical continuity of all enclosures and metal raceways. 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.

*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 grounded 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 grounded.*

*Exception No. 3: A metal elbow shall not be required to be grounded where it is installed in a 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.*

## 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 Services** The non–current-carrying metal parts of equipment indicated in 250.92(A)(1), (A)(2), and (A)(3) shall be effectively bonded together.

(1) The service raceways, cable trays, cablebus framework, auxiliary gutters, or service cable armor or sheath except as permitted in 250.84.
(2) All service enclosures containing service conductors, including meter fittings, boxes, or the like, interposed in the service raceway or armor.
(3) Any metallic raceway or armor enclosing a grounding electrode conductor as specified in 250.64(B). Bonding shall apply at each end and to all intervening raceways, boxes, and enclosures between the service equipment and the grounding electrode.

Section 250.92(A)(3) is intended to clarify that where metal raceways, boxes, or enclosures contain a grounding electrode conductor, both ends of the raceway, box, or enclosure must be bonded to the grounding electrode conductor, as illustrated in Exhibit 250.32. Bonding the raceway to the conductor reduces the impedance and minimizes the potential difference between the electrical equipment and ground. It should be noted that a change in 250.64(E) for the 2005 *Code* requires bonding of only ferrous metal enclosures that contain a grounding electrode conductor. See also 250.64(E) and 250.102(A) for requirements covering the installation of protective enclosures for grounding electrode conductors and for materials permitted as bonding jumpers.

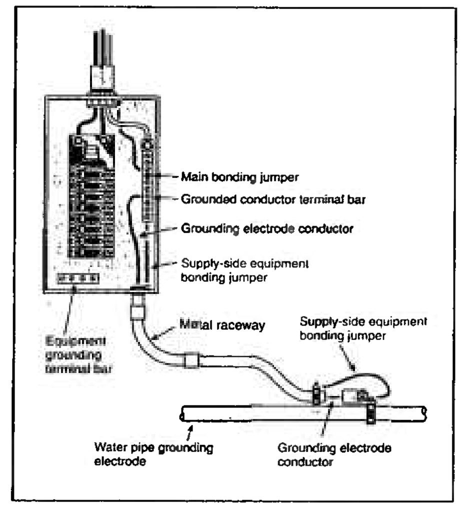



**Exhibit 250.32** Bonding of a metal raceway that contains a grounding electrode conductor to the conductor at both ends, as required by 250.64(E).

**(B) Method of Bonding at the Service** 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 illustrates grounding and bonding at an individual service. Exhibit 250.34 illustrates a grounding and bonding arrangement for up to six switches (three are shown) that serve as the service disconnecting means for an individual service. Section 250.24(C) clarifies that the grounded service conductor must be run to each service disconnecting means and be bonded to the disconnecting means enclosure. Section 250.92(B)(1) permits the bonding of service equipment enclosures to be accomplished by bonding the grounded service conductor to the enclosure.

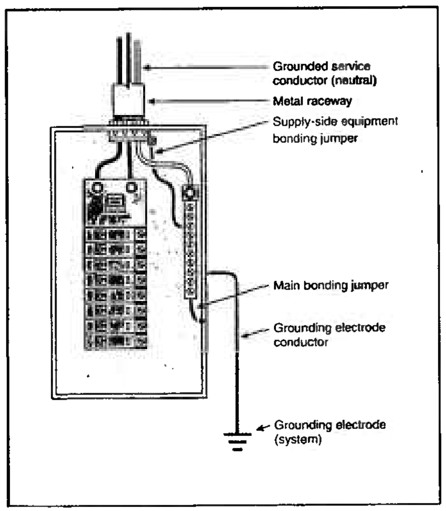



**Exhibit 250.33** Grounding and bonding for a service with one disconnecting means.

(2) Connections utilizing threaded couplings or threaded bosses on enclosures where made up wrenchtight
(3) Threadless couplings and connectors where 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

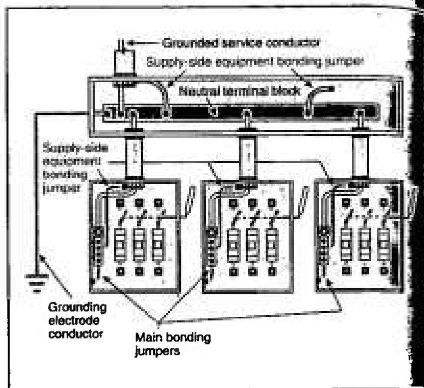



**Exhibit 250.34** A grounding and bonding arrangement for multiple switches that serve as the service disconnecting means for an individual service.

Note that method (4) in 250.92(B) requires other similar devices, such as listed bonding-type locknuts or bushings. Standard locknuts or sealing locknuts are not acceptable as the "sole means" for bonding on the line side of service equipment.

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 rigid or intermediate metal conduit or with tubing (EMT) fittings, such as those shown in Exhibits 250.35 and 250.36, have provisions for connecting a bonding jumper or have means provided by the manufacturer for use in mounting a wire connector. This type of bushing may also have means (usually one or more set screws) to reliably bond the bushing to the conduit. Exhibit 250.37 shows a bonding-type wedge lug used to connect a conduit to a box.

Bonding jumpers meeting the other requirements of this article shall be used around concentric or eccentric knockouts that are punched or otherwise formed so as to impair the electrical connection to ground. Standard locknuts or bushings shall not be the sole means for the bonding required by this section.

For an example of concentric and eccentric knockouts, see the commentary following the definition of *bonding jumper* in Article 100 and Exhibit 100.3.





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

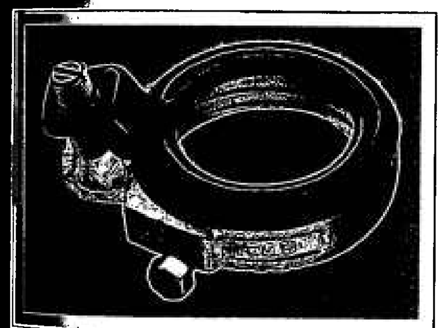


**Exhibit 250.36** A threaded grounding bushing with set screws used to ensure electrical and mechanical connection and a terminal for connection of a grounding conductor or bonding jumper. (Courtesy of Thomas & Betts Corp.)

## 250.94 Bonding for Other Systems

An accessible means external to enclosures for connecting intersystem bonding and grounding electrode conductors shall be provided 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) Exposed grounding electrode conductor
(3) Approved means for the external connection of a copper or other corrosion-resistant bonding or grounding conductor to the grounded raceway or equipment

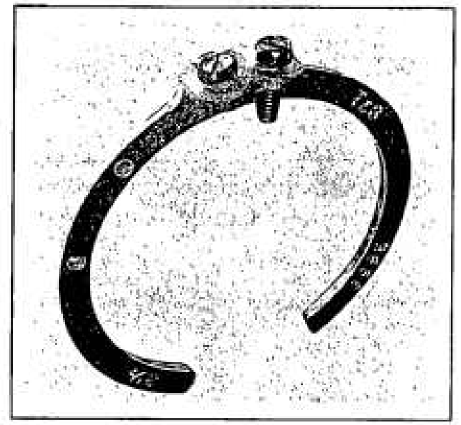


**Exhibit 250.37** A grounding wedge lug used to provide an electrical connection between a conduit and a box. (Courtesy of Thomas & Betts Corp.)

FPN 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(3).

Other accessible external means for intersystem bonding that comply with 250.94, FPN No. 1, are illustrated in Exhibit 250.38. On the left is an illustration of accessible means for the connection. The illustration on the right shows a method of providing the required bonding means when the panelboard is a flush type.

FPN No. 2: See 800.100, 810.21, and 820.100 for bonding and grounding requirements for communications circuits, radio and television equipment, and CATV circuits.

An external accessible bonding means is equally important for separate buildings and mobile homes. In these occupancies, the disconnecting means enclosure on the load side of the service can be considered the equivalent of the service equipment for the purpose of intersystem bonding.

The *Code* requires that separate systems be bonded together to reduce the differences of potential between them due to lightning or accidental contact with power lines. Lightning protection systems, communications, radio and TV, and CATV systems must be bonded together to minimize the potential differences between the systems.

Lack of interconnection can result in a severe shock

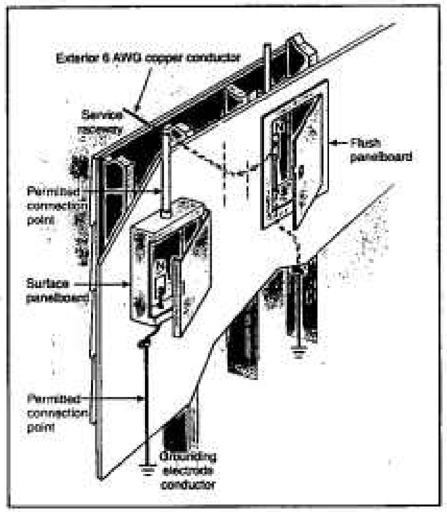



**Exhibit 250.38** Examples of accessible external means for intersystem bonding, as required by 250.94 for service equipment and building or structure disconnecting means.

and fire hazard. The reason for this potential hazard is illustrated in Exhibit 250.39, which shows a CATV cable with its jacket grounded to a separate ground rod and not bonded to the power ground. The 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 widely, depending on soil conditions and the type of grounding electrode. The resistance at the CATV ground is likely to be higher than the power ground resistance, because the power ground is often an underground metal water piping system or concrete-encased electrode, whereas the CATV ground 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 amount could be, and often is, considerably higher. Also assume that the power ground has a resistance of 10 ohms, a very low value in most circumstances (a single ground rod in average soil has a resistance to ground in the neighborhood of 40 ohms).

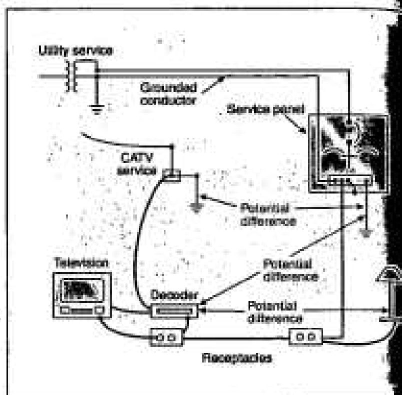



**Exhibit 250.39** A CATV installation that does not comply with the *Code*, illustrating why bonding between different systems is necessary.

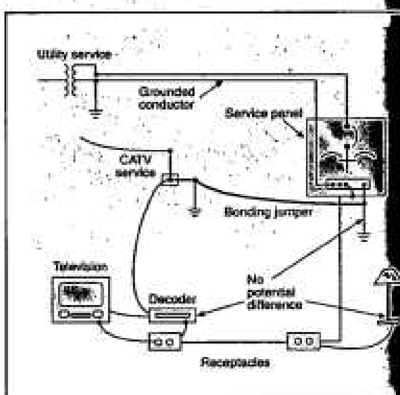



**Exhibit 250.40** A cable TV installation that complies with 250.94.

According to Ohm's law, 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 (e.g., a sink 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 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, which is exactly what the *Code* requires. 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.

These bonding rules are provided to address the difficulties that communications and CATV installers encounter in complying with *Code* grounding and bonding requirements. These difficulties arise from the increasing use of plastic for water pipe, fittings, water meters, and service conduit. 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 metallic water pipe, because the pipe was often used as the power grounding electrode. Thus, the requirement that the power, communications, CATV cable shield, and metallic water piping systems be bonded together was easily satisfied. If the power 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 metallic service raceway, since at least one of these was usually accessible.

With the proliferation of plastic water pipe and the increasing tendency for service equipment (often flush-mounted) to be installed in finished areas, where the grounding electrode conductor is often concealed, as well as the increased use of plastic service-entrance conduit, communications and CATV installers no longer have access to a point for connecting bonding jumpers or grounding conductors. See Exhibit 250.39 and also the commentary following 250.94(B), FPN 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 grounding conductors, with or without the use of supplementary equipment grounding conductors, shall be effectively bonded where necessary to ensure electrical continuity and the capacity to conduct safely any fault current likely to be imposed on them. 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 required 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.

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

To reduce electromagnetic interference, 250.96(B) permits electronic equipment to be isolated from the raceway in a manner similar to that for cord-and-plug-connected equipment. Section 250.96(B) specifies that a metal equipment enclosure supplied by a branch circuit is the subject of the requirement and that subsequent wiring, raceways, or other equipment beyond the insulating fitting is not permitted.

Exhibits 250.41 and 250.42 show examples of installations. In Exhibit 250.41, note that the metal raceway is grounded in the usual manner, by attachment to the grounded service enclosure, satisfying the concern mentioned in the FPN to 250.96(B). In Exhibit 250.42, note that 408.40, Exception, permits, but does not require, the isolated equipment grounding conductor (which is required to be insulated) to pass through the subpanel and run back to the service equipment. The key to this method of grounding electronic equipment is to always ensure that the insulated equipment grounding conductor, regardless of where it terminates in the distribution system, is connected in a manner that creates an effective path for ground-fault current, as required by 250.4(A)(5).

### 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).

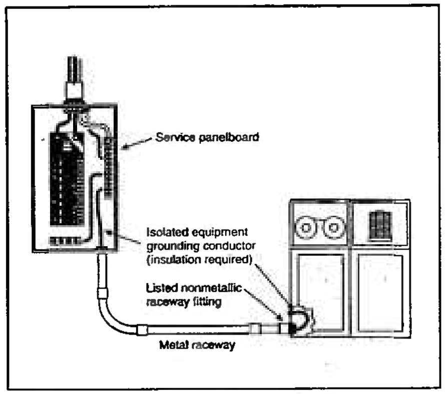



**Exhibit 250.41** An installation in which the electronic equipment is grounded through the isolated equipment grounding conductor.

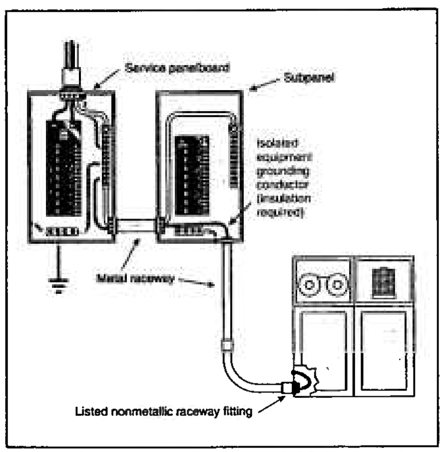



**Exhibit 250.42** An installation in which the isolated equipment grounding conductor is allowed to pass through the subpanel without connecting to the grounding bus to terminate at the service grounding bus.

*Exception: Where oversized, concentric, or eccentric knockouts are not encountered, or where a box or enclosure with concentric or eccentric knockouts is listed to provide a permanent, reliable electrical bond, the following methods shall be permitted:*

*(1) Threadless couplings and connectors for cables with metal sheaths*
*(2) Two locknuts, on rigid metal conduit or intermediate metal conduit, one inside and one outside of boxes and cabinets*
*(3) Fittings with shoulders that seat firmly against the box or cabinet, such as electrical metallic tubing connectors, flexible metal conduit connectors, and cable connectors, with one locknut on the inside of boxes and cabinets*
*(4) Listed fittings*

Bonding around prepunched concentric or eccentric knockouts is not required if the enclosure containing the knockouts has been tested and is listed as suitable for bonding. Guide card information from the UL *General Information for Electrical Equipment Directory* (the UL "White Book") indicates that concentric and eccentric knockouts of all metallic outlet boxes evaluated in accordance with UL 514A, *Metallic Outlet Boxes*, are suitable for bonding in circuits of above or below 250 volts to ground without the use of additional bonding equipment. Metallic outlet boxes are permitted, but not required, to be marked to indicate this condition of use.

The methods in items (1), (2), (3), and (4) in the exception to 250.97 are permitted for circuits over 250 volts to ground only where there are no oversize, concentric, or eccentric knockouts. Note that method (3) permits fittings such as EMT connectors, cable connectors, and similar fittings with shoulders that seat firmly against the metal of a box or cabinet, to be installed with only one locknut on the inside of the box.

### 250.98 Bonding Loosely Jointed Metal Raceways

Expansion fittings and telescoping sections of metal raceways shall be made electrically continuous by equipment bonding jumpers or other means.

### 250.100 Bonding in Hazardous (Classified) Locations

Regardless of the voltage of the electrical system, the electrical continuity of non–current-carrying metal parts of equipment, raceways, and other enclosures in any hazardous (classified) location as defined in Article 500 shall be ensured by any of the methods specified in 250.92(B)(2) through (B)(4) that are approved for the wiring method used. One or more of these bonding methods shall be used whether or not supplementary equipment grounding conductors are installed.





### 250.102 Equipment Bonding Jumpers

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

**(B) Attachment** Equipment bonding jumpers shall be attached in the manner specified by the applicable provisions of 250.8 for circuits and equipment and by 250.70 for grounding electrodes.

**(C) Size — Equipment Bonding Jumper on Supply Side of Service** The bonding jumper shall not be smaller than the sizes shown in Table 250.66 for grounding electrode conductors. Where the service-entrance phase conductors are larger than 1100 kcmil copper or 1750 kcmil aluminum, the bonding jumper shall have an area not less than 12½ percent of the area of the largest phase conductor except that, where the phase conductors and the bonding jumper are of different materials (copper or aluminum), the minimum size of the bonding jumper shall be based on the assumed use of phase conductors of the same material as the bonding jumper and with an ampacity equivalent to that of the installed phase conductors. Where the service-entrance conductors are paralleled in two or more raceways or cables, the equipment bonding jumper, where routed with the raceways or cables, shall be run in parallel. The size of the bonding jumper for each raceway or cable shall be based on the size of the service-entrance conductors in each raceway or cable.

**(D) Size — Equipment Bonding Jumper on Load Side of Service** The equipment bonding jumper on the load side of the service overcurrent devices shall be sized, as a minimum, in accordance with the sizes listed in Table 250.122, but shall not be required to be larger than the largest ungrounded circuit conductors supplying the equipment and shall not be smaller than 14 AWG.

A single common continuous equipment bonding jumper shall be permitted to bond two or more raceways or cables where the bonding jumper is sized in accordance with Table 250.122 for the largest overcurrent device supplying circuits therein.

**(E) Installation** The equipment bonding jumper shall be permitted to be installed inside or outside of a raceway or enclosure. Where installed on the outside, the length of the equipment bonding jumper shall not exceed 1.8 m (6 ft) and shall be routed with the raceway or enclosure. Where installed inside of a raceway, the equipment bonding jumper shall comply with the requirements of 250.119 and 250.148.

*Exception: An equipment bonding jumper longer than 1.8 m (6 ft) shall be permitted at outside pole locations for the purpose of bonding or grounding isolated sections of metal raceways or elbows installed in exposed risers of metal conduit or other metal raceway.*

In many applications, equipment bonding jumpers must be installed on the outside of metal raceways and enclosures. For example, it would be impractical to install the bonding jumper for a conduit expansion joint on the inside of the conduit. For some metal raceway and rigid conduit systems and conduit systems in hazardous (classified) locations, installing the bonding jumper where it is visible and accessible for inspection and maintenance is desirable. An external bonding jumper has a higher impedance than an internal bonding jumper, but by limiting the length of the bonding jumper to 6 ft and routing it with the raceway, the increase in the impedance of the equipment grounding circuit is insignificant. Exhibit 250.43 illustrates a bonding jumper run outside a length of flexible metal conduit. Because the function of a bonding jumper is readily apparent, color identification is permitted, but not required.

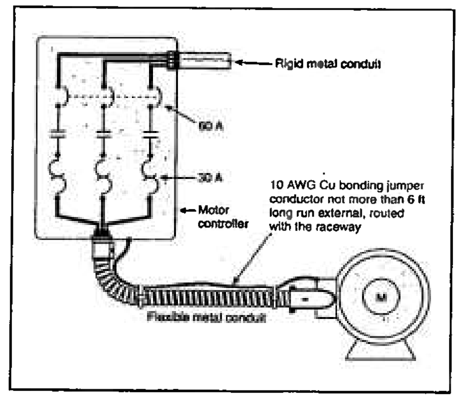



**Exhibit 250.43** A bonding jumper around the outside of a flexible metal conduit.

### 250.104 Bonding of Piping Systems and Exposed Structural Steel

**(A) Metal Water Piping** The metal water piping system shall be bonded as required in (A)(1), (A)(2), or (A)(3) of this section. The bonding jumper(s) shall be installed in accordance with 250.64(A), (B), and (E). The points of attachment of the bonding jumper(s) shall be accessible.

**(1) General** Metal water piping system(s) installed in or attached to a building or structure shall be bonded to the service equipment enclosure, the grounded conductor at the service, the grounding electrode conductor where of sufficient size, or to the one or more grounding electrodes used. The bonding jumper(s) shall be sized in accordance with Table 250.66 except as permitted in 250.104(A)(2) and (A)(3).

Bonding the metal water piping system of a building or structure is not the same as using the metal water piping system as a grounding electrode. Bonding to the grounding electrode system places the bonded components at the same voltage level. For example, a current of 2000 amperes across 25 ft of 6 AWG copper conductor produces a voltage differential of approximately 26 volts. Sections 250.104(A)(1) and 250.104(A)(3) require the metal water piping system of a building or structure to be bonded to the service equipment or grounding electrode conductor or, where supplied by a feeder or branch circuit, to the building or structure disconnecting means or grounding electrode conductor. Information concerning bonding provisions for buildings with multiple occupancies and isolated metal water piping systems is contained in the commentary for 250.104(A)(2).

In those cases where it cannot be reasonably concluded that the hot and cold water pipes are reliably bonded through mechanical connections, an electrical bonding jumper is required to ensure that this connection is made. Some judgment must be exercised for each installation. The special installation requirements provided in 250.64(A), 250.64(B), and 250.64(E) also apply to the water piping bonding jumper.

**(2) Buildings of Multiple Occupancy** In buildings of multiple occupancy where the metal water piping system(s) installed in or attached to a building or structure for the individual occupancies is metallically isolated from all other occupancies by use of nonmetallic water piping, the metal water piping system(s) for each occupancy shall be permitted to be bonded to the equipment grounding terminal of the panelboard or switchboard enclosure (other than service equipment) supplying that occupancy. The bonding jumper shall be sized in accordance with Table 250.122.

Section 250.104(A)(2) recognizes that the increased use of nonmetallic water piping mains can result in the interior metal piping system of a multiple-occupancy building to be isolated from ground and from the other occupancies. Therefore, the water pipe is permitted to be bonded to the panelboard or switchboard that serves only that particular occupancy. The bonding jumper, in this case, is permitted to be sized according to Table 250.122, based on the size of the main overcurrent device supplying the occupancy.

**(3) Multiple Buildings or Structures Supplied by a Feeder(s) or Branch Circuit(s)** The metal water piping system(s) installed in or attached to a building or structure shall be bonded to the building or structure disconnecting means enclosure where located at the building or structure, to the equipment grounding conductor run with the supply conductors, or to the one or more grounding electrodes used. The bonding jumper(s) shall be sized in accordance with 250.66, based on the size of the feeder or branch circuit conductors that supply the building. The bonding jumper shall not be required to be larger than the largest ungrounded feeder or branch circuit conductor supplying the building.

