

# Student Guide TO Wiring

2020 EDITION

Compliments of  
**Georgia EMC**

.....  
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# Georgia's Electric Membership Cooperatives

- ▶ Are member-owned utilities that serve approximately 4.4 million of the state's 10 million residents.
- ▶ Manage a system that covers 73 percent of Georgia's land area in 157 of 159 counties.
- ▶ Operate by far the largest distribution network in the state, with 191,927 miles of electric power lines.
- ▶ Average 10.8 meters per mile of distribution line, compared with 34 meters per mile for investor-owned electric utilities and 48 meters per mile for municipal electric utilities.
- ▶ Operate as not-for-profit cooperatives to offset the cost of serving large land areas.
- ▶ Employ more than 5,900 workers.
- ▶ Pay millions of dollars in local, state and federal taxes each year.



**Georgia EMC**

*Representing Georgia's Electric Cooperatives*

## FOREWORD

The electric membership cooperatives (EMCs) of Georgia assembled this booklet as a training guide to promote standard wiring requirements. This booklet is comprised of sections of the National Electrical Code (NEC). It is intended as a training guide for students to be used in a supervised classroom environment that does not have access to the official NEC standards. The NEC references in this booklet may not be in their entirety. Refer to the 2020 edition of the NEC for complete text.

This booklet is a NOT-FOR-SALE item, intended to be provided to all users free of charge. This booklet should only be used as a wiring guideline and does not supersede any National Electrical Codes, EMC special wiring requirements, or any other authority having jurisdiction. Any consumer or licensed electrician planning to do electrical work should contact their local authorities for approval of their work.

This booklet is intended to be used as a resource in preparation for the EMC/FFA Wiring Contest (Career Development Event). The annual contest is sponsored by the electric cooperatives in cooperation with the FFA. The purpose of the contest is to promote and expand educational programs in electrification for students of agricultural education. The electric membership corporations throughout Georgia sponsor these activities as a means of promoting education in the safe, efficient use of electrical energy.

Participants in the contest are students in grades 9-12 enrolled in agricultural education and active members of the Georgia FFA. Students compete first in area contests; the top two contestants from each area move on to the state competition held each year at the FFA/FCCLA Center in Covington. Scholarships awarded to area and state winners can be used at college or vocational schools.

For more information on this program, contact the Member Services department at your local electric cooperative, speak with an FFA advisor, contact Georgia EMC at [info@georgiaemc.com](mailto:info@georgiaemc.com), or go to [www.gaaged.org](http://www.gaaged.org) or [www.georgiaemc.com](http://www.georgiaemc.com).

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**GEORGIA'S ELECTRIC COOPERATIVES** . . . . . Inside back cover

**I. GENERAL**

- 1.1 The latest issue of the National Electrical Code (NEC) (2020 edition) as published by the National Fire Protection Association (NFPA), along with OSHA Rules and Regulations on Electrical Construction, is cited for the purpose of the practical safeguarding of persons and property from hazards arising from the use of electricity. *NEC 90.1(A)*
- 1.2 Mechanical execution of work: Electrical equipment shall be installed in a neat and workmanlike manner. *NEC 110.12, ANSI/NECA 1-2015*
- 1.3 Conductors used to carry current shall be of copper, aluminum, or copper-clad aluminum unless otherwise provided in this Code. Where the conductor material is not specified, the sizes given in this Code shall apply to copper conductors. Where other materials are used, the size shall be changed accordingly. *NEC 110.5*
- 1.4 Switches or circuit breakers shall not disconnect the grounded conductor of a circuit. *NEC 404.2(B)*
- 1.5 General-use and motor-circuit switches, circuit breakers, and molded case switches, (where mounted in an enclosure listed for the intended purpose) shall indicate, in a location that is visible when accessing the external operating means, whether they are in the open (off) or closed (on) position. Where these switch or circuit breaker handles are operated vertically rather than rotationally or horizontally, the up position of the handle shall be the closed "on" position.  
*Exception No. 1: Vertically operated double-throw switches shall be permitted to be in the closed (on) position with the handle in either the up or down position. NEC 404.7*
- 1.6 The following shall be used only for the grounded circuit conductor: (1) A conductor with continuous white or gray covering, (2) a conductor with three continuous white or gray stripes on other than green insulation (3) a marking of white or gray color at the termination. *NEC 200.7(A) Exception: The grounded conductor of a multi-conductor cable shall be permitted to be bare. NEC 230.22*
- 1.7 The use of insulation that is white or gray or that has three continuous white or gray stripes for other than a grounded conductor shall be permitted only if part of a cable assembly that has the insulation permanently reidentified to indicate its use as an ungrounded conductor by marking tape, painting, or other effective means at its termination and at each location where the conductor is visible and accessible. *NEC 200.7(C)*
- 1.8 Receptacles shall have the terminal intended for connection to the grounded conductor identified as follows: a metal or metal coating that is substantially white or silver in color. *NEC 200.10(B)*

- 1.9 Reference sources identified by initials in parentheses at the end of a paragraph and in table and diagram headings are as follows:
- *NEC* National Electrical Code
  - *OSHA* Occupational Safety and Health Administration
  - *REA* Rural Electrification Administration
  - *RERC* Rural Electricity Resource Council
  - *NFPA* National Fire Protection Association
- 1.10 The licensed electrician, contractor, or consumer planning a wiring installation should contact the local authority having jurisdiction over electrical installations for making interpretations of these Wiring Rules. *NEC 90.4*

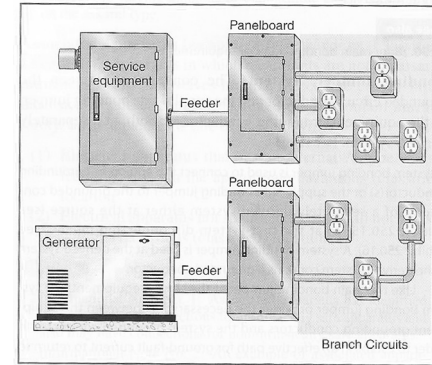
## 2. DEFINITIONS (NEC Article 100)

- 2.1 **ACCESSIBLE:** (As applied to equipment) Capable of being reached for operation, renewal, and inspection.
- 2.2 **ACCESSIBLE:** (As applied to wiring methods) Capable of being removed or exposed without damaging the building structure or finish, or not permanently closed in by the structure or finish of the building.
- 2.3 **ACCESSIBLE, READILY:** (Readily accessible) Capable of being reached quickly for operation, renewal, or inspections, without requiring those to whom ready access is requisite to actions such as to use tools (other than keys), to climb over or under, to remove obstacles, or to resort to portable ladders, and so forth.
- 2.4 **AMPACITY:** The maximum current, in amperes, that a conductor can carry continuously under the conditions of use without exceeding its temperature rating.
- 2.5 **APPLIANCE:** Utilization equipment, generally other than industrial, that is normally built in standardized sizes or types and is installed or connected as a unit to perform one or more functions such as clothes washing, air conditioning, food mixing, deep frying, and so forth.
- 2.6 **APPROVED:** Acceptable to the authority having jurisdiction.
- 2.7 **AUTOMATIC:** Performing a function without the necessity of human intervention.
- 2.8 **BRANCH CIRCUIT:** The circuit conductors between the final over-current device protecting the circuit and the outlet(s).
- 2.9 **BRANCH CIRCUIT, APPLIANCE:** A branch circuit that supplies energy to one or more outlets to which appliances are to be connected and that has no permanently connected luminaires that are not a part of an appliance.
- 2.10 **BRANCH CIRCUIT, GENERAL PURPOSE:** A branch circuit that supplies two or more receptacles or outlets for lighting and appliances.

- 2.11 **BRANCH CIRCUIT, INDIVIDUAL:** A branch circuit that supplies only one utilization equipment.

A single receptacle installed on an individual branch circuit shall have an ampere rating not less than that of the branch circuit. *NEC 210.21(B)(1)*

- 2.12 **BRANCH CIRCUIT, MULTIWIRE:** A branch circuit that consists of two or more ungrounded conductors that have a voltage between them, and a grounded conductor that has equal voltage between it and each ungrounded conductor of the circuit and that is connected to the neutral or grounded conductor of the system.



**NEC Exhibit 100.7** Feeder and Branch Circuits

- 2.13 **CIRCUIT BREAKER:** A device designed to open and close a circuit by nonautomatic means and to open the circuit automatically on a predetermined overcurrent without damage to itself when properly applied within its rating.
- 2.14 **CONCEALED:** Rendered inaccessible by the structure or finish of the building. *Informational note: Wires in concealed raceways are considered concealed, even though they may become accessible by withdrawing them.*
- 2.15 **CONTINUOUS LOAD:** A load where the maximum current is expected to continue for 3 hours or more.
- 2.16 **CONTROLLER:** A device or group of devices that serves to govern, in some predetermined manner, the electrical power delivered to the apparatus to which it is connected.
- 2.17 **DEVICE:** A unit of an electric system, other than a conductor, that carries or controls electric energy as its principle function.
- 2.18 **DISCONNECTING MEANS:** A device, group of devices, or other means by which the conductors of a circuit can be disconnected from their source of supply.

- 2.19 DWELLING UNIT: A single unit, providing complete and independent living facilities for one or more persons, including permanent provisions for living, sleeping, cooking and sanitation.  
 DWELLING, ONE-FAMILY: A building consisting solely of one dwelling unit.  
 DWELLING, TWO-Family: A building consisting solely of two dwelling units.  
 DWELLING, MULTI-FAMILY: A building containing three or more dwelling units.
- 2.20 ENCLOSED: Surrounded by a case, housing, fence, or wall(s) that prevents persons from accidentally contacting energized parts.
- 2.21 EQUIPMENT: A general term, including fittings, devices, appliances, luminaries, apparatus, machinery, and the like used as a part of, or in connection with, an electrical installation.
- 2.22 EXPOSED: (As applied to wiring methods) On or attached to the surface or behind panels designed to allow access.
- 4** 2.23 FEEDER: All circuit conductors between the service equipment, the source of a separately derived system, or other power supply source and the final branch-circuit overcurrent device.
- 2.24 GROUNDED CONDUCTOR: A system or circuit conductor that is intentionally grounded.
- 2.25 GROUNDING CONDUCTOR, EQUIPMENT (EGC): A conductive path(s) that is a part of an effective ground-fault current path and connects normally non-current-carrying metal parts of equipment together and to the system grounded conductor or to the grounding electrode conductor, or both.
- 2.26 GROUNDING ELECTRODE CONDUCTOR: A conductor used to connect the system grounded conductor or the equipment to a grounding electrode or to a point on the grounding electrode system.
- 2.27 IDENTIFIED: (As applied to equipment) Recognizable as suitable for the specific purpose, function, use, environment, application, and so forth, where described in a particular Code requirement.
- 2.28 LOCATION, DAMP: Locations protected from weather and not subject to saturation with water or other liquids but subject to moderate degrees of moisture.  
 LOCATION, DRY: A location not normally subject to dampness or wetness. A location classified as dry may be temporarily subject to dampness or wetness, as in the case of a building under construction.  
 LOCATION, WET: Installations underground or in concrete slabs or masonry in direct contact with the earth; in locations subject to saturation with water or other liquids, such as vehicle washing areas; and in unprotected locations exposed to weather.

- 2.29 OUTLET: A point on the wiring system at which current is taken to supply utilization equipment.
- 2.30 RACEWAY: An enclosed channel designed expressly for holding wires, cables, or bus bars, with additional functions as permitted in this Code.
- 2.31 RAIN-TIGHT: Constructed or protected so that exposure to a beating rain will not result in the entrance of water under specified test conditions.
- 2.32 RECEPTACLE: A contact device installed at the outlet for the connection of an attachment plug.
- 2.33 SERVICE DROP: The overhead conductors between the serving utility and the service point.
- 2.34 SERVICE-ENTRANCE CONDUCTORS, OVERHEAD SYSTEM: The service conductors between the terminals of the service equipment and a point usually outside the building, clear of building walls, where joined by tap or splice to the service drop or the overhead service conductors.
- 2.35 SERVICE-ENTRANCE CONDUCTORS, UNDERGROUND SYSTEM: The service conductors between the terminals of the service equipment and the point of connection to the service lateral or underground service conductors.  
*Informational note: Where service equipment is located outside the building walls, there may be no service-entrance conductors, or they may be entirely outside the building.*
- 2.36 SERVICE EQUIPMENT: The necessary equipment, consisting of a circuit breaker(s) or switch(es) and fuse(s) and their accessories, connected to the serving utility and intended to constitute the main control and disconnect of the serving utility supply.
- 2.37 SPECIAL PERMISSION: The written consent of the authority having jurisdiction.
- 2.38 SWITCH, GENERAL-USE: A switch intended for use in general distribution and branch circuits. It is rated in amperes, and it is capable of interrupting its rated current at its rated voltage.  
 SWITCH, MOTOR-CIRCUIT: A switch rated in horsepower that is capable of interrupting the maximum operating overload current of a motor of the same horsepower rating as the switch at the rated voltage.
- 2.39 WEATHERPROOF: Constructed or protected so that exposure to the weather will not interfere with successful operation.

*Informational Note: Rainproof, rain tight, or watertight equipment can fulfill the requirements for weatherproof where varying weather conditions other than wetness, such as snow, ice, dust, or temperature extremes, are not a factor.*

### 3. SERVICE ENTRANCES

3.1 MEANS OF ATTACHMENT: Multiconductor cables used for overhead service conductors shall be attached to buildings or other structures by fittings identified for use with service conductors. *NEC 230.27*

3.2 VERTICAL CLEARANCE FOR OVERHEAD SERVICE CONDUCTORS:

CLEARANCE FROM BUILDING OPENINGS: Service conductors installed as open conductors or multi-conductor cable without an overall outer jacket shall have a clearance of not less than 900 mm (3 feet) from windows that are design to be opened, doors, porches, balconies, ladders, stairs, fire escapes or similar locations.

*Exception: Conductors run above the top level of a window shall be permitted to be less than the 3 feet (900 mm) requirement. NEC 230.9 (A)*

Overhead service conductors shall not be installed beneath openings through which materials may be moved, such as openings in farm and commercial buildings, and shall not be installed where they obstruct entrance to these building openings. *NEC 230.9(C)*

ABOVE ROOFS: Conductors shall have a vertical clearance of not less than 2.5 m (8 ft.) above the roof surface. The vertical clearance above the roof level shall be maintained for a distance of not less than 900 mm (3 feet) in all directions from the edge of the roof. *NEC 230.24(A)*

Overhead service conductors, where not in excess of 1,000 volts, nominal, shall have the following minimum clearance from final grade:

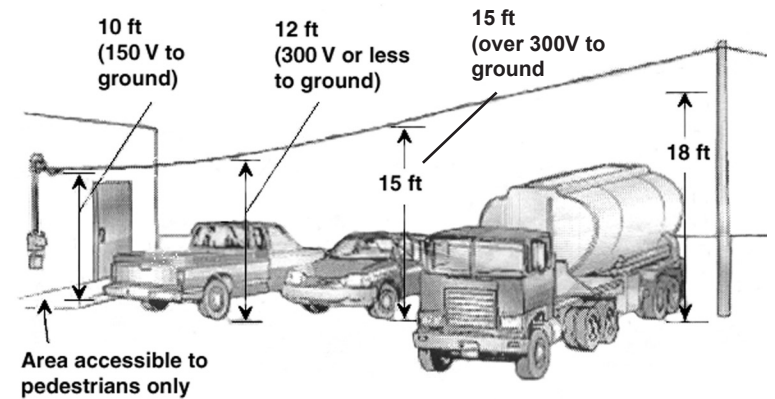
- 3.2.1 3.0 m (10 ft.) - at the electric service entrance to buildings, also at the lowest point of the drip loop of the building electric entrance, and above areas or sidewalks accessible only to pedestrians, measured from final grade or other accessible surface only for overhead service conductors supported on and cabled together with a grounded bare messenger where the voltage does not exceed 150 volts to ground.
- 3.2.2 3.7 m (12 ft.) - over residential property and driveways, and those commercial areas not subject to truck traffic where the voltage does not exceed 300 volts to ground.
- 3.2.3 4.5 m (15 ft.) - for those areas listed in the 3.7 m (12 ft.) classification where the voltage exceeds 300 volts to ground.
- 3.2.4 5.5 m (18 ft.) - over public streets, alleys, roads, parking areas subject to truck traffic, driveways on other than residential property, and other land such as cultivated, grazing, forest, and orchard.
- 3.2.5 7.5 m (24.5 ft.) - over tracks of railroads *NEC 230.24(B)*

3.3 POINT OF ATTACHMENT: The point of attachment of the overhead service-drop conductors to a building or other structure shall provide the minimum clearances as specified in [section 3.2 and *NEC Exhibit 230.22 of this booklet*] and *NEC 230.9* and *230.24*. In no case shall this point of attachment be less than 3.0 m (10 ft.) above finished grade. *NEC 230.26*

3.4 UNDERGROUND SERVICE: Contact your local electric authority office for the latest Underground Service Policy Rules and Regulations.

3.5 RESIDENTIAL SERVICE REQUIREMENTS:

NUMBER OF SERVICES: A building or other structure served shall be supplied by only one service unless permitted in *NEC 230.2(A)* through *(D)*.



**NEC Exhibit 230.22** Clearances for Overhead Services

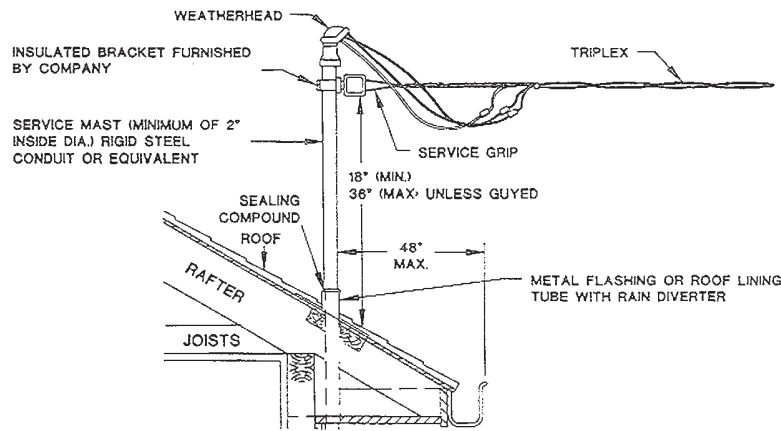
*NOTE: Additional services for certain occupancies may be allowed – that is, written consent of the authority having jurisdiction. Many electric utilities have specifications for, and have adopted special regulations covering, certain types of electrical loads and service equipment. Before electrical services for large buildings and facilities are designed, the serving utility should be consulted to determine line and transformer capacities.*

3.6 CONDUIT:

3.6.1 Only power service-drop or overhead service conductors shall be permitted to be attached to a service mast. *NEC 230.28* The service mast shall be of adequate strength or be supported by braces or guy wires to withstand safely the strain imposed by the service-drop or overhead service conductors. Hubs intended for use with conduit that serves as a service mast shall be identified for use with service-entrance equipment. *NEC 230.28 (A)*



3.6.2 For all services extending through the roof, a minimum of 50.8 mm (2 inches) rigid galvanized steel conduit or intermediate metal conduit is required for mechanical strength in order to support service drop.



