Code Check Electrical 6th Edition is a field guide to common code issues in residential electrical installations. It is based on the 2011 National Electrical Code—the most widely used electrical code in the United States—and the 2009 International Residential Code. Before beginning any electrical project, check with your local building department. In addition to a model code, energy codes and special rules from utility companies could also apply.

Each code line in Code Check Electrical references the two codes named above. Many building jurisdictions use older versions of the codes. If you are in an area that still uses the 2008 NEC, look in the “09 IRC” column of code references to see if the item applies in your area and use the table on p.61 to see changes that were made in the 2008 NEC, 2009 IRC, and 2011 NEC.

When the IRC does not reference a particular rule, the NEC might apply, even where the IRC is the adopted code. The IRC states that items not specifically mentioned in it must comply with the NEC. This applies to issues such as old wiring, outside feeders, and photovoltaics, which are not covered in the IRC.

Thanks to Hamid Naderi, International Code Council, for his invaluable editorial input.

For information on electrical fundamentals and theory, visit: http://www.codecheck.com/cc/OhmsLaw.html.

HOW TO USE CODE CHECK ELECTRICAL

Every IRC code citation, and every figure or table reference, is a hyperlink. Clicking on the figure or table reference will take you to the page of the book where it is located. Clicking the “restore previous view” button above takes you back to the page you had been viewing. If you have an internet connection, clicking on an IRC code citation opens a browser window to the text of the code. For copyright reasons, that cannot be done with the NEC citations.

Each text line ends with two code citations. The code numbers on the left, with straight brackets, refer to the 2009 IRC. The code numbers on the right, in braces, refer to the 2011 NEC. As in the following example from p.9:

☐ Max 6 disconnects to shut off power_________________ [3601.7] {230.71}
This line states that there can be no more than 6 disconnects to shut off the power, and the rule is found in 3601.7 of the IRC and 230.71 of the NEC.

An “EXC” at the end of a line means that an exception—or exceptions—to the rule will follow in the next line, as on p.17:

☐ Size per service conductor size T5 EXC __________[3603.4] {250.66} 
  • 6 AWG Cu largest size GEC needed if ending at rod[T3603.1] {250.66A}
This states that the grounding electrode conductor size is based on the size of the service conductors, in accordance with Table 5, except that the portion of the grounding electrode conductor that solely serves a ground rod need never be larger than 6 AWG.
Significant code changes are highlighted by a code citation in a different color. The superscript after the code citation refers to the table on p.61. The following example is from p.29:

- GFCIs req’d to be in readily accessible locations {n/a} [210.8A]¹⁸

GFCI devices must be located in an area where they remain readily accessible. The rule is not in the IRC. In the NEC it is a change in the 2011 code, summarized as change #19 in Table 23 on p.61.

Text lines ending in OR mean that an alternative rule follows in the next line, as on p.32:

- Separate 20A circuit for bath receptacles only OR [3703.4] (210.11C3)
- Dedicated 20A circuit to each bathroom [3703.4X] (210.11C3X)

A separate 20-amp circuit must be supplied for no other purpose than the bathroom receptacles. Alternatively, each bathroom can be supplied with its own 20-amp circuit, and then other outlets in that bathroom (such as lights) could be on the circuit.

An “n/a” in a code line means the rule is not applicable to that particular code.

**ABBREVIATIONS**

| A  | = amp(s), amperage, amps, such as a 15A breaker |
| AC | = air conditioning |
| AC | = alternating current |
| AC | = armored cable, a.k.a. “BX” |
| AFCI | = arc-fault circuit interrupter |
| AHJ | = Authority Having Jurisdiction |
| Al | = aluminum |
| AMI | = in accordance with manufacturer’s instructions |

| AWG | = American Wire Gauge |
| CATV | = cable television |
| CO | = carbon monoxide |
| cu. | = cubic, as in cu. in. |
| Cu | = copper |
| DC | = direct current |
| EGC | = equipment grounding conductor |
| EMT | = electrical metallic tubing |
| ENT | = electrical nonmetallic tubing, a.k.a. “Smurf tubing” |

| EV | = electric vehicle |
| EXC | = exception(s) |
| FMC | = flexible metal conduit, a.k.a. “Greenfield” |
| ft. | = foot, feet |
| GEC | = grounding electrode conductor |
| GES | = grounding electrode system |
| GFCI | = ground-fault circuit interrupter |
| GFPE | = ground-fault protection of equipment |
| hp | = horsepower |
| IMC | = intermediate metal conduit |
| in. | = inch(es) |
| IRC | = International Residential Code |
| kcmil | = 1,000 circular mil units (conductor size) |
| L&L | = listed & labeled, listing & labeling |
| lb. | = pound(s) |
| LFMC | = liquidtight flexible metal conduit, a.k.a. “Sealtight” |
| LFNMC | = liquidtight flexible nonmetallic conduit |
| manu | = manufacturer(s) |
| max | = maximum |
| MC | = metal-clad cable |
| min | = minimum |
| NEC | = National Electrical Code |
| NFPA | = National Fire Protection Association |
| NM | = nonmetallic-sheathed (cable) |
| OCPD | = overcurrent protection device (breaker or fuse) |
| PV | = photovoltaic |
| PVC | = rigid polyvinyl chloride conduit |
| req | = require, requiring, requirement |
| req’d | = required |
| req’s | = requires |
| RMC | = rigid metal conduit |
| SCCR | = short circuit current rating |
| SE | = service entrance cable |
| SFD | = single-family dwelling |
| sq. | = square, as in sq. in. |
| temp | = temperature |
| UF | = underground feeder cable |
| USE | = underground service entrance cable |
| TR | = tamper-resistant |
| V | = volt(s), such as a 120V circuit |
| VA | = volt-ampere(s), units of apparent power |
| W | = watt(s), units of true (useful) power |
| WR | = weather-resistant |
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GLOSSARY OF ELECTRICAL TERMS

Accessible, as applied to wiring methods: Not permanently concealed or enclosed by building construction.

Accessible, as applied to equipment: Capable of being removed or exposed without damaging the building finish or structure. A piece of equipment can be considered accessible even if tools must be used or other equipment must be removed to gain access to it.

Accessible, readily: Capable of being reached quickly for operation or inspection without the necessity of using tools to remove covers, resorting to ladders, or removing other obstacles.

Alternating current (AC): Current that flows in one direction and then in the other in regular cycles, referred to as frequency or Hertz.

Apparent power: See “Power.”

Approved: Acceptable to the authority having jurisdiction (AHJ). The AHJ will usually approve materials that are listed and labeled.

Arc-fault: An electric current propagated through air.
  • Arc-Fault Circuit Interrupter (AFCI): A device intended to provide protection from the effects of arc faults by recognizing characteristics unique to arcing and by functioning to de-energize the circuit when an arc fault is detected.
  • AFCI, branch/feeder type: “First generation” AFCI devices capable of interrupting parallel arcing faults. They do not meet the present code standard.
  • AFCI, combination type: An AFCI meeting the standard for interrupting both series and parallel arcs.

Authority Having Jurisdiction (AHJ): The building official or persons authorized to act on his or her behalf.

Bonded, bonding: Connected to establish continuity and conductivity.

Branch circuit: The circuit conductors between the final overcurrent protection device (OCPD) (breaker or fuse) protecting the circuit and the outlet or outlets.
  • Branch circuit, general purpose: Branch circuit that supplies 2 or more receptacles or outlets for lighting and appliances.
  • Branch circuit, individual: Branch circuit supplying only 1 piece of equipment.
  • Branch circuit, multiwire, residential: Branch circuit consisting of 2 hot conductors having 240V potential between them and a grounded neutral having 120V potential to each hot conductor F17.
  • Branch circuit, small appliance: Branch circuit supplying portable household appliances in kitchens and related rooms and that has no permanently installed equipment connected to it (see p.33 for exceptions).

Clothes closet: A non-habitable room or space intended primarily for storage of garments & apparel F37.

Controller: A device to directly open and close power to a load.

Derating: A reduction in the allowable ampacity of conductors because of ambient temperatures > 86°F, or more than 3 current-carrying conductors in the same race-way, or for cables without spacing between them.

Device: A piece of equipment that carries or controls electrical energy as its primary function, such as a switch, receptacle, or circuit breaker.

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

Equipment grounding conductor (EGC): A wire or conductive path that limits voltage on metal surfaces and provides a path for fault currents F16.

Feeders: Conductors supplying panelboards other than service panels.

Flexibility after installation: Anticipated movement after initial installation, such as that caused by motor vibration or equipment repositioning.

Gooseneck: A curve at the top of a service entrance cable designed to prevent water from entering the open end of the cable.

Ground: The earth.

Grounded conductor: A current-carrying conductor that is intentionally connected to earth (a neutral).

Grounding electrode conductor (GEC): A conductor used to connect the service neutral or the equipment to a grounding electrode or to a point on the grounding electrode system F6.
Ground fault: An unintentional connection of a current-carrying conductor to equipment, earth, or conductors that are not normally intended to carry current.

* Ground-Fault Circuit Interrupter (GFCI): A device to protect against shock hazards by interrupting current when an imbalance of 6 milliamps or more is detected.
* Ground-Fault Protected Equipment (GFPE): A device to protect equipment from ground faults and allowing higher levels of leakage current than a GFCI.

Hertz: A measure of the frequency of AC. In North America, the standard frequency is 60 Hertz.

Individual branch circuit: See “Branch circuit, individual.”

Interrupting rating: The highest current a breaker or fuse can interrupt without sustaining damage.

Lighting outlet: An outlet intended for the direct connection of a lampholder or a luminaire.

Load: The demand on an electrical circuit measured in amps or watts.

Location, damp: An area protected from the weather, yet subject to moderate degrees of moisture, such as a covered porch.

Location, dry: A location not normally subject to dampness or wetness.

Location, wet: All areas subject to direct saturation with water, and all conduits in wet outdoor locations or underground in or concrete or masonry in earth contact.

Luminaire (formerly lighting fixture): A complete lighting unit including parts to connect it to the power supply, and possibly parts to protect or distribute the light source. A lampholder, such as a porcelain socket, is not itself a luminaire.

Neutral conductor: The conductor connected to the neutral point of a system that is intended to carry current under normal conditions F17.

Open conductors: Individual conductors not contained within a raceway or cable sheathing, such as a typical service drop.

Outlet: The point on a wiring system at which current is taken to supply equipment. A receptacle or a box for a lighting fixture is an outlet; a switch is not an outlet.

Overcurrent: Any current in excess of the rating of equipment or conductor insulation. Overcurrents are produced by overloads, ground faults, or short circuits.

Overfusing: A fuse or breaker that has an overload rating greater than allowed for the conductor it is protecting.

Overload: Equipment drawing current in excess of the equipment or conductor rating and in such a manner that damage would occur if it continued for a sufficient length of time. Short circuits and ground faults are not overloads.

Panelboard: The “guts” of an electrical panel; the assembly of bus bars, terminal bars, etc., designed to be placed in a “cabinet.” What is commonly called an electrical panel or load center is, by NEC terms, a panelboard mounted in a cabinet F16.

Power: There are 2 designations for AC electrical power. Apparent power (input) is expressed in V × A. True power (useful output) is expressed in watts.

Service: The conductors and equipment providing a connection to the utility F2.

Service drop: The overhead conductors supplied by the utility F2.

Service entrance conductors: The conductors from the service point to the service disconnect.

Service equipment: The equipment at which the power conductors entering the building can be switched off to disconnect the premises’ wiring from the utility power source. A meter can be a part of or separate from the service equipment.

Service lateral: Underground service entrance conductors.

Service point: The connection or splice point at which the service drop and service entrance meet—it is the handoff between the utility and the customer.

Short circuit: A direct connection of current-carrying conductors without the interposition of a load, resulting in high levels of current.

Short Circuit Current Rating (SCCR): The amount of current that panelboards and switchboards must be able to carry during a short circuit condition without sustaining damage. See “Interrupting rating”

Snap switch: A typical wall switch, including 3-way and 4-way switches.

Ufer: a concrete-encased grounding electrode, named after the developer of the system, Herbert Ufer F6.

Unit switch: A switch that is an integral part of an appliance.

Within sight (also called “in sight”): Visible, unobstructed, and not more than 50 ft. away.
OVERHEAD SERVICE DROP CLEARANCES

Service drop conductors typically have no outer jacket for physical protection and no overload protection at their source. They are protected by isolation and proper clearances. The codes specify minimum clearances, and the serving utility may have different rules that override the code. Check with your local jurisdiction to determine any variations from the standard clearances below.

**Vertical above Roof F2**
- <4-in-12 slope: min 8 ft. **A** EXC [3604.2.1] (230.24A)
  - 3 ft. OK if roof area guarded or isolated [n/a] (230.24AX5)
- ≥ 4-in-12 slope: min 3 ft. **G** EXC [3604.2.1X2] (230.24AX2)
  - 18 in. OK for ≤4 ft. over eaves **E** [3604.2.1X3] (230.24AX3)
- Maintain req’d distance above roof for 3 ft. past edge EXC [3604.2.1] (230.24A)
  - Edge clearance above roof is not req’d when attached to side of building [3604.2.1X4] (230.24AX4)

**Vertical above Grade F2**
- 10 ft. above final grade to lowest point of drip loop [3604.2.2] (230.24B1)
- Area accessible only to pedestrians: 10 ft. **H** [3604.2.2] (230.24B1)
- General above grade & driveways: 12 ft. **J** [3604.2.2] (230.24B2)
- Above roads or parking areas subject to truck traffic: 18 ft. **B** [3604.2.2] (230.24B4)
- Any direction from swimming pool water: 22½ ft. **[4203.5] (4203.5) (680.8A)

**Openings & Communication Wires F2**
- Vertical above decks & balconies: 10 ft. **C** [n/a] (230.9B)
- From side of area above decks & balconies: 3 ft. **D** [3604.1] (230.9A)
- Below or to sides of openable window: 3 ft. **F** [3604.1] (230.9A)
- Communications wire ≥ 12 in. to parallel power wires **[800.44A4] (800.44A)

The clearances from windows & doors apply to open conductors & not to conductors contained inside a raceway or a cable with an overall outer jacket. The codes do not have a requirement for min. clearance of open conductors above a window. Check to see if your local utility has a requirement.
The connection between the service drop or lateral and the permanently installed building wiring is typically considered the “service point”—the handoff from the utility to the customer. From that point to the service equipment, the conductors are referred to as service entrance conductors. Though the utility does not have exclusive control of these conductors, they may still have jurisdiction over them, including the size of conduits and the placement of metering equipment.

**General**  
09 IRC 11 NEC
- Wire size for SFD per T10 \[T3603.1\] (T310.15B6)  
- Min wire size for SFD 4 AWG Cu or 2 AWG Al \[T3603.1\] (T310.15B6)  
- Conductors & cables exposed to sunlight L&L as sunlight-resistant or covered with material L&L as sunlight-resistant \[3605.6\] (310.8D)  
- Identify (white marking or tape) neutral at both ends \[3407.1\] (200.6B)  
- Service heads/goosenecks above attachment point EXC \[3605.9.3\] (230.54C)  
  - Attachment within 24 in. OK when necessary \[3605.9.3X\] (230.54CX)  
- No branch circuits or feeders in same raceway with service conductors \[3601.4\] (230.7)  
- Form drip loop in conductors \[3605.9.5\] (230.54F)  
- Individual open conductor insulating supports min 2 in. from building surfaces \[n/a\] (230.51C)

**Service Entrance Conductors**

- Protect SE cables subject to damage with metal conduit, PVC-80, EMT, or other approved means \[F58,59,63\] \[3605.5\] (230.50B)  
- Secure SE cable every 30 in. & 12 in. from terminations \[3605.5\] \[3605.7\] (230.51A)  
- Raintight service head or taped gooseneck req’d \[3605.9.2\] (230.54B)  
- Seal SE cable to prevent water entry to box \[3605.9.6\] (230.54G)

### COMMON UTILITY COMPLAINTS

Aside from code issues, utility company rules and standards must be followed. Most utilities publish their gas and electrical service requirements or post them online. The following items are not in the codes, and you should consult with your local utility to comply with their rules on these issues.

**Meter Base(s)**
- Too close to gas meter
- Height incorrect
- Barrier post (bollard) needed to protect meter from vehicles on driveway
- Not readily accessible to meter readers

**Service Entrance Conductors**
- Insufficient conductor length at service head
- Insufficient clearance to communication lines
- Insufficient clearance above windows
- Height above standing surface (roof deck) too low
- Trees under service drop
- Customer performing own cutover from old service to new
SERVICE PANELS

The term "service equipment" refers to the switches, circuit breakers, or fuses that disconnect power from the utility at the customer’s end of the service conductors. A meter is not considered service equipment, though it is sometimes in the same enclosure as the service equipment. As with all electrical equipment that might req access for maintenance, examination, or repair, sufficient working space must be maintained around service equipment.