**(B) Other Metal Piping** Where installed in or attached to a building or structure, metal piping system(s), including gas piping, that is likely to become energized shall be bonded to the service equipment enclosure, the grounded conductor at the service, the grounding electrode conductor where of sufficient size, or to the one or more grounding electrodes used. The bonding jumper(s) shall be sized in accordance with 250.122, using the rating of the circuit that is likely to energize the piping system(s). The equipment grounding conductor for the circuit that is likely to energize the piping shall be permitted to serve as the bonding means. The points of attachment of the bonding jumper(s) shall be accessible.

FPN: Bonding all piping and metal air ducts within the premises will provide additional safety.

Unlike the metal piping systems covered in 250.104(A), this requirement applies only to metal piping systems that are likely to become energized. What this means is that where metal piping systems and electrical circuits interface through mechanical and electrical connections within equipment, failure of electrical insulation can result in the connected piping system(s) becoming energized. Gas appliances are a common example of metal gas piping and electrical circuits being connected to a common piece of equipment, and in this case the 250.104(B) requirements apply. The required bonding of these other piping systems can occur at the same locations specified in 250.104(A), or an additional provision within this paragraph permits the equipment grounding conductor of the circuit that is likely to energize the piping as the means for bonding the piping. Typically, the use of an additional bonding jumper is not necessary to comply with this requirement because the equipment grounding connection to the non–current-carrying metal parts of the appliance also provides a bonding connection to the metal piping attached to the appliance. This is a bonding requirement, and the other piping is not being used as an electrode. Therefore, this requirement does not conflict with 250.52(B)(1), which prohibits the use of metal underground gas piping as a grounding electrode for electrical services or other sources of supply.

**(C) Structural Metal** Exposed structural metal that is interconnected to form a metal building frame and is not intentionally grounded and is likely to become energized shall be bonded to the service equipment enclosure, the grounded conductor at the service, the grounding electrode conductor where of sufficient size, or the one or more grounding electrodes used. The bonding jumper(s) shall be sized in accordance with Table 250.66 and installed in accordance with 250.64(A), (B), and (E). The points of attachment of the bonding jumper(s) shall be accessible.

Section 250.104(C) requires exposed metal building framework that is not intentionally or inherently grounded to be bonded to the service equipment or grounding electrode system. Revised for the 2005 *Code*, this requirement applies to all metal framework, not only to steel framework.

**(D) Separately Derived Systems** Metal water piping systems and structural metal that is interconnected to form a building frame shall be bonded to separately derived systems in accordance with (D)(1) through (D)(3).

**(1) Metal Water Piping System(s)** The grounded conductor of each separately derived system shall be bonded to the nearest available point of the metal water piping system(s) in the area served by each separately derived system. This connection shall be made at the same point on the separately derived system where the grounding electrode conductor is connected. Each bonding jumper shall be sized in accordance with Table 250.66 based on the largest ungrounded conductor of the separately derived system.

*Exception No. 1: A separate bonding jumper to the metal water piping system shall not be required where the metal water piping system is used as the grounding electrode for the separately derived system.*

*Exception No. 2: A separate water piping bonding jumper shall not be required where the metal frame of a building or structure is used as the grounding electrode for a separately derived system and is bonded to the metal water piping in the area served by the separately derived system.*

**(2) Structural Metal** Where exposed structural metal that is interconnected to form the building frame exists in the area served by the separately derived system, it shall be bonded to the grounded conductor of each separately derived system. This connection shall be made at the same point on the separately derived system where the grounding electrode conductor is connected. Each bonding jumper shall be sized in accordance with Table 250.66 based on the largest ungrounded conductor of the separately derived system.

*Exception No. 1: A separate bonding jumper to the building structural metal shall not be required where the metal frame of a building or structure is used as the grounding electrode for the separately derived system.*

*Exception No. 2: A separate bonding jumper to the building structural metal shall not be required where the water piping of a building or structure is used as the grounding electrode for a separately derived system and is bonded to the building structural metal in the area served by the separately derived system.*

Section 250.104(D) requires that where a separately derived system supplies the power, the metal piping system and the exposed structural metal in the area supplied by the separately derived system must be bonded to the grounded conductor at the point nearest the derived system and that this connection must be accessible. Where either of these two building elements is used as the grounding electrode for the separately derived system, it is not necessary to provide an additional bonding jumper.

In addition, two new exceptions for the 2005 *Code* permit the following approaches for bonding of metal piping or metal structures to separately derived systems. Where the building metal structure is used as the grounding electrode for a separately derived system, it is permitted to install a bonding jumper between the metal structure and the water piping, thus eliminating the need to run a separate bonding jumper from the separately derived system source or distribution equipment to the water piping. The same approach can be taken for the structural metal where metal water piping is serving as the electrode for the separately derived system and a bonding jumper is installed from the piping to the metal framework in the area served by that system. Any bonding jumper used for this application is sized from 250.66 based on the largest ungrounded supply conductor of the separately derived system.

**(3) Common Grounding Electrode Conductor** Where a common grounding electrode conductor is installed for multiple separately derived systems as permitted by 250.30(A)(4), and exposed structural metal that is interconnected to form the building frame or interior metal piping exists in the area served by the separately derived system, the metal piping and the structural metal member shall be bonded to the common grounding electrode conductor.

*Exception: A separate bonding jumper from each derived system to metal water piping and to structural metal members shall not be required where the metal water piping and the structural metal members in the area served by the separately derived system are bonded to the common grounding electrode conductor.*

## 250.106 Lightning Protection Systems

The lightning protection system ground terminals shall be bonded to the building or structure grounding electrode system.

FPN No. 1: See 250.60 for use of air terminals. For further information, see NFPA 780-2004, *Standard for the Installation of Lightning Protection Systems*, which contains detailed information on grounding, bonding, and spacing from lightning protection systems.

FPN No. 2: Metal raceways, enclosures, frames, and other non–current-carrying metal parts of electric equipment installed on a building equipped with a lightning protection system may require bonding or spacing from the lightning protection conductors in accordance with NFPA 780-2004, *Standard for the Installation of Lightning Protection Systems*. Separation from lightning protection conductors is typically 1.8 m (6 ft) through air or 900 mm (3 ft) through dense materials such as concrete, brick, or wood.

Section 250.106 specifies that the grounding electrode system of the lightning protection system be bonded to the electrical service grounding electrode system, as shown in Exhibit 250.44. A similar requirement is found in 4.14 of NFPA 780, *Standard for the Installation of Lightning Protection Systems*. Additional bonding between the lightning protection system and the electrical system may be necessary based on proximity and whether separation between the systems is through air or building materials.

FPN No. 2 to 250.106 references NFPA 780 for guidance on determining the need for additional bonding connections. Section 4.21.2 of NFPA 780 includes a method for calculating flashover distances.

Exposed, non–current-carrying metal parts of fixed equipment that are not likely to become energized are not required to be grounded. These parts include some metal nameplates on nonmetallic enclosures and small parts, such as bolts and screws, if they are located so that they are n[ot] likely to become energized.

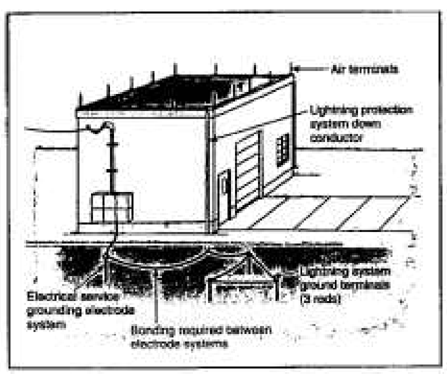



**Exhibit 250.44** Bonding between the lightning system ground terminals and the electrical service grounding electrode system, in accordance with 250.106.

## VI. Equipment Grounding and Equipment Grounding Conductors

### 250.110 Equipment Fastened in Place or Connected by Permanent Wiring Methods (Fixed)

Exposed non–current-carrying metal parts of fixed equip[ment] likely to become energized shall be grounded unde[r] any of the following conditions:

(1) Where within 2.5 m (8 ft) vertically or 1.5 m (5 ft) horizontally of ground or grounded metal objects and subject to contact by persons
(2) Where located in a wet or damp location and not isolated
(3) Where in electrical contact with metal
(4) Where in a hazardous (classified) location as covered by Articles 500 through 517
(5) Where supplied by a metal-clad, metal-sheathed, metal raceway, or other wiring method that provides an equip[ment] ground, except as permitted by 250.86, Exception No. 2, for short sections of metal enclosures
(6) Where equipment operates with any terminal at over 150 volts to ground

*Exception No. 1: Metal frames of electrically heated appli[ances], exempted by special permission, in which case the frames shall be permanently and effectively insulated from ground.*

*Exception No. 2: Distribution apparatus, such as trans[former] and capacitor cases, mounted on wooden poles, a[t] a height exceeding 2.5 m (8 ft) above ground or grade level.*

*Exception No. 3: Listed equipment protected by a system of double insulation, or its equivalent, shall not be required to be grounded. Where such a system is employed, the equip[ment] shall be distinctively marked.*

### 250.112 Fastened in Place or Connected by Permanent Wiring Methods (Fixed) — Specific

Exposed, non–current-carrying metal parts of the kinds o[f] equipment described in 250.112(A) through (K), and non–current-carrying metal parts of equipment and enclo[]sures described in 250.112(L) and (M), shall be grounded regardless of voltage.

**(A) Switchboard Frames and Structures** Switchboard frames and structures supporting switching equipment, ex[]cept frames of 2-wire dc switchboards where effectively insulated from ground.

Section 250.112(A) clarifies that dc switchboards insulat[ed] from ground are not required to be grounded.

**(B) Pipe Organs** Generator and motor frames in an electrically operated pipe organ, unless effectively insulated from ground and the motor driving it.

**(C) Motor Frames** Motor frames, as provided by 430.242.

**(D) Enclosures for Motor Controllers** Enclosures for motor controllers unless attached to ungrounded portable equipment.

**(E) Elevators and Cranes** Electric equipment for elevators and cranes.

**(F) Garages, Theaters, and Motion Picture Studios** Electric equipment in commercial garages, theaters, and motion picture studios, except pendant lampholders supplied by circuits not over 150 volts to ground.

**(G) Electric Signs** Electric signs, outline lighting, and associated equipment as provided in Article 600.

**(H) Motion Picture Projection Equipment** Motion picture projection equipment.

**(I) Power-Limited Remote-Control, Signaling, and Fire Alarm Circuits** Equipment supplied by Class 1 power-limited circuits and Class 1, Class 2, and Class 3 remote-control and signaling circuits, and by fire alarm circuits, shall be grounded where system grounding is required by Part II or Part VIII of this article.

**(J) Luminaires (Lighting Fixtures)** Luminaires (lighting fixtures) as provided in Part V of Article 410.

**(K) Skid Mounted Equipment** Permanently mounted electrical equipment and skids shall be grounded with an equipment bonding jumper sized as required by 250.122.

**(L) Motor-Operated Water Pumps** Motor-operated water pumps, including the submersible type.

The requirement of 250.112(L) is intended to reduce stray voltages and minimize shock hazard during maintenance, when the pump is hauled out of the well casing and might be tested in a barrel of water.

**(M) Metal Well Casings** Where a submersible pump is used in a metal well casing, the well casing shall be bonded to the pump circuit equipment grounding conductor.

Section 250.112(M) is intended to prevent a shock hazard that could exist due to a potential difference between the pump, which is grounded to the system ground, and the metal well casing.

### 250.114 Equipment Connected by Cord and Plug

Under any of the conditions described in 250.114(1) through (4), exposed non–current-carrying metal parts of cord-and-plug-connected equipment likely to become energized shall be grounded.

*Exception: Listed tools, listed appliances, and listed equipment covered in 250.114(2) through (4) shall not be required to be grounded where protected by a system of double insulation or its equivalent. Double insulated equipment shall be distinctively marked.*

The exception to 250.114 recognizes listed double-insulated appliances, motor-operated hand-held tools, stationary and fixed motor-operated tools, and light industrial motor-operated tools as not requiring equipment grounding connections.

(1) In hazardous (classified) locations (see Articles 500 through 517)
(2) Where operated at over 150 volts to ground

*Exception No. 1: Motors, where guarded, shall not be required to be grounded.*

*Exception No. 2: Metal frames of electrically heated appliances, exempted by special permission, shall not be required to be grounded, in which case the frames shall be permanently and effectively insulated from ground.*

(3) In residential occupancies:
   a. Refrigerators, freezers, and air conditioners
   b. Clothes-washing, clothes-drying, dish-washing machines; kitchen waste disposers; information technology equipment; sump pumps and electrical aquarium equipment
   c. Hand-held motor-operated tools, stationary and fixed motor-operated tools, light industrial motor-operated tools
   d. Motor-operated appliances of the following types: hedge clippers, lawn mowers, snow blowers, and wet scrubbers
   e. Portable handlamps
(4) In other than residential occupancies:
   a. Refrigerators, freezers, and air conditioners
   b. Clothes-washing, clothes-drying, dish-washing machines; information technology equipment; sump pumps and electrical aquarium equipment
   c. Hand-held motor-operated tools, stationary and fixed motor-operated tools, light industrial motor-operated tools
   d. Motor-operated appliances of the following types: hedge clippers, lawn mowers, snow blowers, and wet scrubbers

e. Portable handlamps
f. Cord-and-plug-connected appliances used in damp or wet locations or by persons standing on the ground or on metal floors or working inside of metal tanks or boilers
g. Tools likely to be used in wet or conductive locations

*Exception: Tools and portable handlamps likely to be used in wet or conductive locations shall not be required to be grounded where supplied through an isolating transformer with an ungrounded secondary of not over 50 volts.*

Tools must be grounded by an equipment grounding conductor within the cord or cable supplying the tool, except where the tool is supplied by an isolating transformer, as permitted by the exception following 250.114(4). Portable tools and appliances protected by an approved system of double insulation must be listed by a qualified electrical testing laboratory as being suitable for the purpose, and the equipment must be distinctively marked as double insulated.

Cord-connected portable tools or appliances are not intended to be used in damp, wet, or conductive locations unless they are grounded, supplied by an isolation transformer with a secondary of not more than 50 volts, or protected by an approved system of double insulation.

Exhibit 250.45 shows an example of lighting equipment supplied through an isolating transformer operating at 6 or 12 volts that provides safe illumination for work inside boilers, tanks, and similar locations that may be metal or wet.

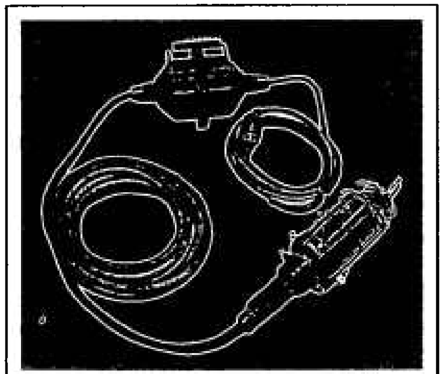


Exhibit 250.45 Lighting equipment supplied through an isolating transformer operating at 6 or 12 volts and therefore not required to be grounded. (Courtesy of Daniel Woodhead Co.)

### 250.116 Nonelectric Equipment

The metal parts of nonelectric equipment described in this section shall be grounded.

(1) Frames and tracks of electrically operated cranes and hoists
(2) Frames of nonelectrically driven elevator cars to which electric conductors are attached
(3) Hand-operated metal shifting ropes or cables of electric elevators

FPN: Where extensive metal in or on buildings may become energized and is subject to personal contact, adequate bonding and grounding will provide additional safety.

Because metal siding on buildings is not electrical equipment, it is outside the scope of the *Code* [see 90.2(A)]. Therefore, the *Code* cannot require that it be grounded. Quite often, however, luminaires, signs, or receptacles are installed on buildings with metal siding that could become energized. Grounding of metal siding reduces the risk of shock to persons who may come in contact with siding that has become energized.

### 250.118 Types of Equipment Grounding Conductors

The equipment grounding conductor run with or enclosing the circuit conductors shall be one or more or a combination of the following:

(1) A copper, aluminum, or copper-clad aluminum conductor. This conductor shall be solid or stranded; insulated, covered, or bare; and in the form of a wire or a busbar of any shape.
(2) Rigid metal conduit.
(3) Intermediate metal conduit.
(4) Electrical metallic tubing.
(5) Listed flexible metal conduit meeting all the following conditions:
   a. The conduit is terminated in fittings listed for grounding.
   b. The circuit conductors contained in the conduit are protected by overcurrent devices rated at 20 amperes or less.
   c. The combined length of flexible metal conduit and flexible metallic tubing and liquidtight flexible metal conduit in the same ground return path does not exceed 1.8 m (6 ft).
   d. Where used to connect equipment where flexibility is necessary after installation, an equipment grounding conductor shall be installed.
(6) Listed liquidtight flexible metal conduit meeting all the following conditions:
   a. The conduit is terminated in fittings listed for grounding.
   b. For metric designators 12 through 16 (trade sizes ⅜ through ½), the circuit conductors contained in the conduit are protected by overcurrent devices rated at 20 amperes or less.
   c. For metric designators 21 through 35 (trade sizes ¾ through 1¼), the circuit conductors contained in the conduit are protected by overcurrent devices rated not more than 60 amperes and there is no flexible metal conduit, flexible metallic tubing, or liquidtight flexible metal conduit in trade sizes metric designators 12 through 16 (trade sizes ⅜ through ½) in the grounding path.
   d. The combined length of flexible metal conduit and flexible metallic tubing and liquidtight flexible metal conduit in the same ground return path does not exceed 1.8 m (6 ft).
   e. Where used to connect equipment where flexibility is necessary after installation, an equipment grounding conductor shall be installed.

In those cases where liquidtight flexible metal conduit (LFMC) or flexible metal conduit (FMC) is used to connect equipment that requires a degree of movement or flexibility as part of its anticipated operating conditions, it is required that an equipment grounding conductor be installed in the LFMC or FMC. Flexible raceways that are used to facilitate connection to equipment but that remain stationary after the connection is made are not covered by the provision of 250.118(5)(d) or 250.118(6)(e).

(7) Flexible metallic tubing where the tubing is terminated in fittings listed for grounding and meeting the following conditions:
   a. The circuit conductors contained in the tubing are protected by overcurrent devices rated at 20 amperes or less.
   b. The combined length of flexible metal conduit and flexible metallic tubing and liquidtight flexible metal conduit in the same ground return path does not exceed 1.8 m (6 ft).
(8) Armor of Type AC cable as provided in 320.108.
(9) The copper sheath of mineral-insulated, metal-sheathed cable.
(10) Type MC cable where listed and identified for grounding in accordance with the following:
   a. The combined metallic sheath and grounding conductor of interlocked metal tape–type MC cable
   b. The metallic sheath or the combined metallic sheath and grounding conductors of the smooth or corrugated tube type MC cable
(11) Cable trays as permitted in 392.3(C) and 392.7.
(12) Cablebus framework as permitted in 370.3.
(13) Other listed electrically continuous metal raceways and listed auxiliary gutters.
(14) Surface metal raceways listed for grounding.

Exhibit 250.46 illustrates the various sizes of rigid metal conduit that enclose the feeder circuit conductors and are equipment grounding conductors with or without the installation of a wire-type equipment grounding conductor in the conduits.

### 250.119 Identification of Equipment Grounding Conductors

Unless required elsewhere in this *Code*, equipment grounding conductors shall be permitted to be bare, covered, or insulated. Individually covered or insulated equipment grounding conductors shall have a continuous outer finish that is either green or green with one or more yellow stripes except as permitted in this section. Conductors with insulation or individual covering that is green, green with one or more yellow stripes, or otherwise identified as permitted by this section shall not be used for ungrounded or grounded circuit conductors.

A new condition in this section of the 2005 *Code* precludes re-identification (such as marking tape to the insulation) of any conductor having green- or green-with-yellow-stripe-colored insulation or covering for use as an ungrounded or grounded conductor.

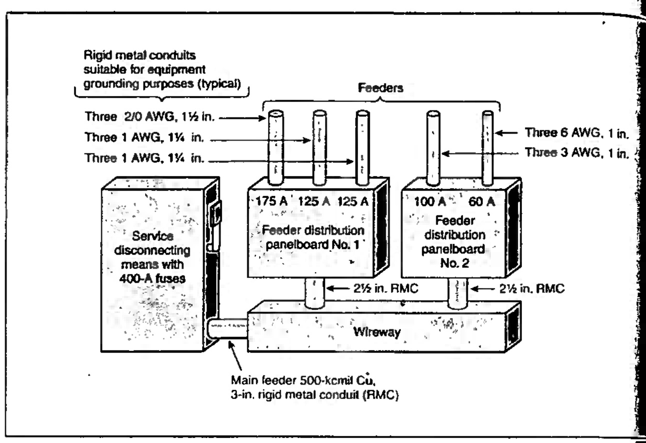
**(A) Conductors Larger Than 6 AWG** Equipment grounding conductors larger than 6 AWG shall comply with 250.119(A)(1) and (A)(2).

(1) An insulated or covered conductor larger than 6 AWG shall be permitted, at the time of installation, to be permanently identified as an equipment grounding conductor at each end and at every point where the conductor is accessible.

*Exception: Conductors larger than 6 AWG shall not be required to be marked in conduit bodies that contain no splices or unused hubs.*

(2) Identification shall encircle the conductor and shall be accomplished by one of the following:
   a. Stripping the insulation or covering from the entire exposed length

Exhibit 250.46 Various sizes of enclosing metal conduits used as equipment grounding conductors, as they apply to a service and feeder system.




b. Coloring the exposed insulation or covering green
c. Marking the exposed insulation or covering with green tape or green adhesive labels

**(B) Multiconductor Cable** Where the conditions of maintenance and supervision ensure that only qualified persons service the installation, one or more insulated conductors in a multiconductor cable, at the time of installation, shall be permitted to be permanently identified as equipment grounding conductors at each end and at every point where the conductors are accessible by one of the following means:

(1) Stripping the insulation from the entire exposed length
(2) Coloring the exposed insulation green
(3) Marking the exposed insulation with green tape or green adhesive labels

**(C) Flexible Cord** An uninsulated equipment grounding conductor shall be permitted, but, if individually covered, the covering shall have a continuous outer finish that is either green or green with one or more yellow stripes.

## 250.120 Equipment Grounding Conductor Installation

An equipment grounding conductor shall be installed in accordance with 250.120(A), (B), and (C).

**(A) Raceway, Cable Trays, Cable Armor, Cablebus, or Cable Sheaths** Where it consists of a raceway, cable tray, cable armor, cablebus framework, or cable sheath or where it is a wire within a raceway or cable, it shall be installed in accordance with the applicable provisions in this Code using fittings for joints and terminations approved for use with the type raceway or cable used. All connections, joints, and fittings shall be made tight using suitable tools.

**(B) Aluminum and Copper-Clad Aluminum Conductors** Equipment grounding conductors of bare or insulated aluminum or copper-clad aluminum shall be permitted. Bare conductors shall not come in direct contact with masonry or the earth or where subject to corrosive conditions. Aluminum or copper-clad aluminum conductors shall not be terminated within 450 mm (18 in.) of the earth.

**(C) Equipment Grounding Conductors Smaller Than 6 AWG** Equipment grounding conductors smaller than 6 AWG shall be protected from physical damage by a raceway or cable armor except where run in hollow spaces of walls or partitions, where not subject to physical damage, or where protected from physical damage.

