UPDATED TO THE CURRENT NATIONAL ELECTRICAL CODE

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FOURTH EDITION

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CODE CHECK® Electrical

Fourth Edition

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Model Codes & Organizations

CSA	=	Canadian Standards Association; www.cssinfo.com/info/csa.html
IAEI	=	International Association of Electrical Inspectors; www.iaei.org
IRC	=	International Residential Code: www.iccsafe.org
NEC	=	National Electrical Code, published by the NFPA
NEMA	=	National Electrical Manufacturers Association; www.nema.org
NFPA	=	National Fire Protection Association; www.nfpa.org
NTRL	=	Nationally Recognized Testing Laboratory, such as UL or CSA
UL	=	Underwriters Laboratory; www.ul.com

Key & Examples

Code references are followed by two bracketed numbers, ex:[123.4] {123.4}.
Code numbers on left, in straight brackets, ex: [123.4], refer to 2002 NEC.
Code numbers on right, in braces, ex: {123.4}, refer to 2005 NEC.
T1 refers to Code Check Electrical table 1.
F1 refers to Code Check Electrical figure 1.
Example (*from page 12*):

☐ Terminal bar for EGCs req to be provided . . . . . **F31,32** [408.20] {408.40}

Panels require a terminal bar for the equipment grounding conductors. This reference is found in 408.20 of the 2002 NEC and 408.40 of the 2005 NEC and is also shown in figures 31 and 32.

[manu] = Typically required by manufacturer's installation instructions.
[energy] = Energy conservation measures based on the Model Energy Codes. Adoption and enforcement varies greatly, so check with your local jurisdiction.
An X after a code number refers to an exception in the code.
EXC = When placed at end of text line signals an exception in following line.
OR = When placed at end of text line signals an alternative in following line.
[n/a] = not addressed by the 2002 NEC.
{n/a} = not addressed by the 2005 NEC.
[Ø] = Prohibited by the 2002 NEC.
Codes ending in numbers separated by commas refer to multiple code sections, ex: [210.8A2,5X2] = 2002 sections 210.8(A)(2) and 210.5(A)exception 2.

A colored code citation followed by a superscript number indicates a change in the code. Ex: {250.50}[1] refers to a code change in the 2005 edition, listed as #1 in the Code Change Summary found on the inside back cover.
Example of code change (*from page 12*):

☐ OCPDs readily accessible {& max height 6ft 7in} . . .[240.24A] {240.24A}[22]

The explanation on the inside back cover is that the 2002 code limited the height of only breakers used as switches, and in 2005 it applies to all breakers.
Example using "EXC" (*from page 11*):

☐ Disc must be rated as service eqpmt EXC . . . . . .[225.36] {225.36}
Garages or outbuildings snap switch or 3-way OK . .[225.36X] {225.36X}

The basic rule requires the disconnecting means to be rated as service equipment with the exception of outbuildings, which have only a circuit that can be controlled by a snap switch.
Example using "OR" (*from page 15*):

☐ Sep 20A ckt for bathroom receps only OR . . . . . .[210.11C3] {210.11C3}
Dedicated 20A ckt to each bathroom . . . . . .[210.11C3X] {210.11C3X}

A circuit dedicated to the bathroom receptacles is required or each bathroom can have its own dedicated circuit that supplies all the equipment in that bathroom.

Abbreviations

A	=	amps (ex.—a 15A breaker)
AC	=	alternating current, air-conditioning, amored cable aka "BX"
addl	=	additional
AFCI	=	arc-fault circuit interrupter
AHJ	=	authority having jurisdiction
AL	=	aluminum
appl(s)	=	appliance(s)
AWG	=	American wire gauge
bldg(s)	=	building(s)
BX®	=	trade name for AC cable
c&p	=	cord and plug
ckt	=	circuit(s)
cond	=	conductor(s)
Cu	=	copper
DB	=	direct burial
DC	=	direct current
dia	=	diameter
DW	=	dishwasher
disc	=	disconnect(s)
EGC	=	equipment grounding conductor
elec	=	electrical
EMT	=	electrical metallic tubing
ENT	=	electrical nonmetallic tubing, aka "Smurf tubing"
eqpmt	=	equipment
etc	=	and so forth
ext	=	exterior
fixt	=	lighting fixture(s) (now called luminaire[s])
FLA	=	full-load amps (motor nameplate current rating)
FLC	=	full-load current
FMC	=	flexible metal conduit, aka "Greenfield"
ft	=	foot, feet
GEC	=	grounding electrode conductor
gen	=	generator
GES	=	grounding electrode system
GFCI	=	ground-fault circuit interrupter
horiz	=	horizontal, horizontally
hp	=	horsepower
hr	=	hour, hours
Hz	=	Hertz (frequency, e.g., 60 cycles per second)
IMC	=	intermediate metal conduit
in	=	inch, inches
incl	=	includes, including
kcmil	=	1,000 circular mill units (conductor size)
KOs	=	knockouts **F9, 10**
K&T	=	knob & tube
KVA	=	kilovolt amperes = 1,000 x volts x amps
L&A	=	lighting & appliance (panelboard)
lb	=	pound(s)
LCDI	=	leakage current detection and interruption
LFMC	=	liquid-tight flexible metal conduit, aka "Sealtight"
LFNMC	=	liquid-tight flexible nonmetallic conduit
L&L	=	listed and labled, listing and labeling
loc	=	location
lum(s)	=	luminaire(s) (lighting fixture[s])
manu	=	manufacturer
max	=	maximum
min	=	minimum, minute
MC	=	metal-clad cable
NM	=	nonmetallic sheathed cable (Romex®)
OCPD	=	overcurrent protection device (breaker or fuse)
PMI	=	per manufacturer's instructions
PV	=	photovoltaic
PVC	=	rigid nonmetallic conduit (RNMC)
recep(s)	=	receptacle outlet(s)
refrig	=	refrigerator
req	=	requires, required, requiring, requirement
RMC	=	rigid metal conduit
RNMC	=	rigid nonmetallic conduit (PVC)
SC	=	short circuit
SE	=	service entrance cable
sep	=	separate
SFD	=	single-family dwelling
spec(s)	=	specification(s), specify, specified
std	=	standard
sq	=	square
temp	=	temperature
UF	=	underground feeder cable
USE	=	underground service entrance cable
util	=	utility
UV	=	ultraviolet
V	=	volt(s)
VA	=	volt amps
W	=	watts
w/	=	with
w/o	=	without

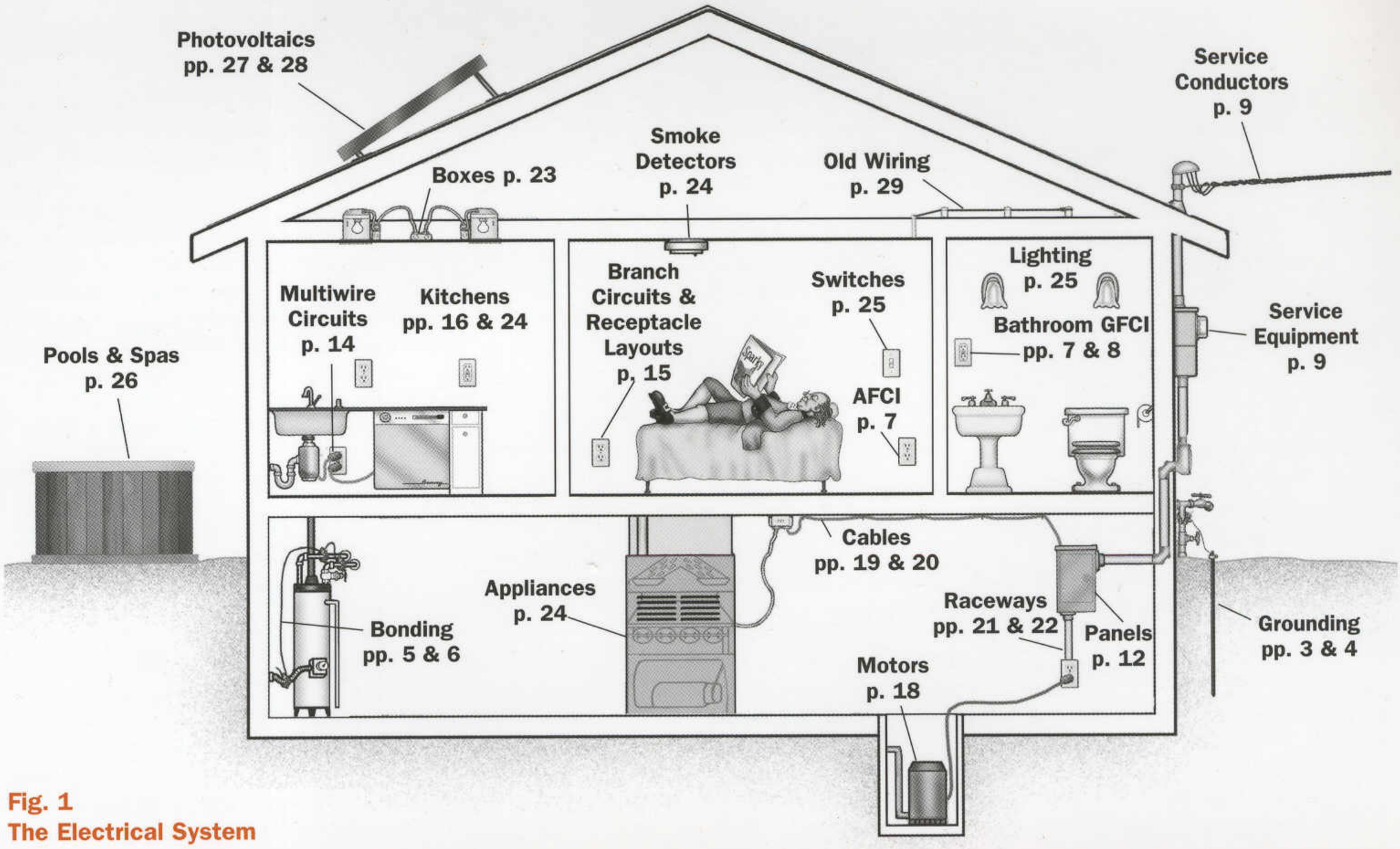


Fig. 1
The Electrical System

Glossary of Electrical Terms

Acccessible: Not permanently concealed or enclosed by building construction.

AFCI, Branch/Feeder Type: An AFCI meeting the standard for interrupting parallel arcs if 75A of current are available at the device.

AFCI, Combination Type: An AFCI meeting the standard for interrupting both series and parallel arcs and requiring <75A available current to facilitate operation

Alternating Current: Current that flows in one direction and then in the other in regular cycles; referred to as frequency or Hertz.

Apparent Power: Available power from a transformer measured in VA.

Appliance: Equipment such as an air-conditioner that uses electrical power.

Branch Circuit: The circuit conductors between the final OCPD (breaker or fuse) and the outlet or outlets it supplies.

Branch Circuit, General Purpose: A branch circuit that supplies a number of outlets for lighting and appliances.

Branch Circuit, Individual: A branch circuit supplying only one piece of equipment.

Branch Circuit, Multiwire (Residential): A branch circuit consisting of two hot conductors with a 240V potential between them and a grounded conductor having a 120V difference between it and each hot conductor. **(F34-38)**

Branch Circuit, Small Appliance: A branch circuit supplying portable (can be unplugged and moved without tools) household kitchen appliances.

Controller: A device to start and stop motors.

Devices: Equipment that carries but does not use electricity; examples are receptacles, switches, and circuit breakers.

Equipment Grounding Conductor: A non-current-carrying conductor that provides an alternative path for equipment faults. **(F14)**

Feeder: Conductors supplying panelboards other than service panels.

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

Grounded Conductor: A current-carrying conductor that is connected to earth and that may be neutral. **(F5)**

Ground Fault: Current returning to the transformer on an unintended path, such as equipment enclosures or ground wires.

Hertz: A measure of the frequency of alternating current; in North America the standard is 60Hz.

In Sight: Visible and within 50ft.

Lighting & Appliance Panel: An electrical panel in which >10% of the circuits are rated ≤30A and are supplied with neutrals.

Load: The electrical demand in watts or horsepower of a piece of electrical equipment.

Luminaire: The term now used to describe lighting fixtures.

Open Conductors: Individual conductors not contained within a raceway or cable sheathing.

Panelboards: The "guts" of an electrical panel; the assembly of busbars, terminal bars, etc. designed to be placed in a "cabinet." What is commonly called an electrical panel is, by NEC terms, a panelboard mounted in a cabinet.

Power: Power is a product of volts and amps and can be expressed as either watts (true power) or VA (apparent power). **(F3)**

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

Service Drop: The overhead conductors supplied by the utility.

Service Entrance Conductors: The conductors on the customer's premises that convey power to the service equipment.

Service Equipment: The equipment at which the power conductors entering the building can be switched off to disconnect the premise's wiring from the utility power source.

Service Lateral: Underground service entrance conductors.

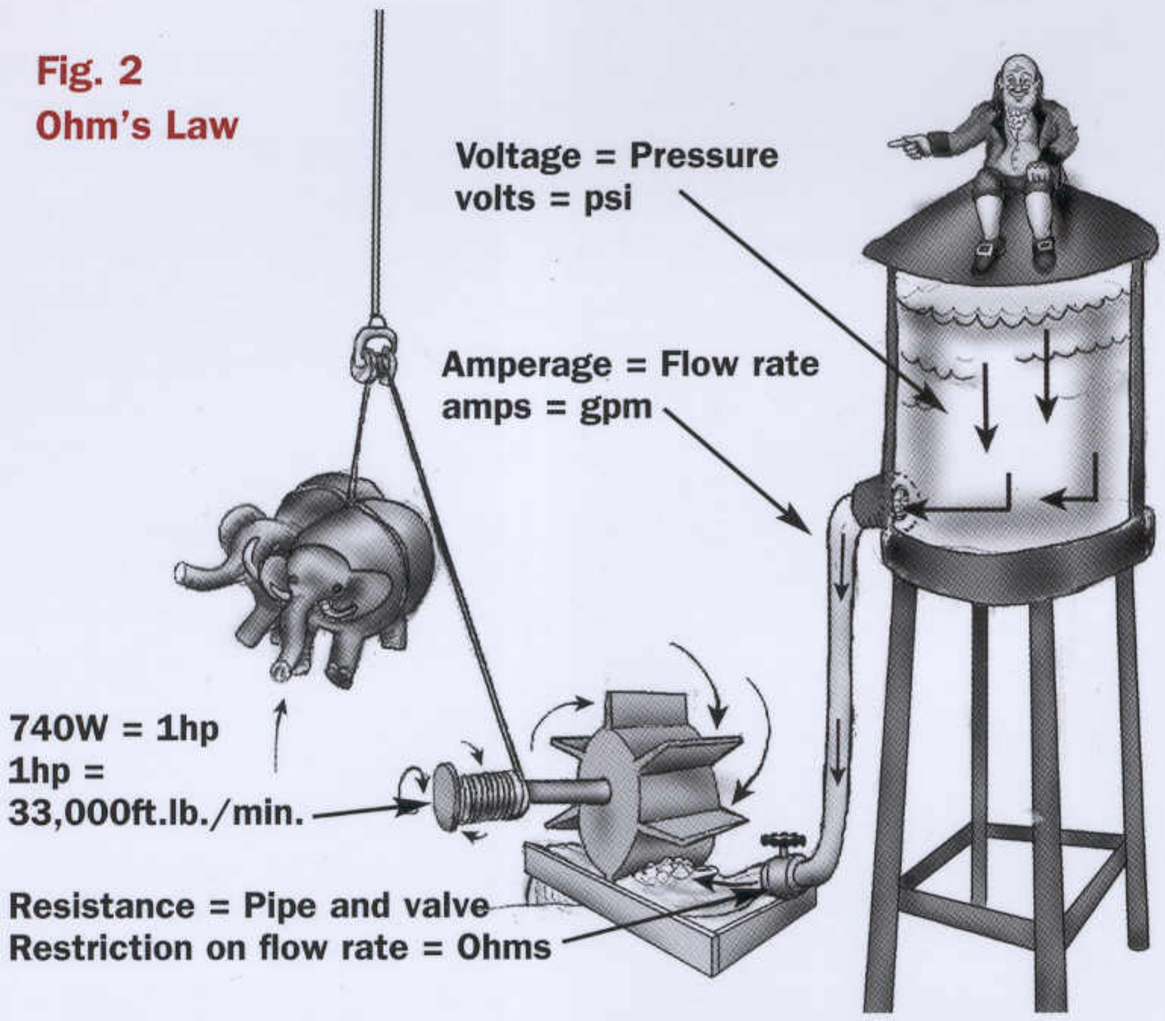
Service Point: The point where the service drop and service entrance meet; the handoff between the utility and the customer.

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.

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

Fig. 2
Ohm's Law



Water flow is often used to describe electricity. In the water analogy, water is the medium to transfer force. In an electrical circuit, the medium is the "free" electrons of a conductive metal like copper or aluminum. Water transmits force through the water in a pipe; in an electrical circuit, the force is transmitted over the electrons of a conductor. In **F2**, we use water to turn a waterwheel. The weight of the water in the tower exerts pressure on the outflow pipe. As the water flows out and under the paddles of the waterwheel, most of the water's kinetic energy (objects in motion) has been converted into rotational force (torque) at the axle of our illustrative contraption. Pressure is said to be dropped across the load. To maintain pressure at the source, new energy must be added—somebody has to scoop up the water, climb the tower and keep the water level constant. In an electrical system, it is the utility that must maintain this pressure, known as voltage.

The force exerted on the axle in **F2** depends on three things: The pressure (volts) in the pipe, the gallons per minute of water flow (amps), and the restrictive effect of the pipe and valve diameter (ohms). There is a simple formula to express this relationship of pressure, flow rate, and resistance. The formula is called Ohm's law after the German scientist George Simon Ohm who first described it. It reads:

I = E/R, if Amps = Volts/Ohms

E = electromotive force = **V** = voltage
I = intensity = **A** = current (measured in amperes)
R = resistance in Ohms

We can use the energy of the spinning axle to do work (convert energy). The job in this example is to lift 33,000lb. 1ft. in 1min. One healthy draft horse can do it, so we'll call this motor a 1horsepower motor (1hp = 33,000ft.lb./min.). Power is the rate in which work is done. More power means more energy is being transferred from one form to another. The rate at which electricity is converted to another form of energy (heat, light, motion) is measured in watts. The power formula is the most commonly used formula for electrical work. It is essential to understanding its application. That formula is expressed as follows:

P (power in watts) = I (amps) x E (volts)

This formula is also useful to utility companies. They can move large amounts of power through small low-current wires by distributing it at high voltage, then lowering the voltage with transformers near the point of use by the customer.

Fig. 3 • Ohm's Law & Power Formula

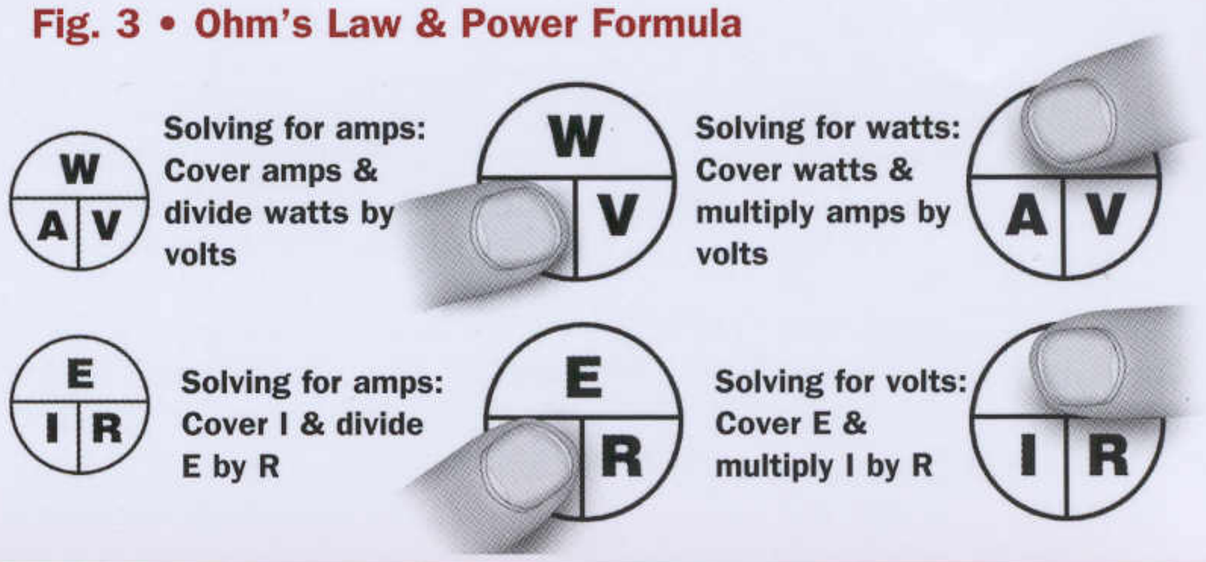


Fig. 4 • Ben's Big Idea

Benjamin Franklin's wildly dangerous kite experiment proved that lightning was electricity and could be discharged over a conductor and into the ground. Ben's lightning rod and conductor provided the lightning an alternative path to the ground.