**General**

- Enclosure L&L as suitable for service equipment [3601.6.1] (230.66)
- Max 6 disconnects to shut off power [3601.7] (230.71)
- Service disconnects labeled as such [3601.6.1] (230.70B)
- In multiple-occupancy building, each occupant must have ready access to disconnect EXC [3601.6.2] (230.72C)
  - OK for management to have only access to service disconnect supplying > 1 occupancy [n/a] (230.72CX)
- Max height of breaker 6 ft. 7 in. [4001.6] (240.24A)
- Provide working space F3 [3405.2] (110.26)

WORKING SPACE

Working space around equipment is essential for worker safety. These requirements apply to any electrical equipment that might require examination, adjustment, servicing, or maintenance while energized. The spaces around electrical equipment should not be used for storage.

**General F3**

- Front working clearance min 36 in. deep [3405.2] (110.26A1)
- Distance measured from face of enclosure or live parts [3405.2] (110.26A1)
- Work space extends to floor EXC [3405.2] (110.26A3)
  - Related equipment may extend 6 in. beyond panel front [3405.2] (110.26A3)
- Clear width min 30 in. wide or width of equipment [3405.2] (110.26A2)

**FIG. 3**

Working Space around Equipment

3 ft. min. depth measured from front edge of panel

Panel door must be openable to at least 90°.

Working space height 6 ft. 6 in., or height of equipment, whichever is greater

Req’d working space must extend to floor or grade.
SEPARATE BUILDINGS

Care must be taken to avoid objectionable currents on the grounding paths between buildings supplied by a common service. Install separate insulated neutral conductors, rather than using the grounding conductors as neutrals. The IRC does not address outside feeders and separate buildings except for the rules on grounding.

Outside Feeders

- Trees may not support overhead conductors (225.26)
- Overhead feeder height rules same as services (225.18&19)
- Provide proper cover for buried cable or conduit (300.5)
- Each building or structure req’s GES EXC F4 (250.32A)
  - Building or structure with only 1 branch circuit with EGC (250.32AX)
- Multiwire circuit considered 1 circuit for above rule (250.32AX)
- Seal underground raceways where entering building (225.27)
- Max 1 feeder or branch circuit to each building (225.30)
- Max 1 feeder or branch circuit back to original building (225.30)
- Disconnect req’d at each building F4 (225.31)
- Disconnect must be rated as service equipment EXC (225.36)
  - Garages or outbuildings snap switches or 3-ways OK (225.36X)
- EGC (4-wire feeder) req’d between buildings EXC (250.32B)
  - Existing installations to separate buildings with no continuous metal paths, e.g., metal water pipe, etc., between 2 structures (250.32BX)
- Do not bond neutral to EGC or enclosure in subpanel (250.32B)

FIG. 4

Separate Buildings

Each building or structure containing more than 1 branch circuit req’s its own GES.

Cover depth per T1

Feeders to separate buildings req an insulated neutral in addition to an EGC.

Panels in separate buildings are subpanels F16.

MULTI-METER SERVICES

Services to 2-family and multi-family dwellings might come to a multi-meter panel, or to a “hot gutter” with splices ahead of any overcurrent protection. See p.29 for bonding requirements on such services

General

- Only 1 service per building (3601.2)
- Provide each occupant access to service disconnect (3601.6.2)
- Bonding req’d at hot gutters F11,12 (3609.2)
- Service disconnects grouped in 1 location (3601.7)
- Service conductors may not pass through interior of 1 building to another building (3601.3)

SEPARATE BUILDINGS ◆ MULTI-METER SERVICES
**TEMPORARY WIRING**

Safety is the highest priority during construction, and GFCI protection is required for all 120V receptacles on construction sites. Some jurisdictions allow a limited number of temporary circuits from a service installation prior to the rough wiring stage (before weather protection). The IRC does not address temporary wiring.

**General**

- Allowed only during construction, repair, remodeling & similar (590.3A)
- Service conductor clearances same as permanent F2 (590.4A)
- Support & brace pole to utility specifications (utility) (590.4C)
- No receptacles on branch circuits supplying temporary lighting (590.4D)
- All multiwire circuits req handle ties (590.4E)
- Lampholders req guards (590.4F)
- Splices in NM cable or MC cable OK without splice box (590.4G)
- Protect cords & cables from accidental damage (590.4H)
- GFCI req’d on all 125V 15, 20 & 30A temporary receptacles EXC 590.6A1
  - Listed GFCI cord-sets OK on existing permanent receptacles (590.6A2)

**UNDERGROUND WIRING**

Underground wiring methods include individual insulated conductors, cables rated for underground installation, and raceways. The most common method is PVC conduit. If there is a significant difference in elevation between the ends of an underground raceway, it may be necessary to install a pull-box for drainage near the downhill end.

**General**

- Burial depth must provide cover per T1, F5 (3803.1)
- Warning ribbon in trench 12 in. above service laterals F5 (3803.2)
- Direct-buried cables or conductors must be protected by enclosures or raceways from req’d burial depth or 18 in. (whichever is less) to termination above grade or 8 ft. high (whichever is less) F52 (3803.3)
- Protect conductors & cables emerging from grade with RMC, IMC, PVC-80, or equivalent F52 (3803.4)
- OK to splice or tap direct-buried conductors without boxes with splicing means listed for the purpose (3803.5)
- Backfill smooth granular material—no rocks (3803.6)
- Bushing req’d between underground cables or individual conductors & protective conduit F52 (3803.7)
- All conductors of circuit in same trench or raceway__ (3803.8)
- Allow provision for earth movement (settlement or frost) using “S” loops, flexible connections &/or expansion fittings_ (3803.9)

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**FIG. 5**

Conductors in Trench

- Cover depth (measure from top of conduit)
- Plywood to protect conduit from rocks (optional)
- Smooth, granular material
- Warning ribbon 12 in. above service lateral
### Service & Feeder Load Calculations

The calculation methods in the codes take into account that not all of the possible electrical loads will be used at the same time. Each of the calculation methods allows the use of “demand factors.” The “long form,” shown below and in T2, is the most common calculation method. For information on multifamily load calculations, refer to the Code Check website at www.codecheck.com.

#### Load Calculation Steps (Long Form) T2

1. Determine the sq. ft. area of the residence & multiply by 3W (exclude garage & covered patios) __________ (220.12)
2. Min of 2 small-appliance circuits at 1,500W each __________ (220.52A)
3. Each additional small appliance circuit at 1,500W __________ (220.52A)
4. Minimum 1 laundry circuit at 1,500W __________ (220.52B)
5. Enter total of appliance circuits & general lighting __________ (220.42)
6. First 3,000W counted at 100% (carries to right column) __________ (T220.42)
7. Subtract 3,000 from amount in line 5 & enter difference in middle column. Multiply the middle column amount by 35% & enter in right column __________ (T220.42)
8. Range loads are calculated at nameplate rating. If a single range is > 8,000W & <12,000W, it still counts as 8,000W (8kW); > 12,000W, add 5% of each additional 1,000W of nameplate load. Nameplates of a counter-mounted range & up to 2 wall ovens can be added together & computed as if they were 1 range. Enter in right column __________ (220.60)
9. Enter dryer circuit at 5,000W (or nameplate rating if greater) __________ (220.54)
10. Enter larger of fixed space heating or AC load __________ (220.60)
11–18. Enter nameplate ratings of appliances that are fixed in place. For appliances rated in amps, multiply amps times voltage to determine watts. If nameplate ratings unknown, use estimates in T4 __________ (220.53)
19. Enter total load of fixed appliances __________ (220.53)
20. If there are < 4 fixed appliances, enter number from line 19 in right column __________ (220.53)
21. If there are ≥ 4 fixed appliances, multiply line 19 by 75% & enter in right column __________ (220.53)
22. Add 25% of the largest motor load. Skip this step if a nameplate rated AC is largest load since number has already been factored into nameplate min conductor ampacity __________ (220.18A)
23. Add numbers in third column __________ (220.40)
24. Divide line 23 by 240 to find req’d min amperage __________ (220.40)

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### Table 1: MIN. COVER REQUIREMENTS IN TRENCH [T3803.1] & (300.5)

<table>
<thead>
<tr>
<th>Cover</th>
<th>UF Cable</th>
<th>Rigid Metal</th>
<th>PVC</th>
<th>GFCI ≤ 20A Circuit</th>
<th>≤ 30V</th>
</tr>
</thead>
<tbody>
<tr>
<td>General</td>
<td>24 in.</td>
<td>6 in.</td>
<td>18 in.</td>
<td>12 in.</td>
<td>6 in.</td>
</tr>
<tr>
<td>2 in. concrete</td>
<td>18 in.</td>
<td>6 in.</td>
<td>12 in.</td>
<td>6 in.</td>
<td>6 in.</td>
</tr>
<tr>
<td>Under building</td>
<td>0A</td>
<td>0</td>
<td>0</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>4 in. slab, no vehicles</td>
<td>18 in.</td>
<td>4 in.</td>
<td>4 in.</td>
<td>6 in.</td>
<td>6 in.</td>
</tr>
<tr>
<td>Street</td>
<td>24 in.</td>
<td>24 in.</td>
<td>24 in.</td>
<td>24 in.</td>
<td>24 in.</td>
</tr>
<tr>
<td>Driveway</td>
<td>18 in.</td>
<td>18 in.</td>
<td>18 in.</td>
<td>12 in.</td>
<td>18 in.</td>
</tr>
</tbody>
</table>

A. MC cable identified for direct burial also OK in 2011 NEC.
## TABLE 2 LOAD CALCULATIONS [T3704.2(1)] & (220.40)

### General Lighting & Receptacle Loads
1. Sq. ft. × 3W

### Small Appliance & Laundry Loads
2. 2 small appliance circuit 3,000
3. Additional small appliance
4. Laundry circuit 1,500
5. Subtotal general light, small appliance & laundry
6. First 3,000W @ 100% 3,000 3,000
7. Balance @ 35% × .35 =

### Special Appliance Loads
8. Range 8,000 up to 12kW nameplate
9. Dryer 5,000 (or nameplate if >)
10. Heating or AC @ 100%

### Appliances Fastened in Place
11. Water heater
12. Microwave
13. Dishwasher
14. Compactor
15. Disposer
16. Attic fan
17. Spa—per manu.
18. Other
19. Subtotal
20. If <4 appliances, enter subtotal @100% or
21. If ≥4 appliances, enter subtotal × 75%
22. Largest motor × 25%
23. Total load
24. Total load ÷ 240V = SERVICE AMPS

### Notes
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- SERVICE & FEEDER LOAD CALCULATIONS
The “optional” method is simpler and can be used to determine if an existing service is adequate for expansion. In the NEC, these methods apply to both services and feeders. In the IRC, the “long form” method, T2, is used for feeders per section E3704 and the “optional” method, T3, is used for services per section E3602. NEC 220.83 provides a specific method for evaluating the adequacy of an existing service for new air-conditioning loads.

**Size Requirements—General**

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Code Ref.</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min size for SFD 100A</td>
<td>[3602.1]</td>
<td>(230.79C)</td>
</tr>
<tr>
<td>Service conductors adequate for load served</td>
<td>[3602.1]</td>
<td>(230.42)</td>
</tr>
<tr>
<td>Feeders adequate for load served</td>
<td>[3701.2]</td>
<td>(215.2A1)</td>
</tr>
<tr>
<td>Branch circuits adequate for load served</td>
<td>[3701.2]</td>
<td>(210.19A1)</td>
</tr>
</tbody>
</table>

**TABLE 3**

<table>
<thead>
<tr>
<th>Min. Size of Electrical Service [T3602.2] &amp; (220.82)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Indoor sq. ft. × 3VA/ft.</td>
</tr>
<tr>
<td>2. Min. 2 small appliance circuits @ 1,500VA each</td>
</tr>
<tr>
<td>3. Laundry circuit @ 1,500VA</td>
</tr>
<tr>
<td>4. Nameplate VA of fixed appliances:</td>
</tr>
<tr>
<td>Dryer @ 5,000VA</td>
</tr>
<tr>
<td>Oven(s)</td>
</tr>
<tr>
<td>Cooktop</td>
</tr>
<tr>
<td>Water heater</td>
</tr>
<tr>
<td>Dishwasher</td>
</tr>
<tr>
<td>Disposer</td>
</tr>
<tr>
<td>Other</td>
</tr>
<tr>
<td>5. Subtotal</td>
</tr>
<tr>
<td>6. First 10,000VA @ 100%</td>
</tr>
<tr>
<td>7. Balance @ 40% (subtract line 6 from line 5) × .40=</td>
</tr>
<tr>
<td>8. Largest of heating or cooling load</td>
</tr>
<tr>
<td>8a. Nameplate rating(s) of air-conditioning &amp; cooling equipment OR</td>
</tr>
<tr>
<td>8b. Heat pump nameplate if no supplemental electric heat OR</td>
</tr>
<tr>
<td>8c. Continuous electric thermal storage @ nameplate rating OR</td>
</tr>
<tr>
<td>8d. 100% of heat pump nameplate rating plus 65% of supplemental electric heat or central electric heat OR</td>
</tr>
<tr>
<td>8e. Space heaters @ 65% of nameplate rating if &lt; 4 units OR</td>
</tr>
<tr>
<td>8f. Space heaters @ 40% of nameplate rating if ≥ 4 units</td>
</tr>
<tr>
<td>9. Total load in VA</td>
</tr>
<tr>
<td>10. Divide by 240 = minimum service rating</td>
</tr>
</tbody>
</table>
### TABLE 4  
**TYPICAL APPLIANCE LOADS**

*Use actual nameplate ratings when known. This table is for estimating purposes when appliances are not yet specified.*

<table>
<thead>
<tr>
<th>Appliance</th>
<th>Typical load (W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central AC or heat pump</td>
<td>1,800 per ton</td>
</tr>
<tr>
<td>Dishwasher</td>
<td>1,200</td>
</tr>
<tr>
<td>Food waste disposer</td>
<td>900</td>
</tr>
<tr>
<td>Trash compactor</td>
<td>1,200</td>
</tr>
<tr>
<td>Microwave</td>
<td>1,500</td>
</tr>
<tr>
<td>Central furnace</td>
<td>1,000</td>
</tr>
<tr>
<td>Central vacuum</td>
<td>1,500</td>
</tr>
<tr>
<td>Electric clothes dryer</td>
<td>5,000</td>
</tr>
<tr>
<td>Water heater</td>
<td>4,500</td>
</tr>
<tr>
<td>Electric cooktop</td>
<td>3,600</td>
</tr>
<tr>
<td>Single wall oven</td>
<td>4,800</td>
</tr>
<tr>
<td>Double wall oven</td>
<td>8,000</td>
</tr>
<tr>
<td>Pool pump</td>
<td>2,000</td>
</tr>
<tr>
<td>Well pump</td>
<td>2,000</td>
</tr>
</tbody>
</table>

**Optional Method (Short Form)**

1. 3W per ft. (exclude garage & covered patios) ____________ (220.82B1)
2. Min 2 small-appliance circuits at 1,500W each, each additional small appliance circuit at 1,500W ____________ (220.82B2)
3. Min 1 laundry circuit at 1,500W ____________ (220.82B2)
4. Nameplate ratings of fixed appliances (see T4 if ratings not known); these include full nameplate rating of ranges & ovens without applying reductions allowed in the “long form” method ____________ (220.82B3)
5. Enter sum of items 1-4 ____________ (220.82B)
6. 100% of first 10,000VA ____________ (220.82B)
7. Subtract line 6 from line 5, multiply by 40% & enter in right column ____________ (220.82B2)
8. Determine largest of the heating or cooling load. When using nameplate rating of heat pumps or AC, multiply “minimum circuit ampacity” times the voltage (240). If only size (tonnage) is known, refer to T4 ____________ (220.82C)
9. Add numbers in right column & enter total ____________ (220.82A)
10. Divide by 240 = amperage

**SERVICE & FEEDER LOAD CALCULATIONS**

15
GROUNDING ELECTRODES

Grounding electrodes are metal conducting objects through which a direct connection to earth is established. These electrodes provide a path for lightning and help reduce electrical noise on communications equipment. The most common grounding electrodes in residential construction are metal underground water piping, ground rods, and concrete-encased electrodes.

**Grounding Electrode System (GES) F6 09 IRC 11 NEC**

- Use all electrodes in F6 when present on premises. [3608.1] (250.50)
- Electrodes bonded together form a single system F6. [3608.1] (250.50)
- Size electrode bonding conductors per GEC rules. [3610.1] (250.53C)
- Underground gas pipe not OK as electrode. [3608.6] (250.52B1)

**Water Pipe 09 IRC 11 NEC**

- Metal water pipe if ≥10 ft. in direct contact with soil. [3608.1.1] (250.52A1)
- Bond around water meters, filters, etc. [3608.1.1] (250.53D1)
- Water pipe cannot be sole electrode. [3608.1.1] (250.53D2)
- Metal well casing that is not bonded to metal pipe (e.g., plastic water service from well) OK as electrode. [3608.1.1] (250.52A8)

**Pipes & Rods 09 IRC 11 NEC**

- Rods min 8 ft. in contact with soil. [3608.1.4.1] (250.53G)
- Pipe electrodes min 3/4 in. diameter. [3608.1.4] (250.52A5)
- Unlisted ground rods min 5/8 in. diameter. [3608.1.4] (250.52A5)
- Listed rods min 1/2 in. diameter. [3608.1.4] (250.52A5)
- Drive rods vertical & fully below grade. EXC. [3608.1.4.1] (250.53G)
  - If bedrock encountered, rod may be buried horizontally 21/2 ft. deep or driven at 45° angle. [3608.1.4.1] (250.53G)
  - Clamp above grade OK if protected F6-10. [3608.1.4.1] (250.53G)
- If rod resistance > 25 ohms, install 2nd rod min 6 ft. from first & bond to 1st rod. [3608.4] (250.56)

Recommended spacing 2x rod length, i.e., 16 ft.