## 250.122 Size of Equipment Grounding Conductors

**(A) General** Copper, aluminum, or copper-clad aluminum equipment grounding conductors of the wire type shall not be smaller than shown in Table 250.122 but shall not be required to be larger than the circuit conductors supplying the equipment. Where a raceway or a cable armor or sheath is used as the equipment grounding conductor, as provided in 250.118 and 250.134(A), it shall comply with 250.4(A)(5) or (B)(4).





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

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

Note: Where necessary to comply with 250.4(A)(5) or (B)(4), the equipment grounding conductor shall be sized larger than given in this table.
*See installation restrictions in 250.120.

The last sentence of 250.122(A) alerts users that, if a long distance exists between a power source and utilization equipment, some of the wiring methods permitted by 250.118 for equipment grounding purposes must be evaluated to ensure that they can provide an effective path for ground-fault current.

**(B) Increased in Size** Where ungrounded conductors are increased in size, equipment grounding conductors, where installed, shall be increased in size proportionately according to circular mil area of the ungrounded conductors.

Equipment grounding conductors on the load side of the service disconnecting means and overcurrent devices are sized based on the size of the feeder or branch-circuit overcurrent devices ahead of them. Where the ungrounded circuit conductors are increased in size to compensate for voltage drop or for any other reason related to proper circuit operation, the equipment grounding conductors must be increased proportionately.

### Example

A 240-volt, single-phase, 250-ampere load is supplied from a 300-ampere breaker located in a panelboard 500 ft away. The conductors are 250-kcmil copper, installed in rigid nonmetallic conduit, with a 4 AWG copper equipment grounding conductor. If the conductors are increased to 350 kcmil, what is the minimum size for the equipment grounding conductor based on the proportional-increase requirement?

Solution

STEP 1. Calculate the size ratio of the new conductors to the existing conductors:

$$\text{Size ratio} = \frac{350{,}000 \text{ circular mils}}{250{,}000 \text{ circular mils}} = 1.4$$

STEP 2. Calculate the cross-sectional area of the new equipment grounding conductor. According to Chapter 9, Table 8, 4 AWG, the size of the existing grounding conductor, has a cross-sectional area of 41,740 circular mils.

STEP 3. Determine the size of the new equipment grounding conductor. Again, referring to Chapter 9, Table 8, we find that 58,436 circular mils is larger than 3 AWG. The next larger size is 66,360 circular mils, which converts to a 2 AWG copper equipment grounding conductor.

**(C) Multiple Circuits** Where a single equipment grounding conductor is run with multiple circuits in the same raceway or cable, it shall be sized for the largest overcurrent device protecting conductors in the raceway or cable.

A single equipment grounding conductor must be sized for the largest overcurrent device. It is not required to be sized for the composite of all the circuits in the raceway because it is not anticipated that all circuits will develop faults at the same time. For example, three 3-phase circuits in the same raceway, protected by overcurrent devices rated 30, 60, and 100 amperes, would require only one equipment grounding conductor, sized according to the largest overcurrent device (in this case, 100 amperes). Therefore, an 8 AWG copper or 6 AWG aluminum conductor or copper-clad aluminum conductor is required, according to Table 250.122.

**(D) Motor Circuits** Where the overcurrent device consists of an instantaneous trip circuit breaker or a motor short-circuit protector, as allowed in 430.52, the equipment grounding conductor size shall be permitted to be based on the rating of the motor overload protective device but shall not be less than the size shown in Table 250.122.

**(E) Flexible Cord and Fixture Wire** The equipment grounding conductor in a flexible cord with the largest circuit conductor 10 AWG or smaller, and the equipment grounding conductor used with fixture wires of any size in accordance with 240.5, shall not be smaller than 18 AWG copper and shall not be smaller than the circuit conductors. The equipment grounding conductor in a flexible cord with a circuit conductor larger than 10 AWG shall be sized in accordance with Table 250.122.

**(F) Conductors in Parallel** Where conductors are run in parallel in multiple raceways or cables as permitted in 310.4, the equipment grounding conductors, where used, shall be run in parallel in each raceway or cable. One of the methods in 250.122(F)(1) or (F)(2) shall be used to ensure the equipment grounding conductors are protected.

**(1) Based on Rating of Overcurrent Protective Device** Each parallel equipment grounding conductor shall be sized on the basis of the ampere rating of the overcurrent device protecting the circuit conductors in the raceway or cable in accordance with Table 250.122.

Where wire-type equipment grounding conductors are installed in multiple raceways or cables used to enclose conductors in parallel, a full-sized equipment grounding conductor selected from Table 250.122 based on the size of the overcurrent device protecting the paralleled circuit is required in each raceway or cable.

The full-sized equipment grounding conductor is required to prevent overloading and possible burnout of the conductor should a ground fault occur along one of the parallel branches. The installation conditions for paralleled conductors prescribed in 310.4 result in proportional distribution of the current-time duty among the several paralleled grounding conductors only for overcurrent conditions downstream of the paralleled set of circuit conductors.

Exhibit 250.47 shows a parallel arrangement with two nonmetallic conduits installed underground. For clarity, a one-line diagram with equipment grounding conductors is shown. A ground fault at the enclosure will cause the equipment grounding conductor in the top conduit to carry more than its proportionate share of fault current. Note that the fault is fed by two different conductors of the same phase, one from the left and one from the right. The shortest and lowest-impedance path to ground from the fault to the supply panelboard is through the equipment grounding conductor in the top conduit. The grounding path from the fault through the bottom conduit is longer and of higher impedance. Therefore, the equipment grounding conductor in each raceway

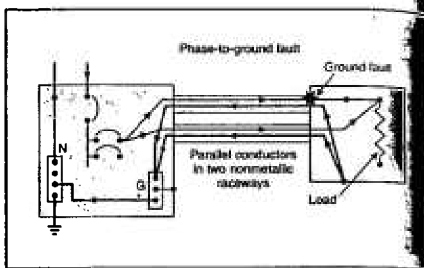



**Exhibit 250.47** Grounding paths for ground fault at the load supplied by parallel conductors in two nonmetallic raceways, illustrating the reason for the requirement of 250.122(F)(1).

must be capable of carrying a major portion of the fault current without burning open.

**(2) Ground-Fault Protection of Equipment Installed** Where ground-fault protection of equipment is installed, each parallel equipment grounding conductor in a multiconductor cable shall be permitted to be sized in accordance with Table 250.122 on the basis of the trip rating of the ground-fault protection where the following conditions are met:

(1) Conditions of maintenance and supervision ensure that only qualified persons will service the installation.
(2) The ground-fault protection equipment is set to trip at not more than the ampacity of a single ungrounded conductor of one of the cables in parallel.
(3) The ground-fault protection is listed for the purpose of protecting the equipment grounding conductor.

Section 250.122(F)(2) applies to cables that are installed in parallel. Because cable assemblies are manufactured in standard conductor size configurations, the equipment grounding conductor in a cable is properly sized for some circuit arrangements but not necessarily for all parallel circuit arrangements. Where the cable is used in large-capacity parallel circuits, the equipment grounding conductor in each cable may not be large enough to comply with Table 250.122, depending on the size of the overcurrent device protecting the circuit.

To address this problem, 250.122(F)(2) permits the sizing of the equipment grounding conductor within a multiconductor cable to be based on the trip rating of an equipment ground-fault protection device. This method of protection is permitted only where the installation is serviced by qualified personnel and the ground-fault device is specifically listed for protecting the equipment grounding conductor. The adjustable trip setting of the ground-fault protection device cannot be set higher than the ampacity of a single ungrounded conductor installed as part of the parallel circuit arrangement. This provision is intended to permit the use of standard cable assembly configurations in large-capacity parallel circuits without having to custom-manufacture the cable to include an equipment grounding conductor sized for a specific parallel circuit arrangement.

**(G) Feeder Taps** Equipment grounding conductors run with feeder taps shall not be smaller than shown in Table 250.122 based on the rating of the overcurrent device ahead of the feeder but shall not be required to be larger than the tap conductors.

This paragraph, which is new for the 2005 *Code*, clarifies how to size a wire-type equipment grounding conductor for feeder tap installations covered in 240.21(B). This requirement specifies that it is the rating of the overcurrent device on the line or supply side of the feeders that is the basis for selection from Table 250.122 rather than the rating of the overcurrent or other device at the load end of the tap conductors. This stands to reason because it is the device on the supply side of the tap conductors that needs to be opened under a ground-fault condition between the point at which they are supplied and the point at which they terminate. In accordance with this paragraph and 250.122(A), the equipment grounding conductor is not required to be larger than the ungrounded conductors under any circumstance.

For example, a 600-kcmil copper conductor is tapped to a 1200-ampere feeder and supplies a fusible switch with 400-ampere fuses. Where the 400-ampere overcurrent protection is installed at the point the 600-kcmil conductors receive their supply, the equipment grounding conductor from Table 250.122 is a 3 AWG copper or 1 AWG aluminum conductor. However, in this tap conductor application, it is the 1200-ampere device that is on the line side of the 600-kcmil tap conductors, and the equipment grounding conductor from Table 250.122 is based on the 1200-ampere device. In this case, the equipment grounding conductor is required to be a 3/0 AWG copper or 250-kcmil aluminum conductor. This provision applies only where a wire-type equipment grounding conductor is run with the feeder tap conductors. Other equipment grounding conductors permitted in 250.118 can also be used where they meet the requirements for tap conductor wiring methods specified in 240.21(B)(1) through 240.21(B)(5).

### 250.124 Equipment Grounding Conductor Continuity

**(A) Separable Connections** Separable connections such as those provided in drawout equipment or attachment plugs and mating connectors and receptacles shall provide for first-make, last-break of the equipment grounding conductor. First-make, last-break shall not be required where interlocked equipment, plugs, receptacles, and connectors preclude energization without grounding continuity.

**(B) Switches** No automatic cutout or switch shall be placed in the equipment grounding conductor of a premises wiring system unless the opening of the cutout or switch disconnects all sources of energy.

### 250.126 Identification of Wiring Device Terminals

The terminal for the connection of the equipment grounding conductor shall be identified by one of the following:

(1) A green, not readily removable terminal screw with a hexagonal head.
(2) A green, hexagonal, not readily removable terminal nut.
(3) A green pressure wire connector. If the terminal for the grounding conductor is not visible, the conductor entrance hole shall be marked with the word *green* or *ground*, the letters *G* or *GR*, a grounding symbol, or otherwise identified by a distinctive green color. If the terminal for the equipment grounding conductor is readily removable, the area adjacent to the terminal shall be similarly marked.

FPN: See FPN Figure 250.126.

**FPN Figure 250.126 One Example of a Symbol Used to Identify the Grounding Termination Point for an Equipment Grounding Conductor.**

## VII. Methods of Equipment Grounding

### 250.130 Equipment Grounding Conductor Connections

Equipment grounding conductor connections at the source of separately derived systems shall be made in accordance with 250.30(A)(1). Equipment grounding conductor connections at service equipment shall be made as indicated in 250.130(A) or (B). For replacement of non–grounding-type receptacles with grounding-type receptacles and for branch-circuit extensions only in existing installations that do not have an equipment grounding conductor in the branch circuit, connections shall be permitted as indicated in 250.130(C).

**(A) For Grounded Systems** The connection shall be made by bonding the equipment grounding conductor to the grounded service conductor and the grounding electrode conductor.

The grounding arrangement for a grounded system is illustrated in Exhibit 250.48.

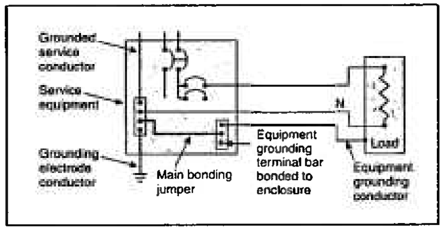



**Exhibit 250.48** Grounding arrangement for grounded systems, per 250.130(A), illustrating connection of the equipment grounding conductor (bus) to the enclosures and the grounded service conductor.

**(B) For Ungrounded Systems** The connection shall be made by bonding the equipment grounding conductor to the grounding electrode conductor.

**(C) Nongrounding Receptacle Replacement or Branch Circuit Extensions** The equipment grounding conductor of a grounding-type receptacle or a branch-circuit extension shall be permitted to be connected to any of the following:

(1) Any accessible point on the grounding electrode system as described in 250.50
(2) Any accessible point on the grounding electrode conductor
(3) The equipment grounding terminal bar within the enclosure where the branch circuit for the receptacle or branch circuit originates
(4) For grounded systems, the grounded service conductor within the service equipment enclosure
(5) For ungrounded systems, the grounding terminal bar within the service equipment enclosure

FPN: See 406.3(D) for the use of a ground-fault circuit-interrupting type of receptacle.

Section 250.130(C) applies to both ungrounded and grounded systems. It permits a nongrounding-type receptacle to be replaced with a grounding-type receptacle under the following conditions.

1. The branch circuit does not contain an equipment ground.
2. An existing branch circuit is being extended for additional receptacle outlets.
3. An equipment grounding conductor is connected between the receptacle grounding terminal to any accessible point on the grounding electrode system, to any accessible point on the grounding electrode conductor, to the grounded service conductor within the service equipment enclosure, or to the equipment grounding terminal bar in the enclosure from which the circuit is supplied.

The requirement in 250.52(A)(1) does not permit this separate equipment grounding conductor to be connected to the metal water piping of a building or structure beyond the first 5 ft of where the piping enters the building or structure unless the conditions of the exception to 250.52(A)(1) can be met.

Exhibit 250.49 shows a branch-circuit extension made from an existing installation. This method is also permitted to ground a replacement 3-wire receptacle in the existing ungrounded box on the left, where no grounding conductor is available.

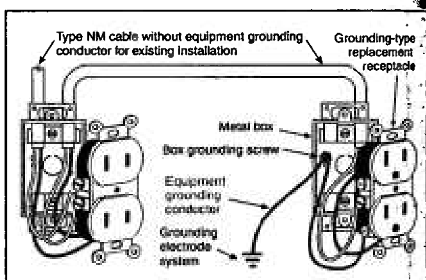



**Exhibit 250.49** Branch-circuit extension to an existing installation, per 250.130(C), illustrating a separate equipment grounding conductor connected to the grounding electrode system.

## 250.132 Short Sections of Raceway

Isolated sections of metal raceway or cable armor, where required to be grounded, shall be grounded in accordance with 250.134.

## 250.134 Equipment Fastened in Place or Connected by Permanent Wiring Methods (Fixed) — Grounding

Unless grounded by connection to the grounded circuit conductor as permitted by 250.32, 250.140, and 250.142, non–current-carrying metal parts of equipment, raceways, and other enclosures, if grounded, shall be grounded by one of the following methods.





Section 250.134 eliminates any conflict between 250.134(A), which requires an equipment grounding conductor to be used for equipment grounding, and 250.32, 250.140, and 250.142, which permit the grounded circuit conductor to be used for equipment grounding if certain specified conditions are met.

**(A) Equipment Grounding Conductor Types** By any of the equipment grounding conductors permitted by 250.118.

**(B) With Circuit Conductors** By an equipment grounding conductor contained within the same raceway, cable, or otherwise run with the circuit conductors.

One of the functions of an equipment grounding conductor is to provide a low-impedance ground-fault path between a ground fault and the electrical source. This path allows the overcurrent protective device to actuate, interrupting the current. To keep the impedance at a minimum, it is necessary to run the equipment grounding conductor in the same raceway or cable as the circuit conductor(s). This practice allows the magnetic field developed by the circuit conductor and the equipment grounding conductor to cancel, reducing their impedance.

Magnetic flux strength is inversely proportional to the square of the distance between the two conductors. By placing an equipment grounding conductor away from the conductor delivering the fault current, the magnetic flux cancellation decreases. This increases the impedance of the fault path and delays operation of the protective device.

*Exception No. 1: As provided in 250.130(C), the equipment grounding conductor shall be permitted to be run separately from the circuit conductors.*

Exception No. 1 to 250.134(B) permits an equipment grounding conductor to be run to the grounding electrode separately from the other conductors of an ac circuit. This practice applies only where a grounding-type receptacle is used on a circuit that does not include an equipment grounding conductor. See the commentary following 250.130(C) for further explanation.

*Exception No. 2: For dc circuits, the equipment grounding conductor shall be permitted to be run separately from the circuit conductors.*

FPN No. 1: See 250.102 and 250.168 for equipment bonding jumper requirements.

FPN No. 2: See 400.7 for use of cords for fixed equipment.

## 250.136 Equipment Considered Effectively Grounded

Under the conditions specified in 250.136(A) and (B), the non–current-carrying metal parts of the equipment shall be considered effectively grounded.

**(A) Equipment Secured to Grounded Metal Supports** Electrical equipment secured to and in electrical contact with a metal rack or structure provided for its support and grounded by one of the means indicated in 250.134. The structural metal frame of a building shall not be used as the required equipment grounding conductor for ac equipment.

Exhibit 250.50 shows an example of electrical equipment secured to and in electrical contact with a metal rack that is effectively grounded in accordance with 250.136(A).

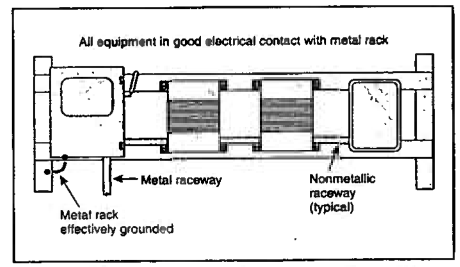



**Exhibit 250.50** An example of electrical equipment considered to be effectively grounded through mechanical connections to a grounded metal rack.

**(B) Metal Car Frames** Metal car frames supported by metal hoisting cables attached to or running over metal sheaves or drums of elevator machines that are grounded by one of the methods indicated in 250.134.

## 250.138 Cord-and-Plug-Connected Equipment

Non–current-carrying metal parts of cord-and-plug-connected equipment, if grounded, shall be grounded by one of the methods in 250.138(A) or (B).

**(A) By Means of an Equipment Grounding Conductor** By means of an equipment grounding conductor run with the power supply conductors in a cable assembly or flexible cord properly terminated in a grounding-type attachment plug with one fixed grounding contact.

*Exception: The grounding contacting pole of grounding-type plug-in ground-fault circuit interrupters shall be permitted to be of the movable, self-restoring type on circuits* *operating at not over 150 volts between any two conductors or over 150 volts between any conductor and ground.*

**(B) By Means of a Separate Flexible Wire or Strap** By means of a separate flexible wire or strap, insulated or bare, protected as well as practicable against physical damage, where part of equipment.

## 250.140 Frames of Ranges and Clothes Dryers

Frames of electric ranges, wall-mounted ovens, counter-mounted cooking units, clothes dryers, and outlet or junction boxes that are part of the circuit for these appliances shall be grounded in the manner specified by 250.134 or 250.138.

*Exception: For existing branch circuit installations only where an equipment grounding conductor is not present in the outlet or junction box, the frames of electric ranges, wall-mounted ovens, counter-mounted cooking units, clothes dryers, and outlet or junction boxes that are part of the circuit for these appliances shall be permitted to be grounded to the grounded circuit conductor if all the following conditions are met.*

*(1) The supply circuit is 120/240-volt, single-phase, 3-wire; or 208Y/120-volt derived from a 3-phase, 4-wire, wye-connected system.*
*(2) The grounded conductor is not smaller than 10 AWG copper or 8 AWG aluminum.*
*(3) The grounded conductor is insulated, or the grounded conductor is uninsulated and part of a Type SE service-entrance cable and the branch circuit originates at the service equipment.*
*(4) Grounding contacts of receptacles furnished as part of the equipment are bonded to the equipment.*

The exception to 250.140 applies only to existing branch circuits supplying the appliances specified in 250.140. The grounded conductor (neutral) of newly installed branch circuits supplying ranges and clothes dryers is no longer permitted to be used for grounding the non–current-carrying metal parts of the appliances. Branch circuits installed for new appliance installations are required to provide an equipment grounding conductor sized in accordance with 250.122 for grounding the non–current-carrying metal parts.

Caution should be exercised to ensure that new appliances connected to an existing branch circuit are properly grounded. An older appliance connected to a new branch circuit must have its 3-wire cord and plug replaced with a 4-conductor cord, with one of those conductors being an equipment grounding conductor. The bonding jumper between the neutral and the frame of the appliance must be removed. Where a new range or clothes dryer is connected to an existing branch circuit without an equipment grounding conductor, in which the neutral conductor is used for grounding the appliance frame, it must be ensured that a bonding jumper is in place between the neutral terminal of the appliance and the frame of the appliance.

The grounded circuit conductor of an existing branch circuit is still permitted to be used to ground the frame of an electric range, wall-mounted oven, or counter-mounted cooking unit, provided all four conditions of 250.140, Exception, are met. In addition, a revision in this provision for the 2005 *Code* permits application of the exception only where the existing branch-circuit wiring method does not provide an equipment grounding conductor. There are many existing branch circuits in which nonmetallic sheath cable with three insulated circuit conductors and a bare equipment grounding conductor was used to supply a range or clothes dryer. The bare equipment grounding conductor was simply not used because it was permitted to ground the equipment with the insulated neutral conductor of the NM cable. This "extra" conductor was on account of the fact that the bare conductor in a Type NM cable is to be used only as an equipment grounding conductor and cannot be used as a grounded (neutral) conductor in the same manner as is permitted for an uninsulated conductor in the service entrance.

In addition to grounding the frame of the range or clothes dryer, the grounded circuit conductor of these existing branch circuits is also permitted to be used to ground any junction boxes in the circuit supplying the appliance, and a 3-wire pigtail and range receptacle are permitted to be used.

Prior to the 1996 *Code*, use of the grounded circuit conductor as a grounding conductor was permitted for all installations. In many instances, the wiring method was service-entrance cable with an uninsulated neutral conductor covered by the cable jacket. Where Type SE cable was used to supply ranges and dryers, the branch circuit was required to originate at the service equipment to avoid neutral current from downstream panelboards on metal objects, such as pipes or ducts.

Exhibit 250.51 shows an existing installation in which Type SE service-entrance cable was used for ranges, dryers, wall-mounted ovens, and counter-mounted cooking units. Junction boxes in the supply circuit were also permitted to be grounded from the grounded neutral conductor.

## 250.142 Use of Grounded Circuit Conductor for Grounding Equipment

**(A) Supply-Side Equipment** A grounded circuit conductor shall be permitted to ground non–current-carrying metal parts of equipment, raceways, and other enclosures at any of the following locations:

(1) On the supply side or within the enclosure of the ac service-disconnecting means
(2) On the supply side or within the enclosure of the main disconnecting means for separate buildings as provided in 250.32(B)





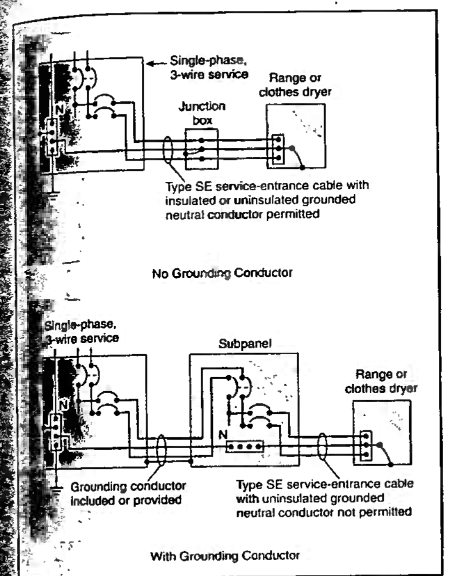



**Exhibit 250.51** An existing installation in which the grounded conductor in Type SE service-entrance cable was used for grounding the frames of ranges and clothes dryers, plus associated metal junction boxes, in accordance with 250.140.