## 8 Rooftop Clearances for Overhead Services

3.6.3 The use of electrical metallic tubing (EMT) shall be permitted for both exposed and concealed work for the following:

- (1) In concrete, in direct contact with the earth or in areas subject to severe corrosive influences where installed in accordance with 358.10(B)
- (2) In dry, damp, and wet locations
- (3) In any hazardous (classified) location as permitted by other articles in this Code

*NEC 358.10 (A)*

EMT shall not be used under the following conditions:

- (1) Where it will be subject to severe physical damage
- (2) For the support of luminaires or other equipment except conduit bodies no larger than the largest trade size of the tubing. *NEC 358.12*

Where practicable, dissimilar metals in contact anywhere in the system shall be avoided to eliminate the possibility of galvanic action. *NEC 358.14*

3.6.4 Galvanized steel and stainless steel EMT, elbows and fittings shall be permitted to be installed in concrete, in direct contact with the earth, or in areas subject to severe corrosive influences where protected by corrosion protection and approved as suitable for the condition. *NEC 358.10(B)(1)*

3.6.5 Where a conduit enters a box, fitting, or other enclosure, a bushing shall be provided to protect the wires from abrasion unless the box, fitting, or enclosure is designed to provide such protection. *NEC 342.46, 344.46, 352.46*

## 3.7 CONDUCTORS:

### 3.7.1 Clearance From Building Openings:

Service conductors installed as open conductors or multi-conductor cable without an overall outer jacket shall have a clearance of not less than 900 mm (3 feet) from windows that are design to be opened, doors, porches, balconies, ladders, stairs, fire escapes or similar locations.

*Exception: Conductors run above the top level of a window shall be permitted to be less than the 3 feet (900 mm) requirement. NEC 230.9 (A)*

Overhead service conductors shall not be installed beneath openings through which materials may be moved, such as openings in farm and commercial buildings, and shall not be installed where they obstruct entrance to these building openings. *NEC 230.9(C)*

3.7.2 For a service rated 100 amperes through 400 amperes, the service conductors supplying the entire load associated with a one-family dwelling, or the service conductors supplying the entire load associated with an individual dwelling unit in a two-family or multifamily dwelling, shall be permitted to have an ampacity not less than 83 percent of the service rating. If no adjustment or correction factors are required, Table 310.12 shall be permitted to be applied. *NEC 310.12 (A)*

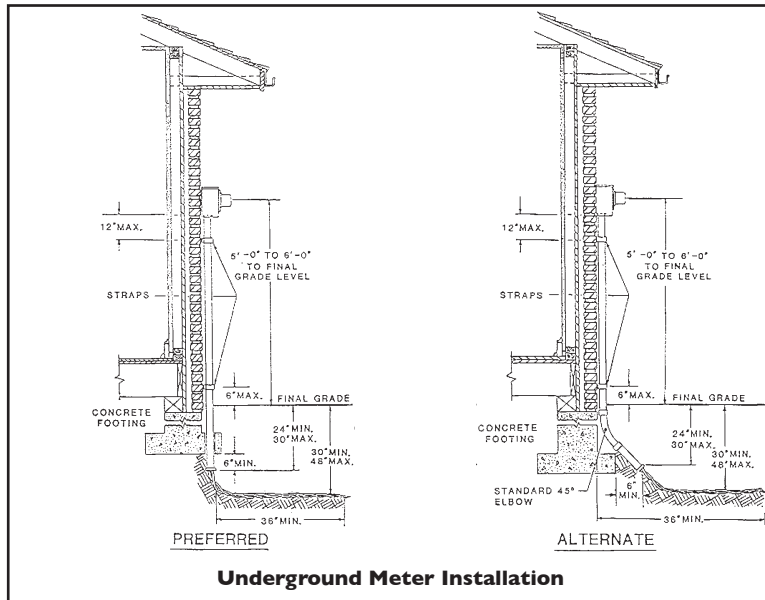
**Table 310.12 Single-Phase Dwelling Services and Feeders**

Service or Feeder Rating (Amperes)	Conductor (AWG or kcmil)	
	Copper	Aluminum or Copper-Clad Aluminum
100	4	2
110	3	1
125	2	1/0
150	1	2/0
175	1/0	3/0
200	2/0	4/0
225	3/0	250
250	4/0	300
300	250	350
350	350	500
400	400	600

Note: If no adjustment or correction factors are required, this table shall be permitted to be applied.

- 3.8 METER BASE:
- 3.8.1 The following equipment shall be permitted to be connected to the supply side of the service disconnecting means: Meters and meter sockets nominally rated not in excess of 1000 volts, meter disconnect switches nominally rated not in excess of 1000 volts  
*NEC 230.82(2),(3)*
- 3.8.2 Meter base installed on a masonry wall shall be of the type approved for this purpose.
- 3.8.3 Meter base installed for an underground service shall be of the type approved for this purpose.
- 3.8.4 Meter base for potential (PT) or current transformer (CT) metering will be supplied by the utility, but the use of equipment must be approved before the installation.
- 3.8.5 Contact your local utility prior to electrical construction as these electrical requirements may vary according to the local authority.

10



#### 4. GROUNDING

- 4.1 SERVICE GROUNDING WIRE:
- 4.1.1 **Size of Alternating Current Grounding Electrode Conductor:** The size of the grounding electrode conductor at the service, at each building or structure where supplied by a feeder(s) or branch circuit(s) or at a separately derived system of a grounded or ungrounded AC system

shall not be less than given in Table 250.66, except as permitted in NEC 250.66(A) through (C).

- 4.1.2 **Connections to Rod, Pipe, or Plate Electrodes:** If the grounding conductor or bonding jumper connected to a single or multiple rod, pipe, or plate electrode(s), or any combination thereof, as described in 250.52(A)(5) or (A)(7), does not extend on to other types of electrodes that require a larger size conductor, the grounding electrode conductor shall not be required to be larger than 6 AWG copper wire or 4 AWG aluminum wire.  
*NEC 250.66(A)*
- 4.1.3 **Connections to Concrete-Encased Electrodes:** If the grounding electrode or bonding jumper connected to a single or multiple concrete-encased electrode(s), as described in NEC 250.52(A)(3), does not extend on to other types of electrodes that require a larger size conductor, the grounding electrode conductor shall not be larger than # 4 AWG copper wire.  
*NEC 250.66(B)*
- 4.1.4 **Connections to Ground Rings:** If the grounding electrode conductor or bonding jumper connected to a ground ring, as permitted in 250.52(A)(4), does not extend on to other types of electrodes that require a larger size conductor, the grounding electrode conductor shall not be required to be larger than the conductor used for the ground ring.  
*NEC 250.66(C)*
- 4.1.5 **Grounding Electrode Conductor Installation:** Grounding electrode conductors shall be installed as specified in NEC 250.64 (A) through (F):
- (A) Aluminum or Copper-Clad Aluminum Conductors
- (1) Bare or covered conductors without an extruded polymeric covering shall not be installed where subject to corrosive conditions or be installed in direct contact with concrete.
  - (2) Terminations made within outdoor enclosures that are listed and identified for the environment shall be permitted 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.
- (1) **Not exposed to physical damage:** A 6 AWG or larger grounding electrode conductor that is not exposed to physical damage shall be permitted to be run along the surface of the building construction without metal covering or protection.
  - (2) **Exposed to physical damage:** A 6 AWG or larger copper or aluminum grounding electrode conductor exposed to physical damage shall be protected in rigid metal conduit (RMC), intermediate metal conduit (IMC), Schedule 80 rigid polyvinyl chloride conduit (PVC), reinforced thermosetting resin conduit Type XW (RTRC-XW), electrical metallic tubing (EMT), or cable armor.

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- (3) **Smaller than 6 AWG:** Grounding electrode conductors smaller than 6 AWG shall be protected in RMC, IMC, PVC, RTRC-XW, EMT or cable armor.
- (4) **In Contact with the Earth:** Grounding electrode conductors and grounding electrode bonding jumpers in contact with the earth shall not be required to meet the minimum cover requirements of NEC Article 300.5, but shall be buried or otherwise protected if subject to physical damage.
- (C) **Continuous:** The grounding electrode shall be installed in one continuous length without splice or joint. If necessary, splices or connections shall be made as permitted in (1) through (4).
  - (1) Splicing of the wire-type grounding electrode conductor 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 connect together to form a grounding electrode.
  - (3) Bolted, riveted, or welded connections of structural metal frames of buildings or structures.
  - (4) Threaded, welded, brazed, soldered, or bolted-flange connections of metal water piping.
- (D) **Building or Structure with Multiple Disconnecting Means in Separate Enclosures:** If a building or structure is supplied by a service or feeder with two or more disconnecting means in separate enclosures, the grounding electrode connections shall be made in accordance with NEC 250.64(D)(1), (D)(2), or (D)(3).
  - (1) **Common Grounding Electrode Conductor and Taps:** A common grounding electrode conductor and grounding electrode conductor taps shall be installed and shall be sized in accordance with NEC 250.66 based on the sum of the circular mil area of the largest ungrounded conductor(s) of each set of conductors that supplies the disconnecting means. Tap conductors shall be connected to the common grounding electrode by one of the following methods in such a manner that the common grounding electrode conductor remains without splice or joint:
    - (1) Exothermic welding
    - (2) Connectors listed as grounding or bonding equipment
    - (3) Connections to an aluminum or copper bus bar not less than 1/4" thick x 2" wide and of sufficient length to accommodate the number of terminations necessary for the installation. The bus bar shall be securely fastened and installed in an accessible location.
  - (2) **Individual Grounding Electrode Conductors:** A grounding electrode conductor shall be connected between the grounding electrode system and one or more of the following if applicable:
    - (1) Grounded conductor in each service equipment disconnecting means enclosure.
    - (2) Equipment grounding conductor installed with the feeder.

- (3) Supply-side bonding jumper.

Each grounding electrode conductor shall be sized in accordance with NEC 250.66.

- (3) **Common Location:** A grounding electrode conductor shall be connected in a wireway or other accessible enclosure on the supply side of the service disconnecting means to one or more of the following as applicable:
  - (1) Grounded conductor in each service equipment disconnecting means enclosure.
  - (2) Equipment grounding conductor installed with the feeder.
  - (3) Supply-side bonding jumper.
- (E) **Raceways and Enclosures for Grounding Electrode Conductors:** Ferrous metal raceways, enclosures and cable armored 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 and shall be bonded at each end of the raceway or enclosure to the grounding electrode or grounding electrode conductor to create an electrically parallel path.
- (F) **Installation to Electrode(s):** The grounding electrode conductor shall be sized for the largest grounding electrode conductor required among all the electrodes connected to it.
  - (1) The grounding electrode conductor can run to any convenient grounding electrode available in the grounding electrode system where the other electrode(s), if any, is connected by bonding jumpers.
  - (2) Grounding electrode conductor(s) shall be permitted to be run to one or more grounding electrode(s) individually
  - (3) Bonding jumper(s) from grounding electrode(s) shall be permitted to be connected to an aluminum or copper busbar not less than 1/4" thick x 2" wide and of sufficient length to accommodate the number of terminations necessary for the installation. The busbar shall be securely fastened and installed in an accessible location.

- 4.2 Bonding shall be provided wherever necessary to ensure electrical continuity and the capacity to conduct safely any fault current likely to be imposed. *NEC 250.90*
- (A) Bonding of Equipment for Services: The normally non-current carrying metal parts of equipment raceways, cable armor and all enclosures containing service conductors shall be bonded together.
  - (B) Bonding Other Enclosures:
    - (1) Metal raceways, cable trays, cable armor, cable sheath, enclosures, frames, fittings and other metal non-current-carrying parts that are to serve as equipment grounding conductors with or without the use of supplementary equipment grounding conductors shall be effectively bonded where necessary to assure 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 so designed as to make such removal unnecessary. *NEC 250.96*

4.2.1 Bonding of Metal Piping Systems and Exposed Structural Metal:  
General: Metal water piping system(s) installed in or attached to a building or structure shall be bonded to any of the following:

- (1) Service equipment enclosure
- (2) Grounded conductor at the service
- (3) Grounding electrode conductor if of sufficient size
- (4) One or more grounding electrodes used, if the grounding electrode conductor or bonding jumper to the grounding electrode is of sufficient size. The bonding jumper(s) shall be sized in accordance with Table 250.102 (C)(1) except that it shall not be required to be larger than 3/0 copper or 250 kcmil aluminum or copper-clad aluminum except as permitted in 250.104 (A)(2) and 250.104 (A)(3).

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4.2.2 *NEC 250.104(A)(2)* - Buildings of Multiple Occupancy: Where the metal water piping system(s) installed in or attached to a building or structure 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 switchboard or panelboard (other than service equipment) that serves only that particular occupancy. The bonding jumper shall be sized in accordance with 250.102(D)

*NEC 250.104(A)(3)* – Buildings or Structures Supplied by a Feeder(s) or Branch Circuit(s). The metal water piping system(s) installed or attached to a building or structure shall be bonded to any of the following:

- (1) Building or structure disconnecting means enclosure where located at the building or structure
- (2) Equipment grounding conductor run with the supply conductor
- (3) One or more grounding electrodes used

The bonding jumper shall be sized in accordance with 250.102(D)

4.2.3 Exposed structural metal that is interconnected to form a metal building frame and is not intentionally grounded or bonded and is likely to become energized shall be bonded to any of the following:

- (1) Service equipment enclosure
- (2) Grounded conductor at the service
- (3) Disconnecting means for buildings or structures supplied by a feeder or branch circuit
- (4) Grounding electrode conductor where of sufficient size
- (5) One or more grounding electrodes used, if the grounding electrode conductor or bonding jumper to the grounding electrode is of sufficient size. The bonding conductor(s)

or jumper(s) shall be sized in accordance with Table 250.102(C)(1) except that it shall not be required to be larger than 3/0 copper or 250 kcmil aluminum or copper-clad aluminum.

SAFETY BONDING: FPN: Bonding all pipes and metal air ducts within the premises will provide additional safety. *NEC 250.104(B)*

4.3 EQUIPMENT GROUNDING:

4.3.1 All receptacles installed on 15 and 20 ampere branch circuits shall be of the grounding type *NEC 406.4(A)*. General use snap switches dimmers and control switches shall be connected to an equipment grounding conductor and shall provide a means to connect metal faceplates to the equipment grounding conductor whether or not a metal faceplate is installed. Metal faceplates shall be bonded to the equipment grounding conductor. Snap switches, dimmers, control switches, and metal faceplates shall be connected to an equipment grounding conductor using either of the following methods

- (A) The switch is mounted with metal screws to a metal box that is connected to an equipment grounding conductor.
- (B) An equipment grounding conductor or bonding jumper is connected to an equipment grounding termination of the snap switch. *NEC 404.9(B)(1)&(2)*

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4.3.2 Surface Mounted Box: If a metal box is mounted on the surface, the direct metal-to-metal contact between the device yoke or strap to the box shall be permitted to provide the effective ground fault current path. At least one of the insulating washers shall be removed from receptacles that do not have a contact yoke or device to ensure direct metal-to-metal contact. Direct metal-to-metal contact for providing continuity applies to cover-mounted receptacles if the box and cover combination are listed as providing satisfactory continuity between the box and the receptacle.

A listed exposed work cover shall be permitted to be the grounding and bonding means under both of the following conditions:

- (1) the device is attached to the cover with at least two fasteners that are permanent (such as a rivet) or have a thread locking or screw or nut locking means.
- (2) when the cover mounting holes are located on a non-raised portion of the cover. *NEC 250.146(A), 404.9, 404.9(B)(1)*

4.3.3 Contact Devices or Yokes: Contact devices or yokes designed and listed as self-grounding shall be permitted in conjunction with the supporting screws to establish the equipment bonding between the device yoke and flush-type boxes. *NEC 250.146(B)*

4.3.4 Continuity and Attachment of Equipment Grounding Conductors and Attachment in Boxes: If circuit conductors are spliced within a box, or terminated on equipment within or supported by a box, all wire-type

equipment grounding conductor(s) associated with any of those circuit conductors shall be connected within the box or to the box with devices suitable for the use in accordance with NEC 250.8 (A), 250.8(B) and 250.148(A) through (D).

Connections depending solely on solder shall not be used

- (A) Connections and Splices: Connections and splices shall be made in accordance with NEC 110.14(B) except that insulation shall not be required.
- (B) Equipment Grounding Conductor Continuity: The arrangement of grounding connections shall be such that the disconnection or the removal of a luminaire, receptacle, or other device fed from the box does not interrupt the electrical continuity of the grounding conductors providing an effective ground-fault path.
- (C) Metal Boxes: A connection used for no other purpose shall be made between the metal box and the equipment grounding conductors by means of machine screw-type fasteners or thread-forming machine screws grounding screw or equipment listed for grounding, or a listed grounding device. Nonconductive coatings (such as paint, laquer, and enamel) on equipment to be grounded or bonded shall be removed from threads and other contact surfaces to ensure good electrical continuity or shall be connected by means of fittings designed a to make such removal unnecessary.
- (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 connection to an equipment grounding conductor.

4.4 GROUNDING ELECTRODE:

- 4.4.1 Rod-Type grounding electrodes of stainless steel and copper or zinc coated steel shall be at least 5/8 inch (15.87 mm) in diameter unless listed. *NEC 250.52(A)(5b)*
- 4.4.2 Grounding electrodes of pipe or conduit shall not be smaller than 3/4 inch trade size (metric designator 21) and, where of steel, shall have the outer surface galvanized or otherwise metal-coated for corrosion protection. *NEC 250.52(A)(5)(a)*
- 4.4.3 The electrode shall be installed such that at least 8 feet (2.44 m) of length is in contact with the soil. It shall be driven to a depth of not less than 8 feet (2.44 m) 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 buried in a trench that is at least 30 inches (750 mm) deep. The upper end of the electrode shall be flush with or below ground level unless the above-ground end and the grounding electrode conductor attachment are protected against physical damage as specified in NEC 250.10. *NEC 250.53(A)(4)*
- 4.4.4 A single electrode consisting of a rod, pipe, or plate that has a resistance to ground greater than 25 ohms shall be augmented by one additional electrode of any of the types specified by 250.53 (A)(2) through (A)(8). Where multiple rod, pipe, or plate electrodes are installed to meet the requirements of this section, they shall be not less than 6 feet (1.8 m) apart. *NEC 250.53(A)(3)*

**NEC Table 250.102(C)(1). Grounding Electrode Conductor or Bonding Conductor for Alternating-Current Systems**

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

**5. SERVICE EQUIPMENT – DISCONNECTING MEANS**

- 5.1 MARKING: Service equipment rated at 1000 volts or less shall be marked to identify it as being suitable for use as service equipment. *(SUSE) NEC 230.66 (A)*  
All service equipment shall be listed or field labeled. Individual socket meters shall not be considered service equipment but shall be listed and rated for the voltage and ampacity of the service unless supplied by and under the exclusive control of an electric utility. *NEC 230.66(B)*. Energized parts of service equipment shall be enclosed so that they will not be exposed to accidental contact, shall be protected from mechanical injury and shall not be located in the vicinity of easily ignitable materials. *NEC 230.62 (A) & (B)*
- 5.2 LOCATION:
  - 5.2.1 General: Means shall be provided to disconnect all ungrounded conductors in a building or other structure from the service-entrance conductors. *NEC 230.70*
  - 5.2.2 Location: The service disconnecting means shall be installed in accordance with NEC 230.70(A)(1), (2), and (3).