**Concrete-Encased Electrode F6 09 IRC 11 NEC**

- Use where inside, no Al. [3608.1] (250.50)
- Ufer must be used if present during construction. [3608.1] (250.50)
- Ufer not req’d in existing building if concrete would have to be disturbed to gain access. [3608.1X] (250.50X)
- Ufer concrete encasement min 2 in. [3608.1.2] (250.52A3)
- OK to bond sections of rebar with ordinary steel tie wires. [3608.1.2] (250.52A3)
- Where multiple concrete-encased electrodes are present, only 1 req’d to be bonded to GES. [3608.1.2] (250.52A3)
- Metal building frame OK as electrode if bonded to Ufer or if ≥ of steel 10 ft. in contact with earth with or without concrete encasement. [3608.1.1] (n/a) (250.52A2)

**A GEC connects the system of metal grounding electrodes in earth to the electrical system. It must have adequate size and protection to withstand the environmental and electrical forces imposed on it. Individual conductors can be run to each electrode of the GES, or a single conductor can be run to one of them or to the conductor that bonds the electrodes to each other.**

**Locations 09 IRC 11 NEC**

- GEC must connect to EGCs, service entrance enclosures, service neutral & grounding electrodes. [3607.4] (250.24D)
- Connect to service neutral anywhere from service point to bonded neutral in service disconnect. [3607.2] (250.24A1)
- Bare Al not OK in masonry or earth. [3610.2] (250.64A)
- Where outside, no Al ≤ 18 in. of earth. [3610.2] (250.64A)
- Connection to metal water pipe that is part of GES not > 5 ft. after water entry to building. [3608.1.1] (250.52A1)
Grounding Electrode System (GES)

**Protection F7–10**
- 8 AWG must be protected by raceway or armor
- 6 AWG OK unprotected if not subject to damage & following building contour
- Bond each end of metal raceway enclosing GEC

**Size 09 IRC 11 NEC**
- Size per service conductor size
  - 6 AWG Cu largest size GEC needed if ending at rod
  - 4 AWG Cu largest size GEC needed if ending at Ufer

**Connections**
- No splices between service & GES EXC
- Listed irreversible compression connectors or exothermic welding OK
- GEC can connect to any electrode of GES
- Buried clamps L&L for direct burial (marked “DB”)
- Cu water tubing clamps L&L for Cu tubing
- Ufer clamps L&L for rebar & encasement
- Strap-type clamps suitable only for indoor telecommunications
- Max 1 conductor per clamp unless listed for more

**Connections must be accessible EXC Buried or encased connections**
- Note: Rebar can be brought through the top of a foundation in a protected location, such as the garage, to provide an accessible point for the GEC to attach to the Ufer. The GEC can also be brought into the foundation and connect to the Ufer with L&L clamps or by exothermic welding.

**TABLE 5**

<table>
<thead>
<tr>
<th>Cu Service Wire (AWG)</th>
<th>Al Service Wire (AWG)</th>
<th>GEC Cu (AWG)</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 2</td>
<td>≤ 1/0</td>
<td>8</td>
</tr>
<tr>
<td>1 or 1/0</td>
<td>2/0 or 3/0</td>
<td>6</td>
</tr>
<tr>
<td>2/0 or 3/0</td>
<td>4/0 or 250kcmil</td>
<td>4</td>
</tr>
<tr>
<td>4/0–350kcmil</td>
<td>&gt; 250–500kcmil</td>
<td>2</td>
</tr>
<tr>
<td>&gt; 350–600kcmil</td>
<td>&gt; 500–900kcmil</td>
<td>1/0</td>
</tr>
</tbody>
</table>
EQUIPMENT GROUNDING CONDUCTORS (EGCs)

EGCs limit the voltage on equipment enclosures and provide a path for fault current. Without EGCs, the conductive frame of an appliance could remain energized if there is a fault from an ungrounded “hot” conductor. Equipment grounding provides a low-impedance path so the overcurrent device will open the circuit. The equipment grounding system has a completely different purpose from the earth grounding system. In fact, earth plays no part in helping clear faults.

### General

- **09 IRC**
  - EGC must provide effective ground-fault current path \([3908.4]\) \((250.4A5)\)
  - Earth is not an effective ground-fault current path \([3908.5]\) \((250.4A5)\)
- **11 NEC**
  - **Size EGCs per T6** \([3908.12]\) \((250.122A)\)
  - RMC, IMC, EMT, AC cable armor, electrically continuous raceways & surface metal raceways OK as EGC
  - Wire EGCs can be bare, covered, or insulated \([F16]\) \((250.118)\)
  - Insulation on EGC green or green with yellow stripes \([n/a]\) \((250.119)\)
  - EGC > 6 AWG OK to strip bare for entire exposed length or use green tape or labels at termination of wire \([n/a]\) \((250.119A)\)
  - FMC & LFMC OK as EGC for non-motor circuits in combined lengths to 6 ft. with grounding fittings \([F60,61]\) \((250.118)\)
  - Remove paint from threads & other contact surfaces for field-installed equipment such as ground terminal bars \([n/a]\) \((3908.17)\) \((250.12)\)
- EGCs must run with other conductors of circuit EXC \([3406.7]\) \((300.3B)\)
  - Replacing nongrounding receptacles (see p.60) \([n/a]\) \((250.130C)\)
  - Neutral not to be used for grounding equipment EXC \([3908.7]\) \((250.142B)\)
  - Existing ranges & dryers \([n/a]\) \((250.142BX1)\)

---

**TABLE 6**

<table>
<thead>
<tr>
<th>Size of Breaker or Fuse Protecting Circuit (Amps)</th>
<th>Size of Cu EGC (AWG)</th>
<th>Size of Al EGC (AWG)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>14</td>
<td>12</td>
</tr>
<tr>
<td>20</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>30–60</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>70–100</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>110–200</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>400</td>
<td>3</td>
<td>1</td>
</tr>
</tbody>
</table>

---

FIG. 7 Armor-clad GEC

“Acorn” clamp

8 AWG must be protected.

6 AWG following the building contour does not need protection.

Clamp must bond metal sheath to GEC.

FIG. 8 Bare GEC

Clamp in Metal Raceway

Conductive protection must be bonded at both ends, making PVC a simpler solution.

FIG. 9 GEC in Metal Raceway

GEC in PVC

FIG. 10 GEC in PVC

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Bonding ensures electrical continuity to limit voltage potential between conductive components. On the line side (ahead of the main disconnect F15), it provides a path back to the utility transformer for faults on service conductors and to limit voltage potential to other systems, such as telephones or CATV. On the load side (after the main overcurrent protection F15), bonding and equipment grounding provide a path to clear faults and protect against shocks.

**Bonding & Equipment Grounding Methods 09 IRC 11 NEC**

- Use listed connectors, terminal bars, exothermic welding, machine screws engaging 2 threads or secured with nut, or thread-forming machine screws engaging 2 threads. Not OK to use sheet metal or drywall screws. (250.8A)
- Connections may not depend solely on solder. (250.8B)
- Clean nonconductive coatings from contact surfaces. (250.12)

**Line-Side Bonding F11, 12, 15 09 IRC 11 NEC**

- Bond all service equipment, raceways & cable armor. (250.92A)
- Bond metal GEC enclosures at each end. (250.64E)
- Threaded fittings OK for bonding service conduit. (250.92B2)
- Meyers hub OK for bonding service conduit. (250.92B2)
- Standard locknuts alone not sufficient. (250.92B2)
- Bonding locknuts if no remaining concentrics. (250.92B4)
- Jumpers req’d around concentric knockouts or reducing washers. (250.92B4)
- Service neutral can bond line-side equipment. (250.142A)
- Size line-side bonding jumpers per T5. (250.102C)
- Service enclosure main bonding jumper must connect enclosure, service neutral & equipment grounds. (250.24B)

**Load-Side Bonding 09 IRC 11 NEC**

- Bond any metal piping system capable of becoming energized, including hot & cold water & gas. (250.104)
- Size water pipe bonding per T5. (250.104A1)
- Size gas pipe bonding per T6. (250.104B)
- Bond metal well casings to EGC of pump motor. (250.112M)
Intersystem Bonding

- Min 6 AWG Cu bond to CATV or phone electrodes [3609.3] (800.100D)
- Bond lightning protection system to GEC [n/a] (250.106)
- Intersystem bonding access req’d external to service equipment & separate structure disconnecting means [3609.3] (250.94)
- Must accept min 3 conductors & be terminal or bonding bar electrically connected to meter or service enclosure [3609.3] (250.94)
- Existing buildings raceway or GEC OK as bond point [n/a] (250.94X)
- Bonding device not to interfere with enclosure cover [3609.3] (250.94)

In new construction, a terminal bar exterior to the service enclosure is req’d for connecting GECs of other systems. The bond to service equipment must be at least 6 AWG copper.

In existing construction, the phone and CATV bonding conductors can be secured to a tap on the grounding electrode conductor, or to the exterior of the service enclosure or to a nonflexible metallic service riser.
What is commonly called an “electrical panel” is referred to as a panelboard (NEC 408) inside a cabinet (NEC 312). See p.9 for working space requirements.

Clearances & Location  
- No panels or OCPDs in clothes closet or bathroom [3405.4] (240.24D&E)  
- No panels or OCPDs over steps of a stairway [3405.4]^a (240.24F)  
- OCPDs readily accessible & max height 6 ft. 7 in. [3705.7] (240.24A)

Enclosures  
- Enclosures weatherproof in wet or damp locations [3907.2] (312.2A)
- Surface-mounted wet or damp location metal enclosures min 1/4 in. air gap between enclosure & wall [3907.2] (312.2A)
- Equipment rated for dry or damp locations must be protected against damage from weather during construction [3404.5] (110.11)
- Open knockouts & twistouts durably filled EXC [3404.6] (110.12A)
  - Manu holes for mounting OK [3404.6&3907.5] (110.12A)
- Protect bus bars & other internal parts from contamination (paint or plaster) during construction [3404.7] (110.12B)
- Max setback in noncombustible wall 1/4 in. [3907.3] (312.3)
- Flush (no setback) in combustible (wood-frame) wall [3907.3] (312.3)
- Max plater gap at side of flush mount panel 1/8 in. [3907.4] (312.4)
- Field labeling to distinguish each circuit from all others [3706.2] (408.4)
- Labeling not based on transient conditions [3706.2]^10 (408.4)
- Unused (spare) breakers labeled [3706.2]^11 (408.4)

Grounding & Bonding  
- Bond neutral bar to enclosure & EGCs in service [3607.5] (250.24B)
- Isolate neutrals in subpanels [3607.2 & 3908.6] (250.24A5)
- Grounding terminal bar req’d if wire EGCs present [3607.2] (408.40)
- Continuity of neutral not to depend on enclosures [3406.11] (200.2B)
- Each neutral conductor req’s individual terminal [3706.4] (408.41)

OCPDs & Wiring  
- Panels req OCPD line side of bus [3706.3] (408.36)
- Breakers listed or classified AMI for panel [3403.3] (110.3B)
- Single-pole breakers with approved handle ties
  - OK for 240V circuits [3403.3] (n/a) (240.15B2)
- All multiwire circuits req handle tie or single handle [3701.5.1]^13 (210.4B)
- Handle tie req’d for 2 circuits to receptacles on same yoke [n/a] (210.7B)
- All conductors of multiwire circuit must be grouped (wire ties or other means) inside panel EXC [3701.5.2]^14 (210.4D)
  - Cable systems where grouping is obvious [3701.5.2X] (210.4DX)
- Backfed breakers secured in place EXC [3706.5] (408.36D)
  - Output circuits from utility interactive PV inverter [n/a] (705.12D6)
- Torque all breakers & terminals AMI [3403.3] (110.3B)
- Antioxidant on Al conductors AMI [local] (local)
- Secure each cable entering panel AMI [3907.8] (312.5C)
- Splices & taps in panels OK to 40% fill [3907.1] (312.8)
- Apply warning label to enclosure identifying power source of feed-through conductors [n/a] (312.8)^15

Click here to view a copy of the UL Marking Guide for Panelboards  
Click here to view a copy of the UL Marking Guide for Circuit Breakers

Beware of electrical shorts!
FIG. 15

Service Panel

Bonding bushing F12 req'd for service conductors entering through concentric knockouts.

GEC

Breaker protects panel & subpanel.

4-conductor feeder

FIG. 16

Subpanel

All multiwire circuits req. handle ties or single-handle 2-pole breaker.

EGC

No wire tie needed for multiwire circuit in cable.

Bond neutral in service enclosure

FIG. 15

Service Panel

Bonding bushing F12 req'd for service conductors entering through concentric knockouts.

GEC

Breaker protects panel & subpanel.

4-conductor feeder

FIG. 16

Subpanel

All multiwire circuits req. handle ties or single-handle 2-pole breaker.

EGC

No wire tie needed for multiwire circuit in cable.

Bond neutral in service enclosure
3-WIRE EDISON CIRCUITS (MULTIWIRES)

Standard electrical services to 1- and 2-family dwellings originate at a utility transformer with two ungrounded “hot” conductors and a neutral derived from the center of the transformer’s secondary coil, as depicted in F17. The neutral is connected to earth and is referred to as the “grounded” conductor. The neutral limits the voltage on either of the hot conductors to 120V to ground. If the neutral is broken or loose, voltages become erratic, as in F17. TV sets, motors, and computers don’t do well with fluctuating voltages. The utility company should be notified if there are signs of unstable voltage, such as incandescent bulbs growing brighter or dimmer as other loads change. Not only is the service to the house a “3-wire” circuit, but 120V branch circuits are often installed with shared neutrals, which are then known as multiwire circuits.

**Multiwire Circuits**

- Hot conductors must originate from opposite poles [3501] (100)
- All conductors must originate from same panel [3701.5] (210.4A)
- Multiwire neutrals may not feed through devices such as receptacles (pigtail lead from neutral to device in box) [3406.10.2] (300.13B)
- All multiwire circuits req handle tie or single handle [3701.5.1] (210.4B)
- Handle tie req’d for 2 circuits to receptacles on same yoke [n/a] (210.7B)
- All conductors of multiwire circuit must be grouped (wire ties or other means) inside panel EXC F16 [3701.5.2] (210.4D)
  - Cable systems where grouping is obvious F16 [3701.5.2X] (210.4DX)

**PROPER CIRCUIT**

2 unequal loads are fed by a 3-wire circuit. The neutral carries the imbalance between the 2 loads.

**OVERLOADED NEUTRAL**

Without voltage potential between the hot conductors, the neutral carries the sum of the loads. In a 3-conductor NM cable, the black & red wires must originate from different poles or the neutral can be overloaded because it carries the sum of the currents.

**OPEN NEUTRAL**

Two unequal loads in series across 240V from the transformer. The load with lowest resistance sees the lower voltage. Voltage at each load depends on other loads and is unstable.
An AFCI protects fire by opening the circuit when an arcing fault is detected. They look similar to GFCI breakers, and AFCIs do provide some protection against shock hazards, though not at the level required for GFCIs. The 2008 NEC and 2009 IRC greatly expanded the areas that require AFCI protection. The time to plan for the AFCIs is during the rough wiring, so that separate cables are provided for the circuits requiring AFCI protection. Not all brands and models of AFCI are compatible with multiwire circuits.

Beginning January 1, 2008, all AFCIs were required to be “combination” type rather than the original “branch/feeder” type. Combination AFCIs provide a broader range of protection. Outlet types are mentioned in the codes, though at press time these were not yet available.

Acceptance of the AFCI code provisions varies widely by jurisdiction. Be sure to check with your local building department for their current AFCI requirements before beginning a wiring project.

AFCI Protection

Combination-type AFCI required for 15A & 20A branch circuits supplying outlets in family rooms, dining rooms, living rooms, parlors, libraries, dens, bedrooms, sunrooms, recreation rooms, hallways & similar rooms or areas (3902.11) [210.12A]

- Not required on individual circuit for central station alarm in RMC, IMC, EMT, or steel-armored cable (type AC) (3902.11X2) [210.12AX2]

Click here for a downloadable article on AFCIs from the authors.

**Fig. 18**

Arc Fault

Loose connections at terminals are a common source of series arcs leading to electrical fires.
Boxes must be large enough to contain all the conductors and devices inside them, and sufficient wire must be brought into the box to safely make up connections. Luminaires that are supported from boxes are generally designed so their connections will be made inside the box, rather than inside the fixture canopy. Device boxes are threaded for 6–32 screws used to mount switches and receptacles. Lighting outlet boxes provide 8–32 (for luminaires) or 10–24 screws (for listed paddle fan boxes).