(3) On the supply side or within the enclosure of the main disconnecting means or overcurrent devices of a separately derived system where permitted by 250.30(A)(1)

In separately derived systems, the grounded circuit conductor is permitted to ground non–current-carrying metal parts of equipment, raceways, and other enclosures only on the supply side of the main disconnecting means.

**(B) Load-Side Equipment** Except as permitted in 250.30(A)(1) and 250.32(B), a grounded circuit conductor shall not be used for grounding non–current-carrying metal parts of equipment on the load side of the service disconnecting means or on the load side of a separately derived system disconnecting means or the overcurrent devices for a separately derived system not having a main disconnecting means.

*Exception No. 1: The frames of ranges, wall-mounted ovens, counter-mounted cooking units, and clothes dryers under the conditions permitted for existing installations by 250.140 shall be permitted to be grounded by a grounded circuit conductor.*

*Exception No. 2: It shall be permissible to ground meter enclosures by connection to the grounded circuit conductor on the load side of the service disconnect where all of the following conditions apply:*

*(1) No service ground-fault protection is installed.*
*(2) All meter socket enclosures are located immediately adjacent to the service disconnecting means.*
*(3) The size of the grounded circuit conductor is not smaller than the size specified in Table 250.122 for equipment grounding conductors.*

*Exception No. 3: Direct-current systems shall be permitted to be grounded on the load side of the disconnecting means or overcurrent device in accordance with 250.164.*

*Exception No. 4: Electrode-type boilers operating at over 600 volts shall be grounded as required in 490.72(E)(1) and 490.74.*

One major reason the grounded circuit conductor is not permitted to be grounded on the load side of the service [except as permitted in 250.30, 250.32(B)(2), and the four exceptions to 250.142(B)] is that, should the grounded service conductor become disconnected at any point on the line side of the ground, the equipment grounding conductor and all conductive parts connected to it would carry the neutral current, raising the potential to ground of exposed metal parts not normally intended to carry current. This could result in arcing in concealed spaces and could pose a severe shock hazard, particularly if the path is inadvertently opened by a person servicing or repairing piping or ductwork. Even without an open grounded conductor (usually referred to as an open neutral), the equipment grounding conductor path would become a parallel path with the grounded conductor, and there would be some potential drop on exposed and concealed dead metal parts. The magnitude of this potential difference would be determined by the relative impedances of the equipment grounding path and the grounded conductor circuits. Not only would the equipment grounding conductor path be affected, but all parallel paths not intended as equipment grounding conductors would be affected as well. This could involve current through metal building structures, piping, and ducts. The requirements of 250.30 and 250.32(B) have been revised in recent editions of the *Code* to prohibit the creation of parallel paths for normal neutral current.

## 250.144 Multiple Circuit Connections

Where equipment is required to be grounded and is supplied by separate connection to more than one circuit or grounded premises wiring system, a means for grounding shall be provided for each such connection as specified in 250.134 and 250.138.

### 250.146 Connecting Receptacle Grounding Terminal to Box

An equipment bonding jumper shall be used to connect the grounding terminal of a grounding-type receptacle to a grounded box unless grounded as in 250.146(A) through (D).

**(A) Surface Mounted Box** Where the box is mounted on the surface, direct metal-to-metal contact between the device yoke and the box or a contact yoke or device that complies with 250.146(B) shall be permitted to ground the receptacle to the box. At least one of the insulating washers shall be removed from receptacles that do not have a contact yoke or device that complies with 250.146(B) to ensure direct metal-to-metal contact. This provision shall not apply to cover-mounted receptacles unless the box and cover combination are listed as providing satisfactory ground continuity between the box and the receptacle.

The main rule of 250.146 requires an equipment bonding jumper to be installed between the device box and the receptacle grounding terminal. However, 250.146(A) permits the equipment bonding jumper to be omitted where the metal yoke of the device is in direct metal-to-metal contact with the metal device box and at least one of the fiber retention washers for the receptacle mounting screws is removed, as illustrated in Exhibit 250.52.

Cover-mounted wiring devices, such as on 4-in. square covers, are not considered grounded. Section 250.146(A) does not apply to cover-mounted receptacles, such [illegible] one illustrated in Exhibit 250.53. Box-cover and devi[illegible] binations listed as providing grounding continuity [illegible] mitted.

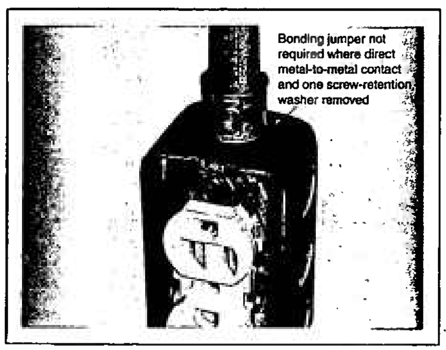



Exhibit 250.52 An example of a box-mounted receptacle attached to a surface box where a bonding jumper is not required provided at least one of the insulating washers is removed.

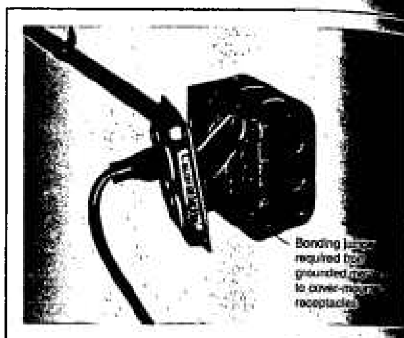



Exhibit 250.53 An example of a cover-mounted recepta[illegible] attached to a surface box where a bonding jumper is [illegible]

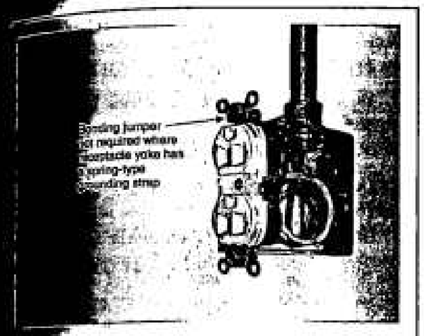
**(B) Contact Devices or Yokes** Contact devices or yo[illegible] designed and listed as self-grounding shall be permit[illegible] in conjunction with the supporting screws to establish [illegible] grounding circuit between the device yoke and flush-ty[illegible] boxes.

Section 250.146(B) is illustrated by Exhibit 250.54, [illegible] shows a receptacle designed with a spring-type grou[illegible] strap for holding the mounting screw and establishin[illegible] grounding circuit so that an equipment bonding jum[illegible] not required. Such devices are listed as "self-groundi[illegible]

**(C) Floor Boxes** Floor boxes designed for and liste[illegible] providing satisfactory ground continuity between the [illegible] and the device shall be permitted.

**(D) Isolated Receptacles** Where required for the reduc[illegible] of electrical noise (electromagnetic interference) on [illegible] grounding circuit, a receptacle in which the grounding te[illegible] nal is purposely insulated from the receptacle moun[illegible] means shall be permitted. The receptacle grounding te[illegible] shall be grounded by an insulated equipment groun[illegible] conductor run with the circuit conductors. This gro[illegible] conductor shall be permitted to pass through one or m[illegible] panelboards without connection to the panelboard groun[illegible] terminal as permitted in 408.40, Exception, so as to te[illegible] within the same building or structure directly at an equip[illegible] grounding conductor terminal of the applicable derived system or service.

FPN: Use of an isolated equipment grounding conductor does not relieve the requirement for grounding the raceway system and outlet box.




[illegible] 250.54 A receptacle designed with a listed spring-type [illegible] strap. The strap that holds the mounting screw captive [illegible] grounding circuit and eliminates the need to provide [illegible] equipment bonding jumper to the box, in accordance [illegible] 250.146(B).

Section 250.146(D) allows an isolated-ground–type recepta[illegible] installed without a bonding jumper between the [illegible] device box and the receptacle grounding terminal. [illegible] equipment grounding conductor, as shown in [illegible] 250.55, is installed with the branch-circuit conduc[illegible] conductor may originate in the service panel, pass [illegible] number of subpanels without being connected to [illegible] ment grounding bus, and terminate at the isolated-[illegible] receptacle ground terminal. However, this does [illegible] the metal device box from being grounded. The [illegible] box must be grounded either by an equipment [illegible] conductor run with the circuit conductors or by [illegible] method that serves as an equipment grounding [illegible] See 250.118 for types of equipment grounding [illegible]

According to 250.146(D), where isolated-ground–type [illegible] are used, the isolated equipment grounding con[illegible] terminate at an equipment grounding terminal of [illegible] able service or derived system in the same building [illegible] eptacle. If the isolated equipment grounding con[illegible] minates at a separate building, a large voltage [illegible] may exist between buildings during lightning tran[illegible] ch transients could cause damage to equipment [illegible] to an isolated-ground–type receptacle and present a shock hazard between the isolated equipment frame and other grounded surfaces.

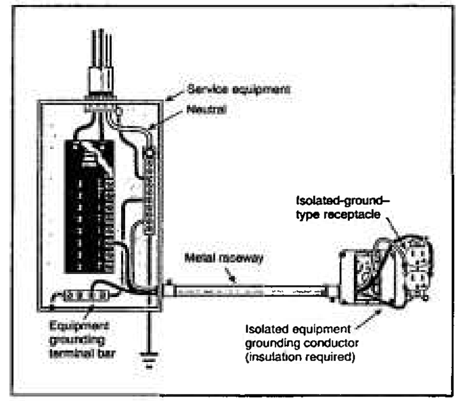



Exhibit 250.55 An isolated-ground–type receptacle with an insulated equipment grounding conductor and with the device box grounded through the metal raceway.

The fine print note to 250.146(D) is a reminder that metallic raceways and boxes are still required to be grounded by one of the usual required methods. This could require a separate grounding conductor, for example, to ground a metal box in a nonmetallic raceway system or to ground a metal box supplied by flexible metal conduit. Where an ordinary grounding-type receptacle is being replaced with an isolated-ground–type receptacle, use of an existing insulated equipment grounding conductor as the isolated receptacle grounding conductor could effectively defeat or seriously compromise the required box or raceway equipment ground.

### 250.148 Continuity and Attachment of Equipment Grounding Conductors to Boxes

Where circuit conductors are spliced within a box, or terminated on equipment within or supported by a box, any equipment grounding conductor(s) associated with those circuit conductors shall be spliced or joined within the box or to the box with devices suitable for the use in accordance with 250.148(A) through (E).

Where a metal box is used in a metal raceway system and there is a wire-type equipment grounding conductor installed in the raceway, it is not required that the wire-type equipment grounding conductor be connected to the pull box provided the box is effectively grounded by the metal raceway and the circuit conductors are not spliced or terminated to equipment in the metal box. An example of this provision would be where conductors are run unbroken through a pull box.

*Exception: The equipment grounding conductor permitted in 250.146(D) shall not be required to be connected to the other equipment grounding conductors or to the box.*

**(A) Connections** Connections and splices shall be made in accordance with 110.14(B) except that insulation shall not be required.

**(B) Grounding Continuity** The arrangement of grounding connections shall be such that the disconnection or the removal of a receptacle, luminaire (fixture), or other device fed from the box does not interfere with or interrupt the grounding continuity.

**(C) Metal Boxes** A connection shall be made between the one or more equipment grounding conductors and a metal box by means of a grounding screw that shall be used for no other purpose or a listed grounding device.

**(D) Nonmetallic Boxes** One or more equipment grounding conductors brought into a nonmetallic outlet box shall be arranged such that a connection can be made to any fitting or device in that box requiring grounding.

**(E) Solder** Connections depending solely on solder shall not be used.

## VIII. Direct-Current Systems

### 250.160 General

Direct-current systems shall comply with Part VIII and other sections of Article 250 not specifically intended for ac systems.

### 250.162 Direct-Current Circuits and Systems to Be Grounded

Direct-current circuits and systems shall be grounded as provided for in 250.162(A) and (B).

**(A) Two-Wire, Direct-Current Systems** A 2-wire, dc system supplying premises wiring and operating at greater than 50 volts but not greater than 300 volts shall be grounded.

*Exception No. 1: A system equipped with a ground detector and supplying only industrial equipment in limited areas shall not be required to be grounded.*

*Exception No. 2: A rectifier-derived dc system supplied from an ac system complying with 250.20 shall not be required to be grounded.*

*Exception No. 3: Direct-current fire alarm circuits having a maximum current of 0.030 amperes as specified in Article 760, Part III, shall not be required to be grounded.*

**(B) Three-Wire, Direct-Current Systems** The neutral conductor of all 3-wire, dc systems supplying premises wiring shall be grounded.

### 250.164 Point of Connection for Direct-Current Systems

**(A) Off-Premises Source** Direct-current systems to be grounded and supplied from an off-premises source shall have the grounding connection made at one or more supply stations. A grounding connection shall not be made at individual services or at any point on the premises wiring.

As shown in the 3-wire dc distribution system in Exhibit 250.56, the neutral is grounded at the off-premises generator site. Grounding of a 2-wire dc system would be accomplished in the same manner. For an on-premises generator, a grounding connection is required and is to be located at the source of the first system disconnecting means or overcurrent device. Other equivalent means that use equipment listed and identified for such use are permitted.

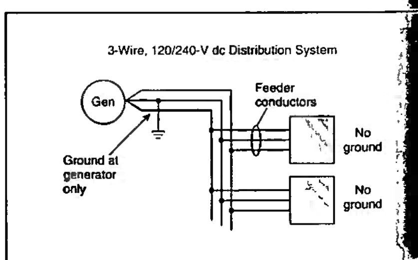



Exhibit 250.56 A 3-wire, 120/240-volt dc distribution system with the neutral grounded at the off-premises generator site.

**(B) On-Premises Source** Where the dc system source is located on the premises, a grounding connection shall be made at one of the following:

(1) The source
(2) The first system disconnection means or overcurrent device
(3) By other means that accomplish equivalent system protection and that utilize equipment listed and identified for the use





### 250.166 Size of Direct-Current Grounding Electrode Conductor

The size of the grounding electrode conductor for a dc system shall be as specified in 250.166(A) through (E).

**(A) Not Smaller Than the Neutral Conductor** Where the dc system consists of a 3-wire balancer set or a balancer winding with overcurrent protection as provided in 445.12(D), the grounding electrode conductor shall not be smaller than the neutral conductor and not smaller than 8 AWG copper or 6 AWG aluminum.

**(B) Not Smaller Than the Largest Conductor** Where the dc system is other than as in 250.166(A), the grounding electrode conductor shall not be smaller than the largest conductor supplied by the system, and not smaller than 8 AWG copper or 6 AWG aluminum.

**(C) Connected to Rod, Pipe, or Plate Electrodes** Where connected to rod, pipe, or plate electrodes as in 250.52(A)(5) or 250.52(A)(6), that portion of the grounding electrode conductor that is the sole connection to the grounding electrode shall not be required to be larger than 6 AWG copper wire or 4 AWG aluminum wire.

**(D) Connected to a Concrete-Encased Electrode** Where connected to a concrete-encased electrode as in 250.52(A)(3), that portion of the grounding electrode conductor that is the sole connection to the grounding electrode shall not be required to be larger than 4 AWG copper wire.

**(E) Connected to a Ground Ring** Where connected to a ground ring as in 250.52(A)(4), that portion of the grounding electrode 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.

### 250.168 Direct-Current Bonding Jumper

For dc systems, the size of the bonding jumper shall not be smaller than the system grounding electrode conductor specified in 250.166.

### 250.169 Ungrounded Direct-Current Separately Derived Systems

Except as otherwise permitted in 250.34 for portable and vehicle-mounted generators, an ungrounded dc separately derived system supplied from a stand-alone power source (such as an engine–generator set) shall have a grounding electrode conductor connected to an electrode that complies with Part III to provide for grounding of metal enclosures, raceways, cables, and exposed non–current-carrying metal parts of equipment. The grounding electrode conductor connection shall be to the metal enclosure at any 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.

The size of the grounding electrode conductor shall be in accordance with 250.166.

## IX. Instruments, Meters, and Relays

### 250.170 Instrument Transformer Circuits

Secondary circuits of current and potential instrument transformers shall be grounded where the primary windings are connected to circuits of 300 volts or more to ground and, where on switchboards, shall be grounded irrespective of voltage.

*Exception: Circuits where the primary windings are connected to circuits of less than 1000 volts with no live parts or wiring exposed or accessible to other than qualified persons.*

### 250.172 Instrument Transformer Cases

Cases or frames of instrument transformers shall be grounded where accessible to other than qualified persons.

*Exception: Cases or frames of current transformers, the primaries of which are not over 150 volts to ground and that are used exclusively to supply current to meters.*

### 250.174 Cases of Instruments, Meters, and Relays Operating at Less Than 1000 Volts

Instruments, meters, and relays operating with windings or working parts at less than 1000 volts shall be grounded as specified in 250.174(A), (B), or (C).

**(A) Not on Switchboards** Instruments, meters, and relays not located on switchboards, operating with windings or working parts at 300 volts or more to ground, and accessible to other than qualified persons, shall have the cases and other exposed metal parts grounded.

**(B) On Dead-Front Switchboards** Instruments, meters, and relays (whether operated from current and potential transformers or connected directly in the circuit) on switchboards having no live parts on the front of the panels shall have the cases grounded.

**(C) On Live-Front Switchboards** Instruments, meters, and relays (whether operated from current and potential transformers or connected directly in the circuit) on switchboards having exposed live parts on the front of panels shall not have their cases grounded. Mats of insulating rubber or other suitable floor insulation shall be provided for the operator where the voltage to ground exceeds 150.

### 250.176 Cases of Instruments, Meters, and Relays — Operating Voltage 1 kV and Over

Where instruments, meters, and relays have current-carrying parts of 1 kV and over to ground, they shall be isolated by elevation or protected by suitable barriers, grounded metal, or insulating covers or guards. Their cases shall not be grounded.

*Exception: Cases of electrostatic ground detectors where the internal ground segments of the instrument are connected to the instrument case and grounded and the ground detector is isolated by elevation.*

### 250.178 Instrument Grounding Conductor

The grounding conductor for secondary circuits of instrument transformers and for instrument cases shall not be smaller than 12 AWG copper or 10 AWG aluminum. Cases of instrument transformers, instruments, meters, and relays that are mounted directly on grounded metal surfaces of enclosures or grounded metal switchboard panels shall be considered to be grounded, and no additional grounding conductor shall be required.

## X. Grounding of Systems and Circuits of 1 kV and Over (High Voltage)

### 250.180 General

Where high-voltage systems are grounded, they shall comply with all applicable provisions of the preceding sections of this article and with 250.182 through 250.190, which supplement and modify the preceding sections.

### 250.182 Derived Neutral Systems

A system neutral derived from a grounding transformer shall be permitted to be used for grounding high-voltage systems.

### 250.184 Solidly Grounded Neutral Systems

Solidly grounded neutral systems shall be permitted to be either single point grounded or multigrounded neutral.

For systems over 1000 volts, the *Code* permits solidly grounded neutral systems that are either single-point grounded or multigrounded systems. For the 2005 *Code*, 250.184 was reorganized, and new requirements for the installation of single-point grounded systems were added. Circuits supplied from a single-point grounded system are required to have an equipment grounding conductor run with the circuit conductors, and this conductor is not to be used as a conductor for continuous line-to-neutral load.

**(A) Neutral Conductor**

**(1) Insulation Level** The minimum insulation level for neutral conductors of solidly grounded systems shall be 600 volts.

*Exception No. 1: Bare copper conductors shall be permitted to be used for the neutral of service entrances and the neutral of direct-buried portions of feeders.*

*Exception No. 2: Bare conductors shall be permitted for the neutral of overhead portions installed outdoors.*

*Exception No. 3: The neutral grounded conductor shall be permitted to be a bare conductor if isolated from phase conductors and protected from physical damage.*

FPN: See 225.4 for conductor covering where within 3.0 m (10 ft) of any building or other structure.

**(2) Ampacity** The neutral conductor shall be of sufficient ampacity for the load imposed on the conductor but not less than 33⅓ percent of the ampacity of the phase conductors.

*Exception: In industrial and commercial premises under engineering supervision, it shall be permissible to size the ampacity of the neutral conductor to not less than 20 percent of the ampacity of the phase conductor.*

**(B) Single Point Grounded System** Where a single point grounded neutral system is used, the following shall apply:

(1) A single point grounded system shall be permitted to be supplied from (a) or (b):
   a. A separately derived system
   b. A multigrounded neutral system with an equipment grounding conductor connected to the multigrounded neutral at the source of the single point grounded system
(2) A grounding electrode shall be provided for the system.
(3) A grounding electrode conductor shall connect the grounding electrode to the system neutral.
(4) A bonding jumper shall connect the equipment grounding conductor to the grounding electrode conductor.
(5) An equipment bonding conductor shall be provided to each building, structure, and equipment enclosure.
(6) A neutral shall only be required where phase to neutral loads are supplied.
(7) The neutral, where provided, shall be insulated and isolated from earth except at one location.
(8) An equipment grounding conductor shall be run with the phase conductors and shall comply with (a), (b), and (c):
   a. Shall not carry continuous load
   b. May be bare or insulated
   c. Shall have sufficient ampacity for fault current duty

**(C) Multigrounded Neutral Systems** Where a multigrounded neutral system is used, the following shall apply:

(1) The neutral of a solidly grounded neutral system shall be permitted to be grounded at more than one point. Grounding shall be permitted at one or more of the following locations:
   a. Transformers supplying conductors to a building or other structure
   b. Underground circuits where the neutral is exposed
   c. Overhead circuits installed outdoors
(2) The multigrounded neutral conductor shall be grounded at each transformer and at other additional locations by connection to a made or existing electrode.
(3) At least one grounding electrode shall be installed and connected to the multigrounded neutral circuit conductor every 400 m (1300 ft).
(4) The maximum distance between any two adjacent electrodes shall not be more than 400 m (1300 ft).
(5) In a multigrounded shielded cable system, the shielding shall be grounded at each cable joint that is exposed to personnel contact.

### 250.186 Impedance Grounded Neutral Systems

Impedance grounded neutral systems in which a grounding impedance, usually a resistor, limits the ground-fault current, shall be permitted where all of the following conditions are met:

(1) The conditions of maintenance and supervision ensure that only qualified persons will service the installation.
(2) Ground detectors are installed on the system.
(3) Line-to-neutral loads are not served.

Impedance grounded neutral systems shall comply with the provisions of 250.186(A) through (D).

**(A) Location** The grounding impedance shall be inserted in the grounding conductor between the grounding electrode of the supply system and the neutral point of the supply transformer or generator.

**(B) Identified and Insulated** The neutral conductor of an impedance grounded neutral system shall be identified, as well as fully insulated with the same insulation as the phase conductors.

**(C) System Neutral Connection** The system neutral shall not be connected to ground, except through the neutral grounding impedance.

**(D) Equipment Grounding Conductors** Equipment grounding conductors shall be permitted to be bare and shall be electrically connected to the ground bus and grounding electrode conductor.