- (1) Readily Accessible Location: The service disconnecting means shall be installed at a readily accessible location either outside of a building or structure or inside nearest the point of entrance of the service conductors. *NEC 230.70(A)(1)*
- (2) Bathrooms: Service disconnecting means shall not be installed in bathrooms. *NEC 230.70(A)(2)*
- (3) Remote Control: Where a remote control device is used to actuate the service disconnecting means, the service disconnecting means shall be located in accordance with *NEC 230.70(A)(1)*.

5.2.3 Marking: Each service disconnect shall be permanently marked to identify it as a service disconnect.

5.2.4 Each service disconnecting means shall be suitable for the prevailing conditions. Service equipment installed in hazardous (classified) locations shall comply with the requirements of Articles 500 through 517.

5.2.5 Hazardous Locations:

- (A) Not in Vicinity of Easily Ignitable Material. Overcurrent devices shall not be located in the vicinity of easily ignitable material, such as in clothes closets. *NEC 240.24(D)*
- (B) Not Located in Bathrooms. In dwelling units, dormitories, and guest rooms or guest suites, overcurrent devices, other than supplementary overcurrent protection, shall not be located in bathrooms as defined in Article 100. *NEC 240.24(E)*
- (C) Not Located Over Steps. Overcurrent devices shall not be located over steps of a stairway. *NEC 240.24(F)*

5.3 MOUNTING OF EQUIPMENT: (*OSHA*)

5.3.1 Protection from Physical Damage. Overcurrent devices shall be protected from physical damage by one of the following *NEC 240.30*

- (1) Installation in enclosures, cabinets, cutout boxes, or equipment assemblies. *NEC 240.30(A)(1)*
- (2) Mounting on open-type switchboards, panelboards, or control boards that are in rooms or enclosures free from dampness and easily ignitable material and are accessible only to qualified personnel. *NEC 240.30(A)(2)*

5.3.2 Damp Or Wet Locations: Enclosures for overcurrent devices in damp or wet locations shall comply with 312.2. Refer to definition of damp and wet locations. *Article 100*

5.3.3 Vertical Positions: Enclosures for overcurrent devices shall be mounted in a vertical position unless that is shown to be impracticable. Circuit breaker enclosures shall be permitted to be installed horizontally where the circuit breaker is installed in accordance with 240.81. Listed busway plug-in units shall be permitted to be mounted in orientations corresponding to the busway mounting position. *NEC 240.33*

5.4 MARKING OF EQUIPMENT:

5.4.1 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 electrical equipment. Other markings that indicate voltage, current, wattage, or other ratings shall be provided as specified elsewhere in this Code. The marking or label shall be of sufficient durability to withstand the environment involved. *NEC 110.21*

Each disconnecting means shall be legibly marked to indicate its purpose unless located and arranged so the purpose is evident. In other than one- or two-family dwellings, the marking shall include the identification of the circuit source that supplies the disconnecting means. The marking shall be of sufficient durability to withstand the environment involved. *NEC 110.22*

5.4.2 Engineered Series Combination Systems: Equipment enclosures for circuit breakers or fuses applied in compliance with the series combination ratings selected under engineering supervision in accordance with *NEC 240.86(A)* shall be legibly marked in the field on the equipment as directed by the engineer to indicate the equipment been applied with a series combination rating. The marking shall meet the requirements in 110.21 (B) and shall be readily visible and state the following:

**CAUTION — ENGINEERED SERIES COMBINATION SYSTEM RATED \_\_\_\_ AMPERES. IDENTIFIED REPLACEMENT COMPONENTS REQUIRED. *NEC 110.22(B)***

*FPN: See Section 240.86(A) for engineered series combination system.*

5.4.3 Tested Series Combination Systems: Equipment enclosures for circuit breakers or fuses applied in compliance with the series combination ratings marked on the equipment by the manufacturer in accordance with *NEC 240.86(B)* shall be legibly marked in the field to indicate the equipment has been applied with a series combination rating. The marking shall meet the requirements in 110.21 (B) and shall be readily visible and state the following:

**CAUTION — SERIES COMBINATION SYSTEM RATED \_\_\_\_ AMPERES. IDENTIFIED REPLACEMENT COMPONENTS REQUIRED. *NEC 110.22(C)***

*FPN: See Section 240.86(B) for tested series combination system.*

5.5 OVERCURRENT PROTECTION (Fuses or Breakers):

5.5.1 The basic purpose of overcurrent protection is to open the circuit before conductors or the conductor insulation are damaged when an overcurrent condition occurs. An overcurrent condition can be the result of an overload, ground fault, or a short circuit and must be eliminated before the conductor insulation damage point is reached.

*FPN: A current in excess of rating may be accommodated by certain equipment and conductors for a given set of conditions. Therefore, the rules for overcurrent protection are specific for particular situations. NEC Article 100*

- 5.5.2 Overcurrent protection for conductors and equipment is provided to open the circuit if the current reaches a value that will cause an excessive or dangerous temperature in conductors or conductor insulation. *NEC 240.1*

Definition of overcurrent: Any current in excess of the rated current of equipment or the ampacity of a conductor. It may result from overload, short circuit, or ground fault. *NEC Article 100*

Circuit Impedence. Short Circuit Rating and Other Characteristics: The overcurrent protective device, the total impedance, the equipment short-circuit rating, and other characteristic of the circuit to be protected shall be selected and coordinated to permit the circuit protective devices used to clear a ground fault without extensive damage to the electrical equipment 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 equipment grounding conductor(s) permitted in 250.118.. Overcurrent protective devices, such as fuses and circuit breakers, should be selected in a manner 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. *NEC 110.10*

- 5.5.3 Used as Switches. Circuit breakers used as switches in 120-volt and 277-volt fluorescent lighting circuits shall be listed and shall be marked SWD or HID. Circuit breaker used as switches in high-intensity discharge lighting circuits shall be listed and shall be marked as HID. *NEC 240.83(D)*

## 6. BRANCH CIRCUIT WIRING

- 6.1 LENGTH OF FREE CONDUCTORS AT OUTLETS, JUNCTIONS, AND SWITCH POINTS:
- 6.1.1 At least 150 mm (6 in.) of free conductor, measured from the point in the box where it emerges from its raceway or cable sheath, shall be left at each outlet, junction, and switch point for splices or the connection of luminaries (fixtures) or devices. *NEC 300.14*
- 6.1.2 Where the opening to an outlet, junction, or switch point is less than 200 mm (8 in.) in any dimension, each conductor shall be long enough to extend at least 75 mm (3 in.) outside the opening. *NEC 300.14*

*Exception: Conductors that are not spliced or terminated at the outlet, junction, or switch point shall not be required to comply with 300.14.*

## 6.2 MECHANICAL AND ELECTRICAL CONTINUITY — CONDUCTORS:

- 6.2.1 General: Conductors in raceways shall be continuous between outlets, boxes, devices, and so forth. *NEC 300.13*. There shall be no splice or tap within a raceway unless permitted by 300.15; 368.56(A); 376.56; 378.56; 384.56; 386.56; 388.56; or 390.56. *NEC 300.13(A)*

- 6.2.2 Device Removal: In multiwire branch circuits, the continuity of a grounded conductor shall not depend on device connections such as lamp holders, receptacles, and so forth, where the removal of such devices would interrupt the continuity. *NEC 300.13(B)*

## 6.3 SPLICES:

- 6.3.1 Conductors shall be spliced or joined with splicing devices identified for the use or by brazing, welding, or soldering with a fusible metal or alloy. Soldered splices shall first be so spliced or joined as to be mechanically and electrically secure without solder and then soldered. All splices and joints and the free ends of conductors shall be covered with insulation equivalent to that of the conductors or with an identified insulating device. *NEC 110.14(B)*

- 6.3.2 If circuit conductors are spliced within a box or terminated on equipment within or supported by a box, all wire-type equipment grounding conductor(s) associated with any of those circuit conductors shall be connected within the box or to the box in accordance with NEC 250.8 and NEC 250.148(A) through (D).

- 6.3.3 A box or conduit body shall be installed at each conductor splice, connection point, outlet point, switch point, junction point, termination point or pull point unless otherwise permitted in NEC 300.15(A) through (L).

- 6.4 CIRCUIT IDENTIFICATION: Ungrounded conductors shall be identified in accordance with NEC 210.5(C)(1) or (2), as applicable.

Posting of Identification Means. The method utilized for conductors originating within each branch circuit panelboard or similar branch-circuit distribution equipment shall be documented in a manner that is readily available or shall be permanently posted at each branch circuit panelboard or similar branch circuit distribution equipment. The label shall be of sufficient durability to withstand the environment involved and shall not be handwritten. *NEC 210.5(C)(1)(b)*

## 6.5 CABLE CLAMPS AND CONNECTORS:

- 6.5.1 Conductors entering boxes, conduit bodies, or fittings shall be protected from abrasion. Openings through which conductors enter shall be adequately closed in an approved manner. *NEC 314.17*

6.5.2 Where cable is used, cable shall be secured to the cabinet, cutout box, or meter socket enclosure. *NEC 312.5(C)*

*Explanation: The main rule 312.5(C) prohibits the installation of several cables bunched together and run through a knockout or chase nipple. Individual cable clamps or connectors are required to be used with only one cable or clamp or connector, unless the clamp or connector is identified for more than a single cable.*

6.5.3 Non-metallic boxes and conduit bodies shall be suitable for the lowest temperature-rated conductor entering the box. Where nonmetallic-sheathed cable or flexible tubing is used to enclose conductor or tubing is used, the sheath shall extend not less than 6 mm (1/4 in.) inside the box and beyond any cable clamp. In all instances, all permitted wiring methods shall be secured to the boxes. *NEC 314.17(A)(B)(C)*

6.6 NON-METALLIC-SHEATHED CABLE: This cable shall be supported and secured at intervals not exceeding 4 1/2 feet (1.4 m) and within 12 inches (300 mm) by staples; cable ties listed and identified for securement and support; or hangers, straps, or similar fittings so designed and installed as not to damage the cable. Cable shall be secured in place from every entry into the enclosure such as outlet boxes, junction boxes, cabinets or fittings. The cable length between the cable entry and the closest cable support shall not exceed 450 mm (18 in.) Flat cable shall not be stapled on edge. *NEC 334.30*

6.6.1 Bored Holes: In both exposed and concealed locations, where a cable or raceway-type wiring method is installed through bored holes in joists, rafters or wood members, holes shall be bored so that the edge of the hole is not less than 32 mm (1 1/4 inch) from the nearest edge of the wood member. Where the distance cannot be maintained, a steel plate or bushing at least 1.6 mm (1/16 inch) thick and of appropriate length and width shall be installed to cover the area of the wiring. *NEC 300.4(A)(1)*

Notches in wood: Cables shall be permitted to be laid in notches in wood studs, joists, rafters, or other wood members where the cable at those points is protected against nails or screws by a steel plate at least 1.6 mm (1/16 in.) thick, and of the appropriate length and width, installed to cover the area of the wiring. *NEC 300.4(A)(2)*

6.6.2 Follow Surface: Cables shall closely follow the surface of the building finish or of running boards. *NEC 334.15(A)*

6.7 UNUSED OPENINGS: Unused openings other than those intended for the operation of equipment, those intended for mounting purposes, or those permitted as part of the design for listed equipment, shall be closed to afford protection substantially equivalent to that of the wall of the equipment. Where metal plugs or plates are used with nonmetallic enclosures, they shall be recessed at least 1/4 inch (6.0 mm) from the outer surface of the enclosure. *NEC 110.12(A)*

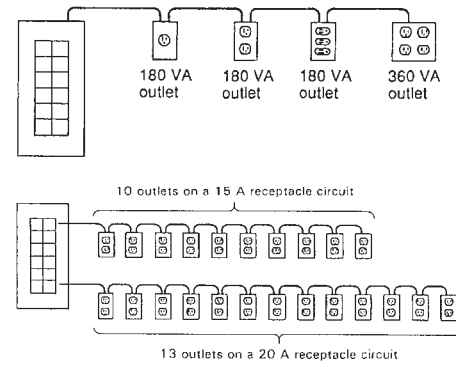
6.8 GENERAL PURPOSE OUTLETS:

6.8.1 Grounding Type: Excerpt as provided in 406.4(D), receptacles installed on 15- and 20-ampere branch circuits shall be of the grounding type. Grounding-type receptacles shall be installed only on circuits of the voltage class and current for which they are rated, except as provided in 210.21(B)(1) for single receptacles or Table 210.21(B)(2) and Table 210.21(B)(3) for two or more receptacles. *NEC 406.3(A)*

6.8.2 Receptacle Outlets. Except as covered in 220.14(J) and (K), receptacle outlets shall be calculated at not less than 180 volt-amperes for each multiple receptacle on one yoke. A single piece of equipment consisting of a multiple receptacle comprised of four or more receptacles shall be calculated at not less than 90 volt-amperes per receptacle. This provision shall not be applicable to the receptacle outlets specified in 210.11(C)(1) and (C)(2) *NEC 220.14(I)*

6.9 SMALL APPLIANCE CIRCUITS: *NEC 210.11*

6.9.1 Branch Circuit Required: Branch circuits for lighting and for appliances, including motor-operated appliances, shall be provided to supply the loads computed in accordance with 220.10. In addition, branch circuits shall be provided for specific loads not covered by 220.10 where required elsewhere in the NEC and for dwelling unit loads as specified in 210.11(C).



15 amperes × 120 volts = 1800 VA ÷ 180 VA = 10 receptacle outlets  
 20 amperes × 120 volts = 2400 VA ÷ 180 VA = 13 receptacle outlets

**Method for Determining # of Receptacles Per Branch Circuit**

6.9.2 Number Of Branch Circuits: The minimum number of branch circuits shall be determined from the total computed load and the size of rating of the circuits used. In all installations, the number of circuits shall be sufficient to supply the load served. In no case shall the load on any circuit exceed the maximum specified by 220.18. *NEC 210.11(A)*



6.9.3 Load Evenly Proportioned Among Branch Circuits: Where the load is computed on a volt-amperes per square meter or per square foot, the wiring system up to and including the branch-circuit panelboard(s) shall be provided to serve not less than the calculated load. This load shall be evenly proportioned among multioutlet branch circuits within the panelboard(s). Branch-circuit-overcurrent devices and circuits shall only be required to be installed to serve the connected load.  
*NEC 210.11(B)*

6.9.4 Dwelling Units:

#### SMALL APPLIANCE BRANCH CIRCUITS

In addition to the number of branch circuits required by other parts of this section, two or more 20-ampere small-appliance branch circuits shall be provided for all receptacle outlets specified by NEC 210.52(B).  
*NEC 210.11(C)(1)*

#### LAUNDRY BRANCH CIRCUITS

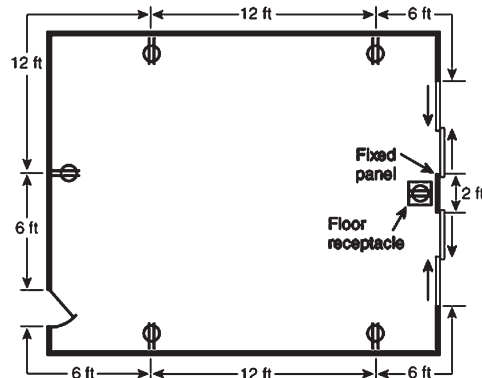
In addition to the number of branch circuits required by other parts of this section, at least one additional 20-ampere branch circuit shall be provided to supply the laundry receptacle outlet(s) required by 210.52(F). This circuit shall have no other outlets.  
*NEC 210.11(C)(2)*

#### BATHROOM BRANCH CIRCUITS

In addition to the number of branch circuits required by other parts of this section, one or more 120-volt, 20-ampere branch circuit shall be provided to supply bathroom(s) receptacle outlet(s) required by 210.52(D) and any countertop and similar work surface receptacle outlets. Such circuits shall have no other outlets.  
*NEC 210.11(C)(3) Exception: Where the 20-ampere circuit supplies a single bathroom, outlets for other equipment within the same bathroom shall be permitted to be supplied in accordance with 210.23(A)(1) and (A)(2).*

*FPN: See Examples D1(A), D1(B), D2(B), and D4(A) in Annex D.*

6.10 DWELLING UNIT RECEPTACLE OUTLETS: *NEC 210.52*



**NEC Exhibit 210.24** Typical room plan view of the location of dwelling unit receptacles meeting the requirements of NEC 210.52(A).

This section provides requirements for 125-volt, 15- and 20-ampere receptacle outlets. Receptacle outlets required by this section shall be in addition to any receptacle that is part of a luminaire (lighting fixture) or appliance, required by 210.52(D) and any countertop and similar work surface receptacle outlets located within cabinets or cupboards, or located more than 1.7 m (5 1/2 ft) above the floor.

Permanently installed electric baseboard heaters equipped with factory-installed receptacle outlets or outlets provided as a separate assembly by the manufacturer shall be permitted as the required outlet or outlets for the wall space utilized by such permanently installed heaters. Such receptacle outlets shall not be connected to the heater circuits.  
*NEC 210.52*

*FPN: Listed baseboard heaters include instructions that may not permit their installation below receptacle outlets.*

6.10.1 General Provisions: In every kitchen, family room, dining room, living room, parlor, library, den, sunroom, bedroom, recreation room, or similar room or area of dwelling units, receptacle outlets shall be installed in accordance with the general provisions specified in 210.52(A)(1) through (A)(4).

(1) SPACING.

Receptacles shall be installed so that no point measured horizontally along the floor line of any wall space is more than 1.8 m (6 ft) from a receptacle outlet.

(2) WALL SPACE.

As used in this section, a wall space shall include the following:

- (1) Any space 600 mm (2 ft) or more in width (including space measured around corners) and unbroken along the floor line by doorways or similar openings, fireplaces, and fixed cabinets that do not have countertops or similar work surfaces.
- (2) The space occupied by fixed panels in exterior walls, excluding sliding panels.
- (3) The space afforded by fixed room dividers such as free-standing bar-type counters or railings.

(3) FLOOR RECEPTACLES.

Receptacle outlets in or on floors shall not be counted as part of the required number of receptacle outlets unless located within 450 mm (18 in.) of the wall.