### General

- **09 IRC**
  - Metal boxes must be grounded [3905.2] (314.4)
  - Box & conduit body covers must remain accessible [3905.11] (314.29)
  - Max 1/4 in. setback from noncombustible surface* F19 [3906.5] (314.20)
  - Box extenders OK to correct excess setback [3906.5] (314.20)
  - Boxes flush with combustible surface* F19 [3906.5] (314.20)
  - Plaster gap max 1/8 in. for flush cover boxes F19 [3906.6] (314.21)
  - Min 6 in. free conductor & 3 in. past box face [3406.10.3] (300.14)
  - Luminaires only in boxes designed for luminaires EXC [3905.6] (312.27a)
  - Wall sconces ≤ 6 lb. on device boxes
    - with 2 #6 screws [3905.6X] (314.27A1X)
  - Wall luminaire boxes max weight marked if ≤ 50 lb. __ [3905.6] (314.27A1)
  - Ceiling luminaire boxes req 50 lb. rating F21 [3905.7] (314.27A2)
  - Ceiling luminaires > 50 lb. req independent support [3905.7] (314.27A2)
  - Smoke alarms OK on device boxes with 2 #6 screws __ [n/a] (314.27DX)
  - Paddle fans req L&L paddle fan box F42 [3905.9] (314.27C)
  - Boxes must be supported [3906.8] (314.23)
  - PVC & EMT not OK for box support [3906.8.5] (314.23E&F)
  - PVC & EMT OK for conduit body support [3906.8.5] (314.23E&F)
  - Wet location boxes req listing for wet locations [3905.12] (314.15)
  - Damp or wet location boxes must keep out water [3905.12] (314.15)

- **11 NEC**
  - Size sufficient to provide free space for conductors [3905.13] (314.16)
  - Standard metal boxes per code tables [3905.13.1.1] (314.16A1)
  - Include volume of marked mud rings & extensions [3905.13.1] (314.16A)
  - Plastic boxes have volume marking [3905.13.1.2] (314.16A2)
  - 4 in. (6 cu. in.) pancake OK only end of 14/2 run F21 [3905.13.2] (314.16B)
  - 18 cu. in. box too small for 3 12/2 Romex T8, F20 [3905.13.2] (314.16B)

### TABLE 7 BOX FILL WORKSHEET [3905.13.2] & (314.16B)

<table>
<thead>
<tr>
<th>Item</th>
<th>Size</th>
<th>#</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>#14 conductors exiting box</td>
<td>2.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>#12 conductors exiting box</td>
<td>2.25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>#10 conductors exiting box</td>
<td>2.50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>#8 conductors exiting box</td>
<td>3.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>#6 conductors exiting box</td>
<td>5.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Largest grounding conductor—count only 1</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Devices—2× times connected conductor size</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internal clamps—1 based on largest wire present</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Fixture fittings—1 for each type based on largest wire</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*The IRC text for section 3906.5 states that the allowed 1/4 in. setback is for walls or ceilings *constructed* with noncombustible material, rather than walls or ceilings *surfaced* with noncombustible material. The IRC also states that this section is derived from NEC 314.20, which states it the way that we do. We think the correct interpretation is as we have written it.*
Box Fill Factors T7,8

09 IRC 11 NEC

☐ Count each conductor exiting box EXC ______ [3905.13.2.1] (314.16B1)
  EGCs from luminaires or up to 4 conductors < 14 AWG
  from luminaires with domed canopies ______ [3905.13.2.1X] (314.16B1X)

☐ Unbroken conductors passing through box count
  as only 1 conductor EXC ___________ [3905.13.2.1] (314.16B1)
  Looped unbroken conductors > 12 in. count as 2 [3905.13.2.1] (314.16B1)

☐ Do not count pigtailed conductors to devices ___ [3905.13.2.1] (314.16B1)

☐ All internal clamps count as 1, based on largest
  conductor in box ______________________ [3905.13.2.2] (314.16B2)

☐ Support fittings count as 1 conductor for each fitting type
  based on largest conductor in box __________ [3905.13.2.3] (314.16B3)

☐ Count devices as 2 conductors based on
  connected wire size ____________________ [3905.13.2.4] (314.16B4)

☐ All EGCs count only as 1 based on largest ___ [3905.13.2.5] (314.16B5)

Table 8: Box Fill Example for F20

<table>
<thead>
<tr>
<th>Item</th>
<th>Size</th>
<th>#</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>#12 conductors exiting box</td>
<td>2.25</td>
<td>6</td>
<td>13.50</td>
</tr>
<tr>
<td>Largest grounding conductor—count only 1</td>
<td>2.25</td>
<td>1</td>
<td>2.25</td>
</tr>
<tr>
<td>Devices—2x times connected conductor size</td>
<td>4.50</td>
<td>1</td>
<td>4.50</td>
</tr>
<tr>
<td>Internal clamps—1 based on largest wire present</td>
<td>2.25</td>
<td>1</td>
<td>2.25</td>
</tr>
</tbody>
</table>

TOTAL: 22.5

3 12/2+G Romex + device overfills 18 cu. in. box.
A ground fault occurs when current leaks out of its normal path and finds a path back to the utility transformer through conductors that are not supposed to carry current. An example of such an abnormal path could include a human body. Ironically, even though the earth is not a sufficiently good conductor to provide a fault path that would trip a breaker, it is a good enough conductor to carry the low levels of current that can cause electrocution. GFCIs respond to very low levels of current imbalance in a circuit, such as those that occur when current returns through a person. GFCIs are designed to limit the duration of leaking current to safe levels.

How does a GFCI work its magic? In F22, equal currents are flowing to & from the load. When any electrical current flows, it generates a magnetic field. The magnetic fields generated by the flow of electrons in these 2 conductors are of opposite polarity (north & south, leaving & returning). The forces are equal & opposite & their magnetic fields cancel each other. The circuit passes through a coil of wire inside the GFCI & the GFCI accounts for the electrons on each conductor. As long as the currents are balanced, GFCI allows current on the circuit.

During a ground fault—such as the flow of current through a person to something that is grounded—the circuit becomes unbalanced F23. Because the circuit is unbalanced, it produces a magnetic field that induces a small voltage on the sensing coil. The resulting current on the sensing coil signals the relay mechanism, which opens the circuit.
A GFCI also detects improper connections of the neutral (grounded conductor) to ground. A second “injector” coil F24 surrounds the monitored circuit & induces a small current. Should the neutral have a downstream connection to the ground, the current will escape outside the circuit & the sensor coil circuit will be activated as described on p.27.

**FIG. 24**

Neutral to Ground Fault

Induced current flows out of monitored loop.

GFCIs take more space inside a box than do conventional receptacles. When adding GFCIs to old houses with shallow boxes, it might be necessary to first add an extension box, as in F25.

A GFCI will operate properly without an equipment ground. The receptacle should be labeled “no equipment ground” & any downstream protected receptacles should also have that label as well as a label stating that they are GFCI protected. Labels are not req’d for properly grounded GFCI-protected receptacles.

**FIG. 25**

Adding GFCI in Old Houses

Backer plate
Box extension
GFCI receptacle
Flexible tubing
Steel box
Older shallow-back boxes might need an extension to accommodate a GFCI.

A GFCI receptacle can provide protection for other receptacles downstream on the circuit. GFCI protection can be provided by GFCI breakers or GFCI receptacles F26.

**FIG. 26**

GFCIs
Circuit breaker
Receptacle

GROUND-FAULT CIRCUIT INTERRUPTERS
Residential GFCI Protection 09 IRC 11 NEC

GFCI protection is req’d for 15A & 20A receptacles in the following locations. It is not req’d for 240V receptacles or 120V-30A receptacles:

- GFCIs req’d to be in readily accessible locations [n/a] (210.8A)19
- All bathroom receptacles [3902.1] (210.8A1)
- All garage & accessory building receptacles [3902.2] (210.8A2)
- All receptacles in unfinished basements EXC [3902.5] (210.8A5)
  - Permanently installed fire or burglar alarm system [3902.5X] (210.8A5X)

The 2005 NEC & 2006 IRC had exceptions for receptacles in garages & unfinished basements when those receptacles served appliances that are not easily moved, such as freezers. Those exceptions have been removed.

- All outdoor receptacles EXC [3902.3] (210.8A3)
  - GFPE circuit dedicated to nonreadily accessible receptacles for snow-melting or deicing equipment [3902.3X] (210.8A3X)
- All receptacles in crawl spaces at or below grade level [3902.4] (210.8A4)
- All receptacles serving kitchen counters F30 [3902.6] (210.8A6)
- Receptacles within 6 ft. of all non-kitchen sinks [3902.7] (210.8A7)21

Pools, Spas, Whirlpool Tubs & Boathouses 09 IRC 11 NEC

- Receptacles ≤ 20 ft. of pools & outdoor hot tubs [4203.1.3] (680.22A4)
- Distance does not apply to cords that would have to pass through window or door [4203.1] (680.22A5)
- Receptacles for 120V or 240V pool pump motors regardless of distance from pool [4203.1.3] (680.22A4)
- Receptacles providing power to indoor spas or hot tubs [n/a] (680.43A3)
- Receptacles ≤ 10 ft. of indoor spas or hot tubs [4203.1.5] (680.43A2)
- Pool cover motor & controller [4206.11] (680.27B2)
- Hydromassage (whirlpool) tubs [4209.1] (680.71)
- Underwater pool lights > 15V F68 [4206.4] (680.23A3)
- Luminaires & lighting outlets < 10 ft. horizontally from outdoor pool or spa edge unless > 5 ft. vertically above water [4203.4.5] (680.22B4)

UL 943—the standard of safety for GFCIs—was revised in 2003, requiring GFCIs to have greater resistance to corrosion & surges. GFCIs have become more reliable & do not have the problems of “nuisance tripping” that characterized these devices in the earlier stages of their development. Thanks to their increased reliability, it is no longer necessary to have the numerous exceptions that once existed for GFCIs associated with motor loads.

The standard includes a line-load reversal test that req’s the receptacle not be capable of resetting if it is miswired & a 2006 revision req’s that there be no power to the face of a miswired receptacle. The contacts on newer GFCIs ensure proper resetting & prevent some miswiring that could appear from manipulation of the controls on the older GFCIs. In addition, manu installation instructions for GFCIs are now standardized for consistency. These instructions req specific methods for checking GFCI operation after installation to ensure that devices are properly wired & that they be tested on a regular basis for the life of the GFCI. As a result, these proven life savers have become more reliable than ever.
Branch circuits are the permanent wiring between the final overcurrent protective devices (fuses or breakers) and the lighting or receptacle outlets from which electrical equipment derives power. During rough-in of branch circuit wiring, care should be taken to ensure they are an adequate size for the load. Circuits for continuous loads and items such as water heaters or space heaters that are treated as continuous loads, must be sized to 125% of the load. There must be sufficient outlets for the needs of the occupants. An insufficient number of outlets could lead to the dangerous substitution of extension cords in place of permanent wiring. During rough-in, boxes are placed in the locations req’d for receptacle and lighting outlets, cables are run, and equipment grounds are connected.

### Circuit Sizes, Number & Load Limitations

- **Rule of thumb:** min 1 general-purpose circuit per 500 sq. ft. [3704.4] (220.12)
- Load not to exceed rating of branch circuit [3701.2] (220.18)
- Min circuit size 125% of continuous load + 100% of noncontinuous load [3701.2] (210.19A)
- Continuous load = max current for 3 hours or more [3501] (100)
- Min size for branch circuit wiring 14 AWG [3702.13] (210.19A4)
- Branch circuit ratings for other than individual circuits must be 15A, 20A, 30A, 40A, or 50A [3702.2] (210.3)
- Single piece of cord-&-plug-connected equipment not permanently fastened in place cannot exceed 80% of 15A or 20A branch circuit [3702.3] (210.23A1)
- Max single cord-&-plug-connected load on multi-receptacle circuit not to exceed 80% of circuit rating [4002.1.2] (210.21B2)

### Receptacle Locations—General

- Receptacles for specific appliances (laundry, garage door opener) within 6 ft. of appliance location [3901.5] (210.50C)
- Flexible cords not OK as fixed or concealed wiring [3909.1] (400.8)

### TABLE 9: RECEPTACLE RATINGS FOR MULTIPLE RECEPTACLES ON 1 CIRCUIT [4002.1.2] & [210.21.B3]

<table>
<thead>
<tr>
<th>Circuit Rating</th>
<th>Receptacle Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>15A</td>
<td>not over 15A</td>
</tr>
<tr>
<td>20A</td>
<td>15 or 20A</td>
</tr>
<tr>
<td>30A</td>
<td>30A</td>
</tr>
<tr>
<td>40A</td>
<td>40 or 50A</td>
</tr>
<tr>
<td>50A</td>
<td>50A</td>
</tr>
</tbody>
</table>
Receptacle Outlets—General Purpose

- **Walls ≥ 2 ft. wide req receptacle**
  - [3901.2.2] (210.52A2)
- **Partitions & bar-type counters count as walls**
  - [3901.2.2] (210.52A2)
- **Doorways & fireplaces not counted as walls**
  - [3901.2.2] (210.52A2)
- **Receptacle req’d within 6 ft. measured horizontally of any point along floor line**
  - [3901.2.1] (210.52A1)
- **Receptacle req’d for hallways ≥ 10 ft. in length**
  - [3901.10] (210.52H)
- **Receptacles that are part of electric baseboard heaters OK as req’d outlets**
  - [3901.1] (210.52)
- **Receptacles > 5½ ft. high not OK as req’d outlets**
  - [3901.1] (210.52)
- **Floor receptacles > 18 in. from wall not OK as req’d outlets**
  - [3901.2.3] (210.52A3)
- **Switched receptacles installed as req’d lighting do not count**
  - as part of req’d receptacle outlets unless “half hot”
  - [3901.1]²⁶ (210.52)
- **Receptacles req’d each wall ≥ 3 ft. in foyers > 60 sq. ft.**
  - [n/a] (210.52I)
- **Garages & unfinished basements req min 1 receptacle**
  - in addition to any for specific equipment
  - [3901.9] (210.52G)

---

**FIG. 27**

6 ft. & 12 ft. Rule

- **Receptacle req’d if wall wider than 2 ft.**
- **Distance at wall/floor line between each of these receptacles is a max. of 12 ft.**
- **Floor receptacle req’d within 6 ft. of beginning of glass & 18 in. of wall**
- **Receptacle req’d if wall wider than 2 ft.**
- **6 ft. & 12 ft. Rule Explained**

Wall receptacles serve spaces for 6 ft. on each side of receptacle. Therefore, max. spacing between wall receptacles is 12 ft.
Bathrooms 09 IRC 11 NEC
- Receptacle req’d on wall or partition within 3 ft. of each basin [3901.6] (210.52D)
- No face-up outlets on vanity countertop [3901.6] (406.4E)
- Listed countertop-mounted receptacles OK [n/a] (210.52D)28
- No receptacles within or directly over tub or shower [4002.11] (406.8C)
- Separate 20A circuit for bath receptacles only OR __ [3703.4] (210.11C3)
  - Dedicated 20A circuit to each bathroom [3703.4X] (210.11C3X)
- Max rating of fixed space heater on general lighting circuit
  15A circuit: 900W; 20A circuit: 1,200W [3702.5] (210.23A2)

Laundry 09 IRC 11 NEC
- Min 1 20A circuit for laundry receptacles [3703.3] (210.11C2)
- No non-laundry outlets on laundry receptacle circuit [3703.3] (210.11C2)
- Receptacle within 6 ft. of intended appliance location [3901.5] (210.50C)
- Electric dryer min 30A circuit (10 AWG Cu, 8 AWG Al) [T3704.2(1)] (220.54)
- Electric dryer req’s 4-conductor branch circuit EXC __ [3908.7] (250.140)
  - Existing 3-wire circuits allowed to remain in use [n/a] (250.140X)

Outdoors 09 IRC 11 NEC
- Receptacle accessible from grade req’d at front & rear of dwelling max 6½ ft. above grade [3901.7] (210.52E1)
- Receptacle req’d at balconies with interior access EXC [3901.7]29 (210.52E3)
  - Not req’d if balcony < 20 sq. ft. [3901.7] (n/a)30
- Receptacles in damp or wet locations req’d to be listed weather-resistant type [4002.8]31 (406.8A&B)
- Outdoor damp location receptacle (e.g., protected porch) req’s weatherproof cover F29 [4002.8] (406.8A)
- Wet location 15A & 20A receptacles req in-use covers F29 [4002.9] (406.8B1)

Lighting Outlets (see p.36 for Switches) 09 IRC 11 NEC
- Wall-switch controlled lighting outlets req’d in all habitable rooms & bathrooms [3903.2] (210.70A1)
- Habitable room lighting outlets may be switched receptacle except in kitchen & bathroom [3903.2X][210.70A1X1]
- Occupancy-sensor wall switches with manual override feature OK [3903.2X] (210.70A1X2)
- Wall-switch controlled lighting outlets req’d in hallways, stairways, attached garages & detached garages with power [3903.3] (210.70A2)
- Min 1 wall-switched lighting outlet in garage [3903.3] (210.70A2a)
- Lighting outlet req’d on exterior side grade level doors [3903.3] (210.70A2b)
- Lighting outlet req’d at garage egress doors [3903.3] (210.70A2b)
- Lighting outlet not req’d at garage vehicle doors [3903.3] (210.70A2b)
A minimum of 2 20A small-appliance branch circuits are req’d for portable appliances that are used in kitchens and dining areas. These circuits are in addition to those that supply lighting or permanently installed appliances. Portable kitchen appliances have short cords so they are not as likely to be run across cooktops or sinks or to hang down in the reach of children. A receptacle is needed to serve every countertop 1 ft. or more in width.