### 250.188 Grounding of Systems Supplying Portable or Mobile Equipment

Systems supplying portable or mobile high-voltage equipment, other than substations installed on a temporary basis, shall comply with 250.188(A) through (F).

*Portable* describes equipment that is easily carried from one location to another. *Mobile* describes equipment that is easily moved on wheels, treads, and so on.

**(A) Portable or Mobile Equipment** Portable or mobile high-voltage equipment shall be supplied from a system having its neutral grounded through an impedance. Where a delta-connected high-voltage system is used to supply portable or mobile equipment, a system neutral shall be derived.

**(B) Exposed Non–Current-Carrying Metal Parts** Exposed non–current-carrying metal parts of portable or mobile equipment shall be connected by an equipment grounding conductor to the point at which the system neutral impedance is grounded.

**(C) Ground-Fault Current** The voltage developed between the portable or mobile equipment frame and ground by the flow of maximum ground-fault current shall not exceed 100 volts.

**(D) Ground-Fault Detection and Relaying** Ground-fault detection and relaying shall be provided to automatically de-energize any high-voltage system component that has developed a ground fault. The continuity of the equipment grounding conductor shall be continuously monitored so as to de-energize automatically the high-voltage circuit to the portable or mobile equipment upon loss of continuity of the equipment grounding conductor.

**(E) Isolation** The grounding electrode to which the portable or mobile equipment system neutral impedance is connected shall be isolated from and separated in the ground by at least 6.0 m (20 ft) from any other system or equipment grounding electrode, and there shall be no direct connection between the grounding electrodes, such as buried pipe and fence, and so forth.

**(F) Trailing Cable and Couplers** High-voltage trailing cable and couplers for interconnection of portable or mobile equipment shall meet the requirements of Part III of Article 400 for cables and 490.55 for couplers.

### 250.190 Grounding of Equipment

All non–current-carrying metal parts of fixed, portable, and mobile equipment and associated fences, housings, enclosures, and supporting structures shall be grounded.

*Exception: Where isolated from ground and located so as to prevent any person who can make contact with ground from contacting such metal parts when the equipment is energized.*

Grounding conductors not an integral part of a cable assembly shall not be smaller than 6 AWG copper or 4 AWG aluminum.

# ARTICLE 110
# Requirements for Electrical Installations

## Summary of Changes

- **110.1:** Revised paragraph to include enclosures intended for personnel entry.
- **110.12:** Added FPN referencing ANSI-approved standards.
- **110.15:** Revised paragraph to clarify application of special identification to the high leg only.
- **110.16:** Revised paragraph to include meter socket enclosures.
- **110.26(C)(2):** Deleted six-ft width limitation so that requirement applies to all equipment rated 1200 amperes and greater and containing overcurrent devices, switching devices, and control devices.
- **Part V, 110.70–110.79:** Moved Article 314, Part IV to Article 110.

## Contents

# I. General

## 110.1 Scope

This article covers general requirements for the examination and approval, installation and use, access to and spaces about electrical conductors and equipment; enclosures intended for personnel entry; and tunnel installations.

## 110.2 Approval

The conductors and equipment required or permitted by this *Code* shall be acceptable only if approved.

FPN: See 90.7, Examination of Equipment for Safety, and 110.3, Examination, Identification, Installation, and Use of Equipment. See definitions of *Approved*, *Identified*, *Labeled*, and *Listed*.

All electrical equipment is required to be approved as defined in Article 100 and, as such, to be acceptable to the authority having jurisdiction (also defined in Article 100). Section 110.3 provides guidance for the evaluation of equipment and recognizes listing or labeling as a means of establishing suitability.

Approval of equipment is the responsibility of the electrical inspection authority, and many such approvals are based on tests and listings of testing laboratories.

## 110.3 Examination, Identification, Installation, and Use of Equipment

**(A) Examination** In judging equipment, considerations such as the following shall be evaluated:

(1) Suitability for installation and use in conformity with the provisions of this *Code*

FPN: Suitability of equipment use may be identified by a description marked on or provided with a product to identify the suitability of the product for a specific purpose, environment, or application. Suitability of equipment may be evidenced by listing or labeling.

(2) Mechanical strength and durability, including, for parts designed to enclose and protect other equipment, the adequacy of the protection thus provided
(3) Wire-bending and connection space
(4) Electrical insulation
(5) Heating effects under normal conditions of use and also under abnormal conditions likely to arise in service
(6) Arcing effects
(7) Classification by type, size, voltage, current capacity, and specific use
(8) Other factors that contribute to the practical safeguarding of persons using or likely to come in contact with the equipment

For wire-bending and connection space in cabinets and cutout boxes, see 312.6, Table 312.6(A), Table 312.6(B), 312.7, 312.9, and 312.11. For wire-bending and connection space in other equipment, see the appropriate *NEC* article and section. For example, see 314.16 and 314.28 for outlet, device, pull, and junction boxes, as well as conduit bodies; 404.3 and 404.18 for switches; 408.3(F) for switchboards and panelboards; and 430.10 for motors and motor controllers.

**(B) Installation and Use** Listed or labeled equipment shall be installed and used in accordance with any instructions included in the listing or labeling.

Manufacturers usually supply installation instructions with equipment for use by general contractors, erectors, electrical contractors, electrical inspectors, and others concerned with an installation. It is important to follow the listing or labeling installation instructions. For example, 210.52, second paragraph, permits permanently installed electric baseboard heaters to be equipped with receptacle outlets that meet the requirements for the wall space utilized by such heaters. The installation instructions for such permanent baseboard heaters indicate that the heaters should not be mounted beneath a receptacle. In dwelling units, it is common to use low-density heating units that measure in excess of 12 ft in length. Therefore, to meet the provisions of 210.52(A) and also the installation instructions, a receptacle must either be part of the heating unit or be installed in the floor close to the wall but not above the heating unit. (See 210.52, FPN, and Exhibit 210.23 for more specific details.)





In itself, 110.3 does not require listing or labeling of equipment. It does, however, require considerable evaluation of equipment. Section 110.2 requires that equipment be acceptable only if approved. The term *approved* is defined in Article 100 as acceptable to the authority having jurisdiction (AHJ). Before issuing approval, the authority having jurisdiction may require evidence of compliance with 110.3(A). The most common form of evidence considered acceptable by authorities having jurisdiction is a listing or labeling by a third party.

Some sections in the *Code* require listed or labeled equipment. For example, 250.8 includes the phrase "listed pressure connectors, listed clamps, or other listed means."

## 110.4 Voltages

Throughout this *Code*, the voltage considered shall be that at which the circuit operates. The voltage rating of electrical equipment shall not be less than the nominal voltage of a circuit to which it is connected.

Voltages used for computing branch-circuit and feeder loads are nominal voltages as listed in 220.5. See the definitions of *voltage (of a circuit)*; *voltage, nominal*; and *voltage to ground* in Article 100. See also 300.2 and 300.3(C), which specify the voltage limitations of conductors of circuits rated 600 volts, nominal, or less, and over 600 volts, nominal.

## 110.5 Conductors

Conductors normally used to carry current shall be of copper unless otherwise provided in this *Code*. Where the conductor material is not specified, the material and the sizes given in this *Code* shall apply to copper conductors. Where other materials are used, the size shall be changed accordingly.

FPN: For aluminum and copper-clad aluminum conductors, see 310.15.

See 110.14 for aluminum conductor material.

## 110.6 Conductor Sizes

Conductor sizes are expressed in American Wire Gage (AWG) or in circular mils.

For copper, aluminum, or copper-clad aluminum conductors up to size 4/0 AWG, this *Code* uses the American Wire Gage (AWG) for size identification, which is the same as the Brown and Sharpe (BS) Gage. Changed for the 2002 *Code*, wire sizes up to size 4/0 AWG are now expressed as XX AWG, XX being the size wire. For example, a wire size expressed as *No. 12* in prior editions of the *Code* is now expressed as *12 AWG*. The resulting expression would therefore appear as *six 12 AWG conductors* instead of *6 No. 12 conductors*.

Conductors larger than 4/0 AWG are sized in circular mils, beginning with 250,000 circular mils. Prior to the 1990 edition, a 250,000-circular-mil conductor was labeled *250 MCM*. The term *MCM* was defined as 1000 circular mils (the first *M* being the Roman numeral designation for 1000). Beginning in the 1990 edition, the notation was changed to 250 *kcmil* to recognize the accepted convention that *k* indicates 1000. UL standards and IEEE standards also use the notation *kcmil* rather than *MCM*.

The circular mil area of a conductor is equal to its diameter in mils squared (1 in. = 1000 mils). For example, the circular mil area of an 8 AWG solid conductor that has a 0.1285-in. diameter is calculated as follows:

$$0.1285 \text{ in.} \times 1000 = 128.5 \text{ mils}$$

$$128.5 \times 128.5 = 16{,}512.25 \text{ circular mils}$$

or 16,510 circular mils (rounded off)

According to Table 8 in Chapter 9, this rounded value represents the circular mil area for one conductor. Where stranded conductors are used, the circular mil area of each strand must be multiplied by the number of strands to determine the circular mil area of the conductor.

## 110.7 Insulation Integrity

Completed wiring installations shall be free from short circuits and from grounds other than as required or permitted in Article 250.

Insulation is the material that prevents the flow of electricity between points of different potential in an electrical system. Failure of the insulation system is one of the most common causes of problems in electrical installations, in both high-voltage and low-voltage systems.

Insulation tests are performed on new or existing installations to determine the quality or condition of the insulation of conductors and equipment. The principal causes of insulation failures are heat, moisture, dirt, and physical damage (abrasion or nicks) occurring during and after installation. Insulation can also fail due to chemical attack, sunlight, and excessive voltage stresses.

Insulation integrity must be maintained during overcurrent conditions. Overcurrent protective devices must be selected and coordinated using tables of insulation thermal-withstand ability to ensure that the damage point of an insulated conductor is never reached. These tables, entitled "Allowable Short-Circuit Currents for Insulated Copper (or Aluminum) Conductors," are contained in the Insulated Cable Engineers Association's publication ICEA P-32-382. See 110.10 for other circuit components.

In an insulation resistance test, a voltage ranging from

100 to 5000 (usually 500 to 1000 volts for systems of 600 volts or less), supplied from a source of constant potential, is applied across the insulation. A megohmmeter is usually the potential source, and it indicates the insulation resistance directly on a scale calibrated in megohms (MΩ). The quality of the insulation is evaluated based on the level of the insulation resistance.

The insulation resistance of many types of insulation varies with temperature, so the field data obtained should be corrected to the standard temperature for the class of equipment being tested. The megohm value of insulation resistance obtained is inversely proportional to the volume of insulation tested. For example, a cable 1000 ft long would be expected to have one-tenth the insulation resistance of a cable 100 ft long, if all other conditions are identical.

The insulation resistance test is relatively easy to perform and is useful on all types and classes of electrical equipment. Its main value lies in the charting of data from periodic tests, corrected for temperature, over a long period so that deteriorative trends can be detected.

Manuals on this subject are available from instrument manufacturers. Thorough knowledge in the use of insulation testers is essential if the test results are to be meaningful. Exhibit 110.1 shows a typical megohmmeter insulation tester.

**Exhibit 110.1** A manual multivoltage, multirange insulation tester.

### 110.8 Wiring Methods

**Only wiring methods recognized as suitable are included in this *Code*. The recognized methods of wiring shall be permitted to be installed in any type of building or occupancy, except as otherwise provided in this *Code*.**

The scope of Article 300 applies generally to all wiring methods, except as amended, modified, or supplemented by other *NEC* chapters. The application statement is found in 90.3, Code Arrangement.

### 110.9 Interrupting Rating

**Equipment intended to interrupt current at fault levels shall have an interrupting rating sufficient for the nominal circuit voltage and the current that is available at the line terminals of the equipment.**

**Equipment intended to interrupt current at other than fault levels shall have an interrupting rating at nominal circuit voltage sufficient for the current that must be interrupted.**

The interrupting rating of overcurrent protective devices is determined under standard test conditions. It is important that the test conditions match the actual installation needs. Section 110.9 states that all fuses and circuit breakers intended to interrupt the circuit at fault levels must have an adequate interrupting rating wherever they are used in the electrical system. Fuses or circuit breakers that do not have adequate interrupting ratings could rupture while attempting to clear a short circuit.

Interrupting ratings should not be confused with short-circuit current ratings. Short-circuit current ratings are further explained in the commentary following 110.10.

### 110.10 Circuit Impedance and Other Characteristics

**The overcurrent protective devices, the total impedance, the component short-circuit current ratings, and other characteristics of the circuit to be protected shall be selected and coordinated to permit the circuit-protective devices used to clear a fault to do so without extensive damage to the electrical components of the circuit. This fault shall be assumed to be either between two or more of the circuit conductors or between any circuit conductor and the grounding conductor or enclosing metal raceway. Listed products applied in accordance with their listing shall be considered to meet the requirements of this section.**

In the 1999 *Code*, the word *current* was substituted for the obsolete word *withstand*. That change correlated the *Code* language with the standard marking language used on equipment. Withstand ratings are not marked on equipment, but short-circuit current ratings are. This marking appears on many pieces of equipment, such as panelboards, switchboards, busways, contactors, and starters. Additionally, the last sentence of 110.10 is meant to address concerns of what exactly constitutes "extensive damage." Because, under product safety requirements, electrical equipment is evaluated for indications of extensive damage, listed products used within their ratings are considered to have met the requirements of 110.10.

The basic purpose of overcurrent protection is to open the circuit before conductors or conductor insulation is damaged when an overcurrent condition occurs. An overcurrent condition can be the result of an overload, a ground fault, or a short circuit and must be eliminated before the conductor insulation damage point is reached.

Overcurrent protective devices (such as fuses and circuit breakers) should be selected to ensure that the short-circuit current rating of the system components is not exceeded should a short circuit or high-level ground fault occur.

System components include wire, bus structures, switching, protection and disconnect devices, and distribution equipment, all of which have limited short-circuit ratings and would be damaged or destroyed if those short-circuit ratings were exceeded. Merely providing overcurrent protective devices with sufficient interrupting rating would not ensure adequate short-circuit protection for the system components. When the available short-circuit current exceeds the short-circuit current rating of an electrical component, the overcurrent protective device must limit the let-through energy to within the rating of that electrical component.

Utility companies usually determine and provide information on available short-circuit current levels at the service equipment. Literature on how to calculate short-circuit currents at each point in any distribution generally can be obtained by contacting the manufacturers of overcurrent protective devices or by referring to IEEE 141-1993, *IEEE Recommended Practice for Electric Power Distribution for Industrial Plants* (Red Book).

For a typical one-family dwelling with a 100-ampere service using 2 AWG aluminum supplied by a 371/2 kVA transformer with 1.72 percent impedance located at a distance of 25 ft, the available short-circuit current would be approximately 6000 amperes.

Available short-circuit current to multifamily structures, where pad-mounted transformers are located close to the multimetering location, can be relatively high. For example, the line-to-line fault current values close to a low-impedance transformer could exceed 22,000 amperes. At the secondary of a single-phase, center-tapped transformer, the line-to-neutral fault current is approximately one and one-half times that of the line-to-line fault current. The short-circuit current rating of utilization equipment located and connected near the service equipment should be known. For example, HVAC equipment is tested at 3500 amperes through a 40-ampere load rating and at 5000 amperes for loads rated more than 40 amperes.

Adequate short-circuit protection can be provided by fuses, molded-case circuit breakers, and low-voltage power circuit breakers, depending on specific circuit and installation requirements.

### 110.11 Deteriorating Agents

**Unless identified for use in the operating environment, no conductors or equipment shall be located in damp or wet locations; where exposed to gases, fumes, vapors, liquids, or other agents that have a deteriorating effect on the conductors or equipment; or where exposed to excessive temperatures.**

FPN No. 1: See 300.6 for protection against corrosion.

FPN No. 2: Some cleaning and lubricating compounds can cause severe deterioration of many plastic materials used for insulating and structural applications in equipment.

**Equipment identified only as "dry locations," "Type 1," or "indoor use only" shall be protected against permanent damage from the weather during building construction.**

### 110.12 Mechanical Execution of Work

**Electrical equipment shall be installed in a neat and workmanlike manner.**

FPN: Accepted industry practices are described in ANSI/NECA 1-2000, *Standard Practices for Good Workmanship in Electrical Contracting*, and other ANSI-approved installation standards.

The regulation in 110.12 calling for "neat and workmanlike" installations has appeared in the *NEC* as currently worded for more than a half-century. It stands as a basis for pride in one's work and has been emphasized by persons involved in the training of apprentice electricians for many years.

Many *Code* conflicts or violations have been cited by the authority having jurisdiction based on the authority's interpretation of "neat and workmanlike manner." Many electrical inspection authorities use their own experience or precedents in their local areas as the basis for their judgments.

Examples of installations that do not qualify as "neat and workmanlike" include exposed runs of cables or raceways that are improperly supported (e.g., sagging between supports or use of improper support methods); field-bent and kinked, flattened, or poorly measured raceways; or cabinets, cutout boxes, and enclosures that are not plumb or not properly secured.

The FPN, new for the 2005 *Code*, directs the user to an industry accepted ANSI standard that clearly describes and illustrates "neat and workmanlike" electrical installations. See Exhibit 110.2.

**(A) Unused Openings** **Unused cable or raceway openings in boxes, raceways, auxiliary gutters, cabinets, cutout boxes, meter socket enclosures, equipment cases, or housings shall**

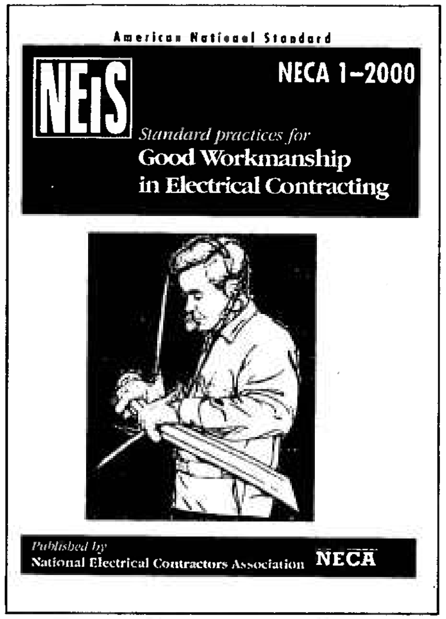



**Exhibit 110.2** Exhibit 110.2. ANSI/NECA 1-2000, *Standard Practice for Good Workmanship in Electrical Contracting*, one example of the many ANSI standards that describe "neat and workmanlike" installations.

be effectively closed to afford protection substantially equivalent to the wall of the equipment. Where metallic plugs or plates are used with nonmetallic enclosures, they shall be recessed at least 6 mm (1/4 in.) from the outer surface of the enclosure.

The phrase *unused cable or raceway openings* clarifies that openings used for normal operation, such as weep holes, are not required to be closed up.

See 408.7 for requirements on unused openings in switchboard and panelboard enclosures.

**(B) Subsurface Enclosures** Conductors shall be racked to provide ready and safe access in underground and subsurface enclosures into which persons enter for installation and maintenance.

**(C) Integrity of Electrical Equipment and Connections** Internal parts of electrical equipment, including busbars, wiring terminals, insulators, and other surfaces, shall not be damaged or contaminated by foreign materials such as paint, plaster, cleaners, abrasives, or corrosive residues. There shall be no damaged parts that may adversely affect safe operation or mechanical strength of the equipment such as parts that are broken; bent; cut; or deteriorated by corrosion, chemical action, or overheating.

### 110.13 Mounting and Cooling of Equipment

**(A) Mounting** Electrical equipment shall be firmly secured to the surface on which it is mounted. Wooden plugs driven into holes in masonry, concrete, plaster, or similar materials shall not be used.

**(B) Cooling** Electrical equipment that depends on the natural circulation of air and convection principles for cooling of exposed surfaces shall be installed so that room airflow over such surfaces is not prevented by walls or by adjacent installed equipment. For equipment designed for floor mounting, clearance between top surfaces and adjacent surfaces shall be provided to dissipate rising warm air.

Electrical equipment provided with ventilating openings shall be installed so that walls or other obstructions do not prevent the free circulation of air through the equipment.

*Ventilated* is defined in Article 100. Panelboards, transformers, and other types of equipment are adversely affected if enclosure surfaces normally exposed to room air are covered or tightly enclosed. Ventilating openings in equipment are provided to allow the circulation of room air around internal components of the equipment; the blocking of such openings can cause dangerous overheating. For example, a ventilated busway must be located where there are no walls or other objects that might interfere with the natural circulation of air and convection principles for cooling. Ventilation for motor locations is covered in 430.14(A) and 430.16. Ventilation for transformer locations is covered in 450.9 and 450.45. In addition to 110.13, proper placement of equipment requiring ventilation becomes enforceable using the requirements of 110.3(B).

### 110.14 Electrical Connections

Because of different characteristics of dissimilar metals, devices such as pressure terminal or pressure splicing connectors and soldering lugs shall be identified for the material of the conductor and shall be properly installed and used. Conductors of dissimilar metals shall not be intermixed in a terminal or splicing connector where physical contact occurs between dissimilar conductors (such as copper and aluminum, copper and copper-clad aluminum, or aluminum and copper-clad aluminum), unless the device is identified for the purpose and conditions of use. Materials such as solder, fluxes, inhibitors, and compounds, where employed, shall be suitable for the use and shall be of a type that will not adversely affect the conductors, installation, or equipment.

FPN: Many terminations and equipment are marked with a tightening torque.

Section 110.3(B) applies where terminations and equipment are marked with tightening torques.

For the testing of wire connectors for which the manufacturer has not assigned another value appropriate for the design, Commentary Tables 1.2 through 1.5 provide data on the tightening torques that Underwriters Laboratories uses. These tables should be used for guidance only if no tightening information on a specific wire connector is available. They should not be used to replace the manufacturer's instructions, which should always be followed.

The information in the tables was taken from UL 486B, *Wire Connections for Use with Aluminum Conductors*. Similar information can be found in UL 486A, *Wire Connections and Solder Lugs for Use with Copper Conductors*.

**(A) Terminals** Connection of conductors to terminal parts shall ensure a thoroughly good connection without damaging the conductors and shall be made by means of pressure connectors (including set-screw type), solder lugs, or splices to flexible leads. Connection by means of wire-binding screws or studs and nuts that have upturned lugs or the equivalent shall be permitted for 10 AWG or smaller conductors.

Terminals for more than one conductor and terminals used to connect aluminum shall be so identified.