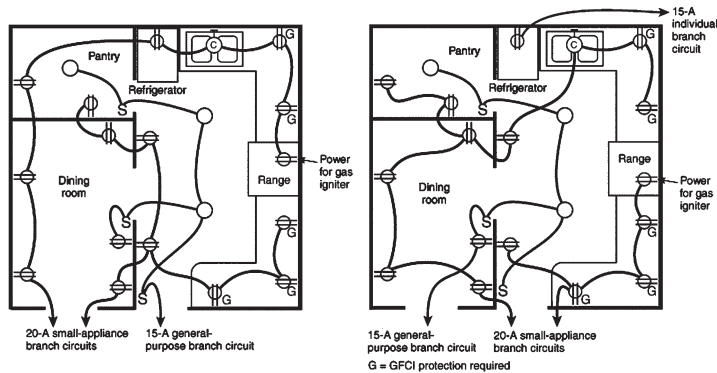
(4) COUNTERTOP OUTLETS SERVED. Receptacles installed for countertop and similar work surfaces as specified in 210.52(C) shall not be considered as the receptacle outlets required by 210.52(A)

6.10.2 Small Appliances: In the kitchen, pantry, breakfast room, dining room, or similar area of a dwelling unit, the two or more 20-ampere small-appliance branch circuits required by 210.11(C)(1) shall serve all wall

and floor receptacle outlets covered by 210.52(C) and receptacle outlets for refrigeration equipment. *NEC 210.52.(B)(1)*

*Exception No. 1: In addition to the required receptacles specified by 210.52, switched receptacles supplied from a general-purpose 15- or 20-ampere branch circuit as required in 210.70(A)(1), Exception No. 1, shall be permitted.*

*Exception No. 2: In addition to the required receptacles specified by 210.52, a receptacle outlet to serve a specific appliance shall be permitted to be supplied from an individual branch circuit rated 15 amperes or greater.*



**NEC Exhibit 210.25** Small-appliance branch circuits as applied to the requirements of NEC 210.52(B)(1), (2), and (3) for all receptacle outlets in the kitchen (including refrigerator), pantry, and dining room.

**NO OTHER OUTLETS**

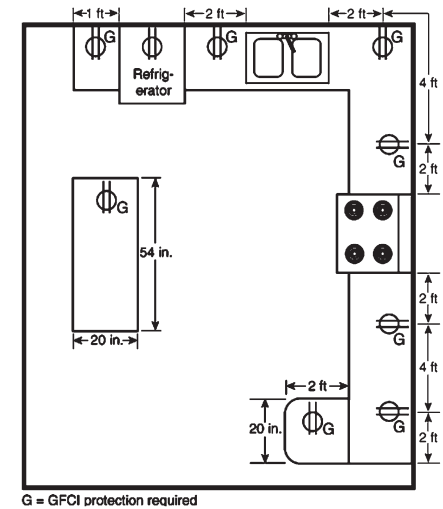
The two or more small-appliance branch circuits specified in 210.52(B)(1) shall have no other outlets. *NEC 210.52(B)(2)*

*Exception No. 1: A receptacle installed solely for the electrical supply to and support of an electric clock in any of the rooms specified in 210.52(B)(1).*

*Exception No. 2: Receptacles installed to provide power for supplemental equipment and lighting on gas-fired ranges, ovens, or counter-mounted cooking units.*

**KITCHEN RECEPTACLE REQUIREMENTS**

Receptacles installed in a kitchen to serve countertop surfaces shall be supplied by not fewer than two small-appliance branch circuits, either or both of which shall also be permitted to supply receptacle outlets in the same kitchen and in other rooms specified in 210.52(B)(1). Additional small-appliance branch circuits shall be permitted to supply receptacle outlets in the kitchen and other rooms specified in 210.52(B)(1). No small-appliance branch circuit shall serve more than one kitchen. *NEC 210.52(B)(3)*



**NEC Exhibit 210.26** Dwelling unit receptacles serving countertop spaces in a kitchen and installed in accordance with 210.52(C).

6.10.3 Countertops and Work Surfaces: In kitchens, pantries, breakfast rooms, dining rooms, and similar areas of dwelling units, receptacle outlets for countertop and work surfaces that are 300 mm (12 in.) or wider shall be installed in accordance with 210.52(C)(1) through (3) and shall not be considered as the receptacle outlets required by 210.52(A). *NEC 210.52(C)*

For the purposes of this section, where using multioutlet assemblies, each 300 mm (12 in.) of multioutlet assembly containing two or more receptacles installed in individual or continuous lengths shall be considered to be one receptacle outlet.

**WALL SPACES**

Receptacle outlets shall be installed so that no point along the wall line is more than 600 mm (24 in.) measured horizontally from a receptacle outlet in that space. *NEC 210.52(C)(1)*

*Exception: Receptacle outlets shall not be required on a wall directly behind a range, counter-mounted cooking unit or sink in the installation described in figure 210.52(C)(1) of the NEC.*

**ISLAND, PENINSULAR COUNTERTOPS and WORK SURFACES**  
Receptacle outlets shall be installed in accordance with 210.52 (C)(2) (a) and (C)(b)

(A) At least one receptacle outlet shall be provided for the first 0.84 m<sup>2</sup> (9 sq. ft.), or fraction thereof, of the countertop or work surface. A receptacle outlet shall be provided for every additional 1.7 m<sup>2</sup> (18 Sq. ft.), or fraction thereof, of the countertop or work surface *NEC 210.52.(C)(2)*

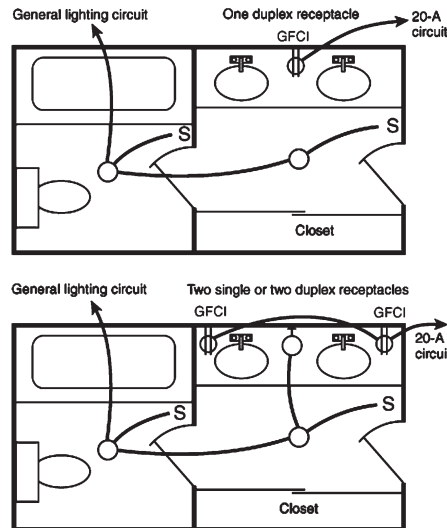
(B) At least one receptacle outlet shall be located within 600 mm (2 ft.) of the outer end of a peninsular countertop or work surface. Additional required receptacle outlets shall be permitted to be located as determined by the installer, designer, or building owner. The location of the receptacle outlets shall be in accordance with 210.52(C)(3). *NEC 210.52(C)(2b)*

**RECEPTACLE OUTLET LOCATION**

Receptacle outlets shall be located in one or more of the following: (1) On or above, but not more than 500 mm (20 in.) above, the countertop or work surface. (2) In countertop or work surfaces: Receptacle outlet assemblies listed for use in countertops or work surfaces. (3) Below countertop or work surfaces: Not more than 300 mm (12 in.) below the countertop or work surface. Receptacles installed below a countertop or work surface shall not be located where the countertop or work surface extends more than 150 mm (6 in.) beyond its support base. Receptacle outlets rendered not readily accessible by appliances fastened in place, appliance garages, sinks or range tops as covered in 210.52(C)(1), exception, or appliances occupying assigned spaces shall not be considered as these required outlets. *NEC 210.52(C)(3)*

**BATHROOMS**

At least one wall receptacle outlet shall be installed in bathrooms within 900 mm (3 ft.) of the outside edge of each basin. The receptacle outlet shall be located on a wall or partition that is adjacent to the basin or basin countertop located on the countertop or installed on the side or face of the basin cabinet. In no case shall the receptacle be located more than 300 mm (12 in.) below the top of the basin or basin countertop. Receptacle outlet assemblies listed for use in countertops shall be installed in the countertop. *NEC 210.52(D)*



**NEC Exhibit 210.9** GFCI-protected receptacles in accordance with 210.8(A)(1) in bathrooms.

**OUTDOOR OUTLETS**

For a one-family dwelling and each unit of a two-family dwelling that is at grade level, at least one receptacle outlet readily accessible from grade and not more than 2.0 m (6 1/2 ft.) above grade level shall be installed at the front and back of the dwelling. *NEC 210.52(E) See 210.8(A)(3).*

**LAUNDRY AREAS**

In dwelling units, at least one receptacle outlet shall be installed in areas designated for the installation of laundry equipment. *NEC 210.52(F)*

*Exception No. 1: A receptacle for laundry equipment shall not be required in a dwelling unit of a multifamily building where laundry facilities are provided on the premises for use by all building occupants.*

*Exception No. 2: A receptacle for laundry equipment shall not be required in other than one-family dwellings where laundry facilities are not to be installed or permitted.*

**BASEMENTS, GARAGES, AND ACCESSORY BUILDINGS**

For a one- and two-family dwelling and multifamily dwellings, at least one receptacle outlet, shall be installed in the areas specified in 210.52(G)(1) through (G)(3). These receptacles shall be in addition to receptacles required for specific equipment in each separate unfinished portion of a basement.

- (1) Garages. In each attached and detached garage with electrical power, at least one receptacle shall be installed in each vehicle bay and not more than 5 1/2ft. above the floor.
- (2) Accessory Buildings. In each accessory building with electric power.
- (3) Basements. In each separate unfinished portion of a basement.

**HALLWAYS**

In dwelling units, hallways of 3.0 m (10 ft.) or more in length shall have at least one receptacle outlet. As used in this subsection, the hallway length shall be considered the length along the centerline of the hallway without passing through a doorway. *NEC 210.52(H)*

**6.11 GROUND-FAULT CIRCUIT-INTERRUPTER PROTECTION FOR PERSONNEL:** Ground-fault circuit-interrupter protection for personnel shall be provided as required in *NEC 210.8(A) thru (F)* . The ground-fault circuit interrupter shall be installed in a readily accessible location

*FPN: See 215.9 for ground-fault circuit-interrupter protection for personnel on feeders.*

*FPN: See 422.5 (A) for GFCI requirements for appliances.*

*FPN: See 555.9 for GFCI requirements for boat hoists.*

For the purposes of this section, when determining distance from receptacles the distance shall be measured as the shortest path the supply cord of an appliance connected to the receptacle would follow

without piercing a floor, wall, ceiling, or fixed barrier, or the shortest path without a window.

- 6.11.1 Dwelling Units: All 125-volt through 250-volt receptacles installed in the locations specified in 210.8 (A) (1) through (A)(11) shall have ground-fault circuit-interrupter protection for personnel.

*NEC 210.8(A)*

- (1) Bathrooms.
- (2) Garages and also accessory buildings that have a floor located at or below grade level not intended as habitable rooms and limited to storage areas, work areas, and areas of similar use.
- (3) Outdoors.

*Exception to (3): Receptacles that are not readily accessible and are supplied by a dedicated branch circuit for electric snow-melting, deicing, or pipeline and vessel heating equipment shall be permitted to be installed in accordance with the applicable provisions of Article 426.28 or 427.22, as applicable.*

- (4) Crawl Spaces at or below grade level
- (5) Basements.

*Exception to (5): A receptacle supplying only a permanently installed fire alarm or burglar alarm system shall not be required to have ground-fault interrupter protection.*

*FBN: See 760.41 (B) and 760.121(B) for power supply requirements for fire alarm systems.*

*Receptacles installed under the exception to 210.8 (A)(5) shall not be considered as meeting the requirements of 210.52(G)*

- (6) Kitchens where the receptacles are installed to serve the counter-top surfaces.
- (7) Sinks located in areas other than kitchens where receptacles are located within 1.8 m (6 ft.) from the top inside edge of the bowl of the sink.
- (8) Boathouses. Boat Hoist outlets not exceeding 240 volts installed in dwelling unit locations. *NEC 210.8(C)*
- (9) Bathtubs or shower stalls – where receptacles are installed within 1.8m (6 ft.) of the outside edge of the bathtub or shower stall.
- (10) Laundry areas.
- (11) Indoor damp and wet locations.

- 6.11.2 Other Than Dwelling Units: All 125-volt through 250-volt receptacles supplied by single phase branch circuits rated 150 volts or less to ground, 50 amperes or less and all receptables supplied by three-phase branch circuits rated 150 volts to ground, 100 amperes or less installed in the following locations shall have ground-fault circuit-interrupter protection for personnel.

*NEC 210.8.(B)(1) through (B)(12)*

- (1) Bathrooms.
- (2) Kitchens or areas with a sink and permanent provisions for either food preparations or cooking.
- (3) Rooftops.

*Exception: Receptacles on rooftops shall not be required to be readily accessible other than from the rooftop.*

- (4) Outdoors.
- (5) Sinks. Where receptacles are installed within 1.8 m (6 ft.) from the top inside edge of the bowl of the sink.

*Exception to (3) and (4): Receptacles that are not readily accessible and are supplied from a dedicated branch circuit for electric snow-melting, deicing, or pipeline and vessel heating equipment shall be permitted to be installed in accordance with 426.28 or 427.22 as applicable.*

- (6) Indoor damp and wet locations.
- (7) Locker Rooms associated with showering facilities.
- (8) Garages, accessory buildings, service bays, and similar areas other than vehicle exhibition halls and showrooms.
- (9) Crawl spaces-at or below grade level.
- (10) Unfinished areas.

- 6.12 ARC-FAULT CIRCUIT INTERRUPTER (AFCI) PROTECTION: *NEC 210.12*

- 6.12.1 Definition: A device intended to provide protection from the effects of arc faults by recognizing characteristics unique to arcing and by functioning to de-energize the circuit when an arc fault is detected.

- 6.12.2 Dwelling Units: All 120-volt, single phase 15- and 20-ampere branch circuits supplying outlets or devices installed in dwelling unit family rooms, dining rooms, living rooms, parlors, libraries, dens, bedrooms, sunrooms, recreation rooms, closets, hallways, laundry areas or similar rooms or areas shall be protected by any of the means described in 210.12(A)(1) through (6):

*FPN No. 1: For information on types of arc-fault interrupters, see UL 1699-2011, Standard for Arc-Fault Circuit Interrupters.*

*FPN No.2 : See 29.6.3(5) of NFPA 72-2013, National Fire Alarm and Signaling Code, for information related to secondary power-supply requirements for smoke alarms installed in dwelling units.*

*FPN No. 3: See 760.41(B) and 760.121(B) for power-supply information for fire alarm systems.*

- 6.13 BOXES:

- 6.13.1 Round Boxes: Round boxes shall not be used where conduits or connectors requiring the use of locknuts or bushings are to be connected to the side of the box. *NEC 314.2*

6.13.2 Nonmetallic Boxes: Nonmetallic boxes shall be permitted only with open wiring on insulators, concealed knob-and-tube wiring, cabled wiring methods with entirely nonmetallic sheaths, flexible cords, and nonmetallic raceways. *NEC 314.3*

*Exception No. 1: Where internal bonding means are provided between all entries, nonmetallic boxes shall be permitted to be used with metal raceways or metal-armored cables.*

*Exception No. 2: Where integral bonding means with a provision for attaching an equipment bonding jumper inside the box are provided between all threaded entries in nonmetallic boxes listed for the purpose, nonmetallic boxes shall be permitted to be used with metal raceways or metal-armored cables.*

6.13.3 Metal Boxes: Metal boxes shall be grounded and bonded in accordance with article 250 as applicable, except as permitted in 250.112(I). *NEC314.4*

6.14 NUMBER OF CONDUCTORS IN OUTLET, DEVICE, AND JUNCTION BOXES, AND CONDUIT BODIES: *NEC 314.16*

Boxes and conduit bodies shall be of an approved size to provide free space for all enclosed conductors. In no case shall the volume of the box, as calculated in 314.16(A), be less than the fill calculation as calculated in 314.16(B). The minimum volume for conduit bodies shall be as calculated in 314.16(C). The provisions of this section shall not apply to terminal housings supplied with motors or generators.

*FPN: For volume requirements of motor or generator terminal housings, see 430.12.*

Boxes and conduit bodies enclosing conductors 4 AWG or larger shall also comply with the provisions of 314.28. Outlet and device boxes shall also comply with 314.24.

6.14.1 Box Volume Calculations: The volume of a wiring enclosure (box) shall be the total volume of the assembled sections, and, where used, the space provided by plaster rings, domed covers, extension rings, and so forth, that are marked with their volume or are made from boxes the dimensions of which are listed in Table 314.16(A). Where a box is provided with one or more securely installed barriers, the volume shall be apportioned to each of the resulting spaces. Each barrier, if not marked with its volume, shall be considered to take up 8.2 cubic cm (1/2 cubic inch) if metal, and 16.4 cubic cm (1.0 cubic inch) if nonmetallic.

Standard Boxes. The volumes of standard boxes that are not marked with their volume shall be as given in Table 314.16(A).

Other Boxes. Boxes 1650 cm<sup>3</sup> (100 in.<sup>3</sup>) or less, other than those described in Table 314.16(A), and nonmetallic boxes shall be durably and legibly marked by the manufacturer with their volume(s). Boxes described in Table 314.16(A) that have a volume larger than is designated in the table shall be permitted to have their volume marked as required. *NEC 314.16*

Box Trade Size			Minimum Volume		Maximum Number of Conductors*							
mm	in.		cm <sup>3</sup>	in. <sup>3</sup>	18	16	14	12	10	8	6	
100 x 32	(4 x 1¼)	round/octagonal	205	12.5	8	7	6	5	5	5	2	
100 x 38	(4 x 1½)	round/octagonal	254	15.5	10	8	7	6	6	5	3	
100 x 54	(4 x 2¼)	round/octagonal	353	21.5	14	12	10	9	8	7	4	
100 x 32	(4 x 1¼)	square	295	18.0	12	10	9	8	7	6	3	
100 x 38	(4 x 1½)	square	344	21.0	14	12	10	9	8	7	4	
100 x 54	(4 x 2¼)	square	497	30.3	20	17	15	13	12	10	6	
120 x 32	(4½ x 1¼)	square	418	25.5	17	14	12	11	10	8	5	
120 x 38	(4½ x 1½)	square	484	29.5	19	16	14	13	11	9	5	
120 x 54	(4½ x 2¼)	square	689	42.0	28	24	21	18	16	14	8	
75 x 50 x 38	(3 x 2 x 1½)	device	123	7.5	5	4	3	3	3	2	1	
75 x 50 x 50	(3 x 2 x 2)	device	164	10.0	6	5	5	4	4	3	2	
75 x 50 x 57	(3 x 2 x 2¼)	device	172	10.5	7	6	5	4	4	3	2	
75 x 50 x 65	(3 x 2 x 2½)	device	205	12.5	8	7	6	5	5	4	2	
75 x 50 x 70	(3 x 2 x 2¾)	device	230	14.0	9	8	7	6	5	4	2	
75 x 50 x 90	(3 x 2 x 3½)	device	295	18.0	12	10	9	8	7	6	3	
100 x 54 x 38	(4 x 2¼ x 1½)	device	169	10.3	6	5	5	4	4	3	2	
100 x 54 x 48	(4 x 2¼ x 1¾)	device	213	13.0	8	7	6	5	5	4	2	
100 x 54 x 54	(4 x 2¼ x 2¼)	device	238	14.5	9	8	7	6	5	4	2	
95 x 50 x 65	(3¾ x 2 x 2½)	masonry box/gang	230	14.0	9	8	7	6	5	4	2	
95 x 50 x 90	(3¾ x 2 x 3½)	masonry box/gang	344	21.0	14	12	10	9	8	7	2	
min. 44.5 depth	FS — single cover/gang (1¾)		221	13.5	9	7	6	6	5	4	2	
min. 60.3 depth	FD — single cover/gang (2¾)		295	18.0	12	10	9	8	7	6	3	
min. 44.5 depth	FS — multiple cover/gang (1¾)		295	18.0	12	10	9	8	7	6	3	
min. 60.3 depth	FD — multiple cover/gang (2¾)		395	24.0	16	13	12	10	9	8	4	

\*Where no volume allowances are required by 314.16(B)(2) through 314.16(B)(5).

**NEC Table 314.16(A) Metal Boxes**

Size of Conductor (AWG)	Free Space Within Box for Each Conductor	
	cm <sup>3</sup>	in. <sup>3</sup>
18	24.6	1.50
16	28.7	1.75
14	32.8	2.00
12	36.9	2.25
10	41.0	2.50
8	49.2	3.00
6	81.9	5.00

**NEC Table 314.16(B) Volume Allowance Required Per Conductor**

6.14.2 Box Fill Calculations: The volumes in paragraphs 314.16(B)(1) through (5), as applicable, shall be added together. No allowance shall be required for small fittings such as locknuts and bushings. Each space within a box installed with a barrier shall be calculated separately.