A century and a half later Franklin's discovery was applied to the newly emerging electrical infrastructure. Transformers were especially vulnerable to the enormously high voltages of lightning and were grounded to help protect them.

The transformer in your neighborhood is a powerful pulsing (60Hz) magnetic field. The high-voltage utility distribution wires transfer energy to the relatively low-voltage (240V) wires connecting to our homes. This 240V secondary coil has a center tap conductor that is grounded, and the voltage between it and either of the "live" ungrounded conductors is 120V. It is important to remember that this intentionally grounded conductor (the "neutral") is designed to carry current all the time. It is a "live" wire.

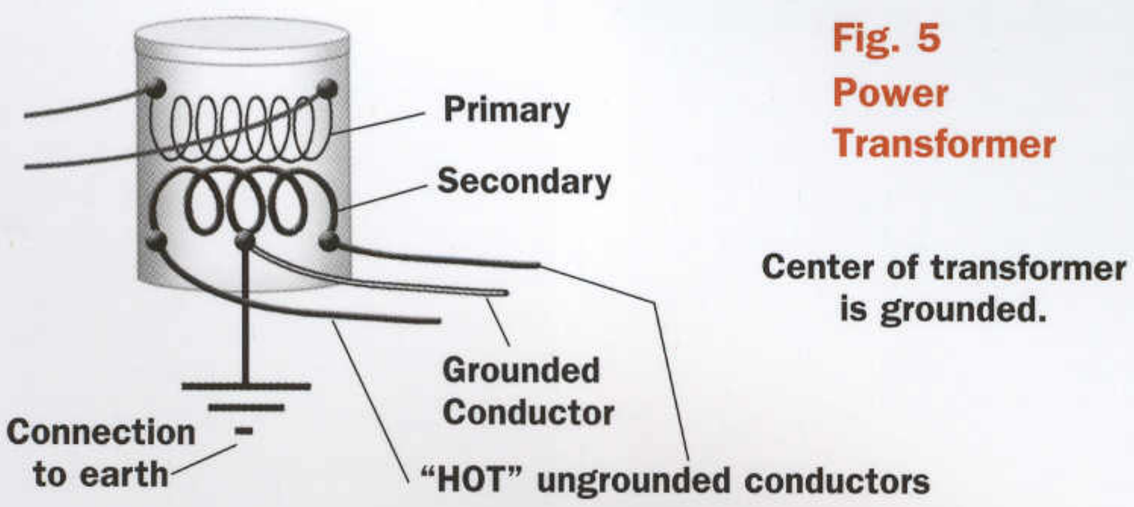


Fig. 5 Power Transformer

Once this grounded conductor comes to the building, we connect it again to the earth and to any metal enclosures up to and including those that contain our electrical disconnects and overcurrent protection.

Grounding Electrode System	2002	2005
☐ Metal water pipe if ≥10ft in contact w/soil . . .	F6 [250.52A1]	{250.52A1}
☐ Bond around water meters, filters, etc	[250.52A1]	{250.52A1}
☐ Water pipe cannot be only electrode	[250.53D2]	{250.53D2}
☐ Cu rods min ½in dia and L&L	[250.52.A5]	{250.52A5}
☐ Rods min 8ft in contact w/ soil	[250.52.A5]	{250.52A5}
☐ Drive rods vertical & fully below grade EXC . . .	F6-8 [250.53G]	{250.53G}
If bedrock encountered, rod may be buried horiz 2½ft deep or driven at 45° angle	[250.53G]	{250.53G}
☐ If water pipe & rod are only electrodes, rod max resistance 25ohms OR install 2nd rod min 6ft from 1st & bond two rods together	[250.56]	{250.56}
☐ Ufer electrode = 20ft #4 rebar near bottom of footing OR 20ft 4AWG Cu wire near bottom of footing . . .	F6 [250.52A3]	{250.52A3}
☐ Ufer must be used if present during construction . . .	[250.50]	{250.50}[1]
☐ Ufer not req in existing bldg if concrete would have to be disturbed to gain access	[n/a]	{250.50X}[1]
☐ Ordinary tie-wires OK for bonding Ufer sections . . .	[250.52A3]	{250.52A3}
☐ Ufer must have 2in min concrete encasement . . .	[250.52A3]	{250.52A3}
☐ Metal well casings unless bonded to metal pipe . .	[250.52A7]	{250.52A7}[2]
☐ Metal bldg frame if bonded to other electrodes or if ≥10ft in contact w/ earth or encased in concrete in earth	[250.52A2]	{250.52A2}[3]
☐ Underground gas pipe not OK as electrode	[250.52B1]	{250.52B1}

Table 1 • GEC Sizing (NEC T250.66)

Copper Service Wire	Aluminum Service Wire	GEC Copper
2 or <	1/0 or <	8
1 or 1/0	2/0 or 3/0	6
2/0 or 3/0	4/0 or 250kcmil	4
4/0–350kcmil	250–500kcmil	2
>350–600kcmil	500–900kcmil	1/0

*The primary function of the **Grounding Electrode System** (**GES**) is to discharge the enormous voltages of a lightning strike away from the property and its inhabitants. Once the high-voltage electrical energy propagates through the soil, it is converted into heat and magnetic energy. The voltage drop is dramatic. During the microseconds of an electrical strike, voltage steps in the ground as short as 3ft. can produce as much as 100,000V of potential.*

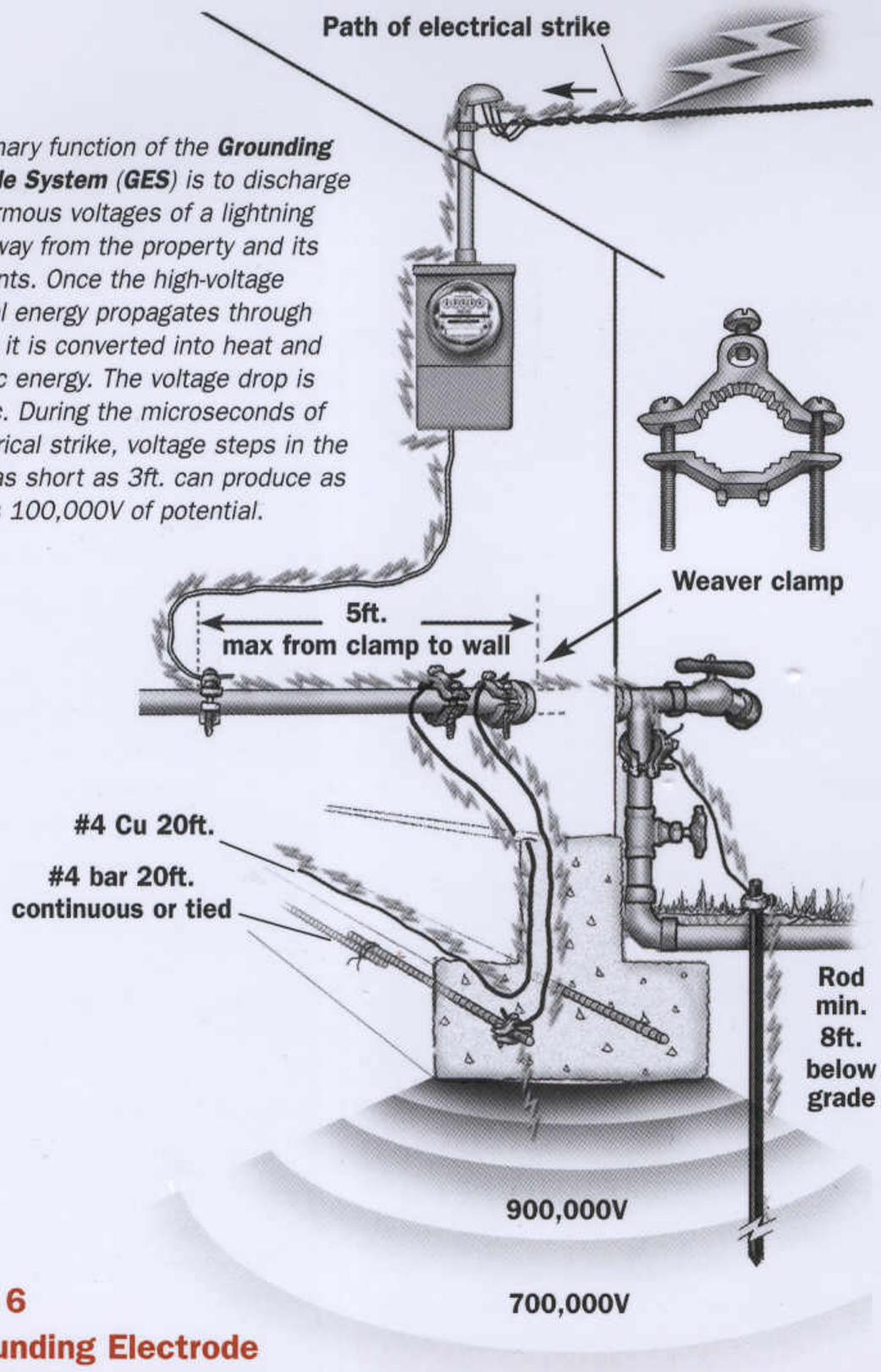


Fig. 6
Grounding Electrode System

Grounding Electrode Conductor (GEC)	2002	2005
☐ GEC must connect to neutral at or before service	[250.24A1]	{250.24A1}
☐ Size per service cond size **T1**	[250.66]	{250.66}
☐ 6AWG Cu largest size GEC needed if ending at rod	[250.66A]	{250.66A}
☐ 4AWG Cu largest size GEC needed if ending at Ufer	[250.66B]	{250.66B}
☐ 8AWG must be protected by raceway or armor	[250.64B]	{250.64B}
☐ 6AWG OK unprotected if not subject to damage & following bldg contour **F7**	[250.64B]	{250.64B}
☐ Bond each end of metal raceway enclosing GEC **F8**	[250.64E]	{250.64E}
☐ No splices between service & GES	[250.64C]	{250.64C}
☐ GEC can connect to any part of GES	[250.64F][4]	{250.64F}
☐ Connections to metal water pipe that is part of GES must be within first 5ft of water pipe inside bldg **F6**	[250.52A1]	{250.52A1}

Fig. 7
Bare GEC

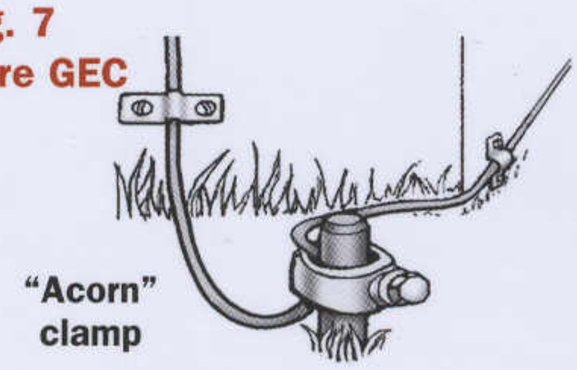


Fig. 8
GEC in Metal Raceway

GEC Connections

☐ Buried clamps must be L&L for direct burial **F6**	[250.70]	{250.70}
☐ Cu water tubing clamps L&L for Cu tubing **F6**	[250.70]	{250.70}
☐ Ufer Clamps L&L for rebar & encasement **F6**	[250.70]	{250.70}

Note: Rebar can be brought through the top of a foundation in a protected location, such as the garage, to provide an accessible location for the Ufer clamp.

☐ Strap-type clamps suitable only for phone systems . .	[250.70]	{250.70}
☐ Max 1 conductor per clamp unless listed for more . . .	[250.70]	{250.70}
☐ Connections must be accessible EXC	[250.68A]	{250.68A}
Buried or encased connections **F6**	[250.70]	{250.70}

Bonding

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

Bonding Methods	**2002**	**2005**
☐ Use listed materials or exothermic welding	[250.8]	{250.8}
☐ No sheet metal screws to cond {or lugs}	[250.8]	{250.8}[5]
☐ Clean nonconductive coatings from contact surfaces	[250.12]	{250.12}
Line-Side Bonding		
☐ Bond all service eqpmt & conduits & GEC enclosures	[250.92A]	{250.92A}
☐ Threaded fittings OK for bonding service conduit	[250.92B2]	{250.92B2}
☐ Meyers hub OK for bonding service conduit	**F10** [250.92B2]	{250.92B2}
☐ Std locknuts alone not sufficient on line side of service	**F10** [250.92B]	{250.92B}
☐ Jumpers req around concentric KOs on line side of service **F9** OR Grounding locknuts OK if no remaining concentrics	**F10** [250.92B4]	{250.92B4}
☐ Service neutral can bond line-side eqpmt	[250.142A]	{250.142A}
☐ Size line-side bonding jumpers per **T1**	[250.102C]	{250.102C

Fig. 9 • Fittings with Concentric Rings

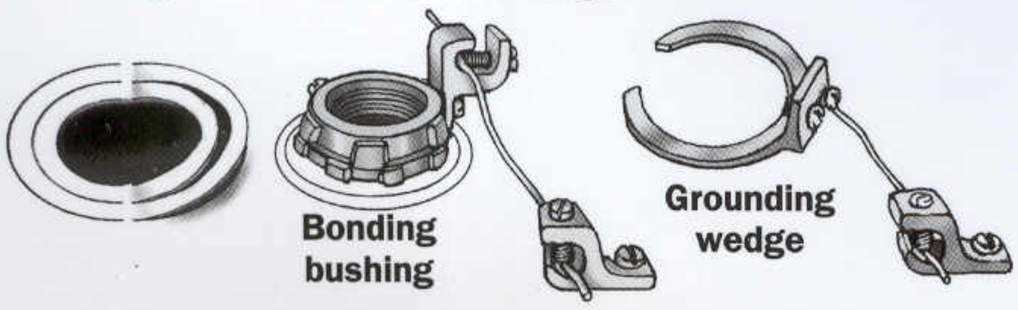


Fig. 10 • Fittings with Clean Hole

Intersystem Bonding	**2002**	**2005**
☐ Min 6AWG Cu bond to CATV or phone electrodes	**F11** [800.40D]	{800.100D}
☐ Bond lightning protection system to GEC	**F11** [250.106]	{250.106}
☐ Provide access for intersystem bonding & GECs on ext of service eqpmt	**F11** [250.94]	{250.94}[6]

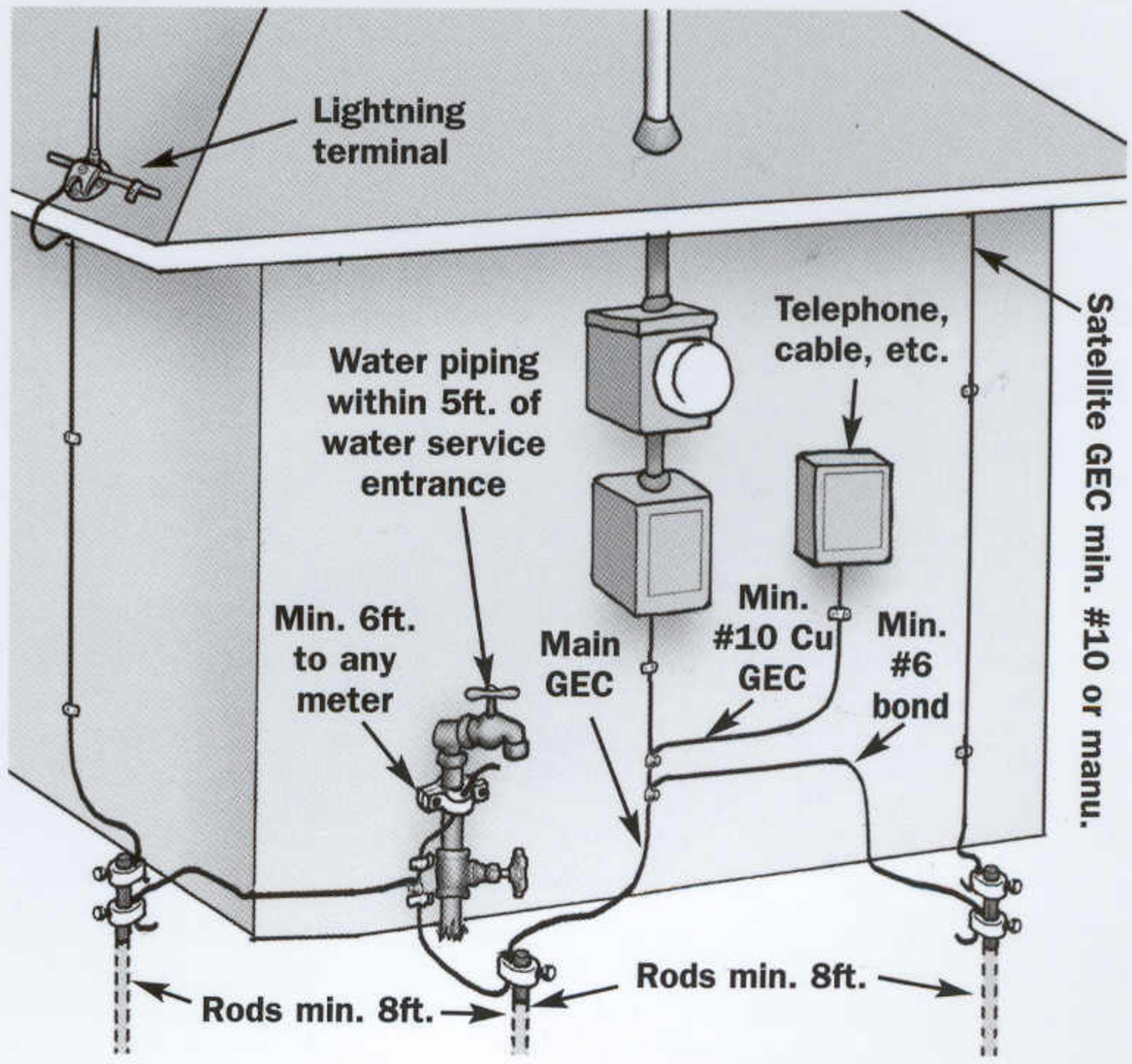


Fig. 11 • Intersystem Electrode Bonding

Load-Side Bonding	**2002**	**2005**
☐ Bond all metal piping, hot, cold, & gas	**F12** [250.104A,B]	{250.104A,B}
☐ Size water pipe bonding per **T1**	[250.104A1]	{250.104A1}
☐ Size gas pipe bonding per **T2**	[250.104B]	{250.104B}
☐ Bond metal well casings to EGC of pump motor	[250.112M]	{250.112M}

Equipment Grounding Conductors (ECGs)

Equipment Grounding Conductors (EGC)	2002	2005
☐ Size eqpmt grounding cond per **T2**	[250.122]	{250.122}
☐ EGCs can be bare, covered, or insulated	[250.119]	{250.119}
☐ EGC insulation green or green w/ yellow stripes	[250.119]	{250.119}
☐ EGC >6AWG OK to strip bare or use green tape for entire exposed length inside panels or boxes	[250.119A]	{250.119A}
☐ RMC, IMC, or EMT OK as EGC	[250.118]	{250.118}
☐ FMC & LFMC OK as EGC for non-motor circuits in combined lengths to 6ft if proper fittings *(see p. 21)*	[250.118]	{250.118}
☐ Remove paint from contact surfaces of conduit fittings & ensure good contact	[250.96]	{250.96}
☐ EGCs must be run w/ other cond of circuit EXC	[300.3B]	{300.3B}
Replacing nongrounding receps *(see p. 29)*	[250.130C]	{250.130C}

Table 2 • Equipment Grounding Conductors (EGCs) Based on NEC T250.122

Size in Amps of Breaker or Fuse Protecting Circuit	AWG size of Copper EGC	AWG size of Aluminum EGC
15	14	12
20	12	10
30	10	8
100	8	6
200	6	4

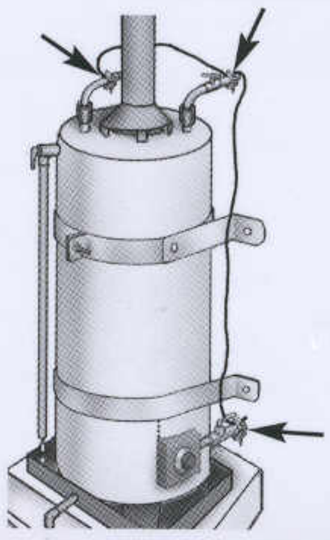


Fig. 12 • Bonding the Piping System

Bonding of piping systems is required by code. Many jurisdictions prefer to have hot, cold, and gas piping systems bonded together at the water heater. Furthermore, some require that a bonding jumper sized the same as the GEC be run from the water heater to the GEC or service.