**(B) Splices** Conductors shall be spliced or joined with splicing devices identified for the use or by brazing, welding,

**Commentary Table 1.2** Tightening Torques for Screws,* in Pound-Inches

| | Slotted Head No. 10 and Larger | | Hexagonal Head-External Drive Socket Wrench | |
|---|---|---|---|---|
| Wire Size (AWG or kcmil) | Slot Width to 3/64 in. or Slot Length to 1/4 in.† | Slot Width Over 3/64 in. or Slot Length Over 1/4 in.† | Split-Bolt Connectors | Other Connectors |
| 30-10 | 20 | 35 | 80 | 75 |
| 8 | 25 | 40 | 80 | 75 |
| 6 | 35 | 45 | 165 | 110 |
| 4 | 35 | 45 | 165 | 110 |
| 3 | 35 | 50 | 275 | 150 |
| 2 | 40 | 50 | 275 | 150 |
| 1 | — | 50 | 275 | 150 |
| 1/0 | — | 50 | 385 | 180 |
| 2/0 | — | 50 | 385 | 180 |
| 3/0 | — | 50 | 500 | 250 |
| 4/0 | — | 50 | 500 | 250 |
| 250 | — | 50 | 650 | 325 |
| 300 | — | 50 | 650 | 325 |
| 350 | — | 50 | 650 | 325 |
| 400 | — | 50 | 825 | 325 |
| 500 | — | 50 | 825 | 375 |
| 600 | — | 50 | 1000 | 375 |
| 700 | — | 50 | 1000 | 375 |
| 750 | — | 50 | 1000 | 375 |
| 800 | — | 50 | 1100 | 500 |
| 900 | — | 50 | 1100 | 500 |
| 1000 | — | 50 | 1100 | 500 |
| 1250 | — | — | 1100 | 600 |
| 1500 | — | — | 1100 | 600 |
| 1750 | — | — | 1100 | 600 |
| 2000 | — | — | 1100 | 600 |

*Clamping screws with multiple tightening means. For example, for a slotted hexagonal head screw, use the torque value associated with the tool used in the installation. UL uses both values when testing.
†For values of slot width or length other than those specified, select the largest torque value associated with conductor size.

**Commentary Table 1.3** Torques in Pound-Inches for Slotted Head Screws* Smaller Than No. 10, for Use with 8 AWG and Smaller Conductors

| Screw-Slot Length (in.)† | Screw-Slot Width Less Than 3/64 in. | Screw-Slot Width 3/64 in. and Larger |
|---|---|---|
| To 5/32 | 7 | 9 |
| 5/32 | 7 | 12 |
| 3/16 | 7 | 12 |
| 7/32 | 7 | 12 |
| 1/4 | 9 | 12 |
| 9/32 | — | 15 |
| Above 9/32 | — | 20 |

*Clamping screws with multiple tightening means. For example, for a slotted hexagonal head screw, use the torque value associated with the tool used in the installation. UL uses both values when testing.
†For slot lengths of intermediate values, select torques pertaining to next-shorter slot length.

**Commentary Table 1.4** Torques for Recessed Allen Head Screws

| Socket Size Across Flats (in.) | Torque (lb-in.) |
|---|---|
| 1/8 | 45 |
| 5/32 | 100 |
| 3/16 | 120 |
| 7/32 | 150 |
| 1/4 | 200 |
| 5/16 | 275 |
| 3/8 | 375 |
| 1/2 | 500 |
| 9/16 | 600 |

**Commentary Table 1.5** Lug-Bolting Torques for Connection of Wire Connectors to Busbars

| Bolt Diameter | Tightening Torque (lb-ft) |
|---|---|
| No. 8 or smaller | 1.5 |
| No. 10 | 2 |
| 1/4 in. or less | 6 |
| 5/16 in. | 11 |
| 3/8 in. | 19 |
| 7/16 in. | 30 |
| 1/2 in. | 40 |
| 9/16 in. or larger | 55 |

**or soldering with a fusible metal or alloy. Soldered splices shall first be spliced or joined so as to be mechanically and electrically secure without solder and then be soldered. All splices and joints and the free ends of conductors shall be covered with an insulation equivalent to that of the conductors or with an insulating device identified for the purpose.**

**Wire connectors or splicing means installed on conductors for direct burial shall be listed for such use.**

Field observations and trade magazine articles indicate that electrical connection failures have been determined to be the cause of many equipment burnouts and fires. Many of these failures are attributable to improper terminations, poor workmanship, the differing characteristics of dissimilar metals, and improper binding screws or splicing devices.

UL's requirements for listing solid aluminum conductors in 12 AWG and 10 AWG and for listing snap switches and receptacles for use on 15- and 20-ampere branch circuits incorporate stringent tests that take into account the factors listed in the preceding paragraph. For further information regarding receptacles and switches using CO/ALR-rated terminals, refer to 404.14(C) and 406.2(C).

Screwless pressure terminal connectors of the conductor push-in type are for use with solid copper and copper-clad aluminum conductors only.

Instructions that describe proper installation techniques and emphasize the need to follow those techniques and practice good workmanship are required to be included with each coil of 12 AWG and 10 AWG insulated aluminum wire or cable. See also the commentary on tightening torque that follows 110.14, FPN.

New product and material designs that provide increased levels of safety of aluminum wire terminations have been developed by the electrical industry. To assist all concerned parties in the proper and safe use of solid aluminum wire in making connections to wiring devices used on 15- and 20-ampere branch circuits, the following information is presented. Understanding and using this information is essential for proper application of materials and devices now available.

### For New Installations

The following commentary is based on a report prepared by the Ad Hoc Committee on Aluminum Terminations prior to publication of the 1975 *Code*. This information is still pertinent today and is necessary for compliance with 110.14(A) when aluminum wire is used in new installations.

**New Materials and Devices.** For direct connection, only 15- and 20-ampere receptacles and switches marked "CO/ALR" and connected as follows under Installation Method should be used.

The "CO/ALR" marking is on the device mounting yoke or strap. The "CO/ALR" marking means the devices have been tested to stringent heat-cycling requirements to determine their suitability for use with UL-labeled aluminum, copper, or copper-clad aluminum wire.

Listed solid aluminum wire, 12 AWG or 10 AWG, marked with the aluminum insulated wire label should be used. The installation instructions that are packaged with the wire should be used.





**Installation Method.** Exhibit 110.3 illustrates the following correct method of connection:

1. The freshly stripped end of the wire is wrapped two-thirds to three-quarters of the distance around the wire-binding screw post, as shown in Step A of Exhibit 110.3. The loop is made so that rotation of the screw during tightening will tend to wrap the wire around the post rather than unwrap it.
2. The screw is tightened until the wire is snugly in contact with the underside of the screw head and with the contact plate on the wiring device, as shown in Step B of Exhibit 110.3.
3. The screw is tightened an additional half-turn, thereby providing a firm connection, as shown in Step C of Exhibit 110.3. If a torque screwdriver is used, the screw is tightened to 12 lb-in.

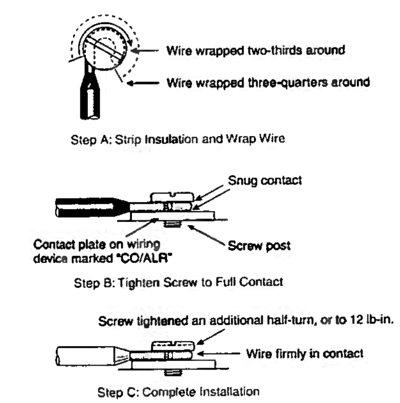



**Exhibit 110.3** Correct method of terminating aluminum wire at wire-binding screw terminals of receptacles and snap switches. (Redrawn courtesy of Underwriters Laboratories Inc.)

4. The wires should be positioned behind the wiring device to decrease the likelihood of the terminal screws loosening when the device is positioned into the outlet box.

Exhibit 110.4 illustrates incorrect methods of connection. These methods should *not* be used.

**Existing Inventory.** Labeled 12 AWG or 10 AWG solid aluminum wire that does not bear the new aluminum wire label should be used with wiring devices marked "CO/ALR" and connected as described under Installation Method. This is the preferred and recommended method for using such wire.

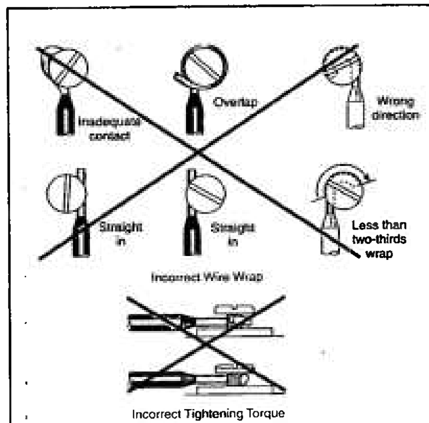



**Exhibit 110.4** Incorrect methods of terminating aluminum wire at wire-binding screw terminals of receptacles and snap switches. (Redrawn courtesy of Underwriters Laboratories Inc.)

For the following types of devices, the terminals should not be directly connected to aluminum conductors but may be used with labeled copper or copper-clad conductors:

1. Receptacles and snap switches marked "AL-CU"
2. Receptacles and snap switches having no conductor marking
3. Receptacles and snap switches that have back-wired terminals or screwless terminals of the push-in type

### For Existing Installations

If examination discloses overheating or loose connections, the recommendations described under Existing Inventory should be followed.

### Twist-On Wire Connectors

Because 110.14(B) requires conductors to be spliced with "splicing devices identified for the use," wire connectors are required to be marked for conductor suitability. Twist-on wire connectors are not suitable for splicing aluminum conductors or copper-clad aluminum to copper conductors unless it is so stated and marked as such on the shipping carton. The marking is typically "AL-CU (dry locations)."

Presently, one style of wire nut and one style of crimp-type connector have been listed as having met these requirements.

On February 2, 1995, Underwriters Laboratories announced the listing of a twist-on wire connector suitable for use with aluminum-to-copper conductors, in accordance with UL 486C, *Splicing Wire Connectors*. That was the first listing of a twist-on type connector for aluminum-to-copper conductors since 1987. The UL listing does *not* cover aluminum-to-aluminum combinations. However, more than one aluminum or copper conductor is allowed when used in combination.

These listed wire-connecting devices are available for pigtailing short lengths of copper conductors to the original aluminum branch-circuit conductors, as shown in Exhibit 110.5. Primarily, these pigtailed conductors supply 15- and 20-ampere wiring devices. Pigtailing is permitted, provided there is suitable space within the enclosure.

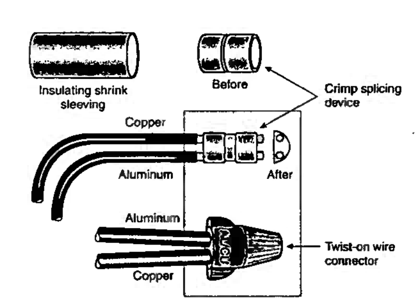



Exhibit 110.5 Pigtailing copper to aluminum conductors using two listed devices.

**(C) Temperature Limitations** The temperature rating associated with the ampacity of a conductor shall be selected and coordinated so as not to exceed the lowest temperature rating of any connected termination, conductor, or device. Conductors with temperature ratings higher than specified for terminations shall be permitted to be used for ampacity adjustment, correction, or both.

**(1) Equipment Provisions** The determination of termination provisions of equipment shall be based on 110.14(C)(1)(a) or (C)(1)(b). Unless the equipment is listed and marked otherwise, conductor ampacities used in determining equipment termination provisions shall be based on Table 310.16 as appropriately modified by 310.15(B)(6).

(a) Termination provisions of equipment for circuits rated 100 amperes or less, or marked for 14 AWG through 1 AWG conductors, shall be used only for one of the following:

(1) Conductors rated 60°C (140°F).
(2) Conductors with higher temperature ratings, provided the ampacity of such conductors is determined based on the 60°C (140°F) ampacity of the conductor size used.
(3) Conductors with higher temperature ratings if the equipment is listed and identified for use with such conductors.
(4) For motors marked with design letters B, C, or D, conductors having an insulation rating of 75°C (167°F) or higher shall be permitted to be used, provided the ampacity of such conductors does not exceed the 75°C (167°F) ampacity.

(b) Termination provisions of equipment for circuits rated over 100 amperes, or marked for conductors larger than 1 AWG, shall be used only for one of the following:

(1) Conductors rated 75°C (167°F)
(2) Conductors with higher temperature ratings, provided the ampacity of such conductors does not exceed the 75°C (167°F) ampacity of the conductor size used, or up to their ampacity if the equipment is listed and identified for use with such conductors

**(2) Separate Connector Provisions** Separately installed pressure connectors shall be used with conductors at the ampacities not exceeding the ampacity at the listed and identified temperature rating of the connector.

FPN: With respect to 110.14(C)(1) and (C)(2), equipment markings or listing information may additionally restrict the sizing and temperature ratings of connected conductors.

Section 110.14(C)(1) states that where conductors are terminated in equipment, the selected conductor ampacities must be based on Table 310.16, unless the equipment is specifically listed and marked otherwise. The intent of this requirement is to clarify which ampacities are used to determine the proper conductor size at equipment terminations.

When equipment of 600 volts or less is evaluated relative to the appropriate temperature characteristics of the terminations, conductors sized according to Table 310.16 are required to be used. The UL *General Information Directory* (White Book, page 3) clearly indicates that the 60°C and 75°C provisions for equipment have been determined using conductors from Table 310.16. However, installers or designers unaware of the UL guide card information might attempt to select conductors based on a table other than Table 310.16, especially if a wiring method that allows the use of ampacities such as those in Table 310.17 is used. That use can result in overheated terminations at the equipment. Clearly, the ampacities shown in other tables (such as Table 310.17) could be used for various conditions to which the wiring method is subject (ambient, ampacity correction, etc.), but the conductor size at the termination must be based on ampacities from Table 310.16. This change does not introduce any new impact on the equipment or the wiring methods; it simply adds a rule from the listing information into the *Code* because it is an installation and equipment selection issue.

Section 110.14(C)(1)(a) requires that conductor terminations, as well as conductors, be rated for the operating temperature of the circuit. For example, the load on an 8 AWG THHN, 90°C copper wire is limited to 40 amperes where connected to a disconnect switch with terminals rated at 60°C. The same 8 AWG THHN, 90°C wire is limited to 50 amperes where connected to a fusible switch with terminals rated at 75°C. The conductor ampacities were selected from Table 310.16. Not only does this requirement apply to conductor terminations of breakers and fusible switches, but the equipment enclosure must also permit terminations above 60°C. Exhibit 110.6 shows an example of termination temperature markings.

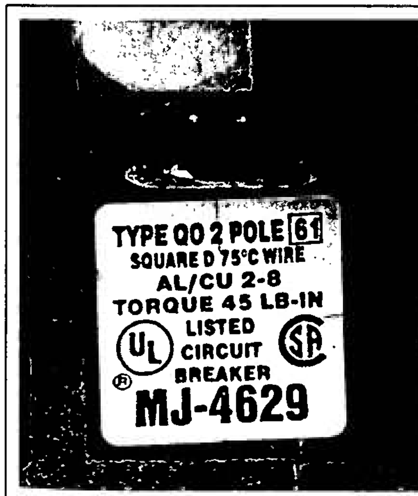



Exhibit 110.6 An example of termination temperature markings on a main circuit breaker. (Courtesy of Square D Co.)

## 110.15 High-Leg Marking

**On a 4-wire, delta-connected system where the midpoint of one phase winding is grounded, only the conductor or busbar having the higher phase voltage to ground shall be durably and permanently marked by an outer finish that is orange in color or by other effective means. Such identification shall be placed at each point on the system where a connection is made if the grounded conductor is also present.**

The high leg is common on a 240/120-volt 3-phase, 4-wire delta system. It is typically designated as "B phase." The high-leg marking, which is required to be the color orange or other similar effective means, is intended to prevent problems due to the lack of complete standardization where metered and nonmetered equipment are installed in the same installation. Electricians should always test each phase relative to ground with suitable equipment to determine exactly where the high leg is located in the system. The requirement in 110.15 previously appeared in 384-3(e) of the 1999 *NEC*. It was moved to Article 110 in 2002, when the application became a more general requirement. For the 2005 *Code*, 110.15 was editorially modified for clarity.

## 110.16 Flash Protection

**Switchboards, panelboards, industrial control panels, meter socket enclosures, and motor control centers that are in other than dwelling occupancies and are likely to require examination, adjustment, servicing, or maintenance while energized shall be field marked to warn qualified persons of potential electric arc flash hazards. The marking shall be located so as to be clearly visible to qualified persons before examination, adjustment, servicing, or maintenance of the equipment.**

This requirement was added in the 2002 *Code*. Field marking that warns electrical workers of potential electrical arc flash hazards is now required because significant numbers of electricians have been seriously burned or killed by accidental electrical arc flash while working on "hot" (energized) equipment. Most of those accidents could have been prevented or their severity significantly reduced if electricians had been wearing the proper type of protective clothing. Requiring switchboards, panelboards, and motor control centers to be individually field marked with proper warning labels will raise the level of awareness of electrical arc flash hazards and thereby decrease the number of accidents.

Exhibit 110.7 shows an electrical employee working inside the flash protection boundary and in front of a large-capacity service-type switchboard that has not been de-energized and that is not under the lockout/tagout procedure. The worker is wearing personal protective equipment (PPE) considered appropriate flash protection clothing for the flash

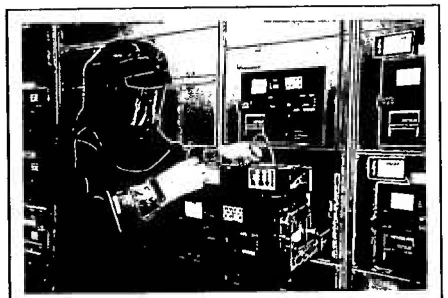


Exhibit 110.7 Electrical worker clothed in personal protective equipment (PPE) appropriate for the hazard involved.

hazard involved. Suitable PPE appropriate to a particular hazard is described in NFPA 70E, *Standard for Electrical Safety in the Workplace*.

Exhibit 110.8 displays one example of a warning sign required by 110.16.

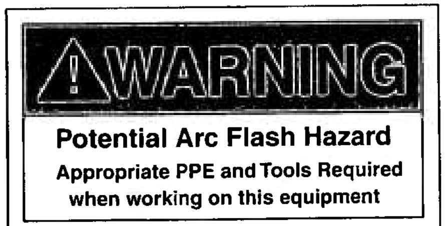



Exhibit 110.8 One example of an arc flash warning sign required by 110.16.

Accident reports continue to confirm the fact that workers responsible for the installation or maintenance of electrical equipment often do not turn off the power source before working on the equipment. Working electrical equipment energized is a major safety concern in the electrical industry. The real purpose of this additional code requirement is to alert electrical contractors, electricians, facility owners and managers, and other interested parties to some of the hazards of working on or near energized equipment and to emphasize the importance of turning off the power before working on electrical circuits.

The information in fine print notes is not mandatory. Employers can be assured that they are providing a safe workplace for their employees if safety-related work practices required by NFPA 70E have been implemented and are being followed. (See also the commentary following the definition of *qualified person* in Article 100.)

In addition to the standards referenced in the fine print notes and their individual bibliographies, additional information on this subject can be found in the 1997 report "Hazards of Working Electrical Equipment Hot," published by the National Electrical Manufacturers Association.

FPN No. 1: NFPA 70E-2004, *Standard for Electrical Safety in the Workplace*, provides assistance in determining severity of potential exposure, planning safe work practices, and selecting personal protective equipment.

FPN No. 2: ANSI Z535.4-1998, *Product Safety Signs and Labels*, provides guidelines for the design of safety signs and labels for application to products.

### 110.18 Arcing Parts

Parts of electric equipment that in ordinary operation produce arcs, sparks, flames, or molten metal shall be enclosed or separated and isolated from all combustible material.

Examples of electrical equipment that may produce sparks during ordinary operation include open motors having a centrifugal starting switch, open motors with commutators, and collector rings. Adequate separation from combustible material is essential if open motors with those features are used.

FPN: For hazardous (classified) locations, see Articles 500 through 517. For motors, see 430.14.

### 110.19 Light and Power from Railway Conductors

Circuits for lighting and power shall not be connected to any system that contains trolley wires with a ground return.

*Exception: Such circuit connections shall be permitted in car houses, power houses, or passenger and freight stations operated in connection with electric railways.*

### 110.21 Marking

The manufacturer's name, trademark, or other descriptive marking by which the organization responsible for the product can be identified shall be placed on all electric equipment. Other markings that indicate voltage, current, wattage, or other ratings shall be provided as specified elsewhere in this *Code*. The marking shall be of sufficient durability to withstand the environment involved.

The *Code* requires that equipment ratings be marked on the equipment and that such markings be located so as to be visible or easily accessible during or after installation.





### 110.22 Identification of Disconnecting Means

Each disconnecting means shall be legibly marked to indicate its purpose unless located and arranged so the purpose is evident. The marking shall be of sufficient durability to withstand the environment involved.

Where circuit breakers or fuses are applied in compliance with the series combination ratings marked on the equipment by the manufacturer, the equipment enclosure(s) shall be legibly marked in the field to indicate the equipment has been applied with a series combination rating. The marking shall be readily visible and state the following:

CAUTION — SERIES COMBINATION SYSTEM
RATED ____ AMPERES. IDENTIFIED
REPLACEMENT COMPONENTS REQUIRED.

FPN: See 240.86(B) for interrupting rating marking for end-use equipment.

Proper identification needs to be specific. For example, the marking should indicate not simply "motor" but rather "motor, water pump"; not simply "lights" but rather "lights, front lobby." Consideration also should be given to the form of identification. Marking often fades or is covered by paint after installation. See 408.4 and its associated commentary for further information on circuit directories for switchboards and panelboards. See 408.4 and its associated commentary for further information on circuit directories for switchboards and panelboards.

The second paragraph of 110.22 requires series-rated overcurrent devices to be legibly marked. The equipment manufacturer can mark the equipment to be used with series combination ratings. If the equipment is installed in the field at its marked series combination rating, the equipment must have an additional label, as specified in 110.22, to indicate that the series combination rating has been used.

### 110.23 Current Transformers

Unused current transformers associated with potentially energized circuits shall be short-circuited.

Because Article 450 specifically exempts current transformers, the practical solution to prevent damage to current transformers not connected to a load or for unused current transformers has been placed in 110.23.

## II. 600 Volts, Nominal, or Less

### 110.26 Spaces About Electrical Equipment

Sufficient access and working space shall be provided and maintained about all electric equipment to permit ready and safe operation and maintenance of such equipment. Enclosures housing electrical apparatus that are controlled by a lock(s) shall be considered accessible to qualified persons.

Key to understanding 110.26 is the division of requirements for spaces about electrical equipment in two separate and distinct categories: working space and dedicated equipment space. The term *working space* generally applies to the protection of the worker, and *dedicated equipment space* applies to the space reserved for future access to electrical equipment and to protection of the equipment from intrusion by non-electrical equipment. The performance requirements for all spaces about electrical equipment are set forth in the first sentence. Storage of materials that blocks access or prevents safe work practices must be avoided at all times.

**(A) Working Space** Working space for equipment operating at 600 volts, nominal, or less to ground and likely to require examination, adjustment, servicing, or maintenance while energized shall comply with the dimensions of 110.26(A)(1), (A)(2), and (A)(3) or as required or permitted elsewhere in this *Code*.

The intent of 110.26(A) is to provide enough space for personnel to perform any of the operations listed without jeopardizing worker safety. These operations include examination, adjustment, servicing, and maintenance of equipment. Examples of such equipment include panelboards, switches, circuit breakers, controllers, and controls on heating and air-conditioning equipment. It is important to understand that the word *examination*, as used in 110.26(A), includes such tasks as checking for the presence of voltage using a portable voltmeter.

Minimum working clearances are not required if the equipment is such that it is not likely to require examination, adjustment, servicing, or maintenance while energized. However, "sufficient" access and working space are still required by the opening paragraph of 110.26.