Conductor Fill. Each conductor that originates outside the box and terminates or is spliced within the box shall be counted once, and each conductor that passes through the box without splice or termination shall be counted once. Each loop or coil of unbroken conductor not less than twice the minimum length required for free conductors in 300.14 shall be counted twice. The conductor fill shall be computed using Table 314.16(B). A conductor, no part of which leaves the box, shall not be counted.

*Exception: An equipment grounding conductor or conductors or not over 4 luminaire (fixture) wires smaller than 14 AWG, or both, shall be permitted to be omitted from the calculations where they enter a box from a domed luminaire (fixture) or similar canopy and terminate within that box.*

Clamp Fill. Where one or more internal cable clamps, whether factory or field supplied, are present in the box, a single volume allowance in accordance with Table 314.16(B) shall be made based on the largest conductor present in the box. No allowance shall be required for a cable connector with its clamping mechanism outside the box.

A clamp assembly that incorporates cable conductors shall be listed and marked for use with specific nonmetallic boxes. Conductors that originate within the clamp assembly shall be included in conductor fill calculations covered in 314.16(B)(1) as though they entered from outside the box. *NEC 314.16(B)(2)*

Support Fittings Fill. Where one or more luminaire (fixture) studs or hickies are present in the box, a single volume allowance in accordance with Table 314.16(B) shall be made for each type of fitting based on the largest conductor present in the box.

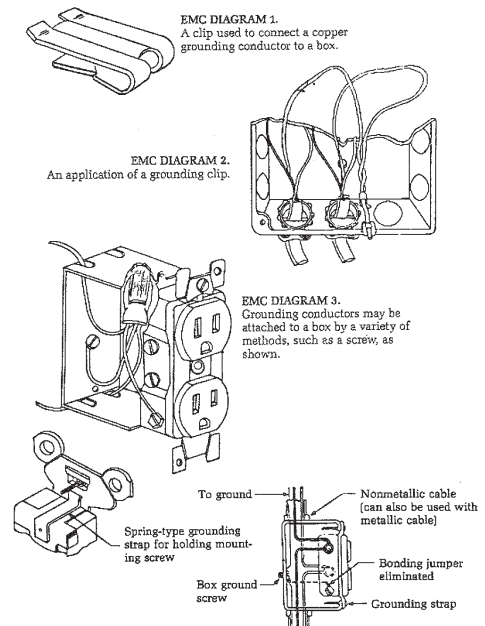
Device or Equipment Fill. For each yoke or strap containing one or more devices or equipment, a double volume allowance in accordance with Table 314.16(B) shall be made for each yoke or strap based on the largest conductor connected to a device(s) or equipment supported by that yoke or strap. A device or utilization equipment wider than a single 50mm (2 in.) device box as described in Table 314.16(A) shall have double volume allowances provided for each gang required for mounting.

Equipment Grounding Conductor Fill. Where up to four equipment grounding conductors or equipment bonding jumpers enter a box, a single volume allowance in accordance with Table 314.16(B) shall be made based on the largest equipment grounding conductor or equipment bonding jumper entering the box. A ¼ volume allowance shall be made

for each additional equipment grounding conductor or equipment bonding jumper that enters the box, based on the largest equipment grounding conductor or equipment bonding conductor.

6.14.2.5 If circuit conductors are spliced within a box or terminated on equipment within or supported by a box, all wire-type equipment grounding conductor(s) associated with any of those circuit conductors shall be connected within the box or to the box with devices suitable for use in accordance with NEC 250.8 and 250.148(A) through (E). *NEC 250.148*

**PROPER INSTALLATION OF BOND WIRES**  
(Bonding screws or clips may be used.)



**EMC Diagram I.** Flush-type Boxes. Receptacle designed with spring-type grounding strap which holds mounting screw captive and eliminates a bonding jumper to the box.

6.14.3 Metal Boxes: A connection used for no other purpose shall be made between the metal box and the equipment grounding conductor(s) in accordance with 250.8. *NEC 250.148(C)*

6.14.3.1 Nonmetallic Boxes. One or more equipment grounding conductors brought into a nonmetallic box shall be arranged such that a connection can be made to any fitting or device in that box requiring connection to an equipment grounding conductor. *NEC 250.148(D)*

6.14.4 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 metal box that is connected to an

equipment grounding conductor, except as permitted NEC 250.146(A) through (D) and following in EMC 6.14.5. The equipment bonding conductor shall be sized according to NEC Table 250.122 based on the rating of the overcurrent device protecting the circuit conductor. A grounding clip (EMC diagrams 1 and 2) or screw as shown (EMC diagrams 3 and 4) may be used to connect grounding conductor to a box. *NEC 250.146*

- 6.14.5 Surface Mounted Box. Where the box is mounted on the surface, the direct metal-to-metal contact between the device yoke or strap to the box shall be permitted to provide the required effective ground fault current path. At least one of the insulating washers shall be removed from receptacles that do not have a contact yoke or device to ensure metal to metal contact. Direct metal-to-metal contact for providing continuity applies to cover-mounted receptacles if the box and cover combination are listed as providing satisfactory continuity between the box and the receptacle. A listed exposed work cover shall be permitted to be the grounding and bonding means under both of the following conditions:
- (1) The device is attached to the cover with at least two fasteners that are permanent (such as a rivet) or have a thread locking or screw or nut locking means.
  - (2) The cover mounting holes are located on a flat non-raised portion of the cover. *NEC 250.146(A)*

- 6.14.6 Outlet Boxes. *NEC Article 314.27*
- (A) Boxes at Luminaire or Lamp-holder Outlets. Outlet boxes or fittings designed for the support of luminaires and lamp-holders, and installed as required by 314.23, shall be permitted to support a luminaire or lamp-holder.

(1) Vertical Surface Outlets. Boxes used at luminaire or lamp-holder outlets in or on a vertical surface shall be identified and marked on the interior of the box to indicate the maximum weight of the luminaire that is permitted to be supported by the box if other than 50 lbs.

*Exception: A wall mount luminaire weighing not more than 3 kg (6 lb.) shall be permitted to be supported on other boxes, or plaster rings that are secured to other boxes, provided the luminaire or its supporting yoke is secured to the box with no fewer than two No. 6 or larger screws.*

(2) Ceiling Outlets. At every outlet used exclusively for lighting, the box shall be designed or installed so that a luminaire or lampholder may be attached. Boxes shall be required to support a luminaire weighing a minimum of 50 lbs. A luminaire that weighs more than 50lb shall be supported independently of the outlet box, unless the outlet box is listed for not less than the weight to be supported. The interior of the box shall be marked by the manufacturer to indicate the maximum weight the box shall be permitted to support.

- (B) Floor Boxes. Boxes listed specifically for this application shall be used for the receptacles located in the floor.

*Exception: Where the authority having jurisdiction judges them free from likely exposure to physical damage, moisture, and dirt, boxes located in elevated floors of show windows and similar locations shall be permitted to be other than those listed for floor applications. Receptacles and covers shall be listed as an assembly for this type of location.*

- (C) Boxes at Ceilings - Suspended (Paddle) Fan Outlets. Outlet boxes or outlet box systems used as the sole support of a ceiling-suspended (paddle) fan shall be listed, shall be marked by their manufacturer as suitable for this purpose, and shall not support ceiling-suspended (paddle) fans that weight more than 32 kg (70 lbs.). For outlet boxes or outlet box systems designed to support ceiling-suspended (paddle) fans that weigh more than 16 kg (35 lbs.), the required marking shall include the maximum weight to be supported.

Outlet boxes mounted in the ceilings of habitable rooms of dwelling occupancies in a location acceptable for the installation of a ceiling-suspended (paddle) fan shall comply with one of the following:

- (1) Listed for the sole support of ceiling-suspended (paddle) fans.

(2) An outlet box complying with the applicable requirements of NEC 314.27 and providing access to structural framing capable of supporting of a ceiling-suspended (paddle) fan bracket or equivalent.

- (D) Utilization Equipment. Boxes used for the support of utilization equipment other than ceiling-suspended (paddle) fans shall meet the requirements of NEC Article 314.27(A) for the support of a luminaire that is the same size and weight.

*Exception: Utilization equipment weighing not more than 3 kg (6 lbs.) shall be permitted to be supported on other boxes or plaster rings that are secured to other boxes, provided the luminaire or its supporting yoke is secured to the box with no fewer than two No. 6 or larger screws.*

## 6.15 CONDUIT:

### 6.15.1 Conduit Uses:

- (A) Intermediate Metal Conduit (IMC): The use of intermediate metal conduit shall be permitted under all atmospheric conditions and occupancies subject to NEC 342.
- Bends: How Made. Bends of IMC shall be so made that the conduit will not be damaged and the internal diameter of the conduit will not be effectively reduced. The radius of the curve of any

field bend to the centerline of the conduit shall not be less than indicated in NEC Table 2, Chapter 9 (NEC 342.24) Number in One Run. There shall not be more than the equivalent of 4 quarter bends (360 degrees total) between pull points, for example, conduit bodies and boxes. (NEC 342.26)

- (B) Rigid Metal Conduit (RMC): The use of rigid metal conduit shall be permitted under all atmospheric conditions and occupancies subject to NEC 344 and NEC 300.6.
- (C) Flexible Metal conduit (FMC): Use of flexible metal conduit shall be permitted under all atmospheric conditions and occupancies subject to NEC 348.10 and NEC 300.6.
- (D) Liquid-Tight Flexible Metal Conduit (LFMC): The use of liquid-tight flexible metal conduit shall be permitted under all atmospheric conditions and occupancies subject to NEC 350.10 and NEC 300.6.
- (E) Rigid Polyvinyl Chloride Conduit (PVC): The use of PVC conduit and fittings shall be permitted under all atmospheric conditions and occupancies subject to NEC 352.10(A) through (H) and NEC 300-6.
- (F) High Density Polyethylene Conduit (HDPE): The use of high density polyethylene conduit shall be permitted under all atmospheric conditions and occupancies subject to NEC 353.10 and NEC 300.6
- (G) Nonmetallic Underground Conduit (NUCC): The use of nonmetallic underground conduit shall be permitted under all atmospheric conditions and occupancies subject to NEC 354.10 and NEC 300.6
- (H) Reinforced Thermosetting Resin Conduit (RTRC): The use of reinforced thermosetting resin conduit shall be permitted under all atmospheric conditions and occupancies subject to NEC 355.10 and NEC 300.6 Liquid-tight Flexible Nonmetallic Conduit: The use of liquid-tight flexible nonmetallic conduit shall be permitted under all atmospheric conditions and occupancies subject to NEC 356.10 and NEC 300.6
- (I) Electrical Metallic Tubing (EMT): The use of electrical metallic tubing shall be permitted for both exposed and concealed work subject to NEC 358.10 (A) through (C) and NEC 300-6.
- (J) Flexible Metallic Tubing (FMT): The use of flexible metallic tubing shall be permitted under all atmospheric conditions and occupancies subject to NEC 360.10 and NEC 300.6.

6.15.2 To determine the maximum number of conductors allowed in conduit refer to NEC Annex C Tables.

## 7. LIGHT CIRCUIT WIRING

### 7.1 LIGHTING OUTLETS REQUIRED:

7.1.1 At least one wall lighting outlet controlled by a listed wall-mounted control device shall be installed in every habitable room, kitchen and

bathroom. The wall-mounted control device shall be located near an entrance to the room on a wall. *NEC 210.70*

7.1.2 At least one lighting outlet controlled by a listed wall-mounted control device outlet shall be installed in hallways, stairways, attached garages, and detached garages with electric power; and at outdoor entrances or exits. A vehicle door in an attached garage is not considered an outdoor entrance or exit. *NEC 210.70(2)*

7.1.3 At least one lighting outlet containing a switch or listed wall-mounted control device shall be installed where these spaces are used for storage or contain equipment requiring servicing. A point of control shall be at each point of entry that permits access to the attic and under floor space, utility room, and basement. Where a lighting outlet is installed for equipment requiring servicing, the lighting outlet shall be installed at or near the equipment. *NEC 210.70(C)*

7.1.4 Where one or more lighting outlet(s) are installed for interior stairways, there shall be a listed wall-mounted control device at each floor level, and landing level that includes an entryway, to control the lighting outlet(s) where the stairway between floor levels has six risers or more. *NEC 210.70(A)(2)(3)*

### 7.2 SWITCHES:

7.2.1 Switches or circuit breakers shall not disconnect the grounded conductor of a circuit. *NEC 404.2(B)*

7.2.2 General use switches and motor-circuit switches, circuit breakers and molded case switches shall indicate, in a location that is visible when accessing the external operating means, whether they are in the open (off) or closed (on) position. Where these switch or circuit breaker handles are operated vertically, the up position of the handle shall be the closed (on) position.

*Exception: Vertically operated double-throw switches shall be permitted to be in the closed (on) position with the handle in either the up or down position. NEC 404.7*

7.2.4 Used as Switches. Circuit breakers used as switches in 120-volt and 277-volt fluorescent lighting circuits shall be listed and shall be marked SWD or HID. Circuit breakers used as switches in high-intensity discharge lighting circuits shall be listed and shall be marked HID. *NEC 240.83(D)*

7.2.5 Three-Way and Four-Way Switches. Three-way and four-way switches shall be wired so that all switching is done only in the ungrounded circuit conductor. *NEC 404.2(A)*

7.2.6 A receptacle controlled by a listed wall mounted control device in other than kitchens and bathrooms shall be permitted in lieu of lighting outlet. Also, in hallways, stairways, and at outdoor entrances, remote control



or automatic control of lighting shall be permitted. *NEC 210.70 Exception No. 1 Exception to (A)(2)(1), (A)(2)(2) and (A)(2)(3)*

### 7.3 INSTALLATION:

7.3.1 All wiring for lighting circuits shall be installed in approved-type boxes. This wiring shall enter boxes through approved type raceways, connectors, or clamps. Conductors may be in rigid conduit, EMT, nonmetallic conduit, or nonmetallic sheathed cable. Switches controlling the lighting shall not disconnect the grounded conductor of the circuit. At least 6 inches (152 mm) of free conductor, measured from the point in the box where it emerges from its raceway or cable sheath, shall be left at each outlet, junction, and switch point for splices or the connection of fixtures or devices. All incandescent lights shall be polarized. The grounded conductor shall be connected to the shell of the light socket. The ungrounded conductor shall be connected to the center contact of the socket. *NEC 300.14, 15; 404.2(B), and 410.50*

### 7.4 REIDENTIFICATION OF CONDUCTORS

**40** 7.4.1 If part of a cable assembly that has the insulation permanently identified to indicate its use as an ungrounded conductor by marking tape, painting, or other effective means at its termination and at each location where the conductor is visible and accessible. Identification shall encircle the insulation and shall be a color other than white, gray, or green. If used for single pole, 3-way or 4-way switch loops, the re-identified conductor with white or gray insulation or three continuous white or gray strips shall be used only for the supply to the switch, but not as a return conductor from the switch to the outlet. *NEC 200.7(C)(1)*

### 7.5 FIXTURES IN CLOTHES CLOSET:

7.5.1 Definition: *NEC 410.2*

Clothes closet storage space shall be defined as the volume bounded by the sides and back closet walls and planes extending from the closet floor vertically to a height of 6 feet (1.83 m) or the highest clothes-hanging rod and parallel to the walls at a horizontal distance of 24 inches (600 mm) from the sides and back of the closet walls, respectively, and continuing vertically to the closet ceiling parallel to the walls at a horizontal distance of 12 inches (300 mm) or the width of the shelf, whichever is greater.

7.5.2 For a closet that permits access to both sides of a hanging rod, the storage space shall include the volume below the highest rod extending 12 inches (300 mm) on either side of the rod on a plane horizontal to the floor extending the entire length of the rod.

### 7.5.3 LUMINAIRES IN CLOTHES CLOSETS *NEC 410.16*

(A) Luminaire Types Permitted *NEC 410.16(A)*. Only luminaires of the following types shall be permitted to be installed in a clothes closet:

- (1) A surface-mounted or recessed incandescent luminaire or LED with completely enclosed light sources.
  - (2) Surface-mounted or recessed fluorescent luminaires.
  - (3) Surface-mounted fluorescent or LED luminaires identified as suitable for installation within the clothes closet storage area.
- (B) Luminaire Types Not Permitted: *NEC 410.16(B)*. Incandescent fixtures with open or partially enclosed lamps and pendant luminaires or lamp holders shall not be permitted.
- (C) Location: *NEC 410.16(C)*. The minimum clearance between luminaires installed in clothes closets and the nearest point of a clothes closet storage space shall be as follows:
- (1) 300 mm (12 in.) for surface-mounted incandescent or LED luminaires with a completely enclosed light source installed on the wall above the door or on the ceiling. *NEC 410.16(C)(1)*
  - (2) 150 mm (6 in.) for surface-mounted fluorescent luminaires installed on the wall above the door or on the ceiling. *NEC 410.16(C)(2)*
  - (3) 150 mm (6 in.) for recessed incandescent or LED luminaires with a completely enclosed light source installed in the wall or the ceiling. *NEC 410.16(C)(3)*
  - (4) 150 mm (6 in.) for recessed fluorescent luminaires installed in the wall or the ceiling. *NEC 410.16(C)(4)*
  - (5) Surface-mounted fluorescent or LED luminaires shall be permitted to be installed within the clothes closet storage space where identified for this use. *NEC 410.16(C)(5)*

7.6 COVE LIGHTING: Coves shall have adequate space and shall be so located that lamps and equipment can be properly installed and maintained. *NEC 410.18*

### 7.7 CLEARANCE AND INSTALLATION *NEC 410.116*

#### (A) Clearance

- (1) Non-Type IC. A recessed luminaire that is not identified for contact with insulation shall have all recessed parts spaced not less than 13 mm (1/2 in.) from combustible materials. The points of support and the trim finishing off the openings in the ceiling, wall, or other finished surface shall be permitted to be in contact with combustible materials.
- (2) Type IC. A recessed luminaire that is identified for contact with insulation, Type IC, shall be permitted to be in contact with combustible materials at recessed parts, points of support, and portions passing through or finishing off the opening in the building structure.

(B) Installation. Thermal insulation shall not be installed above a recessed luminaire or within 75 mm (3 in.) of the recessed luminaire's enclosure, wiring compartment, ballast, transformer, LED driver, or power supply unless it is identified as Type IC for insulation contact.