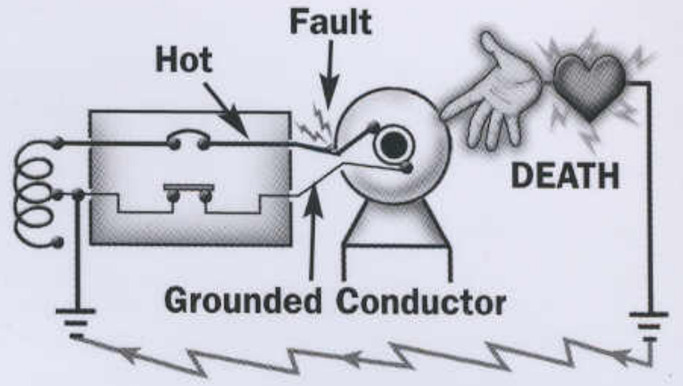


Fig. 13 An Equipment Fault

Unlike the grounded conductors, EGCs are not designed to carry current under normal operation. They are part of a safety backup system that is designed to protect life and property from accidental equipment faults. In **F13**, *the motor has a deadly potential to ground (the earth). The current is looking to return to its source at the transformer. A person contacting a grounded surface—e.g., plumbing, earth, etc.—could provide a parallel return path.*

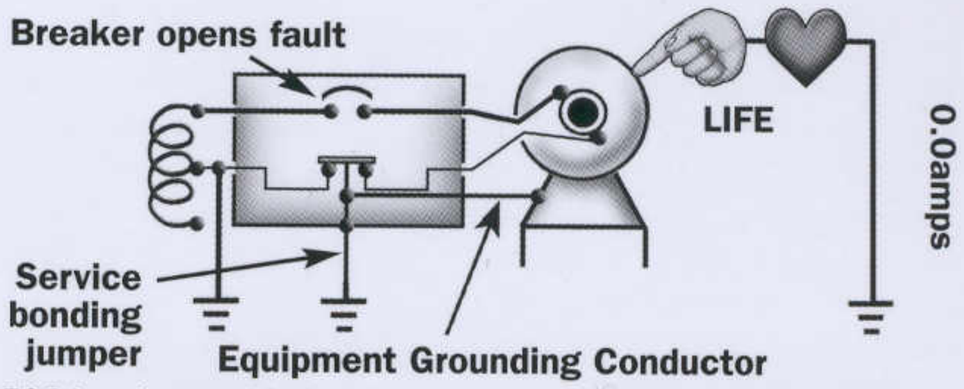


Fig. 14 Clearing a Fault

In **F14**, *an EGC has been added to the motor, and it serves to carry the fault current and trip the breaker. Even if the fault was insufficient to trip the breaker, the EGC would provide electrical equipotential that would help protect anyone touching the motor.*

Fig. 15 Futility of Using Earth as the Equipment Ground

In **F15**, *an attempt has been made to use the earth as an EGC. Ironically, the earth might be a good enough conductor to carry the amount of current necessary to shock or electrocute a person, but it is not a good enough conductor to trip the breaker. The earth can never be relied on to clear faults.*

Ground-Fault Circuit Interrupters (GFCIs)

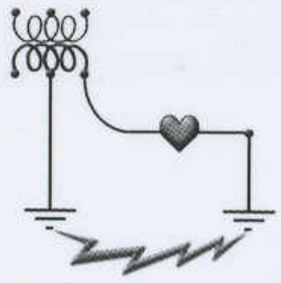
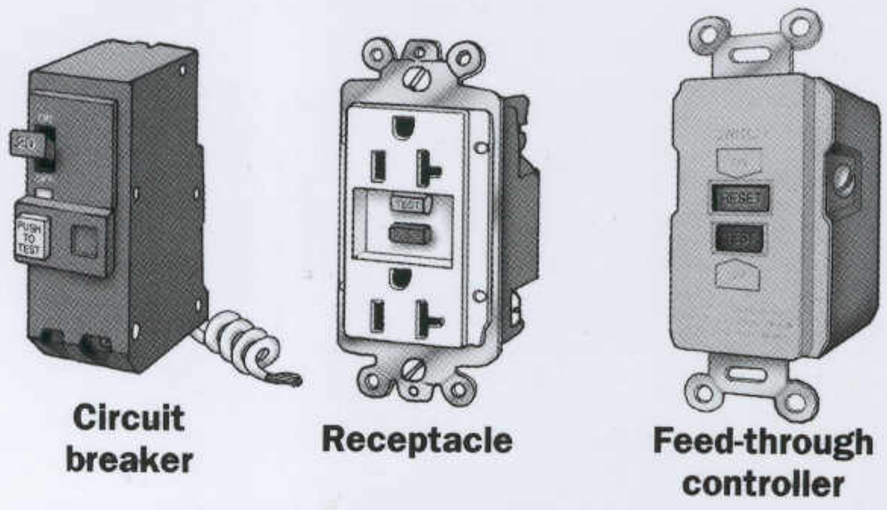


Fig. 16
To Ground or Not to Ground

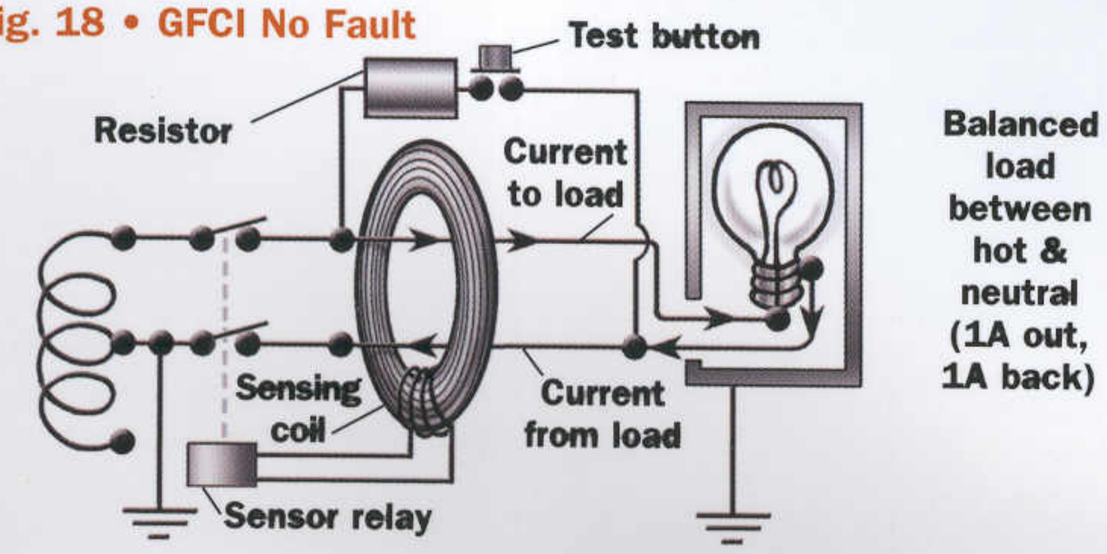
*Ground-fault circuit interrupters (GFCIs) detect the escape of electrical current outside the intended circuit. An example is the current returning to the transformer through a person, as represented in **F16**. GFCIs save lives by limiting the duration of the fault.*

Fig. 17 • Three GFCIs



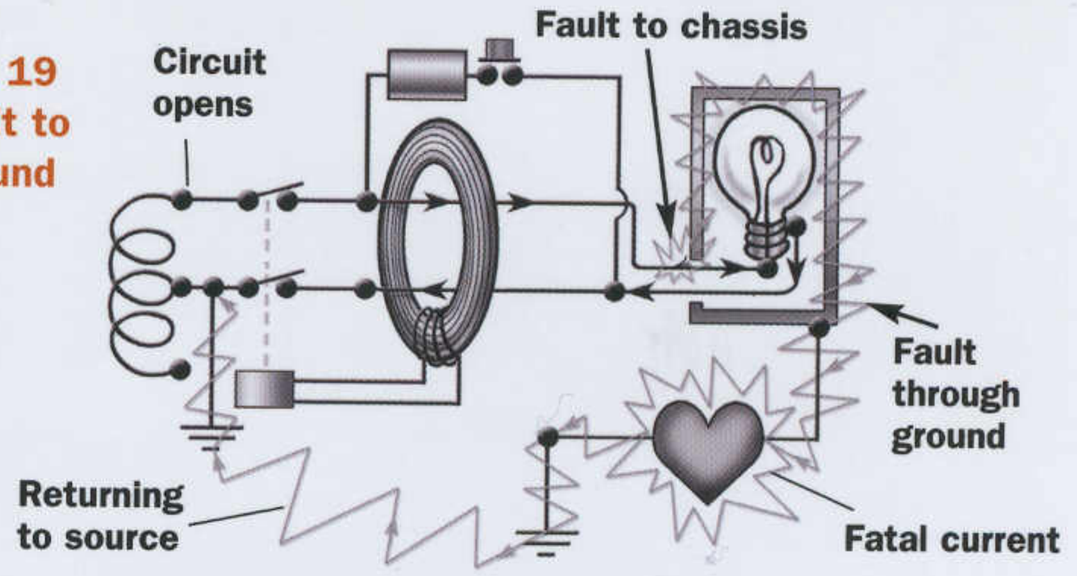
*How does a GFCI work its magic? In **F18**, equal currents are flowing to and from the load. When any electrical current flows, it generates a magnetic field. The magnetic fields generated by the flow of electrons in these two conductors are of opposite polarity (north and south, leaving and returning). The forces are equal and opposite, and their magnetic fields cancel each other. The circuit passes through a coil of wire inside the GFCI, and the GFCI accounts for the electrons on each conductor. As long as the currents are balanced, the GFCI allows current on the circuit.*

Fig. 18 • GFCI No Fault



*During a ground fault, such as the flow of current through a person, the circuit becomes unbalanced **(F19)**. A magnetic field is generated on the coil around the circuit wires. Solid-state circuitry connected to the sensing coil activates a trip mechanism, and the circuit is interrupted.*

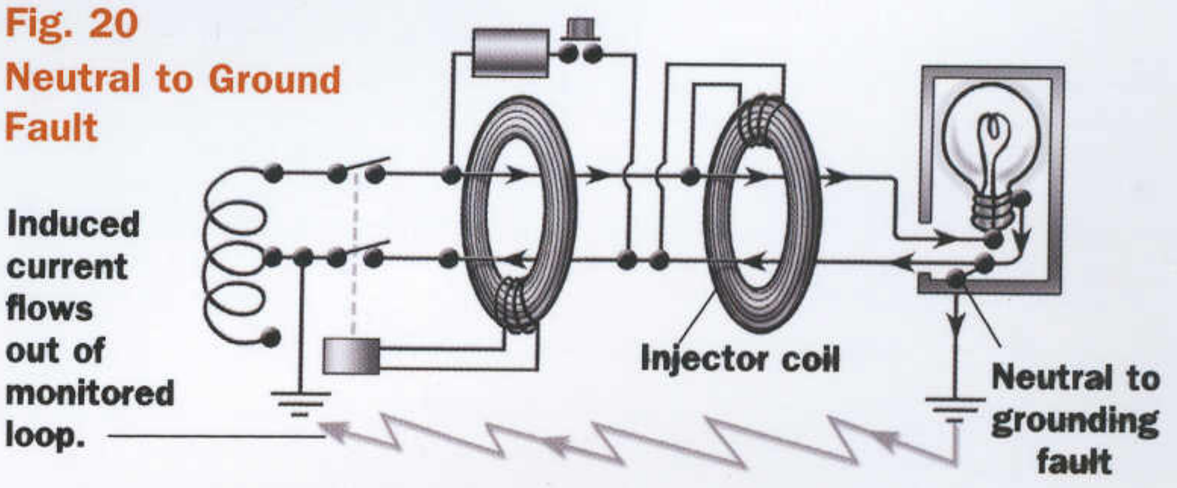
Fig. 19
Fault to Ground



*A GFCI also detects improper connections of the neutral (grounded conductor) to ground. A second "injector" coil **(F20)** surrounds the monitored circuit and induces a small current. Should the neutral have a downstream connection to ground, current will escape outside the circuit, and the sensor coil circuit will be activated as described above.*

*GFCIs take more space inside a box than a conventional receptacle. When adding GFCIs to old houses with shallow boxes, it might be necessary to first add an extension box, as in **F21**.*

Fig. 20
Neutral to Ground Fault



*A GFCI receptacle can provide protection for other receptacles downstream on the circuit. GFCI protection can be provided by GFCI breakers **(F17)** or GFCI receptacles.*

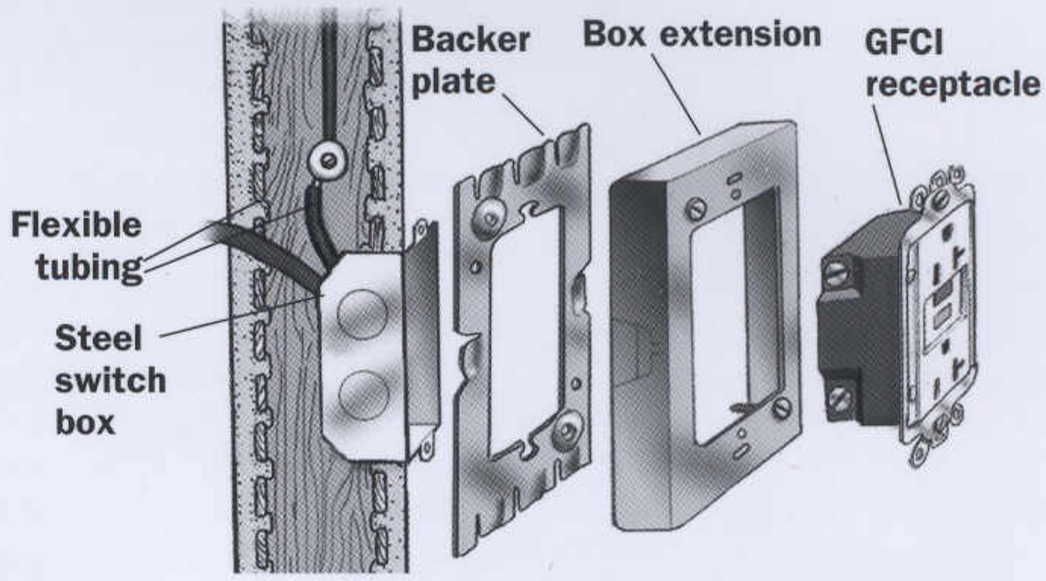
Required GFCI Protection Locations	2002	2005
☐ All receps serving kitchen counters	F41 [210.8A6]	{210.8A6}
☐ All bathroom receps	[210.8A1,B1]	{210.8A1, B1}
☐ All residential ext receps EXC	[210.8A3]	{210.8A3}
De-icing eqpmt receps w/o ready access	[210.8A3,X]	{210.8A3,X}
☐ Receps ≤6ft of {laundry, utility or} wet-bar sinks	[210.8A7]	{210.8A7}[7]
☐ Commercial ext areas accessible to public	[n/a]	{210.8B4}[8]
☐ Commercial kitchen receps {in areas w/ permanent food-preparation facilities}	[210.8B3][9]	{210.8B2}[10]
☐ Commercial 120V receps on rooftops	[210.8B2]	{210.8B3}
☐ Outdoor 120V receps for servicing HVAC eqpmt	[n/a]	{210.8B5}[11]
☐ All garage & unfinished basement receps EXC	[210.8A2,5]	{210.8A2,5}
Receps that are not readily accessible OR	[210.8A2,5X1]	{210.8A2,5X1}
Single receps for appls not easily moved (sump, freezer, clothes washer) or duplex recep for 2 such appls	[210.8A2,5X2]	{210.8A2,5X2}
☐ All 125V, 15A, 20A, & 30A receps for temporary power	[527.6A]	{590.6A}
☐ Receps in boathouses	[210.8A8]	{210.8A8}

Pool, Spa, & Hydromassage Tub GFCI Requirements		
☐ Receps within 20ft of pools & outdoor hot tubs unless cord would have to pass through window or door	[680.22A5,6]	{680.22A5,6}
☐ Receps for pool pump motors any distance from pool	[680.22A5][12]	{680.22A5}
☐ Receps providing spa or hot tub power	[680.43A3]	{680.43A3}
☐ Receps >5ft & <10ft of indoor hot tubs	[680.43A2]	{680.43A2}
☐ Pool cover motor & controller	[680.27B2]	{680.27B2}
☐ Hydromassage (whirlpool) tubs	[680.71]	{680.71}
☐ Underwater pool lights >15V	F83 [680.23A3]	{680.23A3}
☐ Light fixtures <10ft horiz unless >5ft vert from water	[680.22B4]	{680.22B4}
☐ Existing fixtures OK <5ft horiz if >5ft vert from water	[680.22B4]	{680.22B3}
☐ GFCI protect all receps ≤10ft from inside wall of spa	[680.43A2]	{680.43A2}
☐ GFCI protect all outlets that supply spa eqpmt EXC Listed package spa w/ integral GFCI OR Combination pool & spa or hot tub	[680.44]	{680.44}

UL 943*—the standard of safety for GFCIs—was revised in 2003, requiring GFCIs to have greater resistance to corrosion, surge currents, and high voltages. The revised standard also requires a reverse line-load test that prevents the receptacles from resetting if they are miswired. The contacts on these newer GFCIs ensure proper resetting and prevent some miswiring that could occur from manipulation of the controls on the older GFCIs. In addition, all manufacturer's installation instructions for GFCIs are now standardized for consistency. These instructions require specific methods for checking GFCI operation after installation to ensure that devices are properly wired. As a result, these proven life savers have become more reliable than ever.*

Fig. 21 • Adding GFCI in Old Houses

If installing a GFCI breaker is not an option, this might be an acceptable alternative to the AHJ.



A GFCI will operate properly without an equipment ground. The receptacle should be labeled "no equipment ground" and any downstream protected receptacles should also have that label as well as a label stating that they are GFCI protected. Labels are not required for properly grounded GFCI protected receptacles.

Arc-Fault Circuit Interrupters (AFCIs)

Arc-fault circuit interrupters (AFCIs) are intended to provide fire protection by opening the circuit if an arcing fault is detected. Though they look similar to GFCI breakers, they do not provide protection against shock hazards at the same sensitivity as does a GFCI.