**(1) Depth of Working Space** The depth of the working space in the direction of live parts shall not be less than that specified in Table 110.26(A)(1) unless the requirements of 110.26(A)(1)(a), (A)(1)(b), or (A)(1)(c) are met. Distances shall be measured from the exposed live parts or from the enclosure or opening if the live parts are enclosed.

For the 2005 *Code*, some of the text associated with Conditions 1 and 2 was edited for clarity and enforceability. Also, the Condition 2 metric clearance for 151 to 600 volts was revised from 1 m to 1.1 m to reflect an accurate metric conversion.

Included in these clearance requirements is the step-back distance from the face of the equipment. Table 110.26(A)(1) provides requirements for clearances away from the equipment, based on the circuit voltage to ground

Table 110.26(A)(1) Working Spaces

| Nominal Voltage to Ground | Minimum Clear Distance | | |
|---|---|---|---|
| | Condition 1 | Condition 2 | Condition 3 |
| 0–150 | 900 mm (3 ft) | 900 mm (3 ft) | 900 mm (3 ft) |
| 151–600 | 900 mm (3 ft) | 1.1 m (3½ ft) | 1.2 m (4 ft) |

Note: Where the conditions are as follows:
**Condition 1** — Exposed live parts on one side of the working space and no live or grounded parts on the other side of the working space, or exposed live parts on both sides of the working space that are effectively guarded by insulating materials.
**Condition 2** — Exposed live parts on one side of the working space and grounded parts on the other side of the working space. Concrete, brick, or tile walls shall be considered as grounded.
**Condition 3** — Exposed live parts on both sides of the working space.

and whether there are grounded or ungrounded objects in the step-back space or exposed live parts across from each other. The voltages to ground consist of two groups: 0 to 150, inclusive, and 151 to 600, inclusive. Examples of common electrical supply systems covered in the 0 to 150 volts to ground group include 120/240-volt, single-phase, 3-wire and 208Y/120-volt, 3-phase, 4-wire. Examples of common electrical supply systems covered in the 151 to 600 volts to ground group include 240-volt, 3-phase, 3-wire; 480Y/277-volt, 3-phase, 4-wire; and 480-volt, 3-phase, 3-wire (ungrounded and corner grounded). Remember, where an ungrounded system is utilized, the voltage to ground (by definition) is the greatest voltage between the given conductor and any other conductor of the circuit. For example, the voltage to ground for a 480-volt ungrounded delta system is 480 volts. See Exhibit 110.9 for the general working clearance requirements for each of the three conditions listed in Table 110.26(A)(1).

(a) Dead-Front Assemblies. Working space shall not be required in the back or sides of assemblies, such as dead-front switchboards or motor control centers, where all connections and all renewable or adjustable parts, such as fuses or switches, are accessible from locations other than the back or sides. Where rear access is required to work on nonelectrical parts on the back of enclosed equipment, a minimum horizontal working space of 762 mm (30 in.) shall be provided.

The intent of this section is to point out that work space is required only from the side(s) of the enclosure that requires access. The general rule still applies: Equipment that requires front, rear, or side access for electrical activities described in 110.26(A) must meet the requirements of Table 110.26(A)(1). In many cases, equipment of "dead-front" assemblies requires only front access. For equipment that

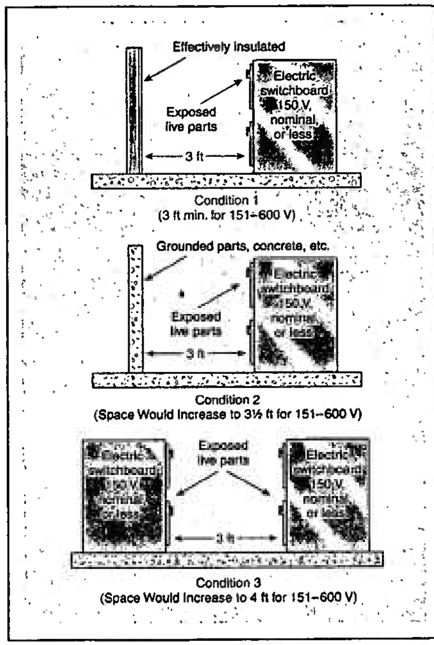



**Exhibit 110.9** Distances measured from the live parts if the live parts are exposed or from the enclosure front if the live parts are enclosed. If any assemblies, such as switchboards or motor-control centers, are accessible from the back and expose live parts, the working clearance dimensions would be required at the rear of the equipment, as illustrated. Note that for Condition 3, where there is an enclosure on opposite sides of the working space, the clearance for only one working space is required.

requires rear access for nonelectrical activity, however, a reduced working space of at least 30 in. must be provided. Exhibit 110.10 shows a reduced working space of 30 in. at the rear of equipment to allow work on nonelectrical parts.

(b) Low Voltage. By special permission, smaller working spaces shall be permitted where all exposed live parts operate at not greater than 30 volts rms, 42 volts peak, or 60 volts dc.

(c) Existing Buildings. In existing buildings where electrical equipment is being replaced, Condition 2 working clearance shall be permitted between dead-front switchboards, panelboards, or motor control centers located across the aisle from each other where conditions of maintenance and supervision ensure that written procedures have been adopted to prohibit equipment on both sides of the aisle from being open at the same time and qualified persons who are authorized will service the installation.





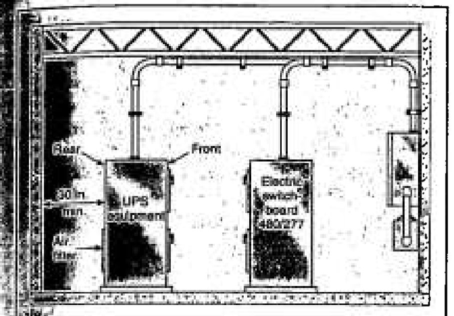



**Exhibit 110.10** Example of the 30 in. minimum working space at the rear of equipment to allow work on nonelectrical parts, such as the replacement of an air filter.

This section permits some relief for installations that are being upgraded. When assemblies such as dead-front switchboards, panelboards, or motor-control centers are replaced in an existing building, the working clearance allowed is that required by Table 110.26(A)(1), Condition 2. The reduction from a Condition 3 to a Condition 2 clearance is allowed only where a written procedure prohibits facing doors of equipment from being open at the same time and where only authorized and qualified persons service the installation. Exhibit 110.11 illustrates this relief for existing buildings.

(2) **Width of Working Space** The width of the working space in front of the electric equipment shall be the width of the equipment or 750 mm (30 in.), whichever is greater. In all cases, the work space shall permit at least a 90 degree opening of equipment doors or hinged panels.

Regardless of the width of the electrical equipment, the working space cannot be less than 30 in. wide. This space allows an individual to have at least shoulder-width space in front of the equipment. The 30 in. measurement can be made from either the left or the right edge of the equipment and can overlap other electrical equipment, provided the other equipment does not extend beyond the clearance re-

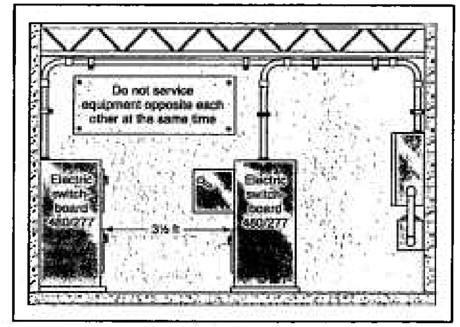



**Exhibit 110.11** Permitted reduction from a Condition 3 to a Condition 2 clearance according to 110.26(A)(1)(c).

quired by Table 110.26(A)(1). If the equipment is wider than 30 in., the left-to-right space must be equal to the width of the equipment. See Exhibit 110.12 for an explanation of the 30 in. width requirement.

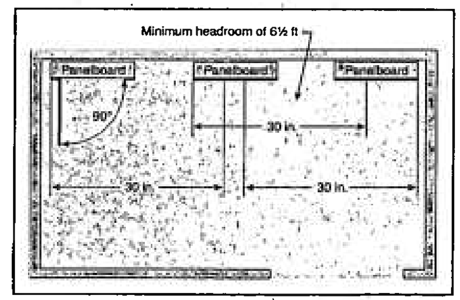



**Exhibit 110.12** The 30 in. wide front working space, which is not required to be directly centered on the electrical equipment if space is sufficient for safe operation and maintenance of such equipment.

Sufficient depth in the working space also must be provided to allow a panel or a door to open at least 90 degrees. If doors or hinged panels are wider than 3 ft, more than a 3 ft deep working space must be provided to allow a full 90-degree opening. (See Exhibit 110.13.)

(3) **Height of Working Space** The work space shall be clear and extend from the grade, floor, or platform to the height required by 110.26(E). Within the height requirements

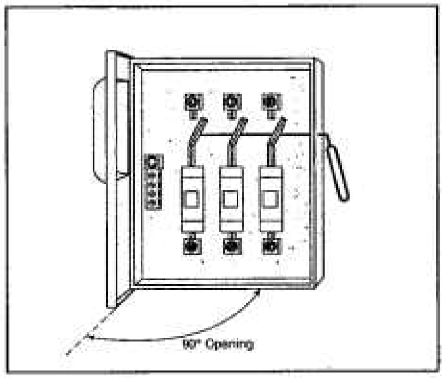



Exhibit 110.13 Illustration of requirement that working space must be sufficient to allow a full 90 degree opening of equipment doors in order to ensure a safe working approach.

of this section, other equipment that is associated with the electrical installation and is located above or below the electrical equipment shall be permitted to extend not more than 150 mm (6 in.) beyond the front of the electrical equipment.

In addition to requiring a working space to be clear from the floor to a height of 61/2 ft or to the height of the equipment, whichever is greater, 110.26(A)(3) permits electrical equipment located above or below other electrical equipment to extend into the working space not more than 6 in. This requirement allows the placement of a 12 in. × 12 in. wireway on the wall directly above or below a 6 in. deep panelboard without impinging on the working space or compromising practical working clearances. The requirement continues to prohibit large differences in depth of equipment below or above other equipment that specifically requires working space. In order to minimize the amount of space required for electrical equipment, it was not uncommon to find installations of large free-standing, dry-type transformers within the required work space for a wall-mounted panelboard. Clear access to the panelboard is compromised by the location of the transformer with its grounded enclosure and this type of installation and is clearly not permitted by this section. Electrical equipment that produces heat or that otherwise requires ventilation also must comply with 110.3(B) and 110.13.

**(B) Clear Spaces** Working space required by this section shall not be used for storage. When normally enclosed live parts are exposed for inspection or servicing, the working space, if in a passageway or general open space, shall be suitably guarded.

Section 110.26(B), as well as the rest of 110.26, does not prohibit the placement of panelboards in corridors or passageways. For that reason, when the covers of corridor-mounted panelboards are removed for servicing or other work, access to the area around the panelboard should be guarded or limited to protect unqualified persons using the corridor.

**(C) Entrance to Working Space**

**(1) Minimum Required** At least one entrance of sufficient area shall be provided to give access to working space about electrical equipment.

**(2) Large Equipment** For equipment rated 1200 amperes or more that contains overcurrent devices, switching devices, or control devices, there shall be one entrance to the required working space not less than 610 mm (24 in.) wide and 2.0 m (6½ ft) high at each end of the working space. Where the entrance has a personnel door(s), the door(s) shall open in the direction of egress and be equipped with panic bars, pressure plates, or other devices that are normally latched but open under simple pressure.

A single entrance to the required working space shall be permitted where either of the conditions in 110.26(C)(2)(a) or (C)(2)(b) is met.

The stipulation that large equipment must be at least 6 ft wide was deleted for the 2005 *Code*. Now, for the purposes of this section, large equipment is simply equipment rated 1200 amperes or more. The removal of the 6 ft condition has the effect of broadening the scope of this requirement to now include all spaces containing "equipment rated 1200 amperes or more that contains overcurrent devices, switching devices, or control devices." The effect of this revision is that the required working space for one 1200-ampere safety switch with a width of approximately 3 ft is now required to be provided with two entrances/exits unless one of the provisions permitting a single entrance can be applied to that space. For equipment of this type, it is not unusual that the provision calling for a continuous and unobstructed way of exit travel from the working space can be applied.

Where the entrance(s) to the working space is through a door, each door must comply with the requirements for swinging open in the direction of egress and have door opening hardware that does not require turning of a door knob or similar action that may preclude quick exit from the area in the event of an emergency.

This requirement affords safety for workers exposed to energized conductors by allowing an injured worker to safely and quickly exit an electrical room without having to turn knobs or pull doors open.

For a graphical explanation of access and entrance requirements to a working space, see Exhibits 110.14 and 110.15. Notice the unacceptable and hazardous situation shown in Exhibit 110.16.





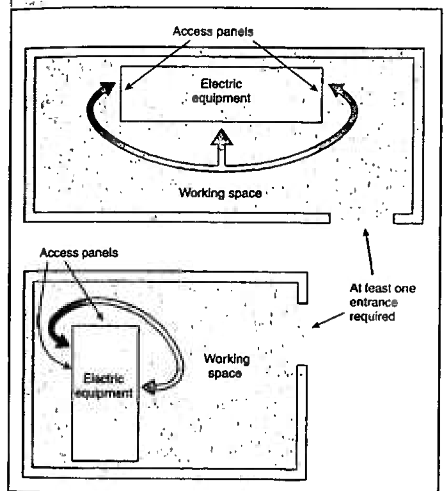



Exhibit 110.14 Basic Rule, first paragraph. At least one entrance is required to provide access to the working space around electrical equipment [110.26(C)(1)]. The lower installation would not be acceptable for a switchboard rated 1200 amperes or more.

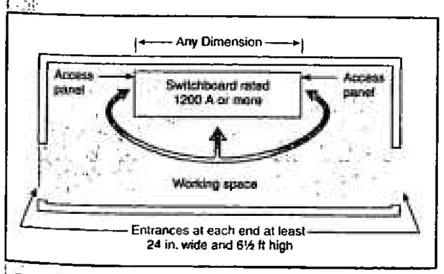



Exhibit 110.15 Basic Rule, second paragraph. For equipment rated 1200 amperes or more, one entrance not less than 24 in. wide and 6½ ft high is required at each end [110.26(C)(2)].

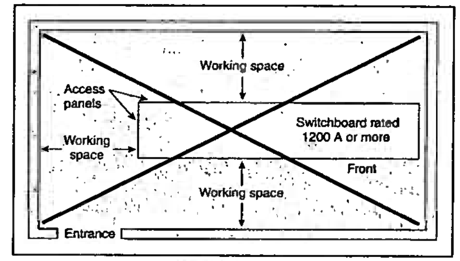



Exhibit 110.16 Unacceptable arrangement of a large switchboard. A person could be trapped behind arcing electrical equipment.

(a) Unobstructed Exit. Where the location permits a continuous and unobstructed way of exit travel, a single entrance to the working space shall be permitted.

(b) Extra Working Space. Where the depth of the working space is twice that required by 110.26(A)(1), a single entrance shall be permitted. It shall be located so that the distance from the equipment to the nearest edge of the entrance is not less than the minimum clear distance specified in Table 110.26(A)(1) for equipment operating at that voltage and in that condition.

For an explanation of paragraphs 110.26(C)(2)(a) and 110.26(C)(2)(b), see Exhibits 110.17 and 110.18.

**(D) Illumination** Illumination shall be provided for all working spaces about service equipment, switchboards, panelboards, or motor control centers installed indoors. Additional lighting outlets shall not be required where the work space is illuminated by an adjacent light source or as permitted by 210.70(A)(1), Exception No. 1, for switched receptacles. In electrical equipment rooms, the illumination shall not be controlled by automatic means only.

**(E) Headroom** The minimum headroom of working spaces about service equipment, switchboards, panelboards, or motor control centers shall be 2.0 m (6½ ft). Where the electrical equipment exceeds 2.0 m (6½ ft) in height, the minimum headroom shall not be less than the height of the equipment.

*Exception: In existing dwelling units, service equipment or panelboards that do not exceed 200 amperes shall be permitted in spaces where the headroom is less than 2.0 m (6½ ft).*

**(F) Dedicated Equipment Space** All switchboards, panelboards, distribution boards, and motor control centers shall be located in dedicated spaces and protected from damage.

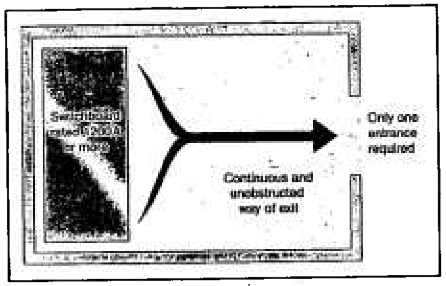



Exhibit 110.17 Equipment location that allows a continuous and unobstructed way of exit travel.

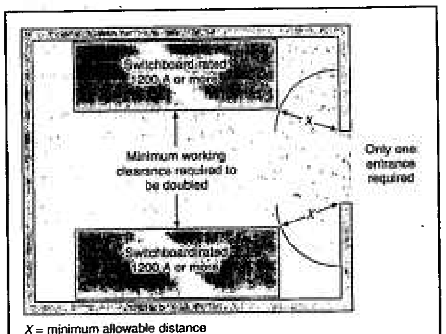



Exhibit 110.18 Working space with one entrance. Only one entrance is required if the working space required by 110.26(A) is doubled. See Table 110.26(A)(1) for permitted dimensions of *X*.

*Exception: Control equipment that by its very nature or because of other rules of the Code must be adjacent to or within sight of its operating machinery shall be permitted in those locations.*

**(1) Indoor** Indoor installations shall comply with 110.26(F)(1)(a) through (F)(1)(d).

(a) Dedicated Electrical Space. The space equal to the width and depth of the equipment and extending from the floor to a height of 1.8 m (6 ft) above the equipment or to the structural ceiling, whichever is lower, shall be dedicated to the electrical installation. No piping, ducts, leak protection apparatus, or other equipment foreign to the electrical installation shall be located in this zone.

*Exception: Suspended ceilings with removable panels shall be permitted within the 1.8-m (6-ft) zone.*

(b) Foreign Systems. The area above the dedicated space required by 110.26(F)(1)(a) shall be permitted to contain foreign systems, provided protection is installed to avoid damage to the electrical equipment from condensation, leaks, or breaks in such foreign systems.

(c) Sprinkler Protection. Sprinkler protection shall be permitted for the dedicated space where the piping complies with this section.

(d) Suspended Ceilings. A dropped, suspended, or similar ceiling that does not add strength to the building structure shall not be considered a structural ceiling.

The dedicated electrical space includes the space defined by extending the footprint of the switchboard or panelboard from the floor to a height of 6 ft above the height of the equipment or to the structural ceiling, whichever is lower. This reserved space permits busways, conduits, raceways, and cables to enter the equipment. The dedicated electrical space must be clear of piping, ducts, leak protection apparatus, or equipment foreign to the electrical installation. Plumbing, heating, ventilation, and air-conditioning piping, ducts, and equipment must be installed outside the width and depth zone.

Foreign systems installed directly above the dedicated space reserved for electrical equipment must include protective equipment that ensures that occurrences such as leaks, condensation, and even breaks do not damage the electrical equipment located below.

Sprinkler protection is permitted for the dedicated spaces as long as the sprinkler or other suppression system piping complies with 110.26(F)(1)(d). A dropped, suspended, or similar ceiling is permitted to be located directly in the dedicated space, as are building structural members.

The electrical equipment also must be protected from physical damage. Damage can be caused by activities performed near the equipment, such as material handling by personnel or the operation of a forklift or other mobile equipment. See 110.27(B) for other provisions relating to the protection of electrical equipment.

Exhibits 110.19, 110.20, and 110.21 illustrate the two distinct indoor installation spaces required by 110.26(A) and 110.26(F), that is, the working space and the dedicated electrical space.

In Exhibit 110.19, the dedicated electrical space required by 110.26(F) is the space outlined by the width and the depth of the equipment (the footprint) and extending from the floor to 6 ft above the equipment or to the structural ceiling (whichever is lower). The dedicated electrical space is reserved for the installation of electrical equipment and for the installation of conduits, cable trays, and so on, entering or exiting that equipment. The outlined area in front of the electrical equipment in Exhibit 110.19 is the working space required by 110.26(A). Note that sprinkler protection is afforded the entire dedicated electrical space and working space without actually entering either space. Also note that the exhaust duct is not located in or directly above the dedicated electrical space. Although not specifically required to be located here, this duct location may be a cost-effective solution that avoids the substantial physical protection requirements of 110.26(F)(1)(b).





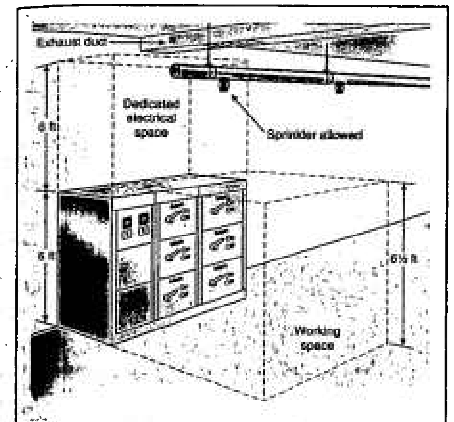



Exhibit 110.19 The two distinct indoor installation spaces required by 110.26(A) and 110.26(F): the working space and the dedicated electrical space.

Exhibit 110.20 The working space in front of a panelboard required by 110.26(A). This illustration supplements the dedicated electrical space shown in Exhibit 110.19.

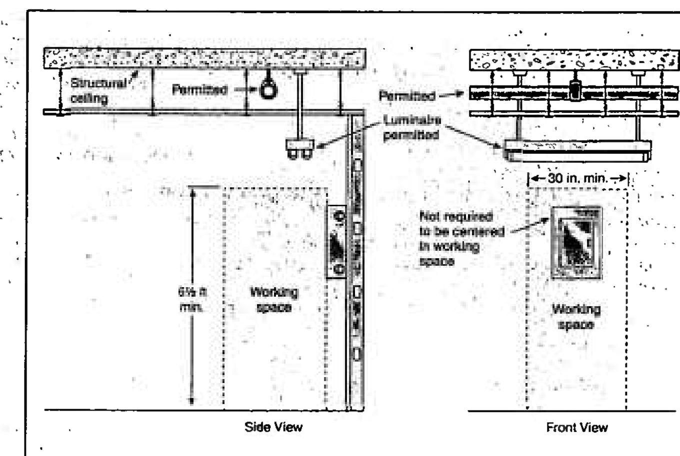



Exhibit 110.20 illustrates the working space required in front of the panelboard by 110.26(A). No equipment, electrical or otherwise, is allowed in the working space.

Exhibit 110.21 illustrates the dedicated electrical space above and below the panelboard required by 110.26(F)(1). This space is for the cables, raceways, and so on, that run to and from the panelboard.