- 7.8 ADJACENT COMBUSTABLE MATERIAL: Luminaires shall be so installed that adjacent combustible material will not be subjected to temperatures in excess of 90°C (194°F). *NEC 410.115(A)*

## 8. CONDUCTOR SIZING BASED ON VOLTAGE DROP

- 8.1 Conductors for branch circuits as defined in Article 100, sized to prevent a voltage drop exceeding 3 percent at the farthest outlet of power, heating and lighting loads, or combinations of such loads, and where the maximum total voltage drop on both feeders and branch circuits to the farthest outlet does not exceed 5 percent, providing reasonable efficiency of operation. See Informational Note No. 2 of 215.2(A)(1) for voltage drop on feeder conductor. *NEC 210.19(A)(1)(Informational Note No. 4)*  
*Also see Agricultural Wiring Handbook Table 16 for conductor sizing based on voltage drop. (See Student Guide to Wiring – Conductor Sizing Table, page 67.)*

## 42 9. COOKING APPLIANCE

- 9.1 INSTALLATION:
- 9.1.1 A range receptacle should be installed on all free-standing range installations of 12 kW or less. Range Receptacle Rating: The ampere rating of a range receptacle shall be permitted to be based on a single range demand load as specified in Table 220.55. *NEC 210.21(B)(4)*
- 9.1.2 Flexible cord shall be permitted as follows:
- (1) To connect appliances to facilitate their frequent interchange or to prevent the transmission of noise or vibration.
  - (2) To facilitate the removal or disconnection of appliances that are fastened in place, where the fastening means and mechanical connections are specifically designed to permit ready removal for maintenance or repair, and the appliance is intended or identified for flexible cord connection. *NEC 422.16(A)*
- 9.1.3 The frame of the range shall be effectively grounded. *NEC 250.140*  
Electric ranges shall be wired with a 4-wire conductor. *NEC 250.138(A) or (B)*  
An existing branch-circuit, for an electric range, consisting of a 3-wire conductor may be bonded to the neutral terminal. *NEC 250.140*
- 9.1.4 Range wiring shall be protected with the proper size fuse or breaker per manufacturer's recommendations. *NEC 422.11(A)*

If a protective device rating is marked on an appliance, the branch-circuit overcurrent device rating shall not exceed the protective device rating marked on the appliance.

## 10. WATER HEATER WIRING

- 10.1 INSTALLATION:
- 10.1.1 For permanently connected appliances rated at not over 300 volt amperes or 1/8 horsepower, the branch-circuit overcurrent device shall be permitted to serve as the disconnected means where the switch or circuit breaker is within sight from the appliance or be capable of being locked in the open position in compliance with 110.25. *NEC 422.31(A)*
- 10.1.2 The branch-circuit overcurrent device and conductors for fixed storage-type water heater that has a capacity of 450 L (120 gal.) or less shall be sized not smaller than 125 percent of the rating of the water heater. *NEC 422.13*  
*Informational Note: For branch-circuit rating, see NEC 422.10*
- 10.1.3 All storage- or instantaneous-type water heater shall be equipped with a temperature-limiting means in addition to its control thermostat to disconnect all ungrounded conductors, and means shall be (1) installed to sense maximum water temperature and (2) either a trip-free, manually reset type or a type having a replacement element. Such water heaters shall be marked to require the installation of a temperature and pressure relief valve. *NEC 422.47*
- 10.1.4 Grounding: The tank of the water heater shall be grounded by EITHER bonding a bare or insulated ground wire from the non-current carrying frame to the equipment grounding conductor/electrode directly or along with circuit conductors in the cord and plug cable (fourth wire). *NEC 250.130, 134, 136, 138*

## 11. CLOTHES DRYER WIRING

- 11.1 In dwelling units, at least one receptacle outlet shall be installed in areas designated for the installation of laundry equipment. *NEC 210.52(F)*
- 11.2 Non-current-carrying metal parts of cord-and-plug-connected equipment, if required to be connected to an equipment grounding conductor, shall be connected by one of the methods in *NEC 250.138(A) or (B)*. *NEC 250.138*
- 11.3 An existing branch-circuit consisting of a 3-wire conductor may be bonded to the neutral terminal. *NEC 250.140 (Exception)*

## 12. ELECTRIC MOTORS

- 12.1 General: This article covers motors, motor branch-circuits and feeder conductors and their protection, motor overload protection, motor controls, motor controllers, and motor control centers. *NEC 430.1*

12.2 Motor-Operated Appliances Rated over 1/8 Horsepower. *NEC 422.31 (C)*  
 The disconnecting means shall comply with 430.109 and 430.110. For permanently connected motor-operated appliances with motors rated over 1/8 hp, the disconnecting means shall be within sight from the appliance or be capable of being locked in the open position in compliance with 110.25.

12.2.1 Single Motor *NEC 430.22*  
 Conductors that supply a single motor used in a continuous duty application shall have an ampacity of not less than 125 percent of the motor full-load current rating, as determined by 430.6(A)(1), or not less than specified in 430.22(A) through (G).

12.3 DEVICES OTHER THAN FUSES:

12.3.1 Where devices other than fuses are used for motor overload protection, *NEC Table 430.37* shall govern the minimum allowable number and location of overload units such as trip coils or relays.

**44** 12.3.2 Thermal Protector or Electronically Protected. A thermal protector integral with the motor shall be approved for use with the motor it protects on the basis that it will prevent dangerous overheating of the motor due to overload and failure to start. An electronically protected motor shall be approved for use on the basis that it will prevent dangerous overheating due to the failure of the electronic control, overload, or failure to start the motor. The ultimate trip current of a thermally or electronically protected motor shall not exceed the following percentage of motor full-load current given in *Table 430.248*, *Table 430.249*, and *Table 430.250*

Motor full-load current 9 amperes or less	170%
Motor full-load current from 9.1 to, and including, 20 amperes	156%
Motor full-load current greater than 20 amperes	140%

*NEC 430.32 (A)(2)*

If the motor current-interrupting device is separate from the motor and its control circuit is operated by a protective device integral with the motor, it shall be arranged so that the opening of the control circuit will result in interruption of current to the motor.

**13. ELECTRIC SPACE HEAT WIRING**

13.1 Equipment Grounding. All non-current-carrying metal parts of fixed, portable, and mobile equipment and associated fences, housings, enclosures, and supporting structures shall be grounded. *NEC 250.190*

13.2 WIRE SIZING FOR RESISTANCE HEATING: (Derived from conductor tables in *NEC 310*)

13.2.1 The minimum wire size to electric heating units shall be as follows:  
 (A) Two-wire No. 12 copper with ground shall be used to units rated 3.5 kW and smaller.  
 (B) Two-wire No. 10 copper with ground shall be used for units rated 3.6 to 5.5 kW and on all 240-volt portable heater outlets serving equipment rated at not more than 5 kW.

13.3 PORTABLE HEATER RECEPTACLES: Receptacles used on portable heater circuits shall be of at least 20 amps. Three-wire polarized receptacles shall be used and heaters shall be grounded. (Derived by *NEC Table 210.24* given the No. 12 copper conductor minimum requirement in 13.2.1 above.)

13.4 DERATING OF CONDUCTORS: *NEC 310.10, Table 310.15(B)(16)*

13.4.1 If a branch or feeder circuit supplies a continuous load, the allowable load on the circuit must be derated.

13.4.2 A continuous load is a load where the maximum current is expected to continue for 3 hours or more. *NEC 100*

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Example: Derating Conductor Load		
Conductor Size	Ampacity/ Overcurrent Protection (Amperes)	Maximum Continuous Load (Amperes)
No. 14 copper	15	12
No. 12 copper	20	16
No. 10 copper	30	24
No. 8 copper	40	32
No. 6 copper	55	44

13.4.3 Where a branch circuit or supplies continuous loads, or any combination of continuous and noncontinuous loads, the rating of the overcurrent device shall not be less than the continuous load plus 125 percent of the continuous load. *NEC 210.12(A), NEC 210.20(A), NEC 215.2(A), NEC 215.3*

13.4.4 The continuous load on the circuit cannot exceed 80 percent of the full load ampere rating of the conductor and overcurrent protection device.

13.5 Thermostatically Controlled Switching Devices - (A) Serving as Both Controllers and Disconnecting Means. Thermostatically con-

trolled switching devices and combination thermostats and manually controlled switches shall be permitted to serve as both controllers and disconnecting means, provided they meet all of the following conditions:

- (1) Provided with a marked "off" position.
- (2) Directly open all ungrounded conductors when manually placed in the "off" position.
- (3) Designed so that the circuit cannot be energized automatically after the device has been manually placed in the "off" position
- (4) Located as specified in NEC 424.19. NEC 424.20(A)
- (5) Located in an accessible location

#### 13.6 BRANCH CIRCUITS

13.6.1 Branch-Circuit Requirements. An individual branch circuit shall be permitted to supply any volt-ampere or wattage rating of fixed electric space heating equipment for which the branch circuit is rated. *NEC 424.4(A)*

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13.6.2 Branch circuits supplying two or more outlets for fixed electric space-heating equipment shall be rated not over 30 amperes. In other than a dwelling unit, fixed infrared heating equipment shall be permitted to be supplied from branch circuits rated not over 50 amperes. *NEC 424.4(A)*

13.6.3 Branch-Circuit Sizing. The branch-circuit conductors for fixed electric space-heating equipment and any associated motors shall be sized not smaller than 125 percent of the load. *NEC 424.4(B)*

### 14. CENTRAL SPACE HEATING AND AIR CONDITIONING

14.1 GENERAL: The provisions of this article apply to electric motor-driven air-conditioning and refrigerating equipment and to the branch circuits and controllers for such equipment. It provides for the special considerations necessary for circuits supplying hermetic refrigerant motor-compressors and for any air-conditioning or refrigerating equipment that is supplied from a branch circuit that supplies a hermetic refrigerant motor-compressor. *NEC 440.1*

14.2 Hermetic Refrigerant Motor-Compressor: A disconnecting means serving a hermetic refrigerant motor-compressor shall be selected on the basis of the nameplate rated-load current or branch-circuit selection current, whichever is greater and locked-rotor current, respectively, of the motor-compressor as follows: (1) Ampere Rating (2) Equivalent Horsepower. *NEC 440.12(A)*

14.3 DISCONNECTING MEANS: Every disconnecting means in the refrigerant motor-compressor circuit between the point of attachment to the feeder and the point of connection to the refrigerant motor-compressor shall comply with the requirements of NEC 440.12. *NEC 440.12(D)*

14.3.1 Location: Disconnecting Means shall be located within sight from and readily accessible from the air-conditioning or refrigerating equipment. The disconnecting means shall be permitted to be installed on or within the air-conditioning or refrigerating equipment. The disconnecting means shall not be located on panels that are designed to allow access to the air-conditioning or refrigeration equipment or to obscure the equipment nameplate(s). *NEC 440.14*

14.3.2 Control and Protection of Fixed Electric Space-Heating Equipment Disconnecting Means. Means shall be provided to simultaneously disconnect the heater, motor controller(s), and supplementary overcurrent protection device(s) of all fixed electric space-heating equipment from ungrounded conductors. The disconnecting means specified in 424.19(a) & (B) shall have an ampere rating not less than 125 percent of the total load of the motors and the heaters and shall be capable of being locked in the open position.

(A) Heating Equipment with Supplementary Overcurrent Protection: The disconnecting means for fixed electric space-heating equipment with supplementary overcurrent protection shall be within sight from the supplementary overcurrent protective device(s), on the supply side of these devices, if fuses, and in addition, shall comply with either NEC 424.19(A)(1) or (2).

(1) Heater containing no motor rated over 1/8 horsepower. The disconnecting means provided shall be within sight from the motor controller(s) and the heater, or shall be lockable as specified in 424.19, or shall be a unit switch complying with 424.19(C)

#### 14.4 OVERCURRENT PROTECTION:

14.4.1 Resistance Elements: Resistance-type heating elements in electric space heating equipment shall be protected at not more than 60 amperes. Equipment rated more than 48 amperes and employing such elements shall have the heating elements subdivided, and each subdivided load shall not exceed 48 amperes. Where a subdivided load is less than 48 amperes the rating of the supplementary overcurrent protective device shall comply with 424.3(B). A boiler employing resistance-type immersion heating elements contained in an ASME rated and stamped vessel shall be permitted to comply with 424.72(A). *NEC 424.22(B)*

14.4.2 Overcurrent protective devices: The supplementary overcurrent protective devices for the subdivided loads specified in 424.22 (B) shall be (1) factory-installed within or on the heater enclosure or supplied for use with the heater as a separate assembly by the heater manufacturer; (2) accessible, but shall not be required to be readily accessible; and (3) suitable for branch-circuit protection. Where cartridge fuses are used to provide this overcurrent protection, a single disconnecting means shall be permitted to be used for the several subdivided loads. *NEC 424.22(C)*

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14.4.3 The main conductors supplying the supplementary overcurrent protective devices shall be considered branch-circuit conductors. *NEC 424.22(D)*

14.5 CIRCUIT CAPACITY:

14.5.1 440.6 Ampacity and Rating: The size of conductors for equipment covered by this article shall be selected from Tables 310.15(B)(16) through 310.15(B)(19) or calculated in accordance with 310.15 as applicable. The required ampacity of conductors and rating of equipment shall be determined according to NEC 440.6(A) and 440.6(B).

14.6 LOW-VOLTAGE FIXED ELECTRIC SPACE-HEATING EQUIPMENT:

14.6.1 Low-voltage fixed electric space-heating equipment shall consist of an isolating power supply, low-voltage heaters, and associated equipment that are all identified for use in dry locations. *NEC 424.100*

- (A) Power unit: The power unit shall be an isolating type with a rated output not exceeding 25 amperes, 30 volts (42.4 volts peak) ac, or 60 volts dc under all load conditions.

**15. AGRICULTURAL BUILDING (NEC 547)**

15.1 SCOPE: *NEC 547.1*

15.1.1 The provisions of this article shall apply to the following agricultural buildings or that part of a building or adjacent areas of similar or like nature as specified in 547.1(A) and (B).

- (A) Excessive Dust and Dust with Water. Agricultural buildings where excessive dust and dust with water may accumulate, including all areas of poultry, livestock, and fish confinement systems, where litter dust or feed dust, including mineral feed particles, may accumulate.
- (B) Corrosive Atmosphere. Agricultural buildings where a corrosive atmosphere exists. Such buildings include areas where the following conditions exist:
  - (C) Poultry and animal excrement may cause corrosive vapors.
  - (D) Corrosive particles may combine with water.
  - (E) The area is damp and wet by reason of periodic washing for cleaning and sanitizing with water and cleansing agents.
  - (F) Similar conditions exist.

15.2 DEFINITIONS: *NEC 547.2*

15.2.1 Distribution Point: An electrical supply point from which service drops, service conductors, feeders, or branch circuits to buildings or structures utilized under single management are supplied.

*Informational Note No. 1: Distribution points are also known as the center pole, meterpole or the common distribution point.*

*Informational Note No. 2: The service point as defined in Article 100 is typically at the distribution point.*

15.2.2 Equipotential Plane (As applied to agricultural buildings): An area where wire mesh or other conductive elements are embedded in or placed under concrete, bonded to all metal structures and fixed non-electrical equipment that may become energized, and connected to the electrical grounding system to minimize voltage differences within the plane and between the planes, the grounded equipment, and the earth.

15.2.3 Site-Isolating Device. A disconnecting means at the distribution point for the purposes of isolation, system maintenance, emergency disconnection of optional standby systems.

15.3 OTHER ARTICLES: *NEC 547.3*

15.3.1 For agricultural buildings not having conditions as specified in 547.1, the electrical installations shall be made in accordance with the applicable articles in the NEC.

15.4 SURFACE TEMPERATURES: *NEC 547.4*

15.4.1 Electrical equipment or devices installed in accordance with the provisions of this article shall be installed in a manner such that they will function at full rating without developing surface temperatures in excess of the specified normal safe operating range of the equipment or device.

15.5 WIRING METHODS: *NEC 547.5*

- (A) Wiring Systems: Types UF, NMC, copper SE cables, jacketed Type MC cable, rigid nonmetallic conduit, liquid-tight flexible nonmetallic conduit, or other cables or raceways suitable for the location, with approved termination fittings, shall be the wiring methods employed. The wiring methods of Article 502, Part II shall be permitted for areas described in 547.1(A).

*Informational Note: See 300.7 and 352.44 and 355.44 for installation of raceway systems exposed to widely different temperatures.*

- (B) Mounting: All cables shall be secured within 200 mm (8 in.) of each cabinet, box, or fitting. Nonmetallic boxes, fittings, conduit and cables shall be permitted to be mounted directly to any building surface covered by this article without maintaining the 6 mm (1/4 in.) airspace in accordance with 300.6(D).

- (C) Equipment Enclosures, Boxes, Conduit Bodies, and Fittings:
  - (1) Excessive Dust. Equipment enclosures, boxes, conduit bodies, and fittings installed in areas of buildings where exces-

sive dust may be present shall be designed to minimize the entrance of dust and shall have no openings (such as holes for attachment screws) through which dust could enter the enclosure.

- (2) Damp or Wet Locations. In damp or wet locations, equipment enclosures, boxes, conduit bodies, and fittings shall be placed or equipped so as to prevent moisture from entering or accumulating within the enclosure, box, conduit body, or fitting. In wet locations, including normally dry or damp locations where surfaces are periodically washed or sprayed with water, boxes, conduit bodies, and fittings shall be listed for use in wet locations and equipment enclosures shall be weatherproof.
- (3) Corrosive Atmosphere: Where wet dust, excessive moisture, corrosive gases or vapors, or other corrosive conditions may be present, equipment enclosures, boxes, conduit bodies, and fittings shall have corrosion resistance properties suitable for the conditions

*Informational Note No. 1: See Table 110.28 for appropriate enclosure type designations.*

*Informational Note No. 2: Aluminum and magnetic ferrous materials may corrode in agricultural environments.*

- (D) Flexible Connections: Where necessary to employ flexible connections, dust-tight flexible connectors, liquid-tight flexible metal conduit, liquid-tight flexible non-metallic conduit, or flexible cord listed and identified for hard usage shall be used.
- (E) Physical Protection: All electrical wiring and equipment subject to physical damage shall be protected.
- (F) Separate Equipment Grounding Conductor: Where an equipment grounding conductor is installed underground within a location falling under the scope of Article 547, it shall be insulated.

*Informational Note: For further information on aluminum and copper-clad aluminum conductors, see 250.120(B).*

- (G) Receptacles: All 125-volt, single-phase, 15- and 20-ampere receptacles installed in (1) through (4) shall have ground-fault circuit-interrupter protection:
  - (1) In areas having an equipotential plane.
  - (2) Outdoors.
  - (3) Damp or wet locations
  - (4) Dirt confinement areas for livestock.

GFCI protection shall not be required for an accessible receptacle supplying a dedicated load where a GFCI protected receptacle is located within 900 mm (3 ft.) of the non-GFCI-protected receptacle.