	2002	2005
☐ AFCI protect all 15A & 20A ckt w/ any outlet (recep, lum, or smoke detector) in bedrooms	[210.12B][13]	{210.12B}
☐ AFCI must be "combination type" after January 1, 2008	[n/a]	{210.12B}[14]
☐ Recep device type OK if ≤6ft from panel & wiring between panel & device is MC or raceway	[n/a]	{210.12BX}[15]

Fig. 22
Arc Fault

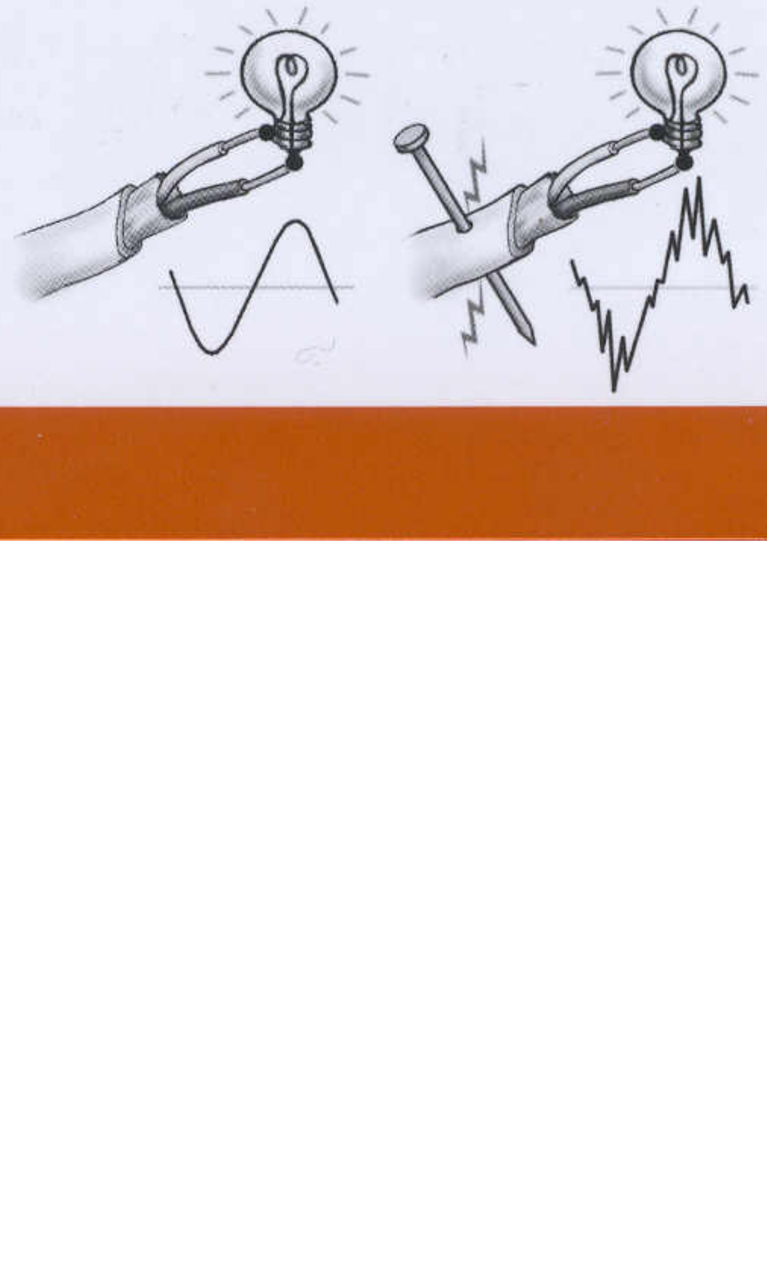
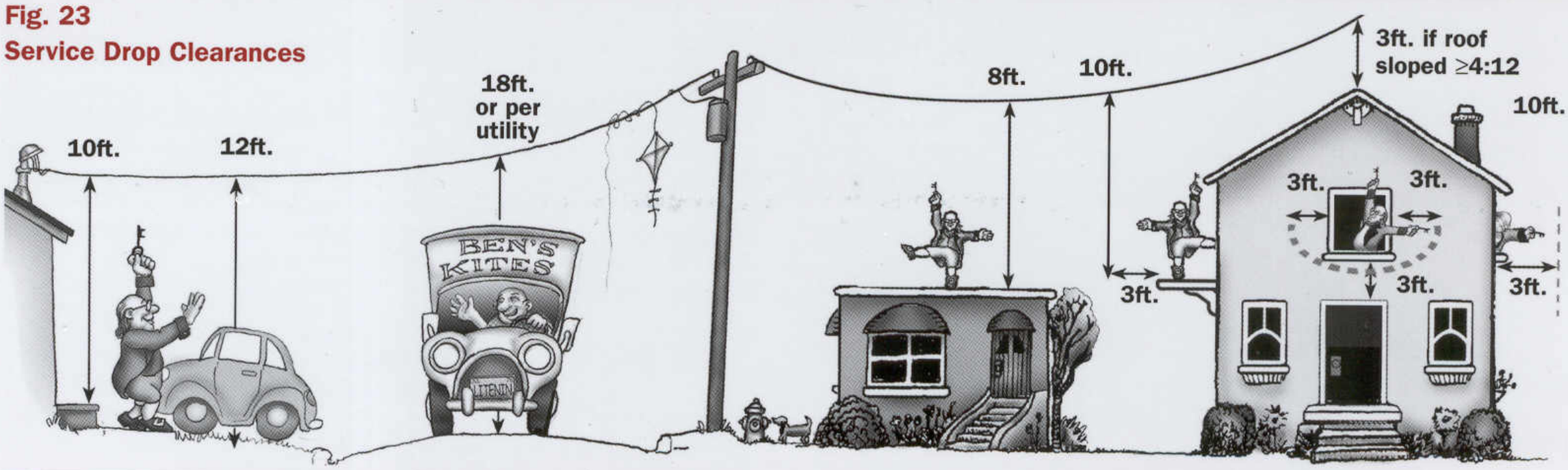


Fig. 23
Service Drop Clearances



Service Drops

The utility company does not necessarily follow the rules in the NEC. Check with your local jurisdiction and utility to find out what rules apply.

Clearances above Ground	2002	2005
☐ Area accessible only to pedestrians—10ft vert	**F23** [230.24B1]	{230.24B1}
☐ General above ground—12ft vert	**F23** [230.24B2]	{230.24B2}
☐ Above driveway—12ft	**F23** [230.24B2]	{230.24B2}
☐ Above roadway—18ft	**F23** [230.24B4]	{230.24B4}
☐ Any direction from pool water—22½ft	[680.8A][16]	{680.8A}[17]
☐ Trees may not support overhead conductors	[230.10][18]	{230.10}
Clearances above Roof		
☐ <4-in-12 slope—min 8ft	**F23** [230.24A]	{230.24A}
☐ 4-in-12 slope or greater—min 3ft EXC	[230.24AX2]	{230.24AX2}
18in OK over eaves if mast ≤4ft horiz to edge	**F26** [230.24AX3]	{230.24AX3}
Clearances from Openings		
☐ Below or to sides of openable window—3ft	**F23** [230.9A]	{230.9A}
☐ Above decks & balconies—10ft out to 3ft horiz	**F23** [230.9B]	{230.9B}

The NEC does not have a requirement for minimum clearance of open conductors above a window. Check to see if your local utility has a requirement.

Underground

☐ Burial depth & cover per **T4**	[300.5]	{300.5}
☐ Protect USE cable where exposed	**F51** [300.5D1]	{300.5D1}
☐ Warning ribbon in trench 12in above lateral	[300.5D3]	{300.5D3}

Service Entrance Conductors

Unlike overhead service drop conductors, the service entrance conductors are part of the building. The handoff from the utility to the customer is referred to as the "service point," and usually it is the splice point at the drip loop. For underground service laterals the service point is specified by the utility.

General	2002	2005
☐ SFD min wire size 4AWG Cu or 2AWG AL	**T10** [T310.15B6]	{T310.15B6}
☐ Identify (white tape) neutral at both ends	[200.6B]	{200.6B}
☐ Protect SE cables where subject to damage w/ metal conduit or RNMC-80 or EMT	[230.50A]	{230.50A}
☐ Secure SE every 30in & 12in from terminations	[230.51A]	{230.51A}
☐ Rain-tight service head req for raceways	[230.54A]	{230.54A}
☐ Rain-tight service head or taped gooseneck OK in SE cable	[230.54B]	{230.54B}
☐ Install drip loop in conductors	[230.54F]	{230.54F}
Service Riser/Lateral		
☐ Clamp RMC within 3ft of service box	[344.30A]	{344.30A}
☐ Plumbing pipe or fittings not permitted	[110.8]	{110.8}
☐ Min size mast per util (typically 1¼–2in RMC)	[util]	{util}
☐ Brace riser to util or local specs	[230.28]	{230.28}
☐ No unsupported couplings above roof	[local]	{local}
☐ Only service conductors may be supported by mast	[230.28]	{230.28}
☐ Service lateral buried at proper depth	T4 [300.5A]	{300.5A}
☐ Check w/ util for other systems in trench	[util]	{util}

Common Utility Complaints

What follows is a list of common infractions cited by utility company installation crews. Most utilities publish a list of standards that are separate from the NEC but need to be considered when installing a new electric service.

Meter Base(s)

- Too close to gas meter **F25**
- Height incorrect (ex: util std—min 48in, max 66in to center of meter) **F24**
- Barrier post needed to protect meter from vehicles on driveway
- Not readily accessible to meter readers

Exposed Portion of Service Entrance Conductors (Drip Loop)

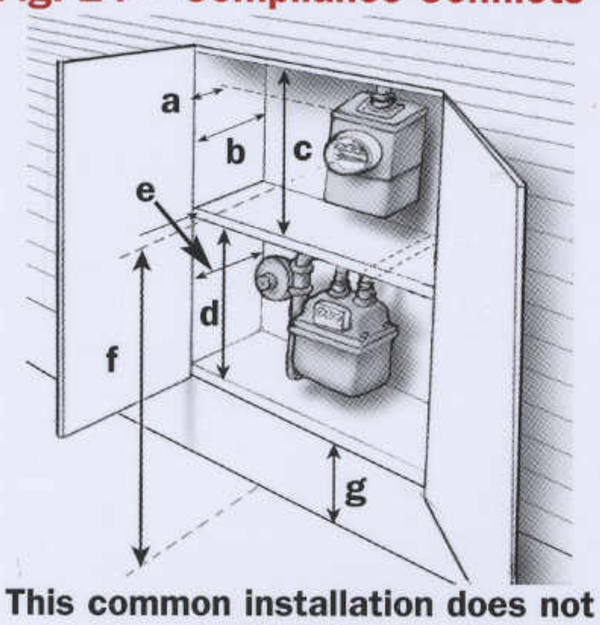
- Insufficient conductor length at service head (typical 18in min)
- Clearance insufficient to communication lines (typically 12in min)
- Clearance above windows insufficient (typically 3 feet)
- Height above standing surface (roof deck) too low
- Customer performing own cutover from old service to new
- Point of attachment too far from service head

Table 3 • Gas & Electric Service Clearances

•	Example	Local
a	15in. max.	
b	18in.–19in.	
c	30in. min.	
d	32in. min.	
e	17in.–19in.	
f	75in. max.	
g	15in. min.	

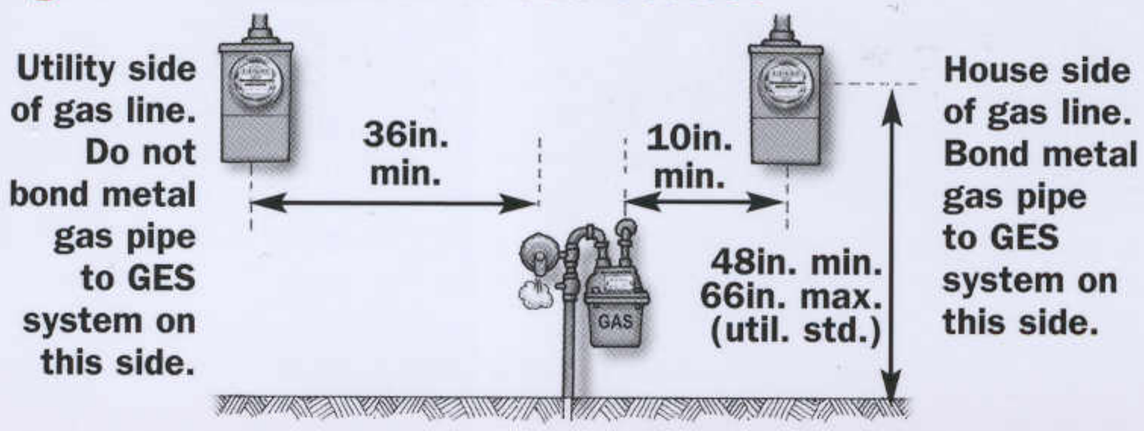
Use this table to help research the specific requirements of the utility or building department in your area. The example dimensions are from a northern California utility.

Fig. 24 • Compliance Conflicts



This common installation does not conform to NEC but might be acceptable to the AHJ.

Fig. 25 • Clearances to Gas Service

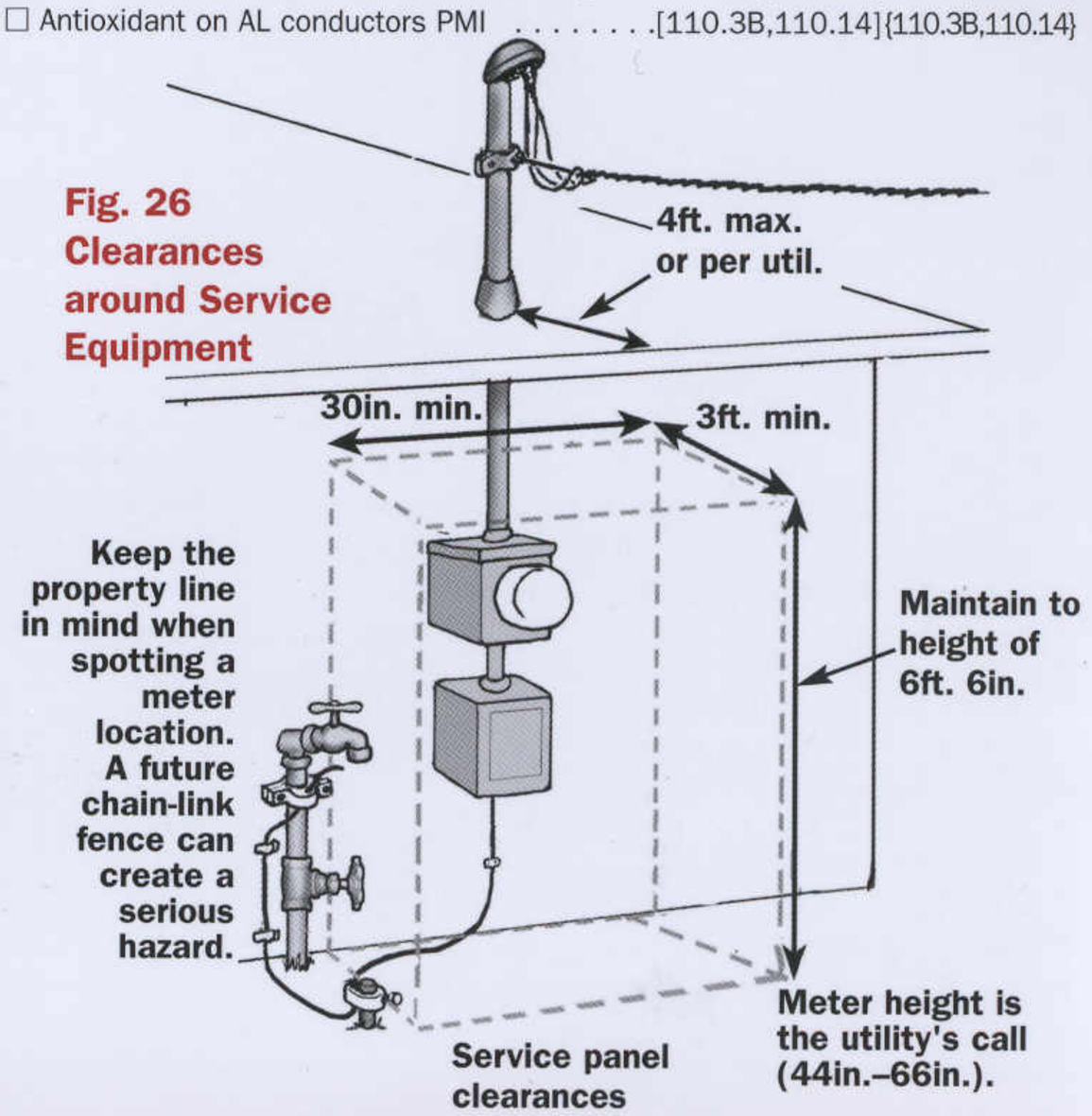


Meters & Service Panels

An overcurrent protective device (OCPD), such as a fuse or circuit breaker, is specifically designed to protect electrical circuits against the hazardous effects of overcurrents. Service equipment encloses the disconnecting means to shut off the power to a building. A meter is not necessarily service equipment.

	2002	2005
☐ Max 6 disc to shut-off power panelboard EXC	[230.71]	{230.71}
Max two OCPDs for L&A panels	[408.16A]	{408.36A}
☐ Provide working space **F26**	[110.26]	{110.26}
☐ Illumination req for indoor eqpmt	[110.26D]	{110.26D}
☐ Occupants must have ready access to all OCPDs EXC	[240.24B]	{240.24B}
Multiunit bldg OK for only management to have access to mains {& to other OCPDs in commercial guest suites)	[240.24BX][19]	{240.24BX}
☐ Max height of breakers [used as switches] 6ft 7in	[404.8A]	{240.24A}[20]
☐ Enclosure must be labeled as suitable for service eqpmt	[230.66]	{230.66}
☐ Verify location & hookup fees with util company	[util]	{util}
☐ Breakers correct brand per panel labeling	[110.3B]	{110.3B}
☐ Antioxidant on AL conductors PMI	[110.3B,110.14]	{110.3B,110.14}

Fig. 26 Clearances around Service Equipment



Temporary Wiring

Temporary power during construction allows wiring methods that would not be acceptable for a permanent installation. Service wire clearances must still follow the same rules shown on pp. 9 and 10 for a permanent service.

	2002	2005
☐ Temporary service cond clearances	F23 [230.9,24]	{230.9,24}
☐ Identify insulated neutral at both ends	[200.6B]	{200.6B}
☐ AL cond terminated properly	[110.14]	{110.14}
☐ Support & brace pole to util specs	[util]	{util}
☐ Running splices OK in cables	[527.4G]	{590.4G}
☐ Lampholders req guards	[527.4F]	{590.4F}
☐ GFCI protect all 125V, 15–30A receps	[527.6A]	{590.6A}

Multimeter Services

Services to two-family and multifamily dwellings might come to a multimeter panel or to a "hot gutter" with splices ahead of any overcurrent protection. See p. 5 for special bonding requirements for such services.