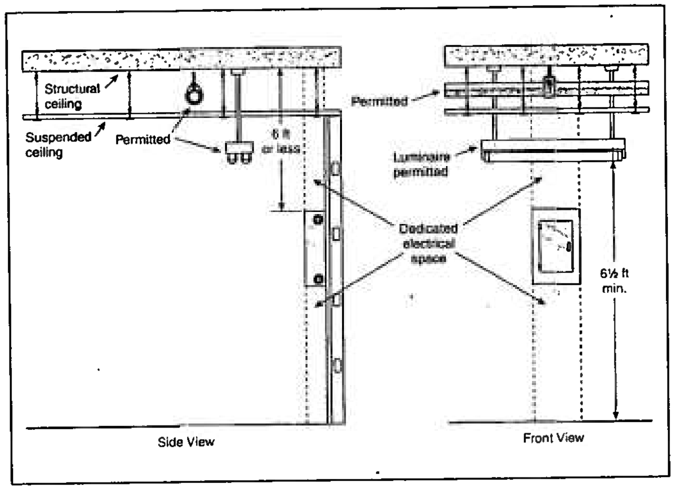
**(2) Outdoor** Outdoor electrical equipment shall be installed in suitable enclosures and shall be protected from accidental contact by unauthorized personnel, or by vehicular traffic, or by accidental spillage or leakage from piping systems. The working clearance space shall include the zone described in 110.26(A). No architectural appurtenance or other equipment shall be located in this zone.

Extreme care should be taken where protection from unauthorized personnel or vehicular traffic is added to existing installations in order to comply with 110.26(F)(2). Any excavation or driving of steel into the ground for the placement of fencing, vehicle stops, or bollards should be done only after a thorough investigation of the belowgrade wiring.

## 110.27 Guarding of Live Parts

**(A) Live Parts Guarded Against Accidental Contact** Except as elsewhere required or permitted by this *Code*, live parts of electrical equipment operating at 50 volts or more shall be guarded against accidental contact by approved enclosures or by any of the following means:

**Exhibit 110.21** The dedicated electrical space above and below a panelboard required by 110.26(F)(1).




(1) By location in a room, vault, or similar enclosure that is accessible only to qualified persons.
(2) By suitable permanent, substantial partitions or screens arranged so that only qualified persons have access to the space within reach of the live parts. Any openings in such partitions or screens shall be sized and located so that persons are not likely to come into accidental contact with the live parts or to bring conducting objects into contact with them.
(3) By location on a suitable balcony, gallery, or platform elevated and arranged so as to exclude unqualified persons.
(4) By elevation of 2.5 m (8 ft) or more above the floor or other working surface.

Contact conductors used for traveling cranes are permitted to be bare by 610.13(B) and 610.21(A). Although contact conductors obviously have to be bare for contact shoes on the moving member to make contact with the conductor, it is possible to place guards near the conductor to prevent its accidental contact with persons and still have slots or spaces through which the moving contacts can operate. The *Code* also recognizes the guarding of live parts by elevation.

**(B) Prevent Physical Damage** In locations where electric equipment is likely to be exposed to physical damage, enclosures or guards shall be so arranged and of such strength as to prevent such damage.

**(C) Warning Signs** Entrances to rooms and other guarded locations that contain exposed live parts shall be marked with conspicuous warning signs forbidding unqualified persons to enter.

FPN: For motors, see 430.232 and 430.233. For over 600 volts, see 110.34.

Live parts of electrical equipment should be covered, shielded, enclosed, or otherwise protected by covers, barriers, mats, or platforms to prevent the likelihood of contact by persons or objects. See the definitions of *dead front* and *isolated (as applied to location)* in Article 100.

## III. Over 600 Volts, Nominal

### 110.30 General

Conductors and equipment used on circuits over 600 volts, nominal, shall comply with Part I of this article and with the following sections, which supplement or modify Part I. In no case shall the provisions of this part apply to equipment on the supply side of the service point.

See "Over 600 volts" in the index to this *Handbook* for articles, parts, and sections that include requirements for installations over 600 volts.

Equipment on the supply side of the service point is outside the scope of the *NEC*. Such equipment is covered





by ANSI C2, *National Electrical Safety Code*, published by the Institute of Electrical and Electronics Engineers (IEEE).

### 110.31 Enclosure for Electrical Installations

Electrical installations in a vault, room, or closet or in an area surrounded by a wall, screen, or fence, access to which is controlled by a lock(s) or other approved means, shall be considered to be accessible to qualified persons only. The type of enclosure used in a given case shall be designed and constructed according to the nature and degree of the hazard(s) associated with the installation.

For installations other than equipment as described in 110.31(D), a wall, screen, or fence shall be used to enclose an outdoor electrical installation to deter access by persons who are not qualified. A fence shall not be less than 2.1 m (7 ft) in height or a combination of 1.8 m (6 ft) or more of fence fabric and a 300-mm (1-ft) or more extension utilizing three or more strands of barbed wire or equivalent. The distance from the fence to live parts shall be not less than given in Table 110.31.

**Table 110.31 Minimum Distance from Fence to Live Parts**

| | Minimum Distance to Live Parts | |
|---|---|---|
| Nominal Voltage | m | ft |
| 601 – 13,799 | 3.05 | 10 |
| 13,800 – 230,000 | 4.57 | 15 |
| Over 230,000 | 5.49 | 18 |

Note: For clearances of conductors for specific system voltages and typical BIL ratings, see ANSI C2-2002, *National Electrical Safety Code*.

FPN: See Article 450 for construction requirements for transformer vaults.

**(A) Fire Resistivity of Electrical Vaults** The walls, roof, floors, and doorways of vaults containing conductors and equipment over 600 volts, nominal, shall be constructed of materials that have adequate structural strength for the conditions, with a minimum fire rating of 3 hours. The floors of vaults in contact with the earth shall be of concrete that is not less than 4 in. (102 mm) thick, but where the vault is constructed with a vacant space or other stories below it, the floor shall have adequate structural strength for the load imposed on it and a minimum fire resistance of 3 hours. For the purpose of this section, studs and wallboards shall not be considered acceptable.

**(B) Indoor Installations**

**(1) In Places Accessible to Unqualified Persons** Indoor electrical installations that are accessible to unqualified persons shall be made with metal-enclosed equipment. Metal-enclosed switchgear, unit substations, transformers, pull boxes, connection boxes, and other similar associated equipment shall be marked with appropriate caution signs. Openings in ventilated dry-type transformers or similar openings in other equipment shall be designed so that foreign objects inserted through these openings are deflected from energized parts.

**(2) In Places Accessible to Qualified Persons Only** Indoor electrical installations considered accessible only to qualified persons in accordance with this section shall comply with 110.34, 110.36, and 490.24.

**(C) Outdoor Installations**

**(1) In Places Accessible to Unqualified Persons** Outdoor electrical installations that are open to unqualified persons shall comply with Parts I, II, and III of Article 225.

FPN: For clearances of conductors for system voltages over 600 volts, nominal, see ANSI C2-2002, *National Electrical Safety Code.*

**(2) In Places Accessible to Qualified Persons Only** Outdoor electrical installations that have exposed live parts shall be accessible to qualified persons only in accordance with the first paragraph of this section and shall comply with 110.34, 110.36, and 490.24.

**(D) Enclosed Equipment Accessible to Unqualified Persons** Ventilating or similar openings in equipment shall be designed such that foreign objects inserted through these openings are deflected from energized parts. Where exposed to physical damage from vehicular traffic, suitable guards shall be provided. Nonmetallic or metal-enclosed equipment located outdoors and accessible to the general public shall be designed such that exposed nuts or bolts cannot be readily removed, permitting access to live parts. Where nonmetallic or metal-enclosed equipment is accessible to the general public and the bottom of the enclosure is less than 2.5 m (8 ft) above the floor or grade level, the enclosure door or hinged cover shall be kept locked. Doors and covers of enclosures used solely as pull boxes, splice boxes, or junction boxes shall be locked, bolted, or screwed on. Underground box covers that weigh over 45.4 kg (100 lb) shall be considered as meeting this requirement.

### 110.32 Work Space About Equipment

Sufficient space shall be provided and maintained about electric equipment to permit ready and safe operation and maintenance of such equipment. Where energized parts are exposed, the minimum clear work space shall not be less than 2.0 m (6½ ft) high (measured vertically from the floor or platform) or less than 900 mm (3 ft) wide (measured parallel to the equipment). The depth shall be as required in 110.34(A). In all cases, the work space shall permit at least a 90 degree opening of doors or hinged panels.

### 110.33 Entrance and Access to Work Space

**(A) Entrance** At least one entrance not less than 610 mm (24 in.) wide and 2.0 m (6½ ft) high shall be provided to give access to the working space about electric equipment. Where the entrance has a personnel door(s), the door(s) shall open in the direction of egress and be equipped with panic bars, pressure plates, or other devices that are normally latched but open under simple pressure.

**(1) Large Equipment** On switchboard and control panels exceeding 1.8 m (6 ft) in width, there shall be one entrance at each end of the equipment. A single entrance to the required working space shall be permitted where either of the conditions in 110.33(A)(1)(a) or (A)(1)(b) is met.

(a) Unobstructed Exit. Where the location permits a continuous and unobstructed way of exit travel, a single entrance to the working space shall be permitted.

(b) Extra Working Space. Where the depth of the working space is twice that required by 110.34(A), a single entrance shall be permitted. It shall be located so that the distance from the equipment to the nearest edge of the entrance is not less than the minimum clear distance specified in Table 110.34(A) for equipment operating at that voltage and in that condition.

**(2) Guarding** Where bare energized parts at any voltage or insulated energized parts above 600 volts, nominal, to ground are located adjacent to such entrance, they shall be suitably guarded.

Section 110.33(A) contains requirements very similar to those of 110.26(C). For further information, see the commentary following 110.26(C)(2), most of which also is valid for over-600-volt installations.

**(B) Access** Permanent ladders or stairways shall be provided to give safe access to the working space around electric equipment installed on platforms, balconies, or mezzanine floors or in attic or roof rooms or spaces.

### 110.34 Work Space and Guarding

**(A) Working Space** Except as elsewhere required or permitted in this *Code*, the minimum clear working space in the direction of access to live parts of electrical equipment shall not be less than specified in Table 110.34(A). Distances shall be measured from the live parts, if such are exposed, or from the enclosure front or opening if such are enclosed.

*Exception: Working space shall not be required in back of equipment such as dead-front switchboards or control assemblies where there are no renewable or adjustable parts (such as fuses or switches) on the back and where all connections are accessible from locations other than the back. Where rear access is required to work on de-energized parts on the back of enclosed equipment, a minimum working space of 750 mm (30 in.) horizontally shall be provided.*

**Table 110.34(A) Minimum Depth of Clear Working Space at Electrical Equipment**

| Nominal Voltage to Ground | Minimum Clear Distance | | |
|---|---|---|---|
| | Condition 1 | Condition 2 | Condition 3 |
| 601–2500 V | 900 mm (3 ft) | 1.2 m (4 ft) | 1.5 m (5 ft) |
| 2501–9000 V | 1.2 m (4 ft) | 1.5 m (5 ft) | 1.8 m (6 ft) |
| 9001–25,000 V | 1.5 m (5 ft) | 1.8 m (6 ft) | 2.8 m (9 ft) |
| 25,001V–75 kV | 1.8 m (6 ft) | 2.5 m (8 ft) | 3.0 m (10 ft) |
| Above 75 kV | 2.5 m (8 ft) | 3.0 m (10 ft) | 3.7 m (12 ft) |

Note: Where the conditions are as follows:
**Condition 1** — Exposed live parts on one side of the working space and no live or grounded parts on the other side of the working space, or exposed live parts on both sides of the working space that are effectively guarded by insulating materials.
**Condition 2** — Exposed live parts on one side of the working space and grounded parts on the other side of the working space. Concrete, brick, or tile walls shall be considered as grounded.
**Condition 3** — Exposed live parts on both sides of the working space.

**(B) Separation from Low-Voltage Equipment** Where switches, cutouts, or other equipment operating at 600 volts, nominal, or less are installed in a vault, room, or enclosure where there are exposed live parts or exposed wiring operating at over 600 volts, nominal, the high-voltage equipment shall be effectively separated from the space occupied by the low-voltage equipment by a suitable partition, fence, or screen.

*Exception: Switches or other equipment operating at 600 volts, nominal, or less and serving only equipment within the high-voltage vault, room, or enclosure shall be permitted to be installed in the high-voltage vault, room or enclosure without a partition, fence, or screen if accessible to qualified persons only.*

**(C) Locked Rooms or Enclosures** The entrance to all buildings, vaults, rooms, or enclosures containing exposed live parts or exposed conductors operating at over 600 volts, nominal, shall be kept locked unless such entrances are under the observation of a qualified person at all times.

Where the voltage exceeds 600 volts, nominal, permanent and conspicuous warning signs shall be provided, reading as follows:

DANGER — HIGH VOLTAGE — KEEP OUT

Equipment used on circuits over 600 volts, nominal, and containing exposed live parts or exposed conductors is required to be located in a locked room or in an enclosure. The provisions for locking are not required if the room or enclosure is under observation at all times, as is the case with some engine rooms.





**(D) Illumination** Illumination shall be provided for all working spaces about electrical equipment. The lighting outlets shall be arranged so that persons changing lamps or making repairs on the lighting system are not endangered by live parts or other equipment.

The points of control shall be located so that persons are not likely to come in contact with any live part or moving part of the equipment while turning on the lights.

**(E) Elevation of Unguarded Live Parts** Unguarded live parts above working space shall be maintained at elevations not less than required by Table 110.34(E).

**Table 110.34(E) Elevation of Unguarded Live Parts Above Working Space**

| Nominal Voltage Between Phases | Elevation | |
|---|---|---|
| | m | ft |
| 601–7500 V | 2.8 | 9 |
| 7501–35,000 V | 2.9 | 9½ |
| Over 35 kV | 2.9 m + 9.5 mm/kV above 35 | 9½ ft + 0.37 in./kV above 35 |

**(F) Protection of Service Equipment, Metal-Enclosed Power Switchgear, and Industrial Control Assemblies** Pipes or ducts foreign to the electrical installation and requiring periodic maintenance or whose malfunction would endanger the operation of the electrical system shall not be located in the vicinity of the service equipment, metal-enclosed power switchgear, or industrial control assemblies. Protection shall be provided where necessary to avoid damage from condensation leaks and breaks in such foreign systems. Piping and other facilities shall not be considered foreign if provided for fire protection of the electrical installation.

### 110.36 Circuit Conductors

Circuit conductors shall be permitted to be installed in raceways; in cable trays; as metal-clad cable, as bare wire, cable, and busbars; or as Type MV cables or conductors as provided in 300.37, 300.39, 300.40, and 300.50. Bare live conductors shall conform with 490.24.

Insulators, together with their mounting and conductor attachments, where used as supports for wires, single-conductor cables, or busbars, shall be capable of safely withstanding the maximum magnetic forces that would prevail when two or more conductors of a circuit were subjected to short-circuit current.

Exposed runs of insulated wires and cables that have a bare lead sheath or a braided outer covering shall be supported in a manner designed to prevent physical damage to the braid or sheath. Supports for lead-covered cables shall be designed to prevent electrolysis of the sheath.

### 110.40 Temperature Limitations at Terminations

Conductors shall be permitted to be terminated based on the 90°C (194°F) temperature rating and ampacity as given in Tables 310.67 through 310.86, unless otherwise identified.

## IV. Tunnel Installations over 600 Volts, Nominal

### 110.51 General

**(A) Covered** The provisions of this part shall apply to the installation and use of high-voltage power distribution and utilization equipment that is portable, mobile, or both, such as substations, trailers, cars, mobile shovels, draglines, hoists, drills, dredges, compressors, pumps, conveyors, underground excavators, and the like.

**(B) Other Articles** The requirements of this part shall be additional to, or amendatory of, those prescribed in Articles 100 through 490 of this *Code*. Special attention shall be paid to Article 250.

**(C) Protection Against Physical Damage** Conductors and cables in tunnels shall be located above the tunnel floor and so placed or guarded to protect them from physical damage.

### 110.52 Overcurrent Protection

Motor-operated equipment shall be protected from overcurrent in accordance with Parts III, IV, and V of Article 430. Transformers shall be protected from overcurrent in accordance with 450.3.

### 110.53 Conductors

High-voltage conductors in tunnels shall be installed in metal conduit or other metal raceway, Type MC cable, or other approved multiconductor cable. Multiconductor portable cable shall be permitted to supply mobile equipment.

### 110.54 Bonding and Equipment Grounding Conductors

**(A) Grounded and Bonded** All non–current-carrying metal parts of electric equipment and all metal raceways and cable sheaths shall be effectively grounded and bonded to all metal pipes and rails at the portal and at intervals not exceeding 300 m (1000 ft) throughout the tunnel.

**(B) Equipment Grounding Conductors** An equipment grounding conductor shall be run with circuit conductors inside the metal raceway or inside the multiconductor cable jacket. The equipment grounding conductor shall be permitted to be insulated or bare.

### 110.55 Transformers, Switches, and Electrical Equipment

All transformers, switches, motor controllers, motors, rectifiers, and other equipment installed below ground shall be protected from physical damage by location or guarding.

### 110.56 Energized Parts

Bare terminals of transformers, switches, motor controllers, and other equipment shall be enclosed to prevent accidental contact with energized parts.

### 110.57 Ventilation System Controls

Electrical controls for the ventilation system shall be arranged so that the airflow can be reversed.

### 110.58 Disconnecting Means

A switch or circuit breaker that simultaneously opens all ungrounded conductors of the circuit shall be installed within sight of each transformer or motor location for disconnecting the transformer or motor. The switch or circuit breaker for a transformer shall have an ampere rating not less than the ampacity of the transformer supply conductors. The switch or circuit breaker for a motor shall comply with the applicable requirements of Article 430.

### 110.59 Enclosures

Enclosures for use in tunnels shall be dripproof, weatherproof, or submersible as required by the environmental conditions. Switch or contactor enclosures shall not be used as junction boxes or as raceways for conductors feeding through or tapping off to other switches, unless the enclosures comply with 312.8.

## V. Manholes and Other Electric Enclosures Intended for Personnel Entry, All Voltages

Prior to the 2005 *Code*, the requirements for manholes were found in Part IV of Article 314. For the 2005 edition, manhole requirements were moved to Article 110 and placed there as the new Part V. Placing the manhole requirements in Article 110 makes sense because manhole working space issues for cabling and other equipment here parallel those same working space issues elsewhere in Article 110. For handhole installations, see Article 314.

### 110.70 General

Electric enclosures intended for personnel entry and specifically fabricated for this purpose shall be of sufficient size to provide safe work space about electric equipment with live parts that is likely to require examination, adjustment, servicing, or maintenance while energized. Such enclosures shall have sufficient size to permit ready installation or withdrawal of the conductors employed without damage to the conductors or to their insulation. They shall comply with the provisions of this part.

*Exception: Where electric enclosures covered by Part V of this article are part of an industrial wiring system operating under conditions of maintenance and supervision that ensure that only qualified persons monitor and supervise the system, they shall be permitted to be designed and installed in accordance with appropriate engineering practice. If required by the authority having jurisdiction, design documentation shall be provided.*

The provisions of Part V are conditional, just like the requirements in 110.26, that is, some of the requirements are applicable only where the equipment "is likely to require examination, adjustment, servicing, or maintenance while energized."

### 110.71 Strength

Manholes, vaults, and their means of access shall be designed under qualified engineering supervision and shall withstand all loads likely to be imposed on the structures.

FPN: See ANSI C2-2002, *National Electrical Safety Code*, for additional information on the loading that can be expected to bear on underground enclosures.

### 110.72 Cabling Work Space

A clear work space not less than 900 mm (3 ft) wide shall be provided where cables are located on both sides, and not less than 750 mm (2½ ft) where cables are only on one side. The vertical headroom shall not be less than 1.8 m (6 ft) unless the opening is within 300 mm (1 ft), measured horizontally, of the adjacent interior side wall of the enclosure.

*Exception: A manhole containing only one or more of the following shall be permitted to have one of the horizontal work space dimensions reduced to 600 mm (2 ft) where the other horizontal clear work space is increased so the sum of the two dimensions is not less than 1.8 m (6 ft):*

*(1) Optical fiber cables as covered in Article 770*
*(2) Power-limited fire alarm circuits supplied in accordance with 760.41(A)*





*(3) Class 2 or Class 3 remote-control and signaling circuits, or both, supplied in accordance with 725.41*

### 110.73 Equipment Work Space

Where electric equipment with live parts that is likely to require examination, adjustment, servicing, or maintenance while energized is installed in a manhole, vault, or other enclosure designed for personnel access, the work space and associated requirements in 110.26 shall be met for installations operating at 600 volts or less. Where the installation is over 600 volts, the work space and associated requirements in 110.34 shall be met. A manhole access cover that weighs over 45 kg (100 lb) shall be considered as meeting the requirements of 110.34(C).

### 110.74 Bending Space for Conductors

Bending space for conductors operating at 600 volts or below shall be provided in accordance with the requirements of 314.28. Conductors operating over 600 volts shall be provided with bending space in accordance with 314.71(A) and 314.71(B), as applicable. All conductors shall be cabled, racked up, or arranged in an approved manner that provides ready and safe access for persons to enter for installation and maintenance.

*Exception: Where 314.71(B) applies, each row or column of ducts on one wall of the enclosure shall be calculated individually, and the single row or column that provides the maximum distance shall be used.*

### 110.75 Access to Manholes

**(A) Dimensions** Rectangular access openings shall not be less than 650 mm × 550 mm (26 in. × 22 in.). Round access openings in a manhole shall not be less than 650 mm (26 in.) in diameter.

*Exception: A manhole that has a fixed ladder that does not obstruct the opening or that contains only one or more of the following shall be permitted to reduce the minimum cover diameter to 600 mm (2 ft):*

*(1) Optical fiber cables as covered in Article 770*
*(2) Power-limited fire alarm circuits supplied in accordance with 760.41*
*(3) Class 2 or Class 3 remote-control and signaling circuits, or both, supplied in accordance with 725.41*

**(B) Obstructions** Manhole openings shall be free of protrusions that could injure personnel or prevent ready egress.

**(C) Location** Manhole openings for personnel shall be located where they are not directly above electric equipment or conductors in the enclosure. Where this is not practicable, either a protective barrier or a fixed ladder shall be provided.

**(D) Covers** Covers shall be over 45 kg (100 lb) or otherwise designed to require the use of tools to open. They shall be designed or restrained so they cannot fall into the manhole or protrude sufficiently to contact electrical conductors or equipment within the manhole.

**(E) Marking** Manhole covers shall have an identifying mark or logo that prominently indicates their function, such as "electric."

### 110.76 Access to Vaults and Tunnels

**(A) Location** Access openings for personnel shall be located where they are not directly above electric equipment or conductors in the enclosure. Other openings shall be permitted over equipment to facilitate installation, maintenance, or replacement of equipment.

**(B) Locks** In addition to compliance with the requirements of 110.34(C), if applicable, access openings for personnel shall be arranged such that a person on the inside can exit when the access door is locked from the outside, or in the case of normally locking by padlock, the locking arrangement shall be such that the padlock can be closed on the locking system to prevent locking from the outside.

### 110.77 Ventilation

Where manholes, tunnels, and vaults have communicating openings into enclosed areas used by the public, ventilation to open air shall be provided wherever practicable.

### 110.78 Guarding

Where conductors or equipment, or both, could be contacted by objects falling or being pushed through a ventilating grating, both conductors and live parts shall be protected in accordance with the requirements of 110.27(A)(2) or 110.31(B)(1), depending on the voltage.

### 110.79 Fixed Ladders

Fixed ladders shall be corrosion resistant.