**Branch Circuits**

- Min 2 20A small-appliance circuits req’d [3703.2] (210.11C)
- Small-appliance circuits must serve refrigerator & all countertop & exposed wall receptacles in kitchen, dining room & pantry EXC [3703.2] (210.52B1)
  - Refrigerator OK on individual branch circuit ≥ 15A [3703.2X] (210.52B1X2)
- Switched receptacle for dining room light OK on non-small-appliance circuit [3901.3X1] (210.52B1X1)
- No other outlets (including lights) on small appliance branch circuits EXC [3901.3.1] (210.52B2)
  - Receptacles for clock or gas range ignition OK [3901.3.1X] (210.52B2X)
- Dishwasher & disposer req separate circuits if combined rating exceeds branch circuit rating [3701.2] (210.19A1)
- Circuits for ranges ≥ 8.75kW min 40A 240V [3702.9.1] (210.19A3)

**Receptacles for Countertop Spaces**

- Receptacles req’d for wall counter spaces ≥ 12 in. wide [3901.4.1] (210.52C1)
- Countertop spaces separated by sinks or ranges considered separate countertop spaces F30 [3901.4.4] (210.52C4)
- Spacing so no point > 24 in. from receptacle F31 [3901.4.1] (210.52C1)
- Area behind sink or range considered countertop space if ≥ 12 in. to wall F32 or ≥ 18 in. to corner F33 [3901.4.1X] (210.52C1X)
- Max 20 in. above countertop [3901.4.5] (210.52C5)
- Peninsulas req receptacle if long dimension ≥ 24 in. & short dimension > 12 in., measured from connecting edge F30 [3901.4.3] (210.52C3)
- Island & peninsula countertop spaces min 1 receptacle per space—no 24 in. rule F30 [3901.4.2&3] (210.52C2&3)
- Sink or range with < 12 in. behind divides counters into separate spaces for above rule [3901.4] [210.52C4]
- Island & peninsula receptacles OK ≤ 12 in. below counter overhanging ≤ & no means of installing receptacle in overhead cabinet F30 [3901.4.5X] (210.52C5X)
- No face-up countertop receptacles [3901.4.5] (406.4E)
- GFCI protection for all receptacles serving countertops [3902.6] (210.8A6)
Kitchen Receptacles

Cord-plug connected range-hood allowed if supplied by individual branch circuit.

Receptacle req’d for peninsula if this dimension < 1 ft.

Max. 12 in. below countertop surface
Max. 6 in. overhang above receptacle

Bar-type counter acts as room divider, so receptacle req. within 6 ft. of end.

This receptacle does not serve countertop or require GFCI protection.

Island or peninsula countertop spaces req. only 1 receptacle—2 ft./4 ft. rule does not apply.

Wall countertop receptacles serve spaces for 2 ft. on each side of the receptacle. Therefore, the max. spacing between receptacles on the same countertop space is 4 ft.

KITCHENS 34
**FIG. 32**

**Extended Range or Sink**

If $X \geq 12$ in., countertops are not considered separate spaces & the 2 ft./4 ft. rule applies to the entire countertop.

If $X < 12$ in., measure from here

When $X$ is $< 12$ in. on an island or peninsula countertop, the countertop spaces to each side of the sink or range are considered separate spaces, and each space is required to be served by a receptacle outlet.

**FIG. 33**

**Corner Range or Sink**

If $X < 18$ in., outlet not req’d here

If $X \geq 18$ in., countertops are not considered separate spaces & the 2 ft./4 ft. rule applies to the entire countertop.

If $X < 18$ in., measure from here

If $X < 18$ in., measure from here
3-Way Switch

3-way switching takes place from a common terminal to one or the other traveler. This traditional method of running power first to the luminaire & then to 3-way switches with a common wire & 2 travelers is no longer allowed unless the cable also contains a neutral conductor of the circuit. (4 conductor +G cable would be OK).

Acceptable 3-way switching with neutral in each switch enclosure

(Example ground not shown but req’d for any new installation)

4-Way Switch

A 4-way switch is a double-pole double-throw switch. Any number can be placed between the 2 3-ways.

FIG. 34

FIG. 35
Lighting outlets and luminaires must be installed with no exposed live parts that could pose a shock hazard. The heating effect of luminaires must be considered, especially around thermal insulation. Lights rated “type IC” are suitable for insulated ceilings. See p.32 for req’d locations. Click here to view the UL Marking Guide for Luminaires.

**General**
- All luminaires & lampholders listed [3403.3] [410.6]
- Exposed metal parts grounded EXC [4003.3] [410.42A]
  - Incidental metal parts such as mounting screws [4003.3] [410.42A]
- Wet location luminaires L&L for wet location [4003.9] [410.10A]
- Damp location luminaires L&L for damp or wet location [4003.9] [410.10A]
- Screw shells for lampholders only—no adapters [4003.4] [410.90]

**Recessed Lights**
- Non-Type IC min ½ in. from combustibles [4004.8] [410.116A1]
- Non-Type IC min 3 in. from insulation [4004.9] [410.116B]
- Type IC OK in contact with combustible material [4004.8] [410.116A2]
- Type IC OK in contact with insulation [4004.9] [410.116B]
- Luminaires that req > 60°C wire must be marked [n/a] [410.74]
- Connect proper temp-rated wire to luminaire [n/a] [410.117A]
- Tap conductors to 60°C wire min 18 in. max 6 ft. [n/a] [410.117C]

**FIG. 36**
**Recessed Lighting with Old Wiring**

**FIG. 37**
**Closet Lights**

- Surface fluorescent or recessed incandescent
- Surface wall lights OK only over door

Shaded areas are designated as storage. The storage area above the shelf is the shelf width or 12 in., whichever is greater.
Track Lighting 09 IRC 11 NEC

☐ Branch circuit rating ≤ track rating [4005.1] (410.151B)
☐ Connected load ≤ track rating [4005.3] (410.151B)
☐ No track concealed, extended through walls or partitions, or
  in damp or wet locations [4005.4] (410.151C)
☐ Track must be securely fastened [4005.5] (410.154)
☐ Track must be grounded [4005.6] (410.155B)

Tub & Shower Areas F38 09 IRC 11 NEC

☐ No cord-connected or pendant luminaires, lighting track, or
  ceiling-suspended paddle fans 1st 8 ft. above tub rim or
  shower threshold & for zone extending 3 ft. outside [4003.10] (410.10D)
☐ Luminaires directly above tub & shower listed for damp locations
  (or wet locations if subject to shower spray) [4003.10] (410.10D)

FIG. 38

Lights directly above tub/shower rated for damp or wet location

APPLIANCES

The term appliances is a generic term for standardized manufactured equipment that uses electricity (other than lighting). Whether portable or permanent, all appliances req a means of disconnecting the power source so the appliance can be safely serviced or replaced. The codes provide general rules for disconnecting appliances as well as specific rules for common built-in (fixed in place) appliances.

Disconnecting Devices 09 IRC 11 NEC

☐ All appliances req disconnecting means [4101.5] (422.30)
☐ Cord-connected appliances req attachment plug [3909.4] (410.7B)
☐ Accessible attachment plug OK as disconnect [T4101.5] (422.33A)
☐ Additional disconnect req’d if plug not accessible [T4101.5] (422.33A)
☐ Breaker alone OK for appliances <300VA or 1/8hp [T4101.5] (422.31A)
☐ In-sight switch or breaker req’d if ≥300VA or 1/8hp,
  or lockable breaker OK when not in sight F39 [T4101.5] (422.31B)
☐ Breaker lockouts req permanent hasp F39 [T4101.5] (422.31B)
☐ Unit switch opening all ungrounded conductors OK [T4101.5] (422.34)
Hydromassage Tub (Whirlpool Bathtub) 09 IRC 11 NEC

- Readily-accessible GFCI protection req’d [4209.1] (680.71)
- Individual branch circuit req’d [4209.1] (680.71)
- Electrical equipment (pump motor) must be accessible [4209.3] (680.73)
- Disconnecting means req’d in sight of motor [T4101.5] (430.102B)
- Bond metal parts in contact with circulating water [T4101.5] (680.74)
- Bonding conductor min solid 8 AWG Cu F40 [4209.4] (680.74)
  • Double-insulated motor [4209.4] (680.74)
- Bonding conductor need not connect to panelboards [4209.4] (680.74)

Kitchens 09 IRC 11 NEC

- Cords must be L&L (no NM cable) [4101.3] (422.16A)
- Garbage disposer cord min 18 in. max 36 in. [T4101.3] (422.16B1)
- Dishwasher or trash compactor cord min 3 ft. max 4 ft. measured from back [T4101.3] (422.16B2)
- Dishwasher & compactor receptacles in same space as appliance or in adjacent space [n/a] (422.16B2)
- Range hoods can be cord & plug connected if L&L for cord & on individual branch circuit [4101.3] (422.16B4)
- Range hood cords min 18 in. max 36 in. [T4101.3] (422.16B4)
- Cord & plug ovens & cooking units OK if L&L [4101.3] (422.16B3)

Central Furnace 09 IRC 11 NEC

- In-sight disconnect req’d [T4101.5] (422.31B&C)
- Refer to manu instructions for possible supplemental OCPD requirements F41.
- Lighting outlet switched at entry to equipment space [3903.4] (210.70A3)
- Central furnace must be on individual circuit EXC [3703.1] (422.12)
  • Associated equipment (electrostatic filters, pumps, etc.) [3703.1] (422.12X1)
- 120V receptacle req’d within 25 ft. on same elevation [3901.11] (210.63)

“SSU” Switch

A fused disconnect provides supplementary overcurrent protection & is sometimes a manufacturer’s instruction. An example might be a furnace requiring 15A overcurrent protection installed on a 20A circuit.
Electric Furnaces & Space Heaters 09 IRC 11 NEC
☐ Branch circuit 125% load (heat watts + motor) [3702.10] (424.3B)
☐ Disconnect in sight or lockable breaker F39 [T4101.5] (424.19)
☐ Unit switch that opens all ungrounded conductors OK as disconnect for space heater with no motor > 1/8hp [T4101.5] (424.19C)

Central Vacuum 09 IRC 11 NEC
☐ Max 80% individual branch circuit rating, 50% of multi-outlet branch circuit rating [3702.3] (210.23A)
☐ Cord must have same ampacity as branch circuit [n/a] (422.15B)
☐ Bond all non-current-carrying metal parts [3908.2] (422.15C)

Water Heater 09 IRC 11 NEC
☐ In-sight or lockable breaker or switch OK F39 [T4101.5] (422.31B)
☐ Breaker lockout hasp req’d to remain in place with lock removed F39 [T4101.5] (422.31B)
☐ Bond hot, cold & gas pipes F13 [3609.7] (250.104)

Outdoor De-icing & Snow Melting Equipment 09 IRC 11 NEC
☐ GFPE protection req’d for de-icing equipment [4101.7] (426.28)

Some jurisdictions allow the GFPE function of an AFCI to meet this rule.

Air-Conditioning 09 IRC 11 NEC
☐ Wiring & OCPD per nameplate of L&L equipment [3702.11] (440.4B)
☐ Disconnect on or within sight of condenser F43 [T4101.5] (440.14)
☐ Disconnect not OK on compressor access panel [n/a] (440.14)
☐ Working space req’d in front of disconnect F43 [3405.1] (110.26A)
☐ Room AC plug disconnect OK if controls ≤ 6 ft. of floor [n/a] (440.63)
☐ Max cord length 120V = 10 ft., 240V = 6 ft. [n/a] (440.64)
☐ AFCI or leakage current detection interrupter (LCDI) in cord or plug for room AC units [n/a] (440.65)

Click here to view the UL Marking Guide for Air Conditioning Equipment

FIG. 42
Paddle Fan Support
Ceiling fans > 70 lb. must be supported independently from box.

Paddle Fans F42 09 IRC 11 NEC
☐ Listed box for fan support (no standard boxes) [3905.9] (314.27C)
☐ Listed fan boxes without weight marking OK to 35 lb. [3905.9] (314.27C)
☐ > 35 lb. & < 70 lb., fan box L&L for suitable weight [3905.9] (314.27C)
☐ Independent support for fans > 70 lb. [3905.9] (314.27C)

FIG. 43
Air-Conditioning Condenser
All ACs req. an in-sight disconnect.

Switch not to be installed directly behind condenser.
Smoke Alarms

☐ NFPA 72 systems OK if permanent part of property [314.2]38
☐ Alarms req’d in each sleeping room & adjoining areas [314.3]
☐ Req’d each story including basements & habitable attics [314.3]
☐ Interconnect so activation of 1 alarm sets off all alarms [314.3]
☐ Power from building wiring & battery backup EXC [314.4]
  • Battery-only OK alterations or repairs with no access to wire path [314.4X2]

Carbon Monoxide Alarms

☐ Req’d outside sleeping areas in dwellings with fuel-fired appliances or with attached garages [315.1]39
☐ Req’d when remodeling requiring permit is performed [315.2]
☐ Install AMI & in compliance with UL 2034 [315.3]39

FIG. 44 Smoke & Carbon Monoxide Alarms

T10 is a “quick reference” guide to the maximum size breaker for a given size of wire. It is an abbreviated version of T11-14. Always consider if the conductors must be “derated” for ambient temperature, grouping, or the other factors on the next page. The sizes given for service entrance conductors apply for wires only with insulation types RHH, RHW, RHW-2, THHN, THHW, THW, THW-2, THWN, THWN-2, XHHW, XHHW-2, SE, USE, and USE-2.

<p>| Fuse or Branch Circuits or Feeders | SIZING CONDUCTORS |</p>
<table>
<thead>
<tr>
<th>Breaker</th>
<th>Cu</th>
<th>Wire Size</th>
<th>Service Conductors (AWG)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cu</td>
<td>Al</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>14</td>
<td>12</td>
<td>n/a</td>
</tr>
<tr>
<td>20</td>
<td>12</td>
<td>10</td>
<td>n/a</td>
</tr>
<tr>
<td>30</td>
<td>10</td>
<td>8</td>
<td>n/a</td>
</tr>
<tr>
<td>40</td>
<td>8</td>
<td>6</td>
<td>n/a</td>
</tr>
<tr>
<td>50</td>
<td>6</td>
<td>4</td>
<td>n/a</td>
</tr>
<tr>
<td>60</td>
<td>6</td>
<td>3</td>
<td>n/a</td>
</tr>
<tr>
<td>70</td>
<td>4</td>
<td>2</td>
<td>n/a</td>
</tr>
<tr>
<td>80</td>
<td>3</td>
<td>1</td>
<td>n/a</td>
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<tr>
<td>90</td>
<td>2</td>
<td>1/0</td>
<td>n/a</td>
</tr>
<tr>
<td>100</td>
<td>2</td>
<td>1/0</td>
<td>4</td>
</tr>
<tr>
<td>110</td>
<td>1</td>
<td>1/0</td>
<td>3</td>
</tr>
<tr>
<td>125</td>
<td>1/0</td>
<td>1/0</td>
<td>2</td>
</tr>
<tr>
<td>150</td>
<td>1/0</td>
<td>2/0</td>
<td>1</td>
</tr>
<tr>
<td>200</td>
<td>3/0</td>
<td>4/0</td>
<td>2/0</td>
</tr>
<tr>
<td>225</td>
<td>4/0</td>
<td>250kcmil</td>
<td>3/0</td>
</tr>
<tr>
<td>400</td>
<td>500kcmil</td>
<td>700kcmil</td>
<td>400kcmil</td>
</tr>
</tbody>
</table>

TABLE 10
When wire overheats, its insulation begins to break down, and we say the wire has exceeded its ampacity. Protecting conductors and equipment from overheating and insulation failure is one of the main principles of electrical safety.

General

- Protect conductors at their ampacity exc [3705.5] (240.4)
- Small conductors protected per note A in T11 [3705.5.3] (240.4D)
- AC protected AMI [3705.5.4] (240.4G)
- OCPD for NM cable not to exceed 60°C ampacity [3705.4.4] (334.80)

Derating

- Apply temp-correction factor T12 [3705.2] (310.15B2)
- Add correction for rooftop conduits per T13 [n/a] (310.15B3c)
- Derate for > 3 current-carrying conductors in raceway or cables grouped without spacing > 24 in. in length [3705.3] (310.15B3a)
- Derate > 2 NM cables in caulked (fireblocked) hole [3705.4.4] (334.80)
- Derate > 2 NM cables installed without spacing in contact with thermal insulation [3705.4.4] (334.80)

The first step in determining the allowable ampacity of a conductor is to look it up in T11 based on the wire size & insulation type. The most common ratings of conductor insulation are 60°C, 75°C & 90°C. We use the 90°C column only for derating (temp. corrections), not for selection of the breaker or fuse. Conductors can be dual rated, with 75°C ratings in wet locations & 90°C ratings in dry locations, such as THWN/THHN.

Breaker & equipment terminations have a temp. rating, typically 60°C and/or 75°C. The overall ampacity of a circuit is limited by the lowest-rated device or conductor in the circuit. The final choice of breaker is, therefore, usually limited by the temp. rating of the breaker terminals; & the insulation rating is used in the derating calculations. Nonmetallic sheathed cable & SE cable as interior wiring are restricted to a 60°C rating despite containing 90°C rated conductors.