☐ Only one service per bldg EXC by special permission	[230.2]	{230.2}
☐ Townhouse is two bldgs if sep by firewall	[100]	{100}
☐ Each occupant needs access to service disc	[230.72C]	{230.72C}
☐ Bonding req at hot gutters	F28 [250.92A]	{250.92A}
☐ Max six disc at service	[230.71A]	{230.71A}
☐ Service cond may not pass through interior of one bldg to another bldg	[230.3]	{230.3}

Fig. 27
Duplex Service from Hot Gutter

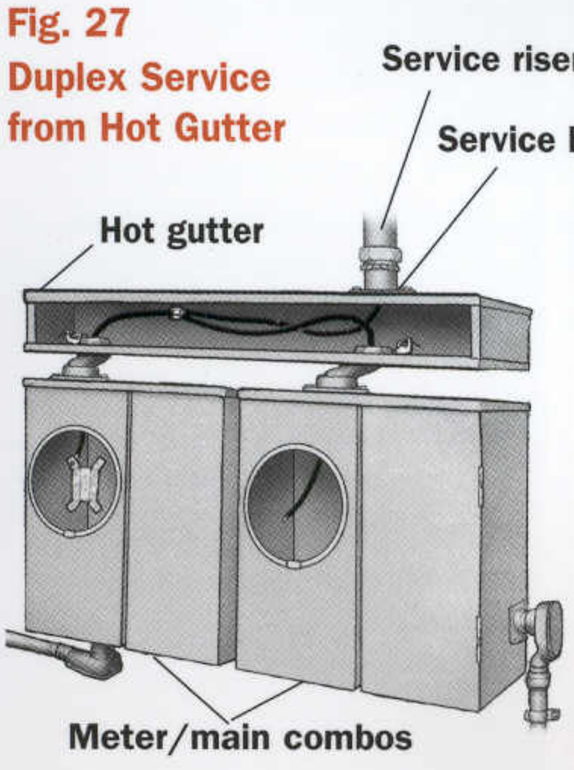
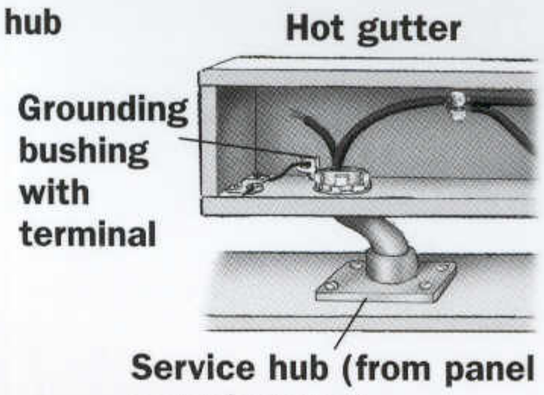


Fig. 28
Bonding Bushing at Offset Nipple



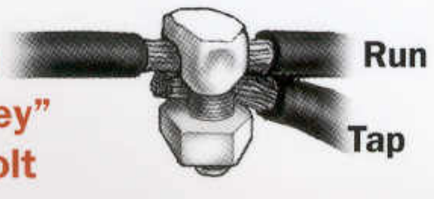


Fig. 29
"Kearney" Split Bolt

Two Buildings

When more than one building is supplied by a service, care must be taken to avoid objectionable currents on the grounding paths between the buildings.

	2002	2005
☐ Each bldg or structure req GES EXC	F30 [250.32A]	{250.32A}
Bldg w/ only one branch ckt w/ EGC	[250.32A,X]	{250.32A,X}
☐ Multiwire ckt considered one ckt for above rule	[n/a]	{250.32A,X}21
☐ Each bldg req disc at bldg	F30 [225.31]	{225.31}
☐ Disc must be rated as service eqpmt EXC	[225.36]	{225.36}
Garages or outbuildings snap switch or 3-way OK	[225.36X]	{225.36X}
☐ EGC (4-wire feeder) req between bldgs EXC	[250.32B1]	{250.32B1}
3-wire feed OK if no other metal path between bldgs	[250.32B1,2]	{250.32B1,2}
☐ Isolate neutral from EGC in feeder & subpanel	[250.32B1]	{250.32B1}
☐ Provide proper cover for buried cable or conduit	T4 [300.5]	{300.5}

Fig. 30 • Grounding at Separate Buildings

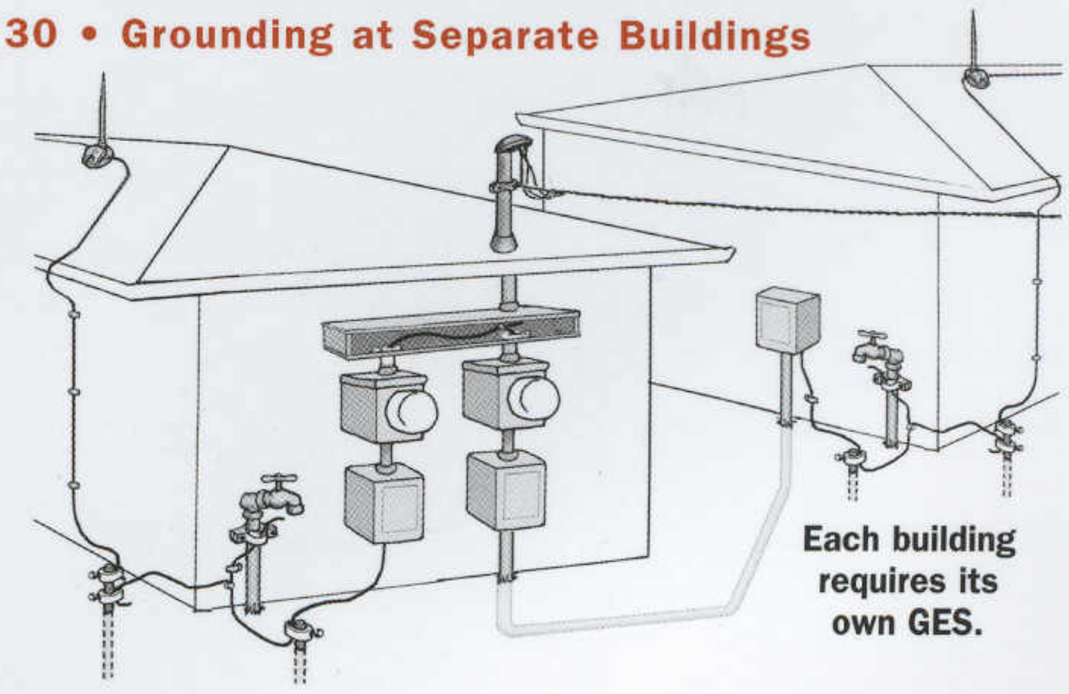


Table 4 • Minimum Cover Requirements in Trench

Cover	UF Cable	Rigid Metal	PVC	GFCI 20amp Circuit	30volts
General	24in.	6in.	18in.	12in.	6in.
2in. concrete	18in.	6in.	12in.	6in.	6in.
Under bldg	n/a	0	0	n/a	n/a
4in. slab no vehicles	18in.	4in.	4in.	6in.	6in.
Street	24in.	24in.	24in.	24in.	24in.
Driveway	18in.	18in.	18in.	12in.	18in.

The neutral conductor is bonded to service enclosures. Once the neutral conductors leave the service panel, they must be isolated from contact with equipment and enclosures, otherwise current could return on EGCs, enclosures, and piping. Subpanel feeders require four conductors—two ungrounded (hot) conductors, a neutral, and an EGC (which can be metal conduit).

Fig. 31
Service Panel

This is a common style of panelboard. When used as a service, the white neutral and the bare or green equipment grounds MUST be bonded together AND to the enclosure. This connection is essential to the safe operation of the grounding system.

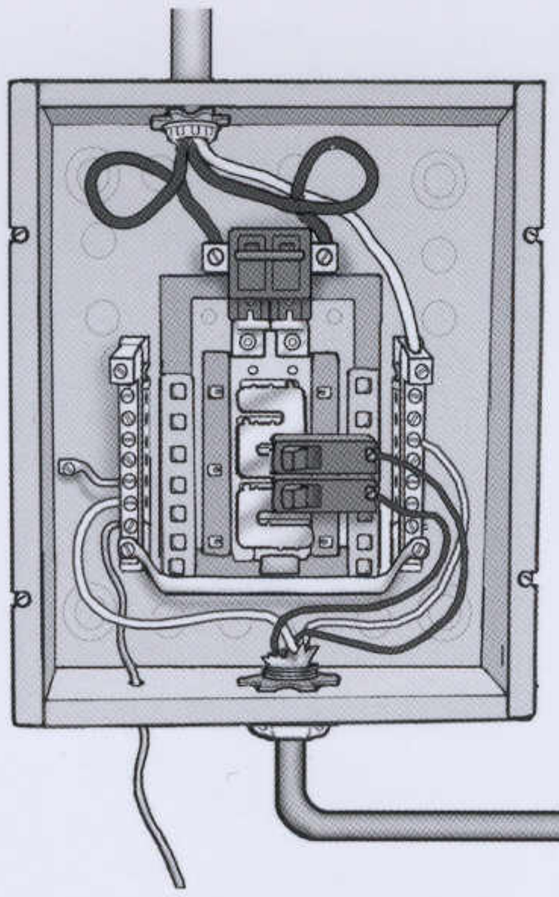
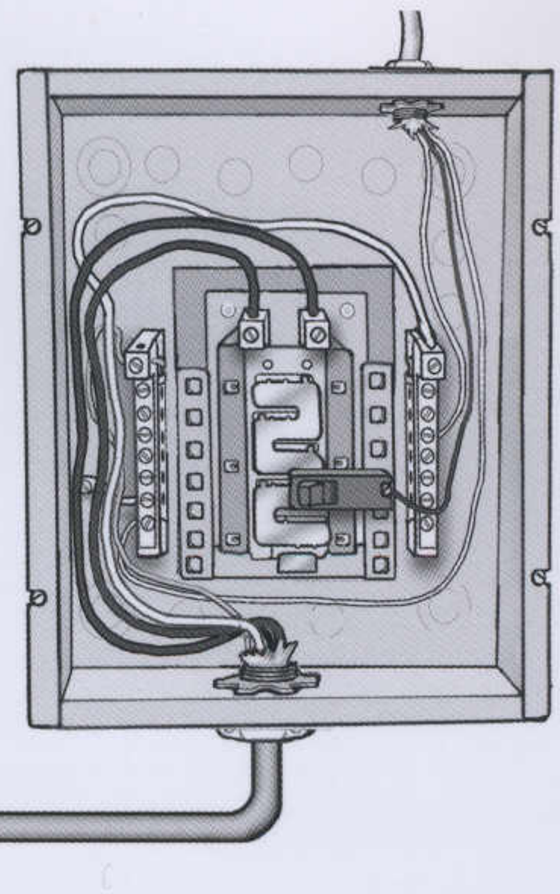


Fig. 32
Subpanel

In a downstream subpanelboard, the white neutral and the equipment grounds must not be bonded together. The neutral MUST "float" on insulators that prevent contact with the metal enclosure and any equipment grounds. Bonding these conductors is hazardous.



Subpanels & Fuse Boxes

Panels and their enclosures must be installed and used in accordance with all instructions and specifications from the manufacturer.

Location & Enclosures	2002	2005
☐ Front working clearance min 30in wide x 36in deep	**F26** [110.26A]	{110.26A}
☐ Wet loc enclosures req to be weatherproof	[312.2A]	{312.2A}
☐ Surface-mounted wet loc boxes ¼ space from wall	[312.2A]	{312.2A}
☐ Open KOs must be filled (not taped)	[110.12A]	{110.12A}
☐ No OCPDs in clothes closet or bathroom	[240.24D,E]	{240.24D,E}
☐ OCPDs readily accessible {& max height 6ft 7in}	[240.24A]	{240.24A}[22]
☐ Max panel setback in noncombustible wall (drywall) ¼in	[312.3]	{312.3}
☐ Max panel setback in combustible wall (wood) 0in	[312.3]	{312.3}
☐ Max plaster gap at side of flush mount panel ¼in	[n/a]	{312.4}[23]
OCPDs & Wiring		
☐ Secure cables entering panel	**F33** [312.5C]	{312.5C}
☐ Breakers correct brand per panel labeling	[110.3B]	{110.3B}
☐ Isolate neutral from EGCs & GES EXC at service	**F31,32** [408.20]	{408.40}
☐ Modifications to split neutral bar PMI	**F31,32** [manu]	{manu}
☐ Terminal bar for EGCs req to be provided	**F31,32** [408.20]	{408.40}
☐ Purpose of breakers & fuses legibly marked	[408.4]	{408.4}
☐ Ckit identification must be clear, evident, & specific	[n/a]	{408.4}[24]
☐ Approved handle ties OK for 240V ckts w/ single-pole breakers	**F42** [240.20B2]	{240.20B2}

OCPDs & Wiring (cont.)	2002	2005
☐ Handle tie for multiwire ckt to same device	**F42** [210.4B]	{210.4B}
☐ Handle tie for 2 ckt to receps on same yoke	[210.7C][25]	{210.7B}
☐ Missing twistouts must have fill plates (not tape)	[110.12A]	{110.12A}
☐ Antioxidant on AL conductors PMI	[110.14]	{110.14}
☐ Each neutral conductor req individual terminal	[408.21][26]	{408.41}

Breakers (OCPDs) serve 4 primary functions:

1. Provide a disconnecting means for a circuit
2. Open circuits (stops current flow) if conductor overloaded
3. Open circuits (stops current flow) if short circuit occurs
4. Open circuits (stops current flow) if ground fault occurs

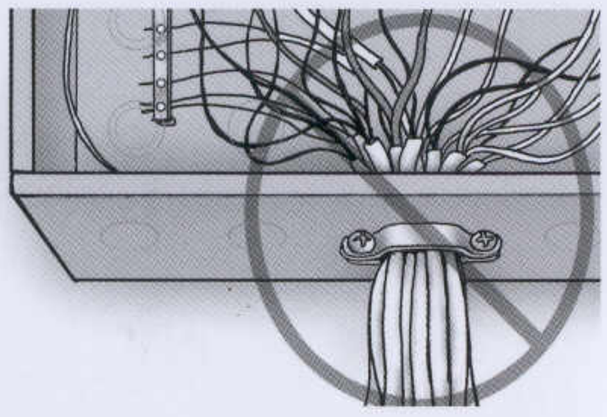


Fig. 33
Improper Cable Bundle

Cables must be secured to the panel with clamps used in accordance with their listing. Some clamps will accept two small cables; a bundle through one clamp is a common defect.

Service & Feeder Calculations

The guidelines in the NEC help anticipate the size and number of circuits needed to supply the loads in a typical residence. As a general rule, service conductors, feeders, and branch circuits must be sufficient to serve the connected load. Where loads may vary depending on the particular user, the NEC allows us to consider "demand factors," i.e., to take into account that not everything will be operated at the same time. The procedures below show how these demand factors are calculated.

Steps for Sizing a Service

	2002	2005
1. Determine the sq-ft area of the residence & multiply by 3W (exclude garage & covered patios)	[220.3A]	{220.12}
2. Min of two 1,500W small-appl ckt	[220.16]	{220.52A}
3. Each addl kitchen—min 2 small appl ckt at 1,500W per ckt	[210.52B3]	{210.52B3}
4. Min 1 laundry ckt at 1,500W	[220.16B]	{220.52B}
5. Total small appl loads & general lighting (enter in middle column)	[220.11]	{220.42}
6. Subtract 3,000W from line 5	[T220.11]	{T220.42}
7. Enter difference in middle column, multiply middle column by 35%, & enter in right column	[T220.11]	{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 addl 1,000W of nameplate load. The nameplates of a counter-mounted range & up to two wall ovens can be added together & computed as if they were one range. Enter in column 3	[220.19]	{220.55}
9. Enter dryer nameplate rating or 5,000W, whichever is greater, in column 3	[220.18]	{220.54}
10. Enter the larger of the fixed space heating or AC load at nameplate rating in column 3	[220.21]	{220.60}
11-18. Enter the nameplate ratings of appls that are fixed in place. To determine the load of appls rated in amps, multiply by the voltage. Enter the actual nameplate ratings; the numbers in the first column are typical examples	[220.17]	{220.53}
19. Enter the total of fixed appls in the middle column	[220.17]	{220.53}
20. If there were <4 fixed appls, enter the number from line 19 in the right column	[220.17]	{220.53}
21. If there were ≥4 fixed appls, multiply line 19 by 75% and enter in the right column	[220.17]	{22053}
22. Add 25% of the largest motor load. If a nameplate-rated air-conditioner is the largest load, this number has already been factored in, & this step is omitted	[220.14]	{220.18A}
23. Add the numbers in the third column	[220.10]	{220.40}
24. Divide line 23 by 240 to find req min amp	[220.10]	{220.40}

Load Calculations	2002	2005
☐ Continuous load = 3hr or more	[100]	{100}
☐ Service conductors sufficient for load	[230.42]	{230.42}
☐ Min rating 100A for SFD	[230.79C]	{230.79C}
☐ Feeders sufficient for load	[215.2A1]	{215.2A1}
☐ Branch ckt sufficient for connected load	[210.19A1]	{210.19A1}
☐ [Min feeder size 30A to subpanel]	[215.2A2]	{n/a}[27]

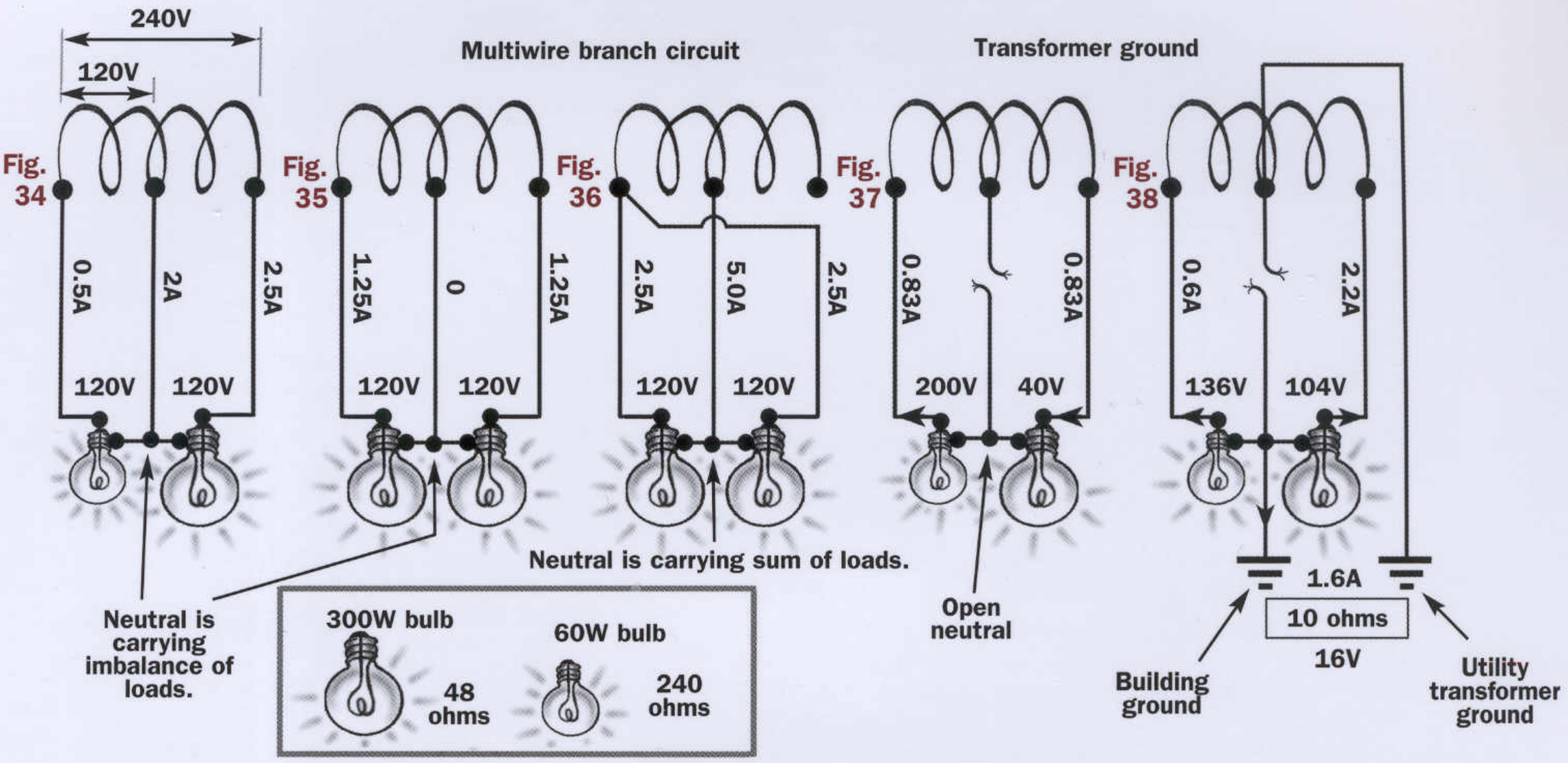
Table 5 • Sizing Electric Services

General lighting & receptacle loads (NEC 220-12)			
Sq.ft. x 3W			1
Small appliance & laundry loads (NEC 220-52A,B)			
2 small appl. ckt.	3,000		2
Addl. small appl.			3
Laundry ckt.	1,500		4
Subtotal gen. light, small appls. & laundry			5
1st 3,000W @100%	3,000	3,000	6
Balance @35%			7
Special appliance loads			
Range (NEC 220-55)	8kW up to 12kW nameplate		8
Dryer (NEC 220-54)	5,000 (or nameplate if >)		9
Heating or AC @100%			10
Appliances fastened in place (NEC 220-53)			
Water heater 4,500*			11
Microwave 1,300*			12
Dishwasher 1,500*			13
Compactor 900*			14
Disposer 800*			15
Attic fan 1,600*			16
Spa—per manu.			17
Other			18
Subtotal			19
If <4 appls, enter subtotal @100% OR			20
If ≥4 appls, enter subtotal x 75%			21
Largest motor x 25%			22
Total load			23
Total load ÷ 240V = SERVICE AMPS			24

*Common ratings—use actual nameplate rating of appliances.