- 15.6 SWITCHES, RECEPTACLES, CIRCUIT BREAKERS, CONTROLLERS, AND FUSES: *NEC 547.6*
- 15.6.1 Switches, including pushbuttons, relays, and similar devices, receptacles, circuit breakers, controllers, and fuses, shall be provided with enclosures as specified in NEC 547.5(C).
- 15.7 MOTORS: *NEC 547.7*
- 15.7.1 Motors and other rotating electrical machinery shall be totally enclosed or designed so as to minimize the entrance of dust, moisture, or corrosive particles.
- 15.8 LUMINAIRES (LIGHTING FIXTURES): *NEC 547.8*
- 15.8.1 Luminaires (lighting fixtures) shall comply with NEC 547.8(A) through (C).
  - (A) Minimize the Entrance of Dust. Luminaires shall be installed to minimize the entrance of dust, foreign matter, moisture, and corrosive material.
  - (B) Exposed to Physical Damage. Luminaires exposed to physical damage shall be protected by a suitable guard.
  - (C) Exposed to Water. Luminaires exposed to water from condensation, building cleansing water, or solution shall be listed for use in wet locations.
- 15.9 ELECTRICAL SUPPLY TO BUILDINGS OR STRUCTURES FROM A DISTRIBUTION POINT: *NEC 547.9*
- 15.9.1 A distribution point shall be permitted to supply any building or structure located on the same premises. The overhead electrical supply shall comply with NEC 547.9(A) and (B), or with NEC 547.9(C). The underground electrical supply shall comply with NEC 547.9(C).
  - (A) Site Isolation Device: Site-isolation devices shall comply with NEC 547.9(A)(1) through (A)(10).
    - (1) Where required. A site-isolating device shall be installed at the distribution point where two or more buildings or structures are supplied from the distribution point.
    - (2) Location: The site-isolating device shall be pole-mounted and be not less than the height above grade required by 230.24 for the conductor it supplies.
    - (3) Operation: The site-isolating device shall simultaneously disconnect all ungrounded service conductors from the premises wiring.
    - (4) Bonding Provisions. The site-isolation device enclosure shall be connected to the grounded circuit conductor and the grounding electrode system.
    - (5) Grounding: At the site-isolating device, the system grounded conductor shall be connected to a grounding electrode system via a grounding electrode conductor.
    - (6) Rating. The site-isolation device shall be rated for the calculated load as determined by NEC Part IV of Article 220.

- (7) Overcurrent Protection. The site-isolating device shall not be required to provide overcurrent protection.
  - (8) Accessibility. The site-isolating device shall be capable of being remotely operated by an operating handle installed at a readily accessible location. The operating handle of the site-isolating device, when in its highest position, shall not be more than 2.0 m (6 ft. 7 in.) above grade or a working platform.
  - (9) Series Devices: An additional site-isolating device for the premises wiring system shall not be required where a site-isolating device meeting all applicable requirements of this section is provided by the serving utility as part of their service requirements.
  - (10) Marking: A site-isolating device shall be permanently marked to identify it as a site-isolating device. This marking shall be located on the operating handle or immediately adjacent thereto.
- (B) Service Disconnecting Means and Overcurrent Protection at the Building(s) or Structures(s): Where the service disconnecting means and overcurrent protection are located at the building(s) or structure(s), the requirements of NEC 547.9(B)(1) through (B)(3) shall apply.
- (1) Conductor Sizing: The supply conductors shall be sized in accordance with NEC Part V of Article 220.
  - (2) Conductor Installation: The supply conductors shall be installed in accordance with the requirements of NEC Part II of Article 225.
  - (3) Grounding and Bonding: For each building or structure, grounding and bonding of the supply conductors shall be in accordance with the requirements of NEC Article 250.32, and the following conditions shall be met:
    - (a) The equipment grounding conductor is not smaller than the largest supply conductor if of the same material, or is adjusted in size in accordance with the equivalent size columns of NEC Table 250.122 if of different materials.
    - (b) The equipment grounding conductor is connected to the grounded circuit conductor and the site-isolating device enclosure at the distribution point.
- (C) Service Disconnection Means and Overcurrent Protection at the Distribution Point: Where the disconnecting means and overcurrent protection for each set of feeder or branch circuits are located at the distribution point, the feeders or branch circuits to building(s) or structure(s) shall comply with the provisions of NEC 250.32 and Article 225, Parts I and II.

*Informational Note: Methods to reduce neutral-to-earth voltages in livestock facilities include supplying buildings or structures with 4-wire, single-phase services, sizing of 3-wire service conductors to limit voltage drop to 2 percent, and connecting loads line-to-line.*

- (D) Identification: Where a site is supplied by more than one distribution point, a permanent plaque or directory shall be installed at each of those distribution points denoting the location of each of the other distribution points and the buildings or structures served by each.

## 15.10 EQUIPOTENTIAL PLANES AND BONDING OF EQUIPOTENTIAL PLANES:

- 15.10.1 The installation of equipotential planes shall comply with NEC 547.10(A) and (B). For purposes of this section, the term livestock shall not include poultry.
- (A) Where Required: Equipotential plans shall be installed where required in (A)(1) and (A)(2).
    - (1) Indoors: Equipotential planes shall be installed in confinement areas with concrete floors where metallic equipment is located that may become energized and is accessible to livestock.
    - (2) Outdoors: Equipotential planes shall be installed in concrete slabs where metallic equipment is located that may become energized and is accessible to livestock. The equipotential plane shall encompass the area where the livestock stands while accessing metallic equipment that may become energized.
  - (B) Bonding: Equipotential planes shall be connected to the electrical grounding system. The bonding conductor shall be solid copper, insulated, covered or bare, and not smaller than 8 AWG. The means of bonding to wire mesh or conductive elements shall be by pressure connectors or clamps of brass, copper, copper alloy, or an equally substantial approved means. Slatted floors that are supported by structures that are part of an equipotential plane shall not require bonding.

*Informational Note No. 1: Methods to establish equipotential planes are described in the American Society of Agricultural and Biological Engineers (ASABE) EP473.2-2001. Equipotential Planes in Animal Containment Areas.*

*Informational Note No. 2: Methods for safe installation of livestock waterers are described in the American Society of Agricultural and Biological Engineers (ASABE) EP342.3-2010. Safety for Electrically Heated Livestock Waterers.*

*Informational Note No. 3: Low grounding electrode system resistances may reduce voltage differences in livestock facilities.*

## 16. OUTSIDE WIRING

### 16.1 CONDUCTOR SIZE AND SUPPORT:

- 16.1.1 Overhead Spans: Overhead individual conductors shall not be smaller than the following: For 1000 volts, nominal or less, 10 AWG copper or 8 AWG aluminum for spans up to 50 feet (15 m) in length and 8 AWG copper or 6 AWG aluminum for a longer span unless supported by a messenger wire. *NEC 225.6(A)(1)*
- 16.1.2 All outbuildings shall have a means provided for disconnecting all ungrounded conductors that supply or pass through the building or structure. *NEC 225.31*
- 16.1.3 Overhead spans of open conductors and open multiconductor cables of not over 1,000 volts, nominal, shall have a clearance of not less than that specified in NEC 225.18 (1) – (5). See Section 3, Student Guide to Wiring - Service Entrances, 3.2(1) through 3.2(5).
- 16.1.4 Protection Against Physical Damage of Conductors: Conductors installed on buildings, structures, or poles shall be protected against physical damage as provided for services in NEC 230.50. *NEC 225.20*

**54** Service Entrance Cables, where subject to physical damage, shall be protected by any of the following: *NEC 230.50 (B)(1)*

- (1) Rigid metal conduit (RMC)
- (2) Intermediate metal conduit (IMC)
- (3) Schedule 80 PVC conduit
- (4) Electrical metallic tubing (EMT)
- (5) Reinforced thermosetting resin conduit (RTRC)
- (6) Other approved means

Underground Service-Entrance Conductors shall be protected against physical damage in accordance with NEC 300.5. *NEC 230.50 (A)*

- 16.1.5 Vegetation as support: Vegetation such as trees shall not be used for support of overhead conductor spans. *NEC 225.26*

## 17. UNDERGROUND FEEDER AND BRANCH CIRCUIT CABLE (Does Not Refer to Service Entrances)

17.1 UNDERGROUND FEEDER (UF):

- 17.1.1 Conductors. The conductors shall be sizes 14 AWG copper or 12 AWG aluminum or copper-clad aluminum through 4/0 AWG. *NEC 340.104*
- (A) Insulation. The conductors of Type UF shall be one of the moisture-resistant types listed in Table 310. (A) that is suitable for branch circuit wiring or one that is identified for such use. Where installed as a substitute wiring method for NM cable, the conductor insulation shall be rated 90°C (194°F). *NEC 340.112*
- (B) Equipment Grounding Conductor. In addition to the insulated

conductors, the cable shall be permitted to have an insulated or bare equipment grounding conductor. *NEC 340.108*

- (C) Sheath. The overall covering shall be flame-retardant; moisture, fungus and corrosion resistant; and suitable for direct burial in the earth. *NEC 340.116*

- 17.1.2 Type UF cable shall be durably marked on the surface. The AWG size or circular mil area shall be repeated at intervals not exceeding 610 mm (24 inches). All other markings shall be repeated at intervals not exceeding 1.0 m (40 inches). *NEC 310.8(B)(1)(4)*

- 17.1.3 A minimum depth of 600 mm (24 inches) shall be maintained for conductors and cables buried directly in the earth. The depth may be reduced to 450 mm (18 inches), provided supplemental protective covering such as a 50 mm (2-inch) concrete pad or non-metallic raceway is used. *NEC Table 300.5*

- 17.1.4 Type UF cable is defined as a factory assembly of one or more insulated conductors with an integral or an overall covering of nonmetallic material suitable for direct burial in the earth. *NEC 340.2*

- 17.1.5 Type UF cable shall be permitted as follows (*NEC 340.10*):

- (1) For use underground, including direct burial in the earth. For underground requirements, see 300.5.
- (2) As single-conductor cables. Where installed as single-conductor cables, all conductors of the feeder grounded conductor or branch circuit, including the grounded conductor and equipment grounding conductor, if any, shall be installed in accordance with 300.3.
- (3) For wiring in wet, dry, or corrosive locations.
- (4) Installed as nonmetallic-sheathed cable. Where so installed, the installation and conductor requirements shall comply with Parts II and III of Article 334 and shall be of the multi-conductor type.
- (5) As single-conductor cables as the non-heating leads for heating cables as provided in 424.43.
- (6) Supported by cable trays. Type UF cable supported by cable trays shall be of the multi-conductor type.

- 17.1.6 Uses not permitted: Type UF cable shall not be used as follows (*NEC 340.12*):

- (1) As service-entrance cables.
- (2) In commercial garages.
- (3) In theaters and similar locations.
- (4) In motion picture studios.
- (5) In storage battery rooms.
- (6) In hoistways, or on elevators or escalators.
- (7) In hazardous (classified) locations, except as specifically permitted by other articles in this *Code*.
- (8) Embedded in poured cement, concrete, or aggregate, except where embedded in plaster as non-heating leads where permitted in 424.43.

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- (9) Where exposed to direct rays of the sun, unless identified as sunlight-resistant.
- (10) Where subject to physical damage.
- (11) As overhead cable, except where installed as messenger-supported wiring in accordance with Part II of Article 396.

**EXAMPLE: RESIDENTIAL WIRING CALCULATIONS**  
(See NEC INFORMATIVE ANNEX D)

**Example D1(a). One-Family Dwelling**

The dwelling has a floor area of 1500 sq. ft. exclusive of an unfinished cellar not adaptable for future use, unfinished attic, and open porches. Appliances are a 12-kW range and a 5.5 kW, 240-V dryer. Assume range and dryer kW ratings equivalent to kVA ratings in accordance with 220.54 and 220.55.

**Calculated Load** [see 220.40]

**General Lighting Load:** 1500 sq. ft. at 3 VA per sq. ft. = 4500 VA

**Minimum Number of Branch Circuits Required** [see 210.11(A)]

General Lighting Load:

4500 VA ÷ 120 V = 38 A: This requires three 15-A, 2-wire or two 20-A, 2-wire circuits.

Small Appliance Load:

Two 2-wire, 20-A circuits [see 210.11(C)(1)]

Laundry Load:

One 2-wire, 20-A circuit [see 210.11(C)(2)]

Bathroom Branch Circuit:

One 2-wire, 20-A circuit (no additional load calculation is required for this circuit) [see 210.11(C)(3)]

**Minimum Size Feeder Required** [see 220.40]

General Lighting . . . . .	4500 VA
Small Appliance . . . . .	3000 VA
Laundry . . . . .	<u>1500 VA</u>
Total . . . . .	9000 VA
3000 VA at 100% . . . . .	3000 VA
9000 VA - 3000 VA = 6000 VA at 35% . . . . .	<u>2100 VA</u>
Net Load . . . . .	5100 VA
Range (see Table 220.55) . . . . .	8000 VA
Dryer Load (see Table 220.54) . . . . .	<u>5500 VA</u>
Net Calculated Load . . . . .	18,600 VA

**Net Calculated Load for 120 / 240-V, 3-wire, single-phase service or feeder:** 18,600 VA ÷ 240 V = 78 A

Sections 230.42(B) and 230.79 require service conductors and disconnecting means rated not less than 100 amperes.

**Calculation for Neutral for Feeder and Service**

Lighting and Small Appliance Load . . . . .	5100 VA
Range: 8000 VA at 70% (see 220.61) . . . . .	5600 VA
Dryer 5500 VA at 70% (see 220.61) . . . . .	<u>3850 VA</u>
Total . . . . .	14,550 VA

**Calculated Load for Neutral:** 14,550 VA ÷ 240 V = 61 A

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**Example D1(b). One-Family Dwelling**

Assume same conditions as Example No. D1(a), plus addition of one 6-A, 230-V, room air-conditioning unit and one 12-A, 115-V, room air-conditioning unit\*, one 8-A, 115-V, rated waste disposer, and one 10-A, 120-V, rated dishwasher. See Article 430 for general motors and Article 440, Part VII, for air-conditioning equipment. Motors have nameplate ratings of 115-V and 230-V for use on 120-V and 240-V nominal voltage systems. \*(For feeder neutral, use larger of the two appliances for unbalance.)

From Example D1(a), feeder current is 78 A (3-wire 240 V).

	Line A	Neutral	Line B
Amperes from Example D1(a)	78	61	78
One 230-V air conditioner	6	—	6
One 115-V air conditioner and 120-V dishwasher	12	12	10
One 115-V disposer	—	8	8
25% of largest motor (see NEC 430.24)	3	3	2
<b>Total amperes per conductor</b>	<b>99</b>	<b>84</b>	<b>104</b>

Therefore, the service would be rated 110 A.

**Example D2(a). Optional Calculation for One-Family Dwelling, Heating Larger than Air Conditioning**

[see 220.82]

The dwelling has a floor area of 1500 sq. ft., exclusive of an unfinished cellar not adaptable for future use, unfinished attic, and open porches. It has a 12-kW range, a 2.5-kW water heater, a 1.2-kW dishwasher, 9 kW of electric space heating installed in five rooms, a 5-kW clothes dryer, and a 6-A 230-V room air-conditioning unit. Assume range, water heater, dishwasher, space heating, and clothes dryer kW ratings equivalent to kVA.

**Air Conditioner kVA Calculation:** 6A x 230V ÷ 1000 = 1.38 kVA

This 1.38 kVA [item 1 from 220.82(C)] is less than 40% of 9 kVA of separately controlled electric heat [item 6 from 220.82(C)], so the 1.38 kVA need not be included in the service calculation.

**General Load**

1500 sq. ft. at 3 VA . . . . .	4500 VA
Two 20-A appliance outlet circuits at 1500 VA each . . . . .	3000 VA
Laundry circuit . . . . .	1500 VA
Range (at nameplate rating) . . . . .	12,000 VA
Water heater . . . . .	2500 VA
Dishwasher . . . . .	1200 VA
Clothes dryer . . . . .	<u>5000 VA</u>
Total . . . . .	29,700 VA

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**Application of Demand Factor** [see 220.82(B)]

First 10 kVA of general load at 100% . . . . .	10,000 VA
Remainder of general load at 40% (19.7 kVA x 0.4) . . . . .	<u>7880 VA</u>
Total of general load . . . . .	17,880 VA
9 kVA of heat at 40% (9000 VA x 0.4) = . . . . .	<u>3600 VA</u>
Total . . . . .	21,480 VA

**Calculated Load for Service Size:**

21.48 kVA = 21,480 VA  
21,480 VA ÷ 240 V = 90 A

Therefore, the minimum service rating would be 100 A in accordance with 230.42 and 230.79.

**Feeder Neutral Load, in Accordance with 220.61**

1500 sq. ft. at 3 VA . . . . .	4500 VA
Three 20-A circuits at 1500 VA . . . . .	<u>4500 VA</u>
Total . . . . .	9000 VA
3000 VA at 100% . . . . .	3000 VA
9000 VA - 3000 VA = 6000 VA at 35%. . . . .	<u>2100 VA</u>
Subtotal . . . . .	5100 VA
Range: 8 kVA at 70% . . . . .	5600 VA
Clothes dryer: 5 kVA at 70% . . . . .	3500 VA
Dishwasher . . . . .	<u>1200 VA</u>
Total . . . . .	15,400 VA

**Calculated Load for Neutral:** 15,400 VA ÷ 240 V = 64 A

**Example D2(b). Optional Calculation for One-Family Dwelling, Air Conditioning Larger than Heating**

[see 220.82(A) and 220.82(C)]

The dwelling has a floor area of 1500 sq. ft. exclusive of an unfinished cellar not adaptable for future use, unfinished attic, and open porches. It has two 20-A small appliance circuits, one 20-A laundry circuit, two 4-kW wall-mounted ovens, one 5.1-kW counter-mounted cooking unit, a 4.5-kW water heater, a 1.2-kW dishwasher, a 5-kW combination clothes washer and dryer, six 7-A 230-V room air-conditioning units, and a 1.5-kW permanently installed bathroom space heater. Assume wall-mounted ovens, counter-mounted cooking unit, water heater, dishwasher, and combination clothes washer and dryer kW ratings equivalent to kVA.

**Air Conditioning kVA Calculation:**

Total Amperes = 6 units x 7A = 42 A  
42 A x 240 V ÷ 1000 = 10.08 kVA ( assume P.F. = 1.0)

**Load included at 100%:**

Air conditioning: Included below [see item 1 in 220.82(C)]  
Space heater: Omit [see item 5 in 220.82(C)]

**General Load:**

1500 sq. ft. at 3 VA . . . . .	4500 VA
Two 20-A small appliance circuits at 1500 VA each . . . . .	3000 VA
Laundry circuit . . . . .	1500 VA
Two ovens . . . . .	8000 VA
One cooking unit. . . . .	5100 VA
Water heater . . . . .	4500 VA
Dishwasher . . . . .	1200 VA
Washer/dryer . . . . .	<u>5000 VA</u>
Total general load . . . . .	32,800 VA
First 10 kVA at 100% . . . . .	10,000 VA
Remainder at 40% (22.8 kVA x 0.4 x 1000). . . . .	<u>9120 VA</u>
Subtotal general load . . . . .	19,120 VA
Air conditioning . . . . .	<u>10,080 VA</u>
Total . . . . .	29,200 VA

**Calculated Load for Service:** 29,200 VA ÷ 240 V = 122 A (service rating)

**Feeder Neutral Load, in Accordance with 220.61**

Assume that the two 4 kVA wall-mounted ovens are supplied by one branch circuit, the 5.1 kVA counter-mounted cooking unit by a separate circuit.