### AMPACITY OF WIRE

<table>
<thead>
<tr>
<th>TABLE 11</th>
<th>WIRE AMPACITIES [T3705.1] (310.15B16)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>60°C</td>
</tr>
<tr>
<td></td>
<td>140°F</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>INSULATION TYPES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cu (AWG)</td>
</tr>
<tr>
<td>14A</td>
</tr>
<tr>
<td>12A</td>
</tr>
<tr>
<td>10A</td>
</tr>
<tr>
<td>8</td>
</tr>
<tr>
<td>6</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>1/0</td>
</tr>
<tr>
<td>2/0</td>
</tr>
<tr>
<td>3/0</td>
</tr>
<tr>
<td>4/0</td>
</tr>
<tr>
<td>250</td>
</tr>
</tbody>
</table>

A. For Cu wire: max OCPD 30A for 10 AWG, 20A for 12 AWG & 15A for 14 AWG.
For Al wire, max OCPD 25A for 10 AWG & 20A for 12 AWG.
In addition to size, material & insulation type, other factors must be considered. These are ambient temp. T12, the rate of heat dissipation into the ambient medium & the adjacent load-carrying conductors T14. Heat dissipates more readily to free air than to water, such as found in underground conduits. Thermal insulation traps heat, so do adjacent conductors when they are grouped together.

To determine the ambient temp. correction; apply the factors of T12 to the ampacity listed in the appropriate column of T11. The heating effect of reflected sunlight must also be added to the temp. correction, per T13.

### TABLE 12
**AMBIENT TEMPERATURE CORRECTION**

<table>
<thead>
<tr>
<th>Ambient Temp. °C</th>
<th>For Ambient Temp. &gt; 30°C (86°F), Multiply the Allowable Ampacities in T11 by the Following Percentages:</th>
<th>Ambient Temp. °F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>60°C</td>
<td>75°C</td>
</tr>
<tr>
<td>31–35</td>
<td>0.91</td>
<td>0.94</td>
</tr>
<tr>
<td>36–40</td>
<td>0.82</td>
<td>0.88</td>
</tr>
<tr>
<td>41–45</td>
<td>0.71</td>
<td>0.82</td>
</tr>
<tr>
<td>46–50</td>
<td>0.58</td>
<td>0.75</td>
</tr>
<tr>
<td>51–55</td>
<td>0.41</td>
<td>0.67</td>
</tr>
<tr>
<td>56–60</td>
<td>–</td>
<td>0.58</td>
</tr>
<tr>
<td>61–70</td>
<td>–</td>
<td>0.33</td>
</tr>
</tbody>
</table>

This table may have little effect on post-1984 90°C-based NM-B wiring. It can be important in remodels with older 60°C wire.

### TABLE 13
**TEMPERATURE ADJUSTMENT FOR CONDUITS EXPOSED TO SUNLIGHT ABOVE ROOFTOPS**

<table>
<thead>
<tr>
<th>Distance between Roof &amp; Conduit</th>
<th>Temp. Added to T12</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 1/2 in.</td>
<td>33°C</td>
</tr>
<tr>
<td>&gt; 1/2 in. – 31/2 in.</td>
<td>22°C</td>
</tr>
<tr>
<td>&gt; 31/2 in. – 12 in.</td>
<td>17°C</td>
</tr>
<tr>
<td>&gt; 12 in.</td>
<td>14°C</td>
</tr>
</tbody>
</table>

Another consideration is conductor proximity, which traps heat & prevents heat dissipation when conductors are grouped. When there are more than 3 current-carrying conductors in a raceway, the derating factors of T14 must be applied, in addition to any ambient temp. correction. These same derating factors also apply to a grouping of cables installed without spacing for a length of 24 in. or more & for groups >2 NM cables passing through an opening in wood framing that is fireblocked with thermal insulation, caulk, or foam & to NM cables installed without spacing & in contact with thermal insulation.

### TABLE 14
**DERATING FOR CONDUCTOR PROXIMITY**

<table>
<thead>
<tr>
<th>Number of Current-Carrying Wires</th>
<th>Ampacity Correction</th>
</tr>
</thead>
<tbody>
<tr>
<td>4–6</td>
<td>80</td>
</tr>
<tr>
<td>7–9</td>
<td>70</td>
</tr>
<tr>
<td>10–20</td>
<td>50</td>
</tr>
</tbody>
</table>

With modern 90°C small conductors this table becomes significant when there are > 9 current-carrying conductors in a conduit or cable group, or when compounded by temp. corrections. Cables installed without spacing > 2 ft. are subject to the above derating. When newer 90°C wire is connected to older 60°C wire, such as pre-1984 NM, the ampacity of the lower-rated conductors applies to the entire circuit.
CABLE SYSTEMS

Cable systems are the most common residential wiring methods. Cables contain all conductors of the circuit inside a protective outer sheath of metal or plastic. Starting with the 2005 edition, the NEC uses a parallel numbering system for rules pertaining to cables and raceways. See the common numbering system table (T24) on p.63. Click here to view the UL Marking Guide for Wire and Cable.

Cable Protection Indoors (NM, AC, MC, UF, SE) 09 IRC 11 NEC

☐ Bored holes & standoff clamps 1 1/4 in. setback F56 [3802.1] (300.4A&D)
☐ Protect cables with 1/16 in. steel plate (or L&L plate)
  if closer than 1 1/4 in. to framing surfaces F45 __ [3802.1] (300.4A&D)
☐ Cables min 1 1/2 in. below sheet steel roof decks __ [n/a] (300.4E)
☐ Provide guard strips within 6 ft. of attic scuttle
  (& up to 7 ft. high if attic has permanent access) __ [3802.2.1] (334.23)
**NM—Nonmetallic Sheathed Cable**

- OK in dry locations only ______________ [3801.4] (334.12B4)
- Protect exposed cable from damage where necessary ______________ [3802.3.2] (334.15B)
- Listed grommets for holes through metal framing ______________ [3802.1] (300.4B1)
- OCPD selection based on 60° column **T11** ______________ [3705.4.4] (334.80)
- Derating & temp correction based on 90° rating ______________ [3705.4.4] (334.80)
- Derate > 2 NM cables in same caulked (fireblocked) hole ______________ [3705.4.4] (334.80)
- Derate > 2 NM cables installed without spacing in contact with thermal insulation ______________ [3705.4.4] (334.80)
- Secure to box with approved NM clamp EXC **F49** ______________ [3905.3.2] (314.17B&C)
  - Single gang (2 1/4 × 4 in.) plastic box stapled within 8 in. ______________ [3905.3.2] (314.17CX)
- Min 1/4 in. sheathing into plastic boxes ______________ [3905.3.1] (314.17C)
- Secure within 12 in. of box & max 4 1/2 ft. intervals ______________ [3802.1] (334.30)
- Do not overdrive staples or staple flat cable on edge ______________ [3802.1] (334.30)
- Bends gradual (min 5× cable diameter) ______________ [3802.5] (334.24)
- Running board for small cable under joists **F47** ______________ [3802.4] (334.15C)

**AC—Armored Cable (BX™)**

- Dry locations only ______________ [3801.4] (320.10)
- Secure within 12 in. of box & max 4 1/2 ft. intervals EXC ______________ [3802.1] (320.30B)
  - 2 ft. where flexibility needed (motors) ______________ [3802.1] (320.30D)
- Insulated (anti-short) bushing at terminations **F50** ______________ [3802.1] (320.40)
- Armor is EGC—don’t bring bond wire into box **F50** ______________ [3908.8] (250.118)
- Underside of joists—secure at each joist ______________ [n/a] (320.15)
**FIG. 51**

**UF – Underground Feeder Cable**

- Interior installation same rules as NM
- May be buried in earth with cover per T1, F52
- Protect where emerging from earth from 18 in. below grade to 8 ft. above
- Single conductors in trench must be grouped
- UV-resistant type OK exposed to sunlight
- Not OK strung through air without support messenger

**FIG. 52**

**Protecting Underground Cable**

UF cable req’s protection where it emerges from the ground & to a height of at least 8 ft.

The protection should extend underground to the burial depth or 18 in., whichever is less.

**FIG. 53**

**SE Cable**

- Threaded Mylar wrap
- 3-wire cable assembly
- Bare sheath
- 4-wire cable assembly
When laying out wiring, consider the voltage drop caused by long runs of wire. Fine-print note #4 of 210.19 of the NEC recommends (though it does not req) a maximum voltage drop of 3% on branch circuits and a 5% overall voltage drop, including the feeders. Excessive voltage drop can cause problems in connected equipment and adds to the monthly utility costs. One way to overcome a voltage drop problem is to use larger wire than the minimum size and to make sure that all connections are tight. Voltage drop increases proportionately to the load on the circuit. Adding more than the minimum number of circuits helps prevent individual circuits from overloading. The added cost of more wiring will pay for itself over time in reduced utility costs and greater equipment efficiency.

In the table below, the distances shown are the maximum length of cable to stay within a 3% branch circuit voltage drop at 80% of the allowable load on the circuit. Multiwire circuits (p.23) act as 240V circuits for voltage drop to the extent that the load on them is balanced. When only one side of the multiwire circuit has a load, the voltage drop is the same as for any other 120V circuit.

<table>
<thead>
<tr>
<th>Wire Size (AWG)</th>
<th>Cu Distance (ft)</th>
<th>Al Distance (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>120V</td>
<td>240V</td>
</tr>
<tr>
<td>14</td>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td>12</td>
<td>60</td>
<td>120</td>
</tr>
<tr>
<td>10</td>
<td>64</td>
<td>128</td>
</tr>
<tr>
<td>8</td>
<td>76</td>
<td>152</td>
</tr>
<tr>
<td>6</td>
<td>94</td>
<td>188</td>
</tr>
</tbody>
</table>

Based on 80% circuit loading for normal OCPD.
Raceways are complete systems of conduit or tubing through which conductors are installed. In the NEC numbering system, all articles pertaining to raceways have a parallel numbering system so the portion after the article number is the same for all types. Article numbers are the first 3 digits before the period inside each section number. See the common numbering system table T24 on p.63.

**General**

- Conductors in raceways stranded if ≥ 8 AWG [3406.4] (310.3)
- Wet-rated conductors req’d in raceways above grade in wet locations [3802.7] (300.9)
- Raceway req to be complete before to wiring EXC [3904.5] (300.18A)
- Short sections of raceway for cable protection [3904.5X] (300.18AX)
- Bends req’d to have even radius—no kinks [3802.5] (**.24)
- 360° max bends between pull points [3802.1] (**.26)
- Raceway must be reamed after cutting [3802.1] (**.28)
- Plastic bushing/liner req’d if conductors ≥ 4 AWG [3906.1.1] (300.4G)
- Box & conduit body covers must remain accessible [3905.11] (314.29)
- No plastic boxes with metal cables or raceways unless bonded through box [3905.3X] (314.3X)
- No splicing in conduit bodies except conduit bodies with sufficient volume per marking [3905.13.3.1] (314.16C2)
- Max 40% fill if > 2 conductors T21, 22 [3904.6] (**.22)
- Derate conductors as needed T11–14 [3705.2&3] (310.15B2a)

**EMT—Electrical Metallic Tubing**

- Direct burial or embedment not OK [3801.4] (358.10B)
- In wet locations use L&L wet fittings [3905.12] (358.42)
- Secure in place max 10 ft. intervals & 3 ft. from each box, conduit body or cabinet [3802.1] (358.30A)

**FIG. 57**

Too Many Bends

Total bends between pull points max. 360°

**FIG. 58**

EMT—Electrical Metallic Tubing

Raintight wet location

Sealing ring

Compression ring

Dry location

Older style EMT connectors with only compression ring were not listed.
RMC—Rigid Metal Conduit F59 09 IRC 11 NEC
- Galvanized RMC typically sufficient corrosion protection for direct burial or embedment [3801.4] (344.10B)
- Coat buried field cut threads with L&L compound [3801.4] (300.6A)
- Provide bushing or fitting at box connection F59 [3802.1] (344.46)
- No threadless connectors on threaded conduit ends [n/a] (344.42)
- Secure in place within 3 ft. of termination [3802.1] (344.30A)
- Horizontal support spacing max 10 ft. [3802.1] (344.30B)

FIG. 59 RMC – Rigid Metal Conduit
- Interior reamed
- Locknut
- Box wall
- Bushing
- Locknut

RMC—Rigid Metal Conduit F59 09 IRC 11 NEC
- Galvanized RMC typically sufficient corrosion protection for direct burial or embedment [3801.4] (344.10B)
- Coat buried field cut threads with L&L compound [3801.4] (300.6A)
- Provide bushing or fitting at box connection F59 [3802.1] (344.46)
- No threadless connectors on threaded conduit ends [n/a] (344.42)
- Secure in place within 3 ft. of termination [3802.1] (344.30A)
- Horizontal support spacing max 10 ft. [3802.1] (344.30B)

FIG. 59 RMC – Rigid Metal Conduit
- Interior reamed
- Locknut
- Box wall
- Bushing
- Locknut

FMC—Flexible Metal Conduit (“Greenfield”) F60 09 IRC 11 NEC
- Dry locations only [3801.4] (348.12)
- Support max spacing 4 1/2 ft. & 12 in. from boxes EXC [3802.1] (348.30A)
  - Lighting whip in accessible ceiling OK to 6 ft. OR [3802.1] (348.30AX4)
  - 36 in. where flexibility is needed [3802.1] (348.30AX1)
- Armor is OK as EGC if fittings listed, circuit ≤ 20A, no flexibility needed for sizes 3/4–1 1/4 in. & no flexibility needed [3908.8.1] (250.118)
- Support max spacing 4 1/2 ft. & 12 in. from boxes EXC [3802.1] (350.30AX2)

FIG. 60 FMC – Flexible Metal Conduit
- “Jake” connector
- Clamp connector
- Angle connector

LFMC—Liquidtight Flexible Metal Conduit F61 09 IRC 11 NEC
- OK for wet locations [3801.4] (350.10)
- OK for direct burial if L&L [3801.4] (350.10)
- OK as EGC up to 6 ft. if fittings listed, circuit ≤ 20A or ≤ 60A for sizes 3/4–1 1/4 in. & no flexibility needed [3908.8.1] (250.118)
- Support max spacing 4 1/2 ft. & 12 in. from boxes EXC [3802.1] (350.30AX2)
  - 36 in. where flexibility is needed [3802.1] (350.30AX2)

FIG. 61 LFMC – Liquidtight Flexible Metal Conduit
- PVC jacket
- Interlocked metal ribbon
- Liquidtight connectors
**LFNC—Liquidtight Flexible Nonmetallic Conduit F62**

- 09 IRC 11 NEC
  - OK in lengths > 6 ft. if secured every 3 ft. [n/a] (356.10)
  - Securing or supporting not req’d up to 3 ft. for motors [3802.1] (356.30)
  - OK for direct burial or encasement when L&L [3801.4] (356.10)
  - EGC req’d [3908.4] (250.4A5)

**PVC—Rigid Polyvinyl Chloride Conduit F63**

- 09 IRC 11 NEC
  - Burial depth per [3803.1] (300.5A)
  - Support to prevent sags per T16 & within 3 ft. of box [3802.1] (352.30)
  - Expansion joints req’d if subject to ≥ 1/4 in. shrinkage [n/a] (352.44)
  - Not OK for support of luminaires or boxes [n/a] (352.12B)
  - Not permitted in environments > 50°C (122°F) [n/a] (352.12D)

**ENT—Electrical Nonmetallic Tubing F64**

- 09 IRC 11 NEC
  - OK embedded in concrete with approved fittings [3801.4] (362.10)
  - Not OK in environments > 50°C (122°F) [n/a] (362.12)
  - Not OK for direct earth burial [3801.4] (362.12)
  - Must be identified as sunlight resistant if outdoors [3801.4] (362.12)
  - Secure or support every 3 ft. EXC [3802.1] (362.30A&B)
    - 6 ft. unsupported OK to luminaires in accessible ceiling [3802.1] (362.30AX2)

**TABLE 16**

<table>
<thead>
<tr>
<th>PVC CONDUIT SUPPORT MAX. SPACING [T3802.1] (T352.30)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Conduit Trade Size</strong></td>
</tr>
<tr>
<td>1/2 in.–1 in.</td>
</tr>
<tr>
<td>1 1/4 in.–2 in.</td>
</tr>
<tr>
<td>2 1/2 in.–3 in.</td>
</tr>
<tr>
<td>3 1/2 in.–5 in.</td>
</tr>
</tbody>
</table>

**FIG. 63**
PVC 80 Conduit & Connector

**FIG. 64**
ENT & Connector

---

TABLE 16

<table>
<thead>
<tr>
<th>PVC CONDUIT SUPPORT MAX. SPACING [T3802.1] (T352.30)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Conduit Trade Size</strong></td>
</tr>
<tr>
<td>1/2 in.–1 in.</td>
</tr>
<tr>
<td>1 1/4 in.–2 in.</td>
</tr>
<tr>
<td>2 1/2 in.–3 in.</td>
</tr>
<tr>
<td>3 1/2 in.–5 in.</td>
</tr>
</tbody>
</table>