For the simplified "optional method" of load calculation, refer to Code Check®, 4th ed.

Multiwire Circuiting



3-Wire Edison Circuits (Multiwire)

Standard electrical services to one- and two-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. 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 **F37**. *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. Not only is the service to the house a "3-wire" circuit, 120V branch circuits are often installed with shared neutrals and are then known as multiwire circuits.*

Multiwire Circuits	**2002**	**2005**
☐ Hot cond must originate from opposite poles	[100]	{100}
☐ All 120V same-amp ckt allowed to be multiwire	[210.4A]	{210.4A}
☐ All cond must originate from same panel	[210.4A]	{210.4A}
☐ Multiwire neutrals may not feed through devices such as receps (should be pigtail neutral in box)	[300.13B]	{300.13B}

F34—Two unequal loads are fed by a 3-wire circuit. The neutral carries the imbalance between the two loads.

F35—Two equal loads are fed by a 3-wire circuit. There is no imbalance for the neutral to carry.

F36—Without voltage potential between hot conductors, the neutral carries the sum of the loads. In a 3-conductor Romex cable, the black and red wires must originate from different poles or the neutral can be overloaded because it carries the sum of the currents.

F37—Two unequal loads in series across the full voltage of the transformer, 240V. The load with the lowest resistance sees the greater voltage drop.

F38—Transformer is grounded to earth. A second connection to earth is made at the building being fed by the transformer. In this example, the neutral connection between transformer and load has opened. The earth becomes an available path for current to return to the transformer. The earth resistance in this example is 10ohms. This secondary ground helps reduce the voltage imbalance but does not eliminate it.

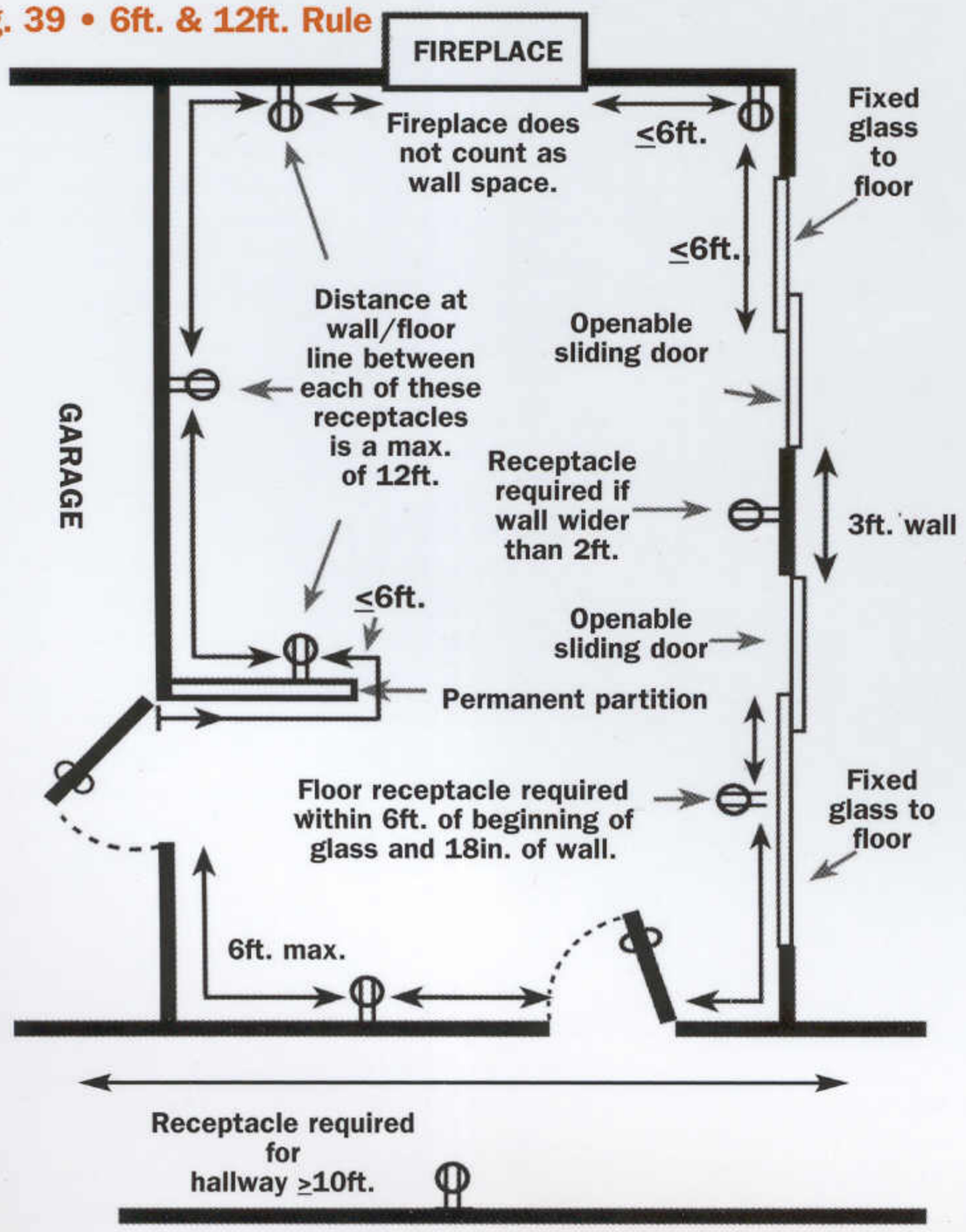
Branch Circuits

The requirements for branch circuits anticipate the loads we are likely to connect to the system. An insufficient number of outlets might lead to the dangerous substitution of extension cords for permanent wiring. The requirements of the NEC are minimal, and in some cases more circuits and outlets are needed for convenience and safety.

General-Purpose Receptacle Outlets	2002	2005
☐ Min size for branch ckt wiring 14AWG	[210.19A4]	{210.19A4}
☐ Rule of thumb: min 1 general-purpose ckt per 500sq ft	[210.11A]	{210.11A}
☐ Distance along wall to recep 6ft max	F39 [210.52A1]	{210.52A1}
☐ Walls ≥2ft req recep	F39 [210.52A2]	{210.52A2}
☐ Hallways ≥10ft req recep	F39 [210.52H]	{210.52H}
☐ Permanent partitions & railings count as wall space	[210.52A2]	{210.52A2}
☐ No cords or cables through or stapled to walls	[400.8]	{400.8}

Garage & Unfinished Basement		
☐ Min 1 wall-switched lighting outlet in garage	[210.70A2a]	{210.70A2a}
☐ Min 1 general-purpose (not laundry) recep	[210.52G]	{210.52G}

Fig. 39 • 6ft. & 12ft. Rule



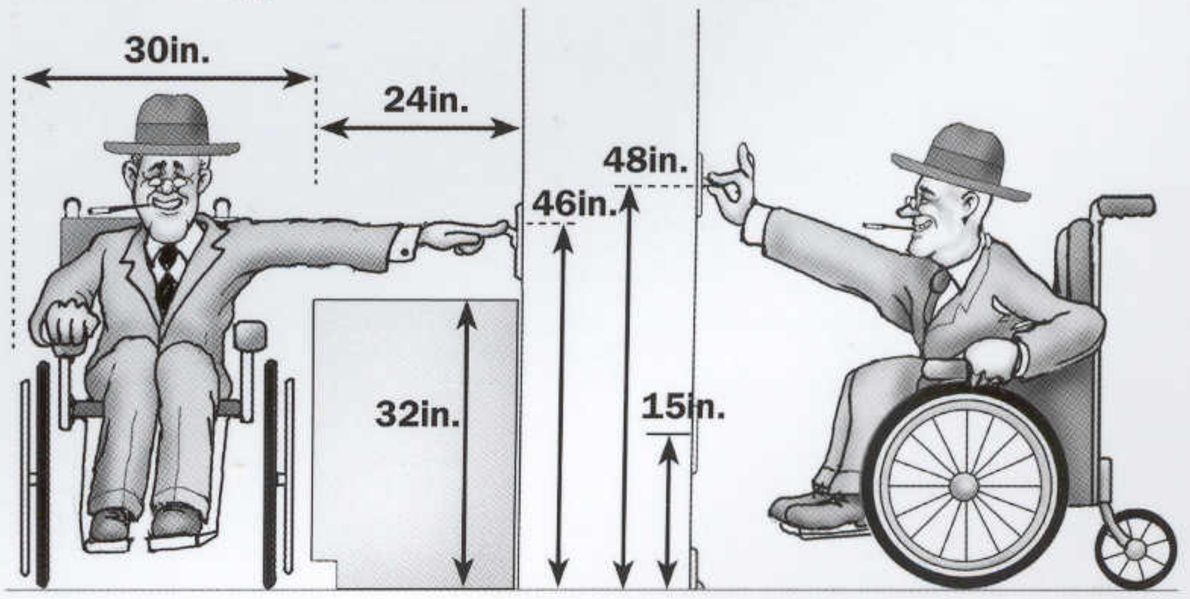
Bathrooms	2002	2005
☐ Recep req on wall within 3ft of each basin EXC	[210.52D]	{210.52D}
May be in cabinet side or face ≤12in below countertop	[n/a]	{210.52DX}[28]
☐ No face-up outlets on vanity countertop	[406.4E][29]	{406.4E}
☐ Sep 20A ckt for bathroom receps only OR	[210.11C3]	{210.11C3}
Dedicated 20A ckt to each bathroom	[210.11C3X]	{210.11C3X}
☐ Comply w/ local energy regulations	[energy]	{energy}
☐ Max rating of space heater on general lighting ckt 15A ckt–900W, 20A ckt–1,200W	[210.23A2]	{210.23A2}
☐ No panelboards in bathrooms	[240.24E]	{240.24E}

Hydromassage (Whirlpool) Tub		
☐ GFCI protection req for all tub eqpmt incl motor	[680.71]	{680.71}
☐ Elec eqpmt (incl motor) req to be accessible	[680.73]	{680.73}
☐ Accessible disc req in sight of motor	[422.32]	{422.32}
☐ Bond together all grounded metal parts in contact w/ circulation water w/ solid Cu 8AWG	[680.74]	{680.74}[30]

Laundry		
☐ Min one 20A ckt to laundry recep(s)	[210.11C2]	{210.11C2}
☐ Recep within 6ft of intended appl loc	[210.50C]	{210.50C}
☐ Elec dryer min 30A ckt (10AWG Cu, 8AWG AL)	[220.18]	{220.54}
☐ New elec dryer req 4-cond branch ckt	[250.138A]	{250.138A}
☐ Receps within 6ft of laundry sinks req GFCI protection	[n/a]	{210.8A7}[7]

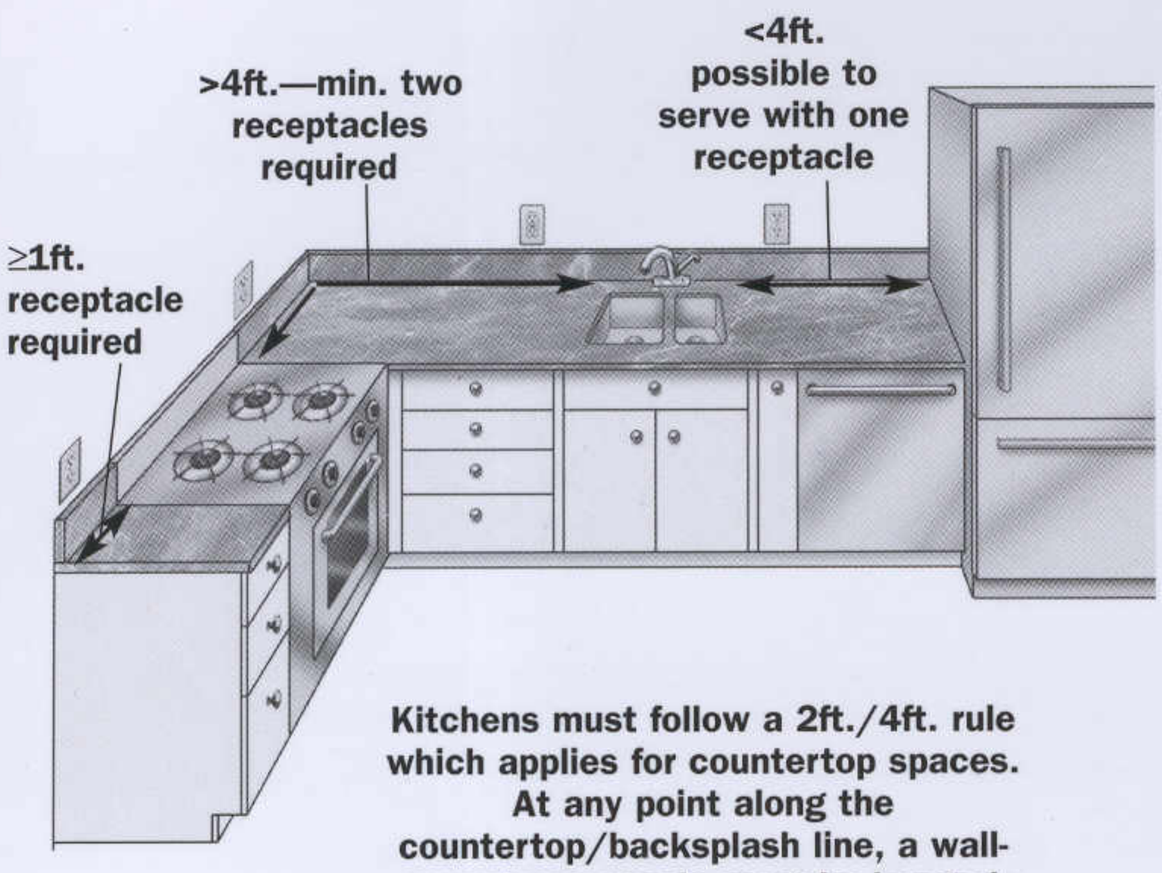
Outdoors		
☐ Lum req on ext side of all grade-level personnel doors (not incl garage vehicle door)	[210.70A2B]	{210.70A2B}
☐ Accessible receps req front & rear max 6½ft above grade	[210.52E]	{210.52E}

Fig. 40 • Receptacle & Switch Heights for Handicapped Access



In most cases, the NEC does not have requirements for switch or receptacle height. The Americans with Disabilities Act (ADA) provides requirements for accessibility. Local building departments often serve as the ADA compliance officers, and when a building or unit requires accessibility, the receptacles must be at least 15in. above the floor and the switches 48in. from the center of the switch to the floor.

Fig. 41 • Receptacle Rules for Kitchen Countertops

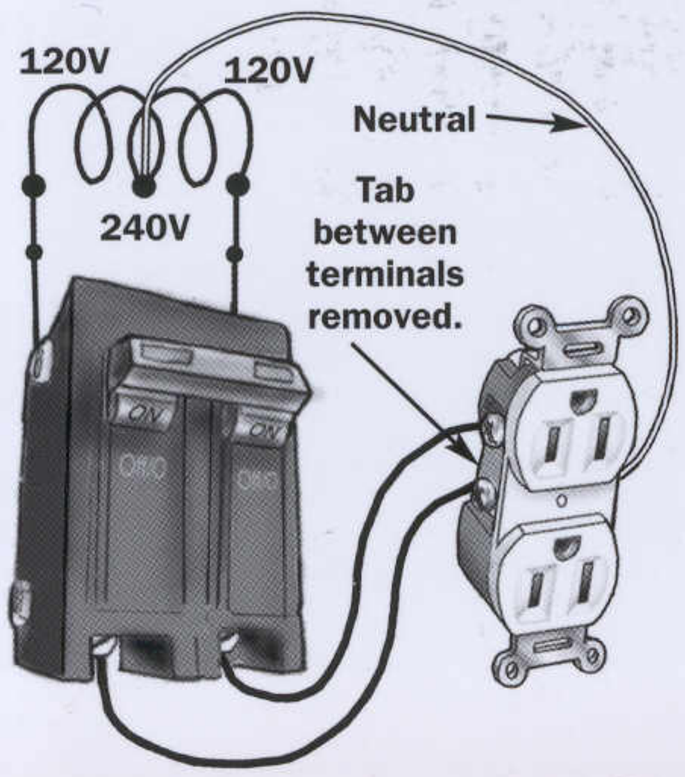


Kitchens must follow a 2ft./4ft. rule which applies for countertop spaces. At any point along the countertop/backsplash line, a wall-mount receptacle must be located within 24in. horizontally.

The "small appliance" circuits supplying these receptacles must be rated 20amps and must serve all receptacles in the kitchen, dining area, and pantry. No other outlets, such as lights or permanently affixed appliances, are allowed on these circuits.

Fig. 42 • 3-Wire Circuit to a Duplex

A common 3-wire circuit in a residence is run to a duplex receptacle for the dishwasher and garbage disposal. By breaking the connecting tab on a duplex receptacle, each half can be fed by separate circuits with a shared neutral. When two circuits supply a single device, their breakers require a common handle tie. It is essential that there be 240V potential between the circuits, otherwise the neutral can be overloaded **(F36)**.



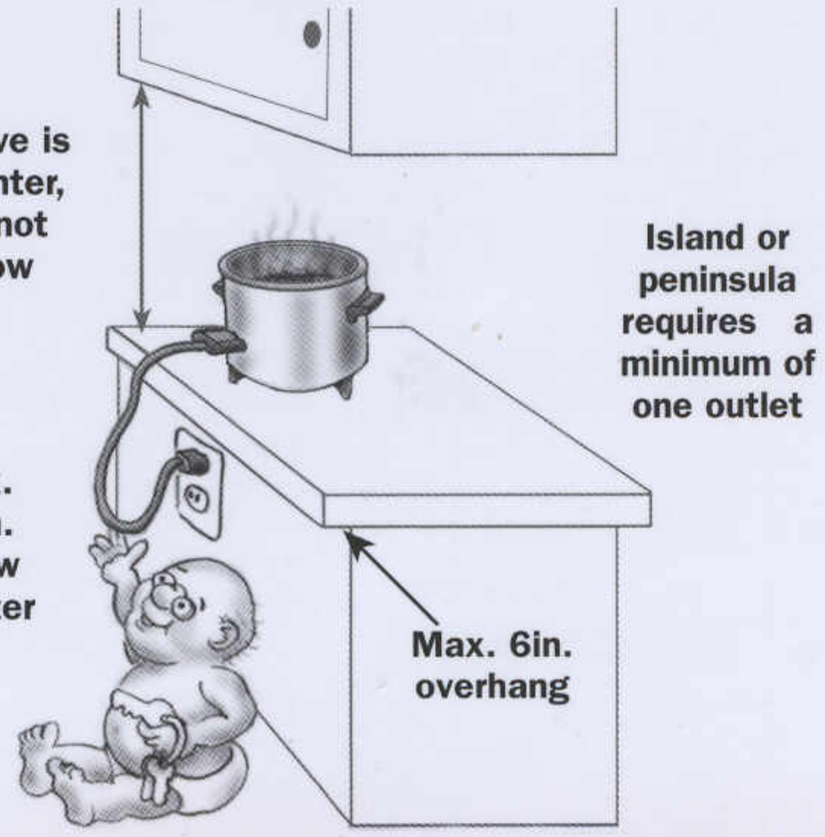
Kitchens

Since the early 1990s, appliances have shorter cords, so they are not as likely to be run across cooktops or sinks or to hang down in the reach of children. As a result, more kitchen counter receptacles are needed. At least two 20A circuits are required for countertops and other food-preparation areas because of the likelihood of using appliances with large loads.