1500 sq. ft. at 3 VA . . . . .	4500 VA
Three 20 A circuits at 1500 VA. . . . .	<u>4500 VA</u>
Subtotal . . . . .	9000 VA
3000 VA at 100% . . . . .	3000 VA
9000 VA - 3000 VA = 6000 VA at 35%. . . . .	<u>2100 VA</u>
Subtotal. . . . .	5100 VA

Two 4 kVA ovens plus one 5.1 kVA cooking unit = 13.1 kVA.  
Table 220.55 permits 55% demand factor or 13.1 kVA x 0.55 = 7.2 kVA feeder capacity

Subtotal from above . . . . .	5100 VA
Ovens and cooking unit: 7200 VA X 70% for neutral load . . . . .	5040 VA
Clothes washer/dryer: 5 kVA X 70% for neutral load . . . . .	3500 VA
Dishwasher . . . . .	<u>1200 VA</u>
Total . . . . .	14,840 VA

**Calculated Load for Neutral:** 14,840 VA ÷ 240 V = 62 A

**Example D2(c). Optional Calculation for One-Family Dwelling with Heat Pump, Single-Phase, 240/120-V Service**

[See 220.82]

The dwelling has a floor area of 2000 sq. ft. exclusive of an unfinished cellar not adaptable for future use, unfinished attic, and open porches. It has a

12-kW range, a 4.5-kW water heater, a 1.2-kW dishwasher, a 5-kW clothes dryer, and a 2-1/2-ton (24-A) heat pump with 15-kW of backup heat.

**Heat Pump kVA Calculation:**  $24\text{ A} \times 240\text{ V} \div 1000 = 5.76\text{ kVA}$

This 5.76 kVA is less than 15 kVA of the backup heat; therefore, the heat pump load need not be included in the service calculation [see 220.82(C)].

**General Load:**

2000 sq. ft. at 3 VA	6000 VA
Two 20-A appliance outlet circuits at 1500 VA each	3000 VA
Laundry circuit	1500 VA
Range (at nameplate rating)	12,000 VA
Water heater	4500 VA
Dishwasher	1200 VA
Clothes dryer	<u>5000 VA</u>
Subtotal general load	33,200 VA
First 10 kVA at 100% =	10,000 VA
Remainder of general load at 40% (23,200 VA X 0.4 =)	<u>9280 VA</u>
Total net general load	19,280 VA

**Heat Pump and Supplementary Heat\*:**  $240\text{ V} \times 24\text{ A} = 5760\text{ VA}$

**15-kW electric heat:**

$5760\text{ VA} + (15,000\text{ VA} \times 65\%) = 5.76\text{ kVA} + 9.75\text{ kVA} = 15.51\text{ kVA}$

\*If supplementary heat is not on at same time as heat pump, heat pump kVA need not be added to total.

**Totals**

Net General load	19,280 VA
Heat pump and supplementary heat	<u>15,510 VA</u>
Total	34,790 VA

**Calculated Load for Service:**  $34.79\text{ kVA} \times 1000 \div 240\text{ V} = 145\text{ A}$

Therefore, this dwelling unit would be permitted to be served by a 150-A service.

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**Example D8. Motor Circuit Conductors, Overload Protection, and Short-Circuit and Ground-Fault Protection**

[See 240.6, 430.6, 430.22, 430.23, 430.24, 430.32, 430.52 and 430.62, Tables 430.52 and Table 430.250]

Determine the minimum required conductor ampacity, the motor overload protection, the branch-circuit short-circuit and ground fault protection, and the feeder protection for three induction-type motors on a 480-V, 3-phase feeder, as follows:

- (A) One 25-hp, 460-V, 3-phase squirrel-cage motor, nameplate full-load current 32 A, Design B, Service Factor 1.15
- (B) Two 30-hp, 460-V, 3-phase wound-rotor motors, nameplate primary full-load current 38 A, nameplate secondary full-load current 65 A, 40 degree C rise.

**Conductor Ampacity**

The full-load current value used to determine the minimum required conductor ampacity is obtained from Table 430.250 (see 430.6(A)) for the squirrel-cage motor and the primary of the wound-rotor motors. To obtain the minimum required conductor ampacity, the full-load current is multiplied by 1.25 (see 430.22 and 430.23(A)).

For the 25-hp motor:  $32\text{ A} \times 1.25 = 40\text{ A}$   
 For the 30-hp motors:  $40\text{ A} \times 1.25 = 50\text{ A}$   
 $65\text{ A} \times 1.25 = 81\text{ A}$

**Motor Overload Protection**

Where protected by a separate overload device, the motors are required to have overload protection rated or set to trip at not more than 125% of the nameplate full-load current. [See 430.6(A) and 430.32(A)(1)]

For the 25-hp motor:  $32\text{ A} \times 1.25 = 40\text{ A}$   
 For the 30-hp motors:  $38\text{ A} \times 1.25 = 48\text{ A}$

Where the separate overload device is an overload relay (not a fuse or circuit breaker) and the overload device selected at 125% is not sufficient to start the motor or carry the load, the trip setting is permitted to be increased in accordance with 430.32(C).

**Branch Circuit Short Circuit and Ground Fault Protection**

The selection of the rating of the protective device depends on the type of motor and the protective device selected, in accordance with 430.52 and Table 430.52.

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**The following is for a 25-hp squirrel-cage motor:**

- (A) Non time-delay fuse: The fuse rating is  $300\% \times 34A = 102 A$ . The next larger standard fuse is 110 A. [See 240.6 and 430.52(C)(1), Exception No. 1]. If the motor will not start with a 110-A non time-delay fuse, the fuse rating is permitted to be increased to 125 A because this rating does not exceed 400%. [See 430.52(C)(1), Exception No.2(a)]
- (B) Time-delay fuse: The fuse rating is  $175\% \times 34 A = 59.5 A$ . The next larger standard fuse is 60 A [see 240.6 and 430.52(C)(1), Exception No. 1]. If the motor will not start with a 60-A time-delay fuse, the fuse rating is permitted to be increased to 70 A because this rating does not exceed 225%. [See 430.52(C)(1), exception No. 2(b)]

**The following is for the 30-hp wound-rotor motors:**

- (A) Non time-delay fuse: The fuse rating is  $150\% \times 40 A = 60 A$ . If the motor will not start with a 60 A non time-delay fuse, the fuse rating is permitted to be increased to 150 A because this rating does not exceed 400% (see 430.52(C)(1), Exception No. 2(a)).
- (B) Time-delay fuse: The fuse rating is  $150\% \times 40 A = 60 A$ . If the motor will not start with a 60 A time-delay fuse, the fuse rating is permitted to be increased to 90 A because this rating does not exceed 225% (see 430.52(C)(1), Exception No. 2(b)).
- (C) Inverse time circuit breaker: The breaker rating is  $150\% \times 40 A = 60 A$ . If the motor will not start with a 60 A breaker, the breaker rating is permitted to be increased to 150 A because this rating does not exceed 400% (see 430.52(C)(1), Exception No. 2(c) for motor full-load currents of 100 A or less).

**Feeder Short-Circuit and Ground-Fault Protection**

Example using non time-delay fuse:

The rating of the feeder protective device is based on the sum of the largest branch-circuit protective device for the specific type of device protecting the feeder. In the previous step above, the calculation for the 25-hp squirrel-cage motor results in the largest branch-circuit protective device:  $300\% \times 34 A = 102 A$  (therefore the next largest standard size, 110 A, would be used) plus the sum of the full-load currents of the other motors, or  $110 A + 40 A + 40 A = 190 A$ . The nearest standard fuse that does not exceed this value is 175 A (see 240.6, Table 430.52, and 430.62(A)).

Example using inverse time circuit breaker:

The rating of the feeder protective device is based on the sum of the largest branch-circuit protective device for the specific type of device protecting the feeder. The calculation for the 25-hp squirrel-cage motor results in the largest branch-circuit protective device.

$250\% \times 34 A = 85 A$ . The next larger standard size is 90 A, plus the sum of the full-load currents of the other motors, or  $90 A + 40 A + 40 A = 170 A$ . The nearest standard inverse time circuit breaker that does not exceed this value is 150 A [See 240.6, Table 430.52, and 430.62(A)]

**TABLES**

**NEC Table 310.15(B)(1) Ambient Temperature Correction Factors Based on 30°C (86°F)**

For ambient temperatures other than 30°C (86°F), multiply the ampacities specified in the ampacity tables by the appropriate correction factor shown below.

Ambient Temperature (°C)	Temperature Rating of Conductor			Ambient Temperature (°F)
	60°C	75°C	90°C	
10 or less	1.29	1.20	1.15	50 or less
11–15	1.22	1.15	1.12	51–59
16–20	1.15	1.11	1.08	60–68
21–25	1.08	1.05	1.04	69–77
26–30	1.00	1.00	1.00	78–86
31–35	0.91	0.94	0.96	87–95
36–40	0.82	0.88	0.91	96–104
41–45	0.71	0.82	0.87	105–113
46–50	0.58	0.75	0.82	114–122
51–55	0.41	0.67	0.76	123–131
56–60	—	0.58	0.71	132–140
61–65	—	0.47	0.65	141–149
66–70	—	0.33	0.58	150–158
71–75	—	—	0.50	159–167
76–80	—	—	0.41	168–176
81–85	—	—	0.29	177–185

**NEC Table 310.16 Ampacities of Insulated Conductors with Not More Than Three Current-Carrying Conductors in Raceway, Cable, or Earth (Directly Buried)**

*modified elsewhere in the Code*

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.104(A)]						Size AWG or kcmil
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	
	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, XHWN, USE, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, PFA, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, XHHN, Z, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, XHWN, USE	Types TBS, SA, SIS, THHN, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, XHHN	
COPPER			ALUMINUM OR COPPER-CLAD ALUMINUM				
18*	—	—	14	—	—	—	—
16*	—	—	18	—	—	—	—
14*	15	20	25	—	—	—	—
12*	20	25	30	15	20	25	12*
10*	30	35	40	25	30	35	10*
8	40	50	55	35	40	45	8
6	55	65	75	40	50	55	6
4	70	85	95	55	65	75	4
3	85	100	115	65	75	85	3
2	95	115	130	75	90	100	2
1	110	130	145	85	100	115	1
1/0	125	150	170	100	120	135	1/0
2/0	145	175	195	115	135	150	2/0
3/0	165	200	225	130	155	175	3/0
4/0	195	230	260	150	180	205	4/0
250	215	255	290	170	205	230	250
300	240	285	320	195	230	260	300
350	260	310	350	210	250	280	350
400	280	335	380	225	270	305	400
500	320	380	430	260	310	350	500
600	350	420	475	285	340	385	600
700	385	460	520	315	375	425	700
750	400	475	535	320	385	435	750
800	410	490	555	330	395	445	800
900	435	520	585	355	425	480	900
1000	455	545	615	375	445	500	1000
1250	495	590	665	405	485	545	1250
1500	525	625	705	435	520	585	1500
1750	545	650	735	455	545	615	1750
2000	555	665	750	470	560	630	2000

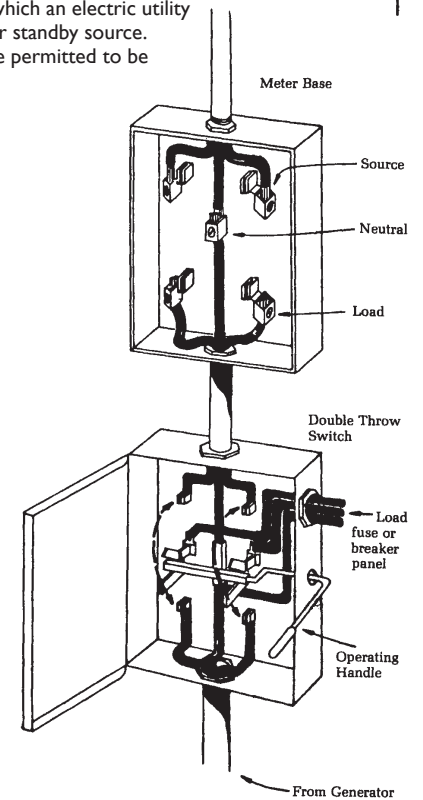
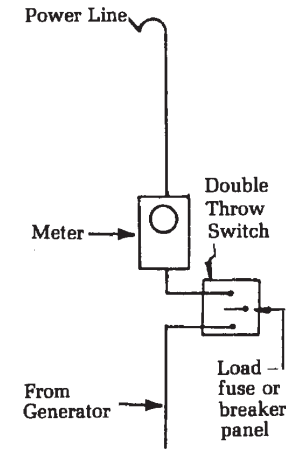
**NOTES:**  
 1. Section 310.15(B) shall be referenced for ampacity correction factors where the ambient temperature is other than 30°C (86°F).  
 2. Section 310.15(C)(1) shall be referenced for more than three current-carrying conductors.  
 3. Section 310.16 shall be referenced for conditions of use.  
 \* Section 240.4(D) shall be referenced for conductor overcurrent protection limitations, except as modified elsewhere in the Code.

**FOOTNOTE FOR TABLE 310.16:**

Unless specifically permitted in 240.4(E) or (G), the overcurrent protection shall not exceed 15 amperes for 14 AWG, 20 amperes for 12 AWG, and 30 amperes for 10 AWG copper, or 15 amperes for 12 AWG and 25 amperes for 10 AWG aluminum and copper-clad aluminum after any correction factors for ambient temperature and number of conductors have been applied. NEC 240.4(D)

**EMC Diagram 2. Double-Throw Transfer Switch Installation.**

Transfer equipment shall be suitable for the intended use and shall be listed, designed and installed so as to prevent the inadvertent interconnection of all sources of supply in any operation of the transfer equipment. (702.5(D)). Transfer equipment and electric power production systems installed to permit operation in parallel with the normal source shall also meet the requirements of Article 705 (702.5(E)). In other than dwelling units, the short-circuit current rating of the transfer equipment, based on the specific overcurrent protective device type and settings protecting the transfer equipment, shall be field marked on the exterior of the transfer equipment (702.5(C)). Transfer equipment shall be required for all standby systems subject to the requirements of NEC Article 702 and for which an electric utility supply is either the normal or standby source. Transfer switches shall not be permitted to be reconditioned (702.5(A)).



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**Table C.1 NEC Informative Annex C. Maximum Number of Conductors or Fixture Wires in Electrical Metallic Tubing (EMT) (Based on Chapter 9: Table 1, Table 4 and Table 5)**

Type	CONDUCTORS										
	Conductor Size (AWG kcmil)	Trade Size (Metric Designator)									
		½ (16)	¾ (21)	1 (27)	1¼ (35)	1½ (41)	2 (53)	2½ (63)	3 (78)	3½ (91)	4 (103)
RHH, RHW, RHW-2	14	4	7	11	20	27	46	80	120	157	201
	12	3	6	9	17	23	38	66	100	131	167
	10	2	5	8	13	18	30	53	81	105	135
	8	1	2	4	7	9	16	28	42	55	70
	6	1	1	3	5	8	13	22	34	44	56
	4	1	1	2	4	6	10	17	26	34	44
	3	1	1	1	4	5	9	15	23	30	38
	2	1	1	1	3	4	7	13	20	26	33
	1	0	1	1	1	3	5	9	13	17	22
	1/0	0	1	1	1	2	4	7	11	15	19
	2/0	0	1	1	1	2	4	6	10	13	17
	3/0	0	0	1	1	1	3	5	8	11	14
	4/0	0	0	1	1	1	3	5	7	9	12
	250	0	0	0	1	1	1	3	5	7	9
	300	0	0	0	1	1	1	3	5	6	8
	350	0	0	0	1	1	1	3	4	6	7
	400	0	0	0	1	1	1	2	4	5	7
	500	0	0	0	0	1	1	2	3	4	6
	600	0	0	0	0	1	1	1	3	4	5
	700	0	0	0	0	0	1	1	2	3	4
	750	0	0	0	0	0	1	1	2	3	4
800	0	0	0	0	0	1	1	2	3	4	
900	0	0	0	0	0	1	1	1	3	3	
1000	0	0	0	0	0	1	1	1	2	3	
1250	0	0	0	0	0	0	1	1	1	2	
1500	0	0	0	0	0	0	1	1	1	1	
1750	0	0	0	0	0	0	1	1	1	1	
2000	0	0	0	0	0	0	1	1	1	1	
TW, THHW, THW, THW-2	14	8	15	25	43	58	96	168	254	332	424
	12	6	11	19	33	45	74	129	195	255	326
	10	5	8	14	24	33	55	96	145	190	243
	8	2	5	8	13	18	30	53	81	105	135
RHH*, RHW*, RHW-2*	14	6	10	16	28	39	64	112	169	221	282
	12	4	8	13	23	31	51	90	136	177	227
	10	3	6	10	18	24	40	70	106	138	177
	8	1	4	6	10	14	24	42	63	83	106

Note: \* Types RHH, RHW and RHW-2 without outer covering.

**Agricultural Wiring Handbook Table 8. Single-Phase A.C. Motor Currents (Full Load and 125% of Full Load)**

Motor Horsepower	115 Volts		208 Volts		230 Volts	
	Full Load (Amps)	125% Full Load (Amps)	Full Load (Amps)	125% Full Load (Amps)	Full Load (Amps)	125% Full Load (Amps)
1/6	4.4	5.5	2.4	3	2.2	2.8
1/4	5.8	7.2	3.2	4	2.9	3.6
1/3	7.2	9.0	4.0	5	3.6	4.5
1/2	9.3	12.2	5.4	6.8	4.9	6.1
3/4	13.8	17.2	7.6	9.5	6.9	8.6
1	16	20	8.8	11	8.0	10
1-1/2	20	25	11	13.8	10	12.5
2	24	30	13.2	16.5	12	15
3	34	42	18.7	23.4	17	21
5	56	70	30.8	38.5	28	35
7-1/2	80	100	44	55	40	50
10	100	125	55	68.8	50	62

(Derived from NEC Table 430.248)

Source: Agricultural Wiring Handbook, 17th Edition available from www.ElecLearning.org. The Agricultural Wiring Handbook is owned by R.S. Hiatt, LLC.



**EMC****MAIN OFFICE**

Altamaha EMC  
Amicalola EMC  
Blue Ridge Mountain EMC  
Canoochee EMC  
Carroll EMC  
Central Georgia EMC  
Coastal Electric Cooperative  
Cobb EMC  
Colquitt EMC  
Coweta-Fayette EMC  
Diverse Power, Inc.  
Excelsior EMC  
Flint Energies  
Grady EMC  
GreyStone Power Corp.  
Habersham EMC  
Hart EMC  
Irwin EMC  
Jackson EMC  
Jefferson Energy Cooperative  
Little Ocmulgee EMC  
Middle Georgia EMC  
Mitchell EMC  
North Georgia EMC  
Ocmulgee EMC  
Oconee EMC  
Okefenoke Rural EMC  
Planters EMC  
Rayle EMC  
Satilla Rural EMC  
Sawnee EMC  
Slash Pine EMC  
Snapping Shoals EMC  
Southern Rivers Energy  
Sumter EMC  
Three Notch EMC  
Tri-County EMC  
Tri-State EMC  
Upton EMC  
Walton EMC  
Washington EMC

Lyons  
Jasper  
Young Harris  
Reidsville  
Carrollton  
Jackson  
Midway  
Marietta  
Moultrie  
Palmetto  
LaGrange  
Metter  
Reynolds  
Cairo  
Douglasville  
Clarksville  
Hartwell  
Ocilla  
Jefferson  
Wrens  
Alamo  
Vienna  
Camilla  
Dalton  
Eastman  
Dudley  
Nahunta  
Millen  
Washington  
Alma  
Cumming  
Homerville  
Covington  
Barnesville  
Americus  
Donalsonville  
Gray  
Blue Ridge  
Thomaston  
Monroe  
Sandersville



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