---

RACEWAYS
### TABLE 17
**EMT FILL [3904.6(1)] {ANNEX T C.1}**

<table>
<thead>
<tr>
<th>Size (AWG)</th>
<th>Number of Conductors in THHN, THWN</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/0</td>
<td>1</td>
</tr>
<tr>
<td>2/0</td>
<td>0</td>
</tr>
<tr>
<td>3/0</td>
<td>0</td>
</tr>
<tr>
<td>4/0</td>
<td>0</td>
</tr>
<tr>
<td>250</td>
<td>0</td>
</tr>
</tbody>
</table>

### TABLE 18
**EMT FILL {ANNEX T C.1(A)}**

<table>
<thead>
<tr>
<th>Size (AWG)</th>
<th>Number of Conductors in XHHW (Compact Stranding)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/0</td>
<td>1</td>
</tr>
<tr>
<td>2/0</td>
<td>0</td>
</tr>
<tr>
<td>3/0</td>
<td>0</td>
</tr>
<tr>
<td>4/0</td>
<td>0</td>
</tr>
<tr>
<td>250</td>
<td>0</td>
</tr>
</tbody>
</table>

### TABLE 19
**SCHEDULE 80 PVC FILL [3904.6(9)] {ANNEX T C.9}**

<table>
<thead>
<tr>
<th>Size (AWG)</th>
<th>Number of Conductors in THHN, THWN</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/0</td>
<td>1</td>
</tr>
<tr>
<td>2/0</td>
<td>0</td>
</tr>
<tr>
<td>3/0</td>
<td>0</td>
</tr>
<tr>
<td>4/0</td>
<td>0</td>
</tr>
<tr>
<td>250</td>
<td>0</td>
</tr>
</tbody>
</table>

### TABLE 20
**SCHEDULE 80 PVC FILL {ANNEX T C.9(A)}**

<table>
<thead>
<tr>
<th>Size (AWG)</th>
<th>Number of Conductors in XHHW (Compact Stranding)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/0</td>
<td>1</td>
</tr>
<tr>
<td>2/0</td>
<td>0</td>
</tr>
<tr>
<td>3/0</td>
<td>0</td>
</tr>
<tr>
<td>4/0</td>
<td>0</td>
</tr>
<tr>
<td>250</td>
<td>0</td>
</tr>
</tbody>
</table>

**CONDUIT FILL**
Conduit Fill Calculations

When all conductors are the same size, use T17–20. When different sized conductors are used, use T21 to find the wire areas, add them up, and use T22 to find the minimum size conduit. Example: 3 2 AWG THHN + 3 8 AWG XHHW in FMC: (3 × 0.1158) + (3 × 0.0394) = 0.4656, and the next greater size in the 40% column is 0.511. Therefore, a 1 1⁄4 in. FMC conduit meets code. When conductor calculation is close to conduit table values, one size larger is recommended.

### TABLE 21. SQ. IN. AREA OF CONDUCTORS (BASED ON NEC T5 CHAPTER 9)

<table>
<thead>
<tr>
<th></th>
<th>14</th>
<th>12</th>
<th>10</th>
<th>8</th>
<th>6</th>
<th>4</th>
<th>2</th>
<th>1</th>
<th>1/0</th>
<th>2/0</th>
<th>3/0</th>
<th>4/0</th>
<th>250</th>
</tr>
</thead>
<tbody>
<tr>
<td>TW</td>
<td>.0139</td>
<td>.0181</td>
<td>.0243</td>
<td>.0437</td>
<td>.0726</td>
<td>.0973</td>
<td>.1333</td>
<td>.1901</td>
<td>.2233</td>
<td>.2624</td>
<td>.3117</td>
<td>.3718</td>
<td>.4596</td>
</tr>
<tr>
<td>THHN</td>
<td>.0097</td>
<td>.0133</td>
<td>.0211</td>
<td>.0366</td>
<td>.0507</td>
<td>.0824</td>
<td>.1158</td>
<td>.1562</td>
<td>.1855</td>
<td>.2233</td>
<td>.2679</td>
<td>.3237</td>
<td>.3970</td>
</tr>
<tr>
<td>XHHW</td>
<td></td>
<td>.0394</td>
<td>.0530</td>
<td>.0730</td>
<td>.1017</td>
<td>.1352</td>
<td>.1590</td>
<td>.1885</td>
<td>.2290</td>
<td>.2733</td>
<td>.3273</td>
<td>.3421</td>
<td></td>
</tr>
</tbody>
</table>

1. Based on compact-stranded conductors (Annex C, table 5A)

### TABLE 22. CONDUIT & TUBING FILL (BASED ON NEC T4 CHAPTER 9)

#### Trade Size

<table>
<thead>
<tr>
<th></th>
<th>Internal Diameter</th>
<th>2 wire sq. in. Fill 31%</th>
<th>2 wire sq. in. Fill 40%</th>
<th>&gt; 2 Wire sq. in. Fill 40%</th>
</tr>
</thead>
<tbody>
<tr>
<td>EMT</td>
<td>FMC</td>
<td>LFMC</td>
<td>LFMC</td>
<td>IMC</td>
</tr>
<tr>
<td>3⁄8</td>
<td>0.384</td>
<td>0.494</td>
<td>0.496</td>
<td>–</td>
</tr>
<tr>
<td>1⁄2</td>
<td>0.622</td>
<td>0.635</td>
<td>0.630</td>
<td>0.660</td>
</tr>
<tr>
<td>3⁄4</td>
<td>0.824</td>
<td>0.824</td>
<td>0.825</td>
<td>0.864</td>
</tr>
<tr>
<td>1</td>
<td>1.049</td>
<td>1.020</td>
<td>1.043</td>
<td>1.105</td>
</tr>
<tr>
<td>11⁄4</td>
<td>1.380</td>
<td>1.275</td>
<td>1.383</td>
<td>1.448</td>
</tr>
<tr>
<td>11⁄2</td>
<td>1.610</td>
<td>1.538</td>
<td>1.588</td>
<td>1.603</td>
</tr>
<tr>
<td>2</td>
<td>2.067</td>
<td>2.040</td>
<td>2.063</td>
<td>2.150</td>
</tr>
</tbody>
</table>

1. Dimensions for LFNMC are for type A; type B has an interior diameter identical to LFMC.
Modern inverters with integral AC & DC disconnects eliminate the need for multiple components.

Inverters should be located in a cool location out of the afternoon sun.

PV wires must be in conduit or MC cable when passing through house ahead of a disconnect.

Structural issues and wind uplift must be considered; several manufacturers now make rack support systems specifically for PV. The NEC requirements for lightning protection are minimal & lightning can severely damage PV equipment. Surge suppressors can be permanently installed for component protection.
PHOTOVOLTAICS

In most states, the utility will rebate a portion of the cost of a PV system. Time-of-use and net metering can reduce or eliminate monthly utility costs. The quality and efficiency of PV equipment have improved greatly in the last few years. What once req’d numerous separate components is often integrated into a single piece of equipment. Contact the utility and building department before beginning any project involving renewable energy sources. (note- the IRC does not include PV.)

Definitions

Array: An assembly of panels that forms the power-producing unit F66.

Combiner: The location where parallel PV source circuits are connected to create a PV output circuit.

Hybrid system: A system with multiple power sources (not including the utility or batteries). An example would be a system with a generator & a PV source.

Interactive system: A solar PV system that operates in parallel to the utility.

Inverter: Equipment that converts the DC current & voltage of a PV output circuit to an AC waveform F65.

Inverter output circuit: The AC conductors from an inverter to an AC panel-board or service F65.

Module: A group of PV cells connected together & encapsulated in an environmentally protective laminate—usually tempered glass—to generate DC power when exposed to the sun.

Panel: A group of modules preassembled onto a common frame & designed to be field installed.

PV output circuit: Conductors between the PV source circuits & the inverter F66.

PV source circuits: Circuits between modules & circuits from modules to the common connection points (combiners) of the DC system.

Stand-alone system: Solar PV system supplying power independent of the utility.

General 11 NEC

☐ Inverters, modules, panels, source circuit combiners L&L for PV ___ (690.4D)
☐ PV req’d to be installed by only qualified persons __________ (690.4E)
☐ Max voltage = sum of rated open-circuit voltage of series connected modules times correction factors for cold temp F67 ___________ (690.7A)
☐ All power sources req disconnects ____________________ (690.15)
☐ DC disconnect req’d for ungrounded conductors F65 ________ (690.13)
☐ PV output circuits req in-sight disconnect _________________ (690.16B)
☐ Disconnect for ungrounded conductors must be readily accessible switch or breaker with no exposed live parts F65_________________ (690.17)
☐ Warning req’d at DC disconnect if all terminals hot while open F65 __________ (690.17)
☐ Rated max currents & voltages labeled on DC disconnect ________ (690.53)
☐ No disconnect on grounded conductor if it would be left energized (690.13)
☐ PV disconnecting means req’d to be on outside or inside nearest point of entrance of conductors EXC___________________ (690.14C1)
☐ Source circuits through interior OK in metal conduit F66 ___________ (690.31E)
☐ AC disconnects energized from 2 directions req warning label F65 ___ (690.17)
☐ Backfed breakers not req’d to be secured in place EXC_______(705.12D6)
  • Stand-alone systems (non-utility-interactive)______________ (609.10E)

Arrays & Inverters 11 NEC

☐ Req’d markings on modules: polarity, max OCPD rating for module protection, open-circuit voltage, operating voltage, max system voltage, operating current, short-circuit current & max power ____________ (690.51)
☐ PV circuits may not share raceways with non-PV systems EXC_____ (690.4B)
  • OK with barriers, tagging & grouping _____________________ (690.4B)
☐ DC ground-fault protection (DC GFP) req’d________________ (690.5)
☐ Inverter listed as interactive if used in interactive system_______ (690.60)
☐ DC arc-fault protection req’d systems > 80V_________________ (690.11)
☐ Interactive systems to automatically disconnect in grid outage EXC (690.61)
  • OK to feed subpanel isolated from service by transfer switch ____ (690.61)
**Grounding**

- Module frames & all metal parts must be grounded (690.43A)
- Size EGCs of PV output circuit per T6 & min 14 AWG (690.45)
- EGCs must be run in same raceway as PV array circuit conductors (690.43F)
- Bond ground-mounted array structures (690.43C)
- DC 2-wire system > 50V must have grounded conductor (690.41)
- Same conductor can perform DC grounding, AC grounding & bonding between AC & DC systems (690.47C3)
- When grounded conductor bonded to EGC internal within DC GFP device, bond not to be duplicated with an external connection (690.42X)

**Overcurrent Protection & Wiring**

- Single OCPD OK for series-connected string (690.9E)
- Sum of PV & main breakers not > 120% of panel rating (705.12D2)
- Source circuit currents = 125% x sum of parallel circuit currents (690.8A1)
- Locate PV breaker opposite end of bus from main or feeder input (705.12D7)
- Apply label warning against moving PV breaker (680.7B)
- Size conductors for 125% of max PV source short circuit currents (690.8B1)
- Max allowable voltage in SFD 600V (690.7C)
- Consider high ambient temp (use 90°C wire) (690.31)
- No multiwire or 240V circuits in panels with 120V supply (690.10C)
- Single conductor cables type USE or L&L as PV wire in exposed outdoor source circuits (behind modules) (690.31B)

**SWIMMING POOL**

Electricity and water can be a lethal mix. Precautions must be taken for shock hazard protection and to prevent corrosion of electrical equipment. Bonding is important to eliminate voltage gradients in the pool area. For GFCI requirements, see p.29. Click here to view the UL Marking Guide for Pool & Spa Equipment.

**Overhead Conductor Clearances** 09 IRC 11 NEC

- 22½ ft. clearance in any direction from water (T4203.5) (680.8A)
- 14½ ft. in any direction from diving platform (T4203.5) (680.8A)

**Underground Wiring** 09 IRC 11 NEC

- Non-pool underground wiring min 5 ft. from pool EXC (4203.7) (680.10)
  - If space limited, RMC, IMC, or PVC systems OK (4203.7) (680.10)
- Cover depth min 6 in. for RMC or IMC, 18 in. for PVC (T4203.7) (680.10)

**Feeders to Pool Panelboards** 09 IRC 11 NEC

- New feeder req’s RMC, IMC, LFNMC, or PVC EXC (T4202.1) (680.25A)
  - EMT OK on or within buildings (T4202.1) (680.25A)
- Raceway req’s min 12 AWG insulated EGC EXC (T4202.1) (680.25B)
  - Existing FMC or cable with EGC OK (4205.6X) (680.25AX)

**Pool Pump Motors** 09 IRC 11 NEC

- RMC, IMC, PVC, or listed MC OK for branch circuit (T4202.1) (680.21A1)
- Branch circuits in AC, FMC, or NM only within building (T4202.1) (680.21A1)
- EMT branch circuit OK on or within building (T4202.1) (680.21A2)
  - Flexible connection OK in LFMC or LFNMC (T4202.1) (680.21A3)
- Cord & plug connected motors OK with cord ≤ 3 ft. (4202.2) (680.21A4)
- Cords req EGC min 12 AWG & per T6 (4202.2) (680.7B)

**Underwater Wet-Niche Lighting** F68 09 IRC 11 NEC

- Min 18 in. below water level (4206.4.2) (680.23A5)
- Luminaire bonded & secured to shell with locking device (4206.5) (680.23B5)
- Luminaire must req tool for removal (4206.5) (680.23B5)
Underwater Wet-Niche Lighting (cont.) F68 09 IRC 11 NEC

- Low-voltage transformers req L&L for pool [4206.1] (680.23A2)
- Conductors from load side of GFCI or transformer not in same raceway or box as non-GFCI wires [4206.3] (680.23F3)
- Forming shell req’s bonding terminal if PVC conduit [4206.5] (680.23B1)
- Nonmetallic conduit req’s 8 AWG bonding conductor [4205.3] (680.23B2)
- Bonding conductor insulated & potted in forming shell [4205.3] (680.23B2)
- Min 16 AWG EGC in cord to wet-niche fixture [4205.4] (680.23F2)
- EGC connections on terminals only—no splices [4205.2]

Equipotential Bonding F68 09 IRC 11 NEC

- Purpose of bonding is to reduce voltage gradients [4204.1] (680.26A)
- Bond metal parts of pool structure, ladders, equipment, fences & screens or structures < 5 ft. from pool EXC [4204.2] (680.26B47)
  - Small isolated parts < 4 in. or < 1 in. into pool structure [4204.2] (680.26B2)
- Bond motors except listed & double-insulated type [4204.2] (680.26B6X)
- Provide bond wire to area of double-insulated motor [4204.2] (680.26B6)
- Bonding conductor min #8 solid Cu [4204.2] (680.26B8)
- Unencapsulated steel shell req’d to be bonded [4204.2] (680.26B1)
- Cu conductor grid req’d if pool shell steel encapsulated in nonconductive compounds (coated rebar) [4204.2] (680.26B1)
- Cu conductor grid req’s 8 AWG Cu in 12 × 12 in. pattern, conforming to contour of pool & deck, ≤ 6 in. from outer contour of pool shell, all conductors bonded at crossings [4204.2] (680.26B1)
- Perimeter surfaces for 3 ft. beyond pool req equipotential bonding with steel wire or reinforcement [4204.2] (680.26B2b)
- Connect perimeter to unencapsulated steel pool shell or Cu conductor grid at min 4 points [4204.2] (680.26B2)
- Min 9 sq. in. bonded metal contacting pool water [4204.3] (680.26C)

Receptacles (see p.29 for GFCI requirements) 09 IRC 11 NEC

- Min 1 receptacle ≥ 6 ft. & ≤ 20 ft. from pool walls [4203.1.2] (680.22A3)
- Pump motor receptacles not < 10 ft. from pool wall EXC 6 ft. OK for single-receptacle twist-lock types [4203.1.1] (680.22A1)
- Dimensions include distance around barriers without penetrating a floor, wall, doorway, or window opening [4203.1] (680.22A5)

Lighting Outlets & Luminaires 09 IRC 11 NEC

- Outdoors ≥ 5 ft. from pool edge unless 12 ft. above [4203.4.1] (680.22C1)
- Indoors ≥ 7 ft. 6 in. above water if enclosed & GFCI [4203.4.2] (680.22C2)
- Existing lighting OK if GFCI & ≥ 5 ft. from pool edge & ≥ 5 ft. high [4203.4.3] (680.22C3)
- Switches min 5 ft. from pool edge or separated by barrier [4203.2] (680.22D)

---

**FIG. 68**

**Swimming Pool**

- Box min. 4 ft. from pool edge, min. 8 in. above max. water level
- Metal awning
- Aluminum window frame ≤ 5 ft. from pool edge
- L&L for pools

**Bonding grid min. 3 ft. past pool edge**

- Encapsulated structural reinforcing steel
- Uncapsulated structural reinforcing steel

1 or 2 are options for creating an equipotential bonding grid.
**HOT TUB/SPA**

Outdoor hot tubs and spas follow the same rules as swimming pools in addition to the general rules below. A hydromassage tub (p. 39) is not a spa because it is emptied after each use.