Branch Circuits	1999	2002
☐ Min two 20A small-appl ckt req	[210.11C]	{210.11C}
☐ Small-appl ckt must serve refrig & all countertop & exposed wall receps in kitchen, dining room, & pantry	[210.52B1]	{210.52B1}
☐ No other outlets (incl lights) on branch ckt EXC	[210.52B2]	{210.52B2}
Clock or gas range ignition	[210.52B2X]	{210.52B2X}
☐ Refrig may be on individual branch ckt ≥15A	[210.52B1X2]	{210.52B1X2}
☐ Multiwire ckt split recep req breaker handle tie	**F42** [210.4B]	{210.4B}
☐ DW & disposer usually req sep ckt	[210.23A2]	{210.23A2}

Lighting & Receptacle Outlets		
☐ Comply w/ local energy regulations	[energy]	{energy}
☐ All individual counter spaces ≥12in req receps **F41**	[210.52C1]	{210.52C1}
☐ Individual counter space = undivided by sink or cooktop	**F41** [210.52C4]	{210.52C4}
☐ Spacing so no point >24in from recep	**F41** [210.52C1]	{210.52C1}
☐ Recep not req for area behind sink unless deeper than 12in for straight wall or 18in for corner sink	[n/a]	{210.52C1X}[31]
☐ Max 20in above countertop	[210.52C5][32]	{210.52C5}
☐ Island & peninsula counter spaces min 1 recep **F43**	[210.52C2,3]	{210.52C2,3}
☐ Islands & peninsulas w/ no backsplash or overhead cabinet may be mounted no more than 12in below counter if max 6in counter overhang	**F43** [210.52C5X][33]	{210.52C5X}
☐ No face-up countertop receps	[406.4E][29]	{406.4E}
☐ GFCI protect all recep serving countertops	[210.8A6]	{210.8A6}

Fig. 43 • Islands & Peninsulas



Ampacity of Wire

As current flows through a wire, voltage (pressure) is converted to heat as a squared function of the current. In other words, 4A gives off 16 times as much heat as 1A would through the same wire. Heat can be expressed mathematically as watts = I^2R. Too much current through a wire causes it to get hot. Paper burns at about 451°F. Many electrical fires can be traced back to dangerous I^2R losses. Minimizing these losses is at the heart of the NEC. When wire overheats, its insulation begins to break down, and we say the wire has exceeded its ampacity.

Wire ampacity is based on the temperature rating of its insulation. Conductor insulation has various temperature ratings, 60°C, 75°C, and 90°C being the most common. Typical breakers and equipment terminations also have a temperature rating, typically 60°C and/or 75°C (many are dual rated). One of the mechanisms inside every circuit breaker is a bimetallic element that opens (shuts off) the breaker if it gets too hot (above the overload rating of the breaker).

In determining the overall ampacity of a circuit, ampacity is limited by the lowest-rated device or conductor in the circuit. In residential wiring this generally means a 60°C rating. Until recently, most breakers under 100A were rated only 60°C. These 60°C breakers would limit the ampacity of the conductor to a 60°C rating. In addition, Romex is restricted to a 60°C rating, despite containing 90°C-rated conductors.

The ambient temperature **(T6)** must also be considered when determining the ampacity of a wire, as in the following example:

Ambient Temperature Example: An abandoned 30A NM-fed (60°C wire) dryer circuit runs through a 115°F (46°C) attic (a common summertime occurrence). Could we reuse it to feed a 22A AC unit? Because of the contributed heat of the attic, this 60°C Romex (TW wire) must be derated to 58% of its ampacity or 17.4A, the maximum current flow that can be safely carried by the conductors. To carry a 22A load through the attic would have required that the old NM cable be 8AWG (40 x 0.58 = 23.2).

Table 7 • Wire Ampacities (based on NEC T310.16)

Size	60°C 140°F	75°C 167°F	90°C 194°F	60°C 140°F	75°C 167°F	90°C 194°F	Size
	TYPES						
AWG kcmil	TW UF	THHW THW THWN USE	THHN THHW THW-2 THWN2 USE-2	TW UF	XHHW USE	USE-2, XHHW-2	AWG kcmil
	COPPER			ALUMINUM			
14*	20	20	25	—	—	—	—
12*	25	25	30	20	20	25	12
10*	30	35	40	25	30	35	10
8	40	50	55	30	40	45	8
6	55	65	75	40	50	60	6
4	70	85	95	55	65	75	4
3	85	100	110	65	75	85	3
2	95	115	130	75	90	100	2
1	110	130	150	85	100	115	1
1/0	125	150	170	100	120	135	1/0
2/0	145	175	195	115	135	150	2/0
3/0	165	200	225	130	155	175	3/0
4/0	195	230	260	150	180	205	4/0
250	215	255	290	170	205	230	250

This table is at the heart of the National Electrical Code. Use the 60°C column for up to 100A or #1 conductors and the 75°C column for larger conductors. The 75°C and 90°C columns are also used for derating.
* Max 30A OCPD for #10CU, 20A for #12, and 15A for #14. For aluminum, max 25A for #10 and 20A for #12.

Derating Example: Twelve current-carrying conductors through a conduit supply a wood shop. Wire ampacity of a #12 THHN wire would be found by multiplying its 90°C rating, 30A x 0.50 (ET-4) = 15A. The #12 wires in this conduit must not carry more than 15A and must be protected by 15A breakers.

Table 6 • Correcting for High Ambient Temperatures

Ambient Temp, °C	For Ambient Temperatures >30°C (86°F), Multiply the Allowable Ampacities in T7 by the Following Percentages:			Ambient Temp, °F
	60°C	75°C	90°C	
31–35	0.91	0.94	0.96	87–95
36–40	0.82	0.88	0.91	96–104
41–45	0.71	0.82	0.87	105–113
46–50	0.58	0.75	0.82	114–122
51–55	0.41	0.67	0.76	123–131
56–60	—	0.58	0.71	132–140
61–70	—	0.33	0.58	141–158

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 8 • Correcting for Wires in Conduit or Bundled Cable. Percent Derating for More Than Three Conductors

# of Current-Carrying Wires	%
4–6	80
7–9	70
10–20	50

With modern 90°C small conductors this table becomes significant only when there are more than nine current-carrying conductors in a conduit or Romex bundle. When Romex is bundled more than 2ft., it is subject to the above derating. Be careful about mixing the newer 90°C wire with older 60°C wire, such as TW. Adding the lower-rated wire means that the higher-rated wire must be rated like the lower-rated conductors.

Sizing a Motor Circuit

Motor circuits require two forms of overcurrent protection. Short-circuit and ground-fault protection is supplied at the source of the circuit. The conductors and motor are protected against overload by thermal devices located either in the equipment or in a separate motor controller. For a brief instant, when motors start, they draw a large amount of current, and the OCPD ahead of the motor must be sized to accommodate this "locked rotor" in-rush current. A breaker typically would be sized for 250% of the full-load current (FLC) based on the motor hp, or a time-delay (TD) fuse would be sized to 175% of the FLC. These oversize breakers or fuses do not protect the motor or conductors from burning up due to an overload. Some motors or equipment, such as air-conditioning condensers, have thermal protection in the motor. Larger motors will have melting alloy "heaters" in the motor controller. This thermal protection protects the motor and wire from sustained overheating. A disconnect must be installed ahead of the motor controller so it can be safely serviced; the disconnect is not intended to be used to turn the motor on and off. Small motors may require overload protection in the form of an "SSU switch" shown in **(F81)**. *Listed appliances such as air-conditioners have all these calculations taken into account before their required conductor and OCPD sizes are listed on the nameplate.*

Motor Branch Circuits & OCPDs	1999	2002
☐ Use nameplate FLA only for overload protection size	[430-32]	{430.32}
☐ Find ckt FLC from hp & V per **T9**	[430-6a1]	{430.6A1}
☐ Size ckt cond to 125% of value in **T9**	[430-22a]	{430.22A}
☐ Breaker size 250% FLC or TD fuse 175%	[430-52c]	{430.52C}
☐ Next higher std OCPD OK	[430-52X]	{430.52X}

Table 9 • Full-Load Current for Single-Phase Motors [T430.248]

hp	115V	200V	208V	230V
1/6	4.4	2.5	2.4	2.2
1/4	5.8	3.3	3.2	2.9
1/3	7.2	4.1	4.0	3.6
1/2	9.8	5.6	5.4	4.9
3/4	13.8	7.9	7.6	6.9
1	16	9.2	8.8	8
1 1/2	20	11.5	11	10
2	24	13.8	13.2	12
3	34	19.6	18.7	17
5	56	32.2	30.8	28
7 1/2	80	46	44	40
10	100	57.5	55	50

Table 10 • Sizing Conductors

Fuse or Breaker	Branch Circuits or Feeders Wire Size[a]		Service Conductors Wire Size[b]	
	Copper	Aluminum	Copper	Aluminum
15	14	12		
20	12	10		
25	10	10		
30	10	8		
35	8	6		
40	8	6		
45	6	4		
50	6	4		
60	6	3		
70	4	2		
80	3	1		
90	2	1/0		
100	2	1/0	4	2
110	1	1/0	3	1
125	1/0	1/0	2	1/0
150	1/0	2/0	1	2/0
175	2/0	3/0	1/0	3/0
200	3/0	4/0	2/0	4/0
225	4/0	250kcmil	3/0	250kcmil
250	4/0	300kcmil	4/0	300kcmil
300	300kcmil	400kcmil	250kcmil	350kcmil
350	400kcmil	600kcmil	350kcmil	500kcmil
400	500kcmil	700kcmil	400kcmil	600kcmil

a. Branch circuit and feeder wire sizes are based on table 310.16 of the NEC. The 60°C column is used for sizes #1 or smaller, and the 75°C column is used for larger sizes.
b. Service conductor sizes are based on the wire types in NEC table 310.15(B)(6).

Sizing Example

Motor nameplate = 3hp, 1Ø, FLA = 15A, 230V, SF = 1.15
Overload protection = 15 X 125% = 18.75
FLC = 17A **(T9)**
Conductor ampacity ≥17A X 125% = 21.25A
Breaker size = 17A X 250% = 42.5A
TD fuse size = 17A X 175% = 38.75A

A 12AWG THW wire is OK (75°C column).
A 45A breaker is OK (next higher standard size).
A 40A TD fuse is OK (next higher standard size).

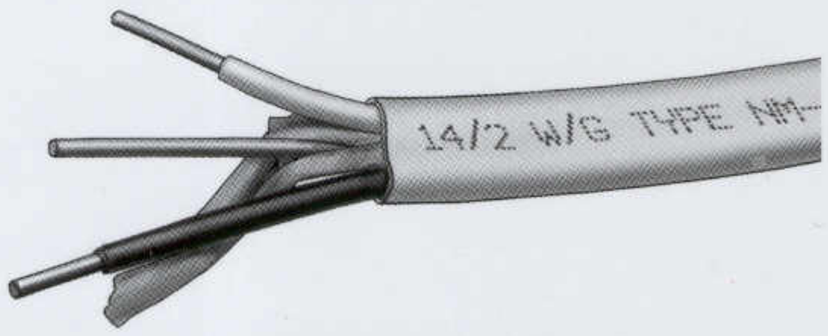
Wire Codes in T7
T = Thermoplastic
W = Wet
R = Thermoset (formerly rubber)
H = Heat resistant
N = Nylon jacketed
U = Underground
-2 = 90°C dry or wet

Fig. 44 • THHN Is the Most Common Copper Wire Insulation Used in Raceways

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.

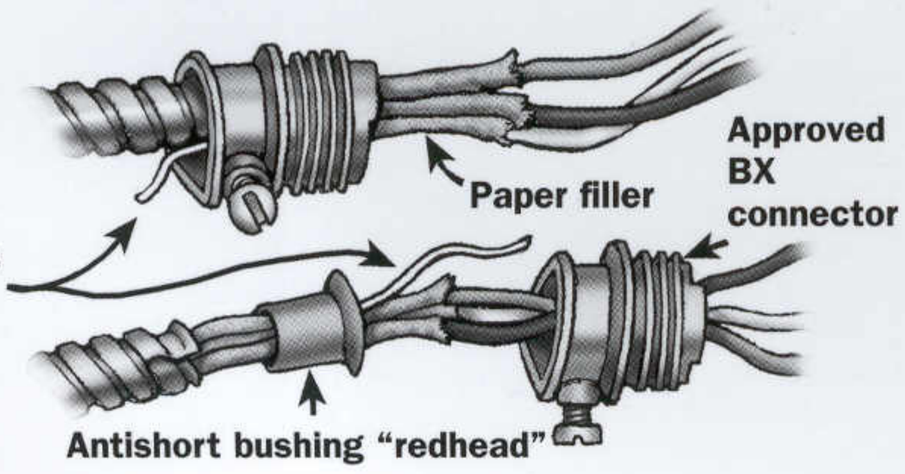
Fig. 45
NM (Nonmetallic Sheathed Cable) Romex



Cable Protection Indoors (NM, AC, MC, UF, SE)	2002	2005
☐ Protect cables w/ 1/16in steel plate {or L&L plate} if closer than 1¼in to framing surfaces **F55**	[300.4A,D]	{300.4A,D}[34]
☐ Provide guard strips within 6ft of attic scuttle **F53**	[320,30,34.23]	{320,30,34.23}
☐ Provide guard strips up to 7ft high in attic w/ ladder or permanent stairs	[320,30,34.23]	{320,30,34.23}

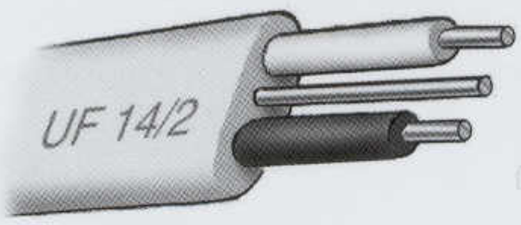
NM—Nonmetallic Sheathed Cable (Romex)		
☐ OK in normally dry loc only	[334.10A]	{334.10A}
☐ Protect exposed cable from damage	[334.15B]	{334.15B}
☐ Listed grommets for holes through metal framing	[300.4B1][35]	{300.4B1}
☐ OCPD selection based on 60° column	[334.80]	{334.80}
☐ OCPD derating & temp correction based on 90° rating for cables marked w/ "-B"	[334.80]	{334.80}
☐ Derate cable bundles through insulation or firestop caulking	[n/a]	{334.80}[36]
☐ Secure to box w/ approved NM clamp EXC **F52**	[314.17B,C]	{314.17B,C}
Single gang (2¼X4in) plastic box if stapled within 8in	[314.17CX]	{314.17CX}
☐ Min ¼in sheathing into plastic boxes	[314.17C]	{314.17C}
☐ Secure within 12in of box & max 4½ft intervals	[334.30]	{334.30}
☐ Do not overdrive staples or place flat cable on its edge	[334.30]	{334.30}
☐ Bends gradual (min 5X cable dia)	[334.24]	{334.24}
☐ Running board for small cable under joists **F54**	[334.15C]	{334.15C}

Fig. 46
BX—Armored Cable



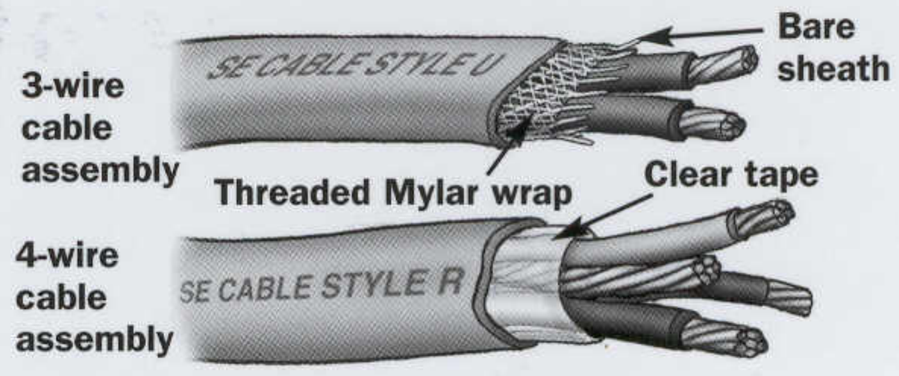
AC—Armored Cable (BX)		
☐ Dry loc only	[320.10(3)]	{320.10(3)}
☐ Secure within 12in of box & max 4½ft intervals EXC	[320.30A]	{320.30B}
2ft where flexibility needed (motors)	[320.30B]	{320.30D}
☐ Insulated bushing at terminations **F46**	[320.40]	{320.40}
☐ Armor is EGC—don't bring bond wire into box . . **F46**	[320.108]	{320.108}
☐ Underside of joists—secure at each joist **F54**	[320.15]	{320.15}

Fig. 47
UF Cable



UF—Underground Feeder	2002	2005
☐ Interior installation same rules as NM	[340.10]	{340.10}
☐ May be buried in earth w/ cover per **T4** **F51**	[340.10]	{340.10}
☐ Protect where emerging from earth from 18in below grade to 8ft above **F51**	[300.5D1]	{300.5D1}
☐ Single conductors in trench must be grouped	[340.10]	{340.10}
☐ UV-resistant type OK exposed to sunlight	[340.12]	{340.12}
☐ May not be strung through air w/o support messenger	[340.12]	{340.12}

Fig. 48
USE Cable with Bare Wire and 4-Wire SE Cable



SE—Service Entrance and USE—Underground Service Entrance		
☐ OK as service entrance conductor (see p. 9)	[338.10A]	{338.10A}
☐ Interior installation same rules as NM EXC		
☐ 60° limit does not apply if terminals rated >60° . .	[338.10B4a]	{338.10B4a}
☐ Direct buried cable same rules as UF cable	[338.10A,B4]	[338.10A,B4]
☐ Insulated neutral (type SER) req after service EXC . .	[338.10B1]	{338.10B1}
☐ Bare conductor in type SEU OK as EGC or in feeder to sep bldg if no continuous metal path between bldg (see p. 11)	[338.10B2]	{338.10B2}
☐ Bends gradual (min 5X cable dia)	[338.24]	{338.24}

Fig. 49 • MC Cable

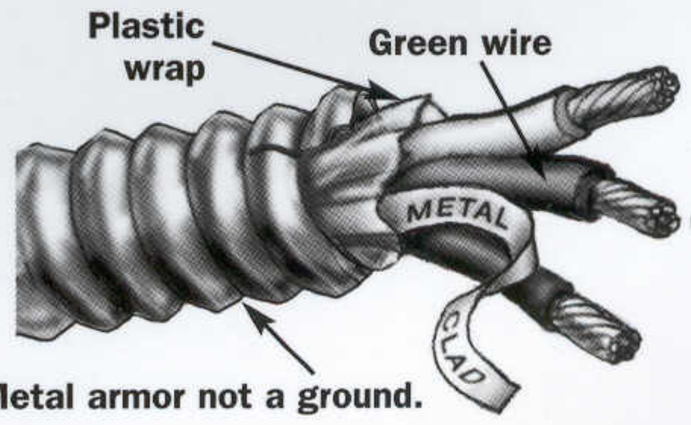
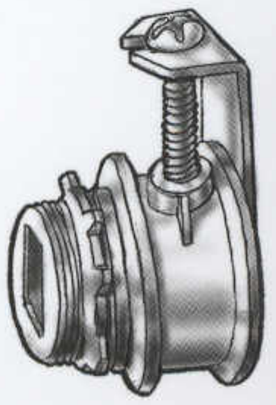


Fig. 50 • MC Cable Connector



MC—Metal-Clad Cable		
☐ Secure within 12in of box & max 6ft intervals EXC	[330.30A,C]	{330.30B,C}
>10AWG or where fished or to lum above ceiling	[330.30B]	{330.30D}
☐ Bends gradual (min 7X cable dia)	[330.24]	{330.24}

Voltage Drop

When laying out wiring, consider the voltage drop caused by long runs of wire. The NEC recommends (though it does not require) a maximum voltage drop of 3% on branch circuits and a 5% overall voltage drop including the feeders. 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. Using fewer than the maximum number of outlets on each circuit will help prevent overloading. Compliance with modern codes now requires separate runs of wire for bedroom outlets (so the entire circuit can be AFCI protected) and for the 20A bathroom-receptacle circuits.