**General**
- **09 IRC**
- **11 NEC**
- LFMC or LFNMC up to 6 ft. OK for package unit [T4202.1] (680.42A1)
- Cord up to 15 ft. OK for GFCI-protected package unit [4202.2] (680.42A2)
- Bands to secure hot tub staves exempt from bonding [4204.4] (680.42B)

**Indoor Spas**
- **09 IRC**
- **11 NEC**
- Indoor packaged units ≤20A OK for cord & plug [4202.2] (680.43X)
- Min 1 receptacle 6–10 ft. from inside wall of spa [4203.1.4] (680.43A1)
- Wall switches min 5 ft. from inside wall of spa [4203.2] (680.43C)

**GENERATORS**

Generators provide a source of emergency power during a utility outage. Care must be taken to ensure that the 2 sources of power—utility and generator—cannot be connected simultaneously. This dangerous condition results from failure to install proper transfer switches and improper use of portable generators.

**Generators**
- **11 NEC**
- Must be suitable for environment, rainproof if outdoors [445.10]
- Rainproof generators not OK enclosed indoors [110.3B]
- Conductors sized 115% of nameplate current rating [445.13]
- Live or moving parts guarded against accidental contact [445.14]
- GEC req’d for permanently installed generators [250.30A3]
- Remove bonding jumper if transfer switch does not switch neutral F69 [250.24A5]

**Transfer Switches F69**
- **11 NEC**
- Sign req’d at service indicating generator location [702.8A]
- Transfer equipment must prevent simultaneous connection of generator & utility service [702.6]

**ELECTRIC VEHICLE CHARGING**

**Electric Vehicle (EV) Charging Systems**
- **11 NEC**
- Systems >20A 125V no exposed live parts [625.13]
- Coupler L&L for EV [625.16]
- Interlock must de-energize connector when uncoupled from EV [625.18]
- Electric vehicle OK as standby power source through listed utility interactive connection [625.26]
OLD WIRING

A high percentage of residential electrical fires occur in older homes. Proper overcurrent protection helps prevent insulation failure, though in some cases time and exposure take too great a toll on wiring, and it must be replaced with new materials. Fuses provide overcurrent protection only if they are the right size. Too often, they are altered or bypassed (a penny behind the fuse). Older ceramic fuse panels and panels with cartridge fuses also pose a risk of electrocution because of exposed electrical contacts. For these reasons, many insurance companies req upgrading of fuse systems. The references below are from the NEC. The IRC is a code for new construction and does not address old wiring.

Fuses

11 NEC

☐ No exposed contact fuseholders (must be dead front) F70 (240.50D)
☐ Edison base (plug fuses) not OK for 240V circuits (240.51A)
☐ Type S fuse req’d if tampering or overfusing exists F70 (240.51B)
☐ Type S fuse adapter must be proper size for wire (240.4D)
☐ No fuses in neutral conductor F70 (240.22)
KNOB & TUBE (K&T)

K&T wiring is the oldest wiring method found in American homes. When left in its original state, it can be reliable; safety was inherent in its design. As a wiring method in uninsulated joist and stud cavities it is protected from damage and provided with air circulation, which prevents heat buildup. Unfortunately, when these systems are modified by unqualified persons, the inherent safety of K&T is often compromised. Adding new loads to an old system is tricky and seldom done correctly. Rubber insulation on K&T wiring becomes brittle over time and is prone to mechanical damage, especially when thermal insulation is added to an attic. Older rubber insulation has only a 60°C rating.

General

☐ No new K&T

☐ Additions to existing K&T OK if properly protected (394.10)

☐ Must enter plastic boxes through separate holes (314.17C)

☐ Must be protected with loom where entering box (314.17B&C)

☐ Loom must extend from last insulator to 1/4 in. inside box (314.17B&C)

☐ Do not envelop with thermal insulation (394.12)

☐ Wires must be kept out of direct contact with wood framing (394.17)

☐ Tubes req’d where passing through framing members (394.17)

☐ 3 in. min between wires, 1 in. to surfaces (394.19A1)

☐ Conductors on sides (not face) of exposed joists & rafters EXC (394.23A&B)
  - OK on edges or faces of rafters or joists in attics < 3 ft. high (394.23BX)

☐ Provide protection where exposed < 7 ft. above floor (398.15C)
houses built before adoption of the 1962 NEC will not have 3-hole receptacles in all locations. Appliances with 3-prong cords are designed to be used with only grounded 3-hole receptacles. A GFCI can provide shock hazard protection for 2-conductor circuits; though without an EGC, it may not protect equipment.

**General**

- AFCI protection req’d for replacements in areas where circuit req’s AFCI protection (p.24) effective 1/1/2014 (406.4D4)$^50$
- Protection can be breaker, AFCI outlet device, or upstream AFCI outlet (406.4D4)$^50$
- Replacement receptacles must be tamper-resistant (406.4D5)$^50$
- Outdoor wet location replacement receptacles must be WR (406.4D6)$^50$

**Replacements When No Grounding Present**

- 2-hole receptacle OK if in area where GFCI not req’d (406.4D2a)
- Must have GFCI protection in area that now req’s GFCI (406.4D3)
- OK to install GFCI even if no ground present (406.4D2b&c)
- Non-grounded GFCI or GFCI-protected receptacles req label stating “No Equipment Ground” (406.4D2b)
- Ungrounded 3-hole receptacle supplied through a GFCI also req label stating “GFCI Protected” (406.4D2d)
- Separate EGC can be added from receptacle box & connect to service enclosure, GEC, or ground bar of panel at circuit origin (250.130C)
- OK to run EGC separately from circuit conductors (300.3B2)
- Not OK to jumper neutral & EGC (250.142B)

**Replacements When Grounding Present in Box**

- Replacements must be 3-hole if EGC present (406.4D1)
- Bond 3-hole receptacle to grounded box with wire OR (250.146)
  - Use grounding-type receptacle (captive metal screw from yoke) (250.146B)

**OLD NM**

Pre-1984 nonmetallic sheathed cable contained conductors with insulation rated 60°C. When installed in a hot attic, the ampacity of this old wire is easily exceeded. Precautions must also be taken to isolate this low-temperature wiring from luminaires that req high-temperature rated connections F36. Much of this old wire was used in houses with problematic electrical equipment. Replacement circuit breakers for older panels can be very expensive—providing one more incentive to replace such systems. For further information on old wiring, refer to the Code Check website, www.codecheck.com.

**Aluminum Wiring**

- Snap switches with direct Al connection req L&L as “CO/ALR” (404.14C)
- Receptacles ≤ 20A with direct Al connection req L&L as “CO/ALR” (406.2C)
- Al to Cu splicing devices must be listed for same (110.14)
- Terminals (including breaker terminals) for Al req L&L (110.14A)

**Pre-1984 NM**

- Derate for ambient temp (310.10, T310.16)
- No 60°C conductors in attics > 131°F (T310.16)
- No direct connection to luminaires that req > 60°C conductors (410.117A)
- Isolate old wiring from high-temp wiring F36 (410.117A)
- Box for tap conductors min 1 ft. from luminaire, max 6 ft. wire (410.117C)
### TABLE 23

**SIGNIFICANT CHANGES IN THE 2011 NEC & THE 2009 IRC / 2008 NEC**

<table>
<thead>
<tr>
<th>#</th>
<th>Page</th>
<th>Code &amp; Year</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7</td>
<td>11 NEC</td>
<td>Exemption for guarded/isolated roof areas</td>
</tr>
<tr>
<td>2</td>
<td>10</td>
<td>11 NEC</td>
<td>Seal underground conduits entering buildings</td>
</tr>
<tr>
<td>3</td>
<td>10</td>
<td>11 NEC</td>
<td>Max 1 branch circuit back to source building</td>
</tr>
<tr>
<td>4</td>
<td>11</td>
<td>11 NEC</td>
<td>Clarified when cord-set GFCIs req’d</td>
</tr>
<tr>
<td>5</td>
<td>16</td>
<td>08 NEC &amp; 09 IRC</td>
<td>Allows isolated foundation pier rebar as Ufer</td>
</tr>
<tr>
<td>6</td>
<td>19</td>
<td>08 NEC &amp; 09 IRC</td>
<td>List of specific acceptable grounding connection methods replaced simple prohibition against sheet metal screws</td>
</tr>
<tr>
<td>7</td>
<td>19</td>
<td>11 NEC</td>
<td>Bonding req’d at line-side reducing washers</td>
</tr>
<tr>
<td>8</td>
<td>20</td>
<td>08 NEC &amp; 09 IRC</td>
<td>Intersystem bonding method specified</td>
</tr>
<tr>
<td>9</td>
<td>21</td>
<td>08 NEC &amp; 09 IRC</td>
<td>OCPDs not allowed over steps of a stairway</td>
</tr>
<tr>
<td>10</td>
<td>21</td>
<td>08 NEC &amp; 09 IRC</td>
<td>Labeling independent of transient conditions</td>
</tr>
<tr>
<td>11</td>
<td>21</td>
<td>08 NEC &amp; 09 IRC</td>
<td>Labeling of spare breakers</td>
</tr>
<tr>
<td>12</td>
<td>21</td>
<td>08 NEC &amp; 09 IRC</td>
<td>Neutral current not allowed through enclosure</td>
</tr>
<tr>
<td>13</td>
<td>21</td>
<td>08 NEC &amp; 09 IRC</td>
<td>All multiwire circuits handle tie or single-handle 2-pole</td>
</tr>
<tr>
<td>14</td>
<td>21</td>
<td>08 NEC &amp; 09 IRC</td>
<td>Multiwire circuits req’d to be grouped in panel</td>
</tr>
<tr>
<td>15</td>
<td>21</td>
<td>11 NEC</td>
<td>Warning label to identify source of feed-through circuits in panel</td>
</tr>
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</table>

### CODE CHANGE SUMMARY

<table>
<thead>
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<th>#</th>
<th>Page</th>
<th>Code &amp; year</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>16</td>
<td>24</td>
<td>08 NEC &amp; 09 IRC</td>
<td>Expanded AFCI other rooms than bedrooms</td>
</tr>
<tr>
<td>17</td>
<td>24</td>
<td>11 NEC</td>
<td>AFCI req’d for replacement or extension circuits</td>
</tr>
<tr>
<td>18</td>
<td>25</td>
<td>09 IRC</td>
<td>Conformed to NEC luminaire box ratings</td>
</tr>
<tr>
<td>19</td>
<td>29</td>
<td>11 NEC</td>
<td>GFCI controls req’d to be readily accessible</td>
</tr>
<tr>
<td>20</td>
<td>29</td>
<td>08 NEC &amp; 09 IRC</td>
<td>GFCI exceptions eliminated for garages &amp; unfinished basements</td>
</tr>
<tr>
<td>21</td>
<td>29</td>
<td>08 NEC &amp; 09 IRC</td>
<td>GFCI within 6 ft. of laundry, utility, or bar sinks</td>
</tr>
<tr>
<td>22</td>
<td>29</td>
<td>11 NEC</td>
<td>GFCI within 6 ft. all sinks in addition to those req’d for kitchen countertops</td>
</tr>
<tr>
<td>23</td>
<td>29</td>
<td>08 NEC &amp; 09 IRC</td>
<td>GFCI protection req’d for 240V boat hoists</td>
</tr>
<tr>
<td>24</td>
<td>30</td>
<td>08 NEC &amp; 09 IRC</td>
<td>Receptacles req’d by NEC 210.52 or IRC 3901.1 also req’d to be TR</td>
</tr>
<tr>
<td>25</td>
<td>30</td>
<td>11 NEC</td>
<td>Exceptions for tamper-resistant receptacles</td>
</tr>
<tr>
<td>26</td>
<td>31</td>
<td>08 NEC &amp; 09 IRC</td>
<td>Clarification that switched receptacles do not count as part of req’d receptacles</td>
</tr>
<tr>
<td>27</td>
<td>31</td>
<td>11 NEC</td>
<td>New requirement for receptacles in foyers</td>
</tr>
<tr>
<td>28</td>
<td>32</td>
<td>11 NEC</td>
<td>Countermounted bath receptacles allowed</td>
</tr>
<tr>
<td>29</td>
<td>32</td>
<td>08 NEC &amp; 09 IRC</td>
<td>Receptacles req’d for balconies &gt; 20 sq. ft.</td>
</tr>
<tr>
<td>30</td>
<td>32</td>
<td>11 NEC</td>
<td>Removed exemption for balconies &lt; 20 sq. ft.</td>
</tr>
<tr>
<td>31</td>
<td>32</td>
<td>08 NEC &amp; 09 IRC</td>
<td>Weather-resistant receptacles req’d</td>
</tr>
<tr>
<td>#</td>
<td>Page</td>
<td>Code &amp; year</td>
<td>Description</td>
</tr>
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<td>-------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>32</td>
<td>33</td>
<td>08 NEC &amp; 09 IRC</td>
<td>Clarified when range or sink divides island or peninsula countertop into separate spaces</td>
</tr>
<tr>
<td>33</td>
<td>36</td>
<td>11 NEC</td>
<td>Neutral req’d in switch box</td>
</tr>
<tr>
<td>34</td>
<td>36</td>
<td>11 NEC</td>
<td>Exceptions if neutral can be added at later time</td>
</tr>
<tr>
<td>35</td>
<td>37</td>
<td>08 NEC &amp; 09 IRC</td>
<td>L&amp;L LEDs allowed in closet storage areas</td>
</tr>
<tr>
<td>36</td>
<td>39</td>
<td>08 NEC &amp; 09 IRC</td>
<td>Hydromassage tub req’s individual circuit</td>
</tr>
<tr>
<td>37</td>
<td>39</td>
<td>08 NEC &amp; 09 IRC</td>
<td>Hydromassage area piping bonded to motor</td>
</tr>
<tr>
<td>38</td>
<td>41</td>
<td>09 IRC</td>
<td>NFPA 72 systems must become permanent part of property to replace req’d alarms</td>
</tr>
<tr>
<td>39</td>
<td>41</td>
<td>09 IRC</td>
<td>CO alarms req’d–hardwired like smoke alarms</td>
</tr>
<tr>
<td>40</td>
<td>42</td>
<td>08 NEC &amp; 09 IRC</td>
<td>Derate &gt; 2 NM cables in contact with thermal insulation</td>
</tr>
<tr>
<td>41</td>
<td>44</td>
<td>11 NEC</td>
<td>No cables or raceways other than RMC or IMC allowed &lt; 1½ in. from sheet steel roof deck</td>
</tr>
<tr>
<td>42</td>
<td>46</td>
<td>08 NEC &amp; 09 IRC</td>
<td>SE cable no longer exempt from 60° limitation that applies to NM</td>
</tr>
<tr>
<td>43</td>
<td>48</td>
<td>08 NEC &amp; 09 IRC</td>
<td>Wiring in raceways above grade in wet locations req’d to be wet-rated</td>
</tr>
<tr>
<td>44</td>
<td>49</td>
<td>08 NEC &amp; 09 IRC</td>
<td>FMC no longer allowed in wet locations</td>
</tr>
<tr>
<td>45</td>
<td>54</td>
<td>11 NEC</td>
<td>PV installations req qualified personnel</td>
</tr>
<tr>
<td>46</td>
<td>54</td>
<td>11 NEC</td>
<td>DC AFCI protection req’d</td>
</tr>
<tr>
<td>47</td>
<td>56</td>
<td>11 NEC</td>
<td>Screens &amp; metal windows &lt; 5 ft. from pool edge included in equipotential bonding</td>
</tr>
<tr>
<td>48</td>
<td>56</td>
<td>08 NEC &amp; 09 IRC</td>
<td>Specific methods for creating equipotential bonding grid for nonconductive pool shells &amp; for extending past pool edge</td>
</tr>
<tr>
<td>49</td>
<td>56</td>
<td>08 NEC &amp; 09 IRC</td>
<td>Contact with pool water to equipotential bond</td>
</tr>
<tr>
<td>50</td>
<td>60</td>
<td>11 NEC</td>
<td>Replacement receptacles req type &amp; protection of new receptacles for the area in which they are installed</td>
</tr>
</tbody>
</table>
### TABLE 24
**COMMON NUMBERING SYSTEM FOR WIRE, CABLE & RACEWAY ARTICLES (BASED ON NEC CHAPTER 3)**

<table>
<thead>
<tr>
<th>I. GENERAL</th>
<th>II. INSTALLATION</th>
<th>III. CONSTRUCTION SPECIFICATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>xxx.1 Scope</td>
<td>xxx.10 Uses Permitted</td>
<td>xxx.100 Construction</td>
</tr>
<tr>
<td>xxx.2 Definitions</td>
<td>xxx.12 Uses Not Permitted</td>
<td>xxx.104 Conductors</td>
</tr>
<tr>
<td>xxx.6 Listing Requirements</td>
<td>xxx.14 Dissimilar Metals</td>
<td>xxx.108 Equipment grounding</td>
</tr>
<tr>
<td>xxx.16 Temperature Limits</td>
<td>xxx.16 Number of Conductors</td>
<td>xxx.120 Marking</td>
</tr>
<tr>
<td>xxx.20 Size</td>
<td>xxx.22 Bending radius</td>
<td></td>
</tr>
</tbody>
</table>
In 1752, Benjamin Franklin, aided by his son, William, conducted the famous, but highly dangerous kite experiment. For an animated explanation, visit: www.codecheck.com/cc/BenAndTheKite.html.
Side Cutters