Table 11 • Cable Length to Limit Voltage Drop to 3%

Wire Size	Cu Distance	AL Distance
14AWG	50ft.	N/A
12AWG	60ft.	36ft.
10AWG	64ft.	38ft.
8AWG	76ft.	46ft.
6AWG	94ft.	57ft.

Based on 120V and 80% circuit loading for normal OCPD. Distance doubles for 240V.

Fig. 51 • Protecting Underground Cable

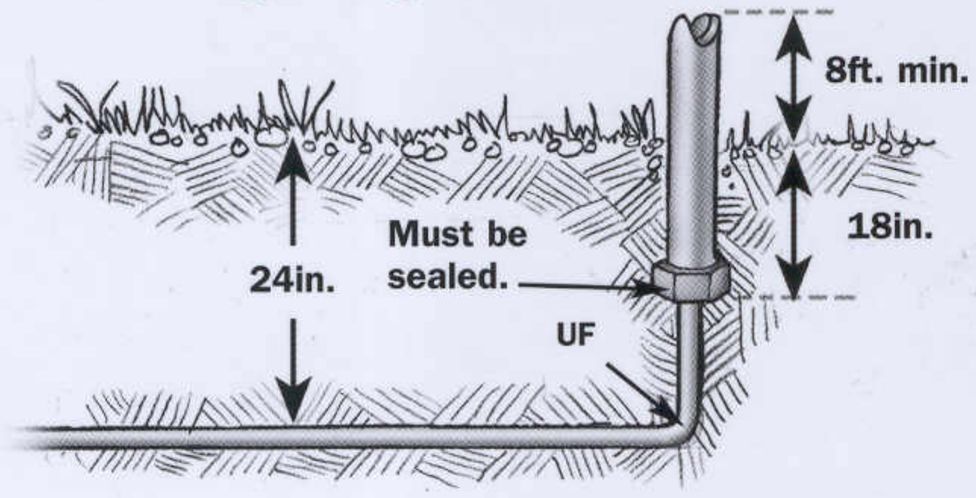


Fig. 52 • Romex Clamps

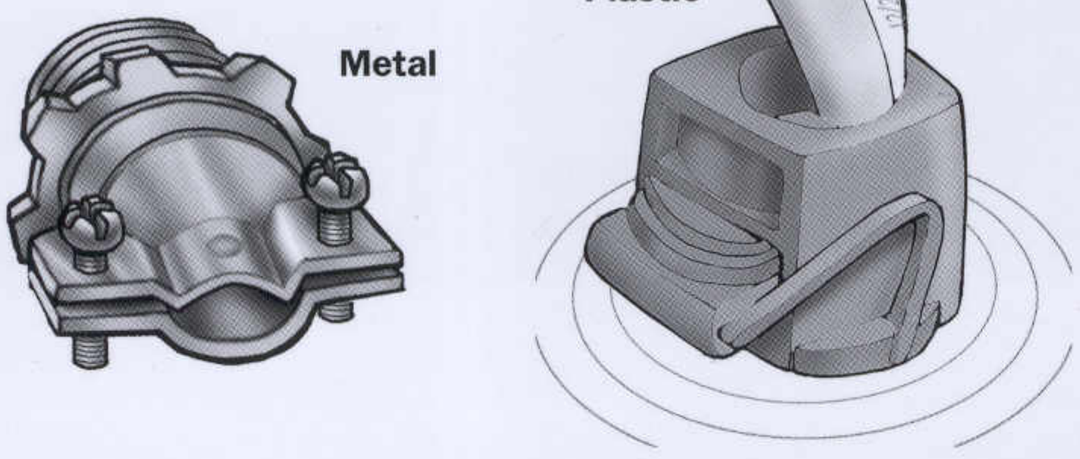


Fig. 53 • Cable in an Attic

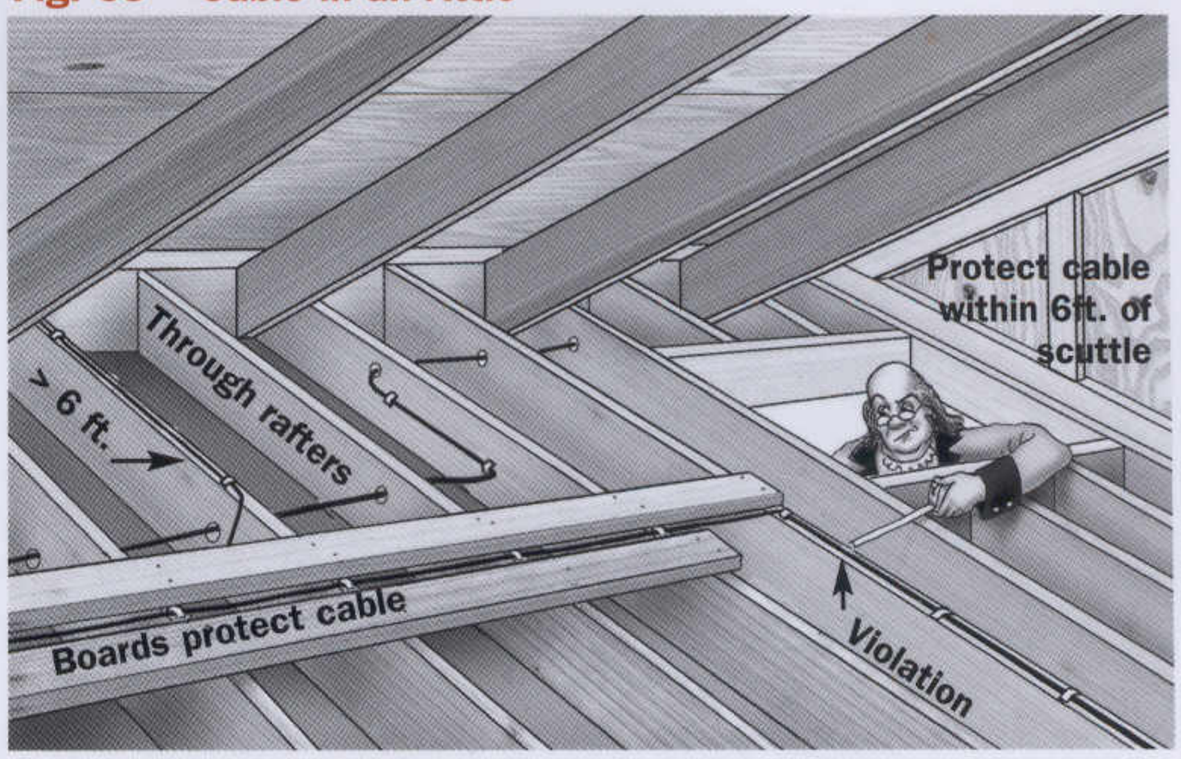


Fig. 54 • Cable under Floor

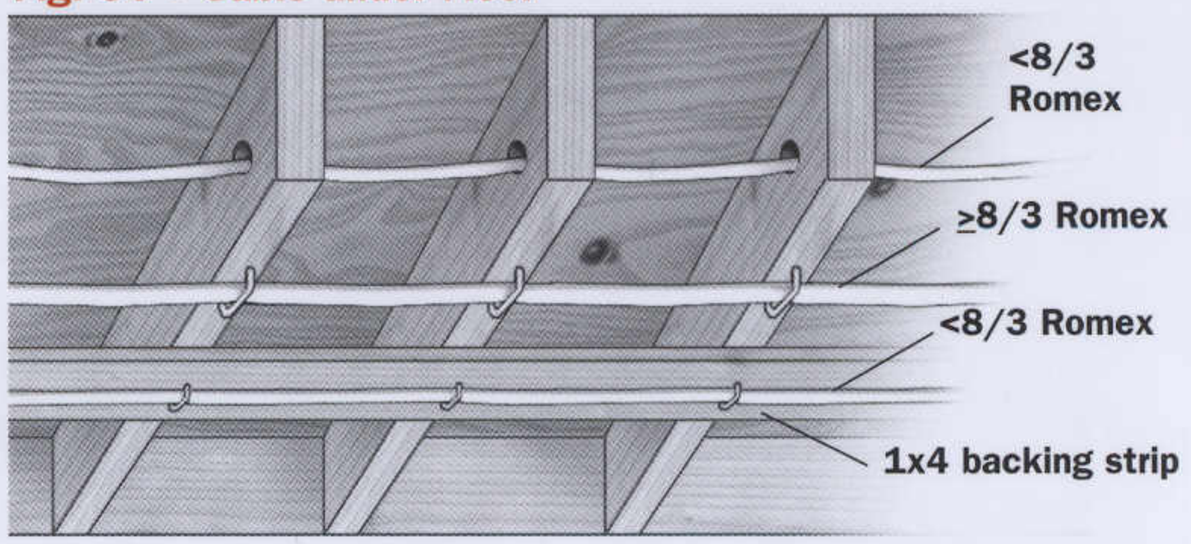


Fig. 55 • Nail-Plate Protection

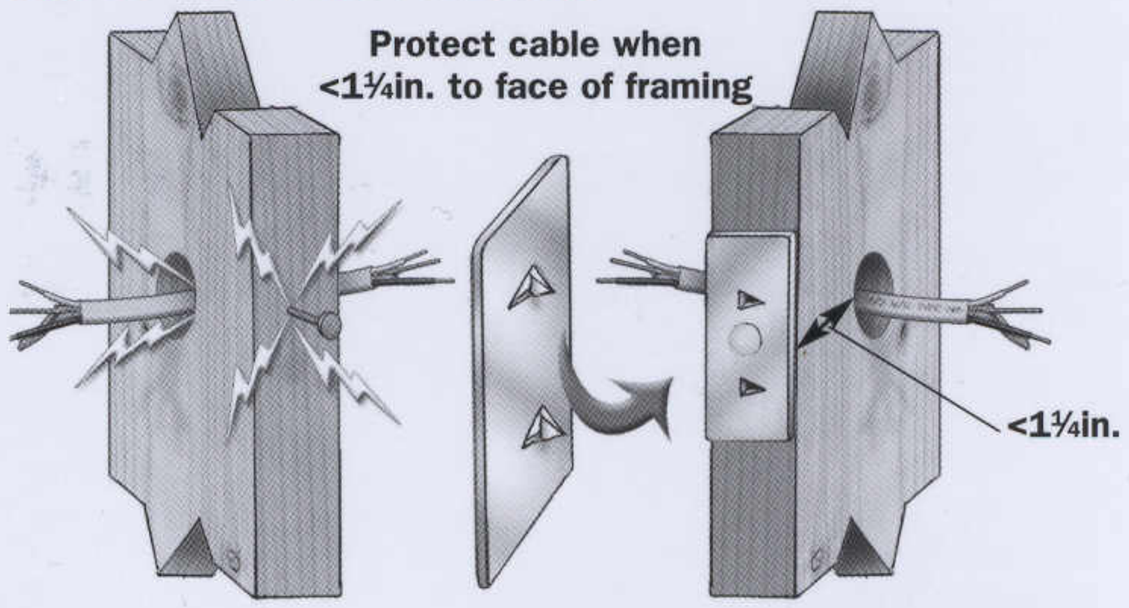


Fig. 56
Standoff Clamp

Used to maintain clearances to stud or joist edge.

Raceways

*Raceways are complete systems of conduit or tubing through which conductors are installed. In the 2002 & 2005 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. In the first four three-code citations below, the designation "***" is used for articles that share a common ending. For example, the rule for maximum bends is found in 344.26, 348.26, 350.26, etc., all ending with ".26" after the period. See* **T21**

Installation Requirements (All Conduits & Tubing)	2002	2005
☐ 360° max bends between pull points	**F63** [***.26]	{***.26}
☐ Raceway must be reamed after cutting	[***.28]	{***.28}
☐ Bends req to have even radius—no kinks	**F63** [***.24]	{***.24}
☐ Box & conduit body covers must remain accessible	[314.29]	{314.29}
☐ No plastic boxes w/ metal cables or raceways unless bonded through box	[314.3X]	{314.3X}
☐ No splicing in conduit bodies EXC conduit bodies w/ sufficient volume per marking	[314.16C2]	{314.16C2}
☐ Fittings req plastic bushing if cond ≥4AWG	[300.4F]	{300.4F}
☐ Max 40% fill if >2 cond (incl EGC)	**T12-17** [9-T1]	{9-T1}
☐ Derate cond per bundling & ambient temp	**T7** [310.15B2a]	{310.15B2a}

Fig. 57 • EMT

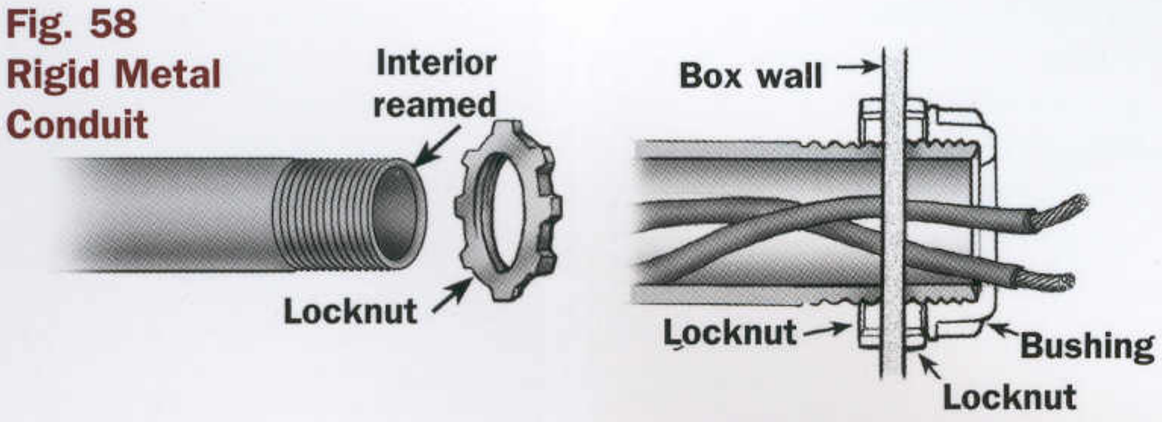
EMT—Electrical Metallic Tubing

☐ EMT not OK for burial in soil or concrete	[358.10B]	{358.10B}
☐ Raintight couplings & connectors req in wet loc	**F57** [358.42]	{358.42}
☐ Secure in place max 10ft intervals & 3ft from terminations (box, conduit body, cabinet)	[358.30A]	{358.30A}
☐ Horiz runs OK to support in framing holes if securely fastened within 3ft of terminations	[358.30B]	{358.30B}
☐ OK to support conduit bodies, not boxes	[358.12]	{358.12}

RMC—Rigid Metal Conduit

☐ OK for burial in soils	[344.10B]	{344.10B}
☐ Coat buried field cut threads w/ L&L compound	[300.6A]	{300.6A}
☐ Provide bushing or fitting at box connection	**F58** [344.46]	{344.46}
☐ Plastic bushings if any cond ≥4AWG	[300.4F]	{300.4F}
☐ No threadless connectors on threaded conduit ends	[344.42][36]	{344.42}
☐ Secure in place within 3ft of termination	[344.30A]	{344.30A}
☐ Horiz support spacing max 10ft	[344.30B]	{344.30B}

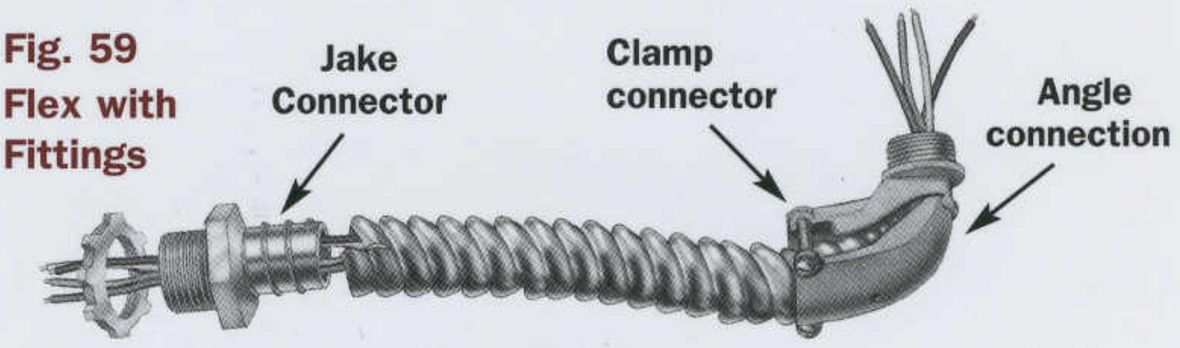
Fig. 58
Rigid Metal Conduit



FMC—Flexible Metal Conduit ("Greenfield")

	2002	2005
☐ Dry loc only EXC	[350-5]	{348.12}
OK wet w/ drip loop & "W"-rated conductors	**F73** [348.12]	{348.12}
☐ Supports: General—4½ft & within 12in of boxes EXC	[348.30A]	{348.30A}
• When fished—not req	[348.30AX1]	{348.30AX1}
• Lighting thermal whip conductor OK to 6ft	**F77** [348.30AX3]	{348.30AX3}
• To lum or other eqpmt in drop ceiling OK to 6ft	[n/a]	{348.30AX4}[37]
• ½–1¼in sizes OK to 3ft where flexibility req	[348.30AX2]	{348.30AX2}[38]
• 1½–2in sizes OK to 4 ft where flexibility req	[348.30AX2]	{348.30AX2}[38]
☐ OK as EGC if fittings L&L, ckt ≤20A, no motors, & ≤6ft long	[250.118]	{250.118}
☐ Angle connections may not be concealed	**F59** [348.42]	{348.42}

Fig. 59
Flex with Fittings



LFMC—Liquid-Tight Flexible Metal Conduit

☐ Same as flex EXC OK for wet loc	[350.10]	{350.10}
☐ OK as EGC if fittings L&L, no motors, ≤6ft long, & ckt ≤20A up to ½in size or <60A for ¾–1¼in size	[250.118]	{250.118}

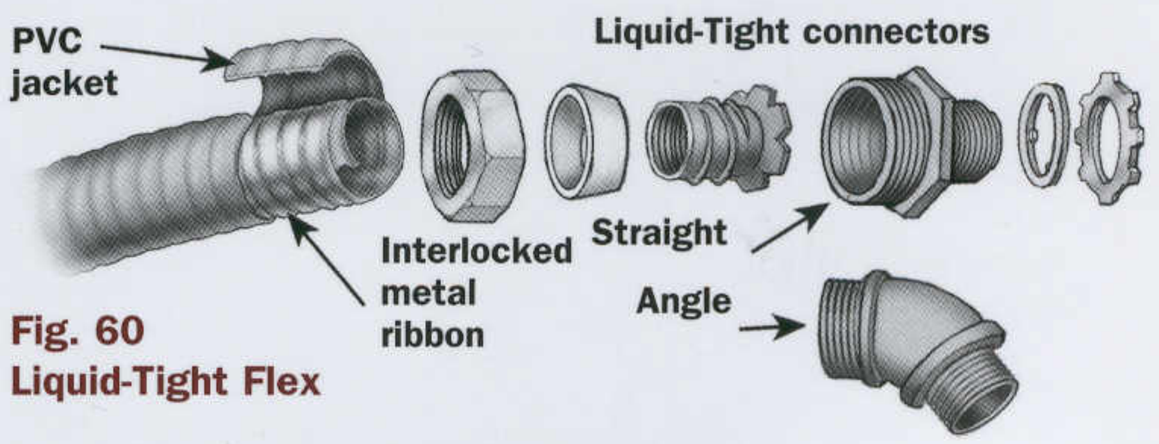


Fig. 60
Liquid-Tight Flex

ENT—Electrical Nonmetallic Tubing ("Smurf")

☐ OK embedded in concrete w/ approved fittings	[362.10]	{362.10}
☐ Not permitted in environments >50°C (122°F)	[362.12]	{362.12}
☐ Not permitted for direct burial	[362.12]	{362.12}
☐ Must be identified as sunlight resistant if outdoors	[362.12]	{362.12}
☐ Secure or support every 3ft EXC	[362.30A,B]	{362.30A,B}
To lum or other eqpmt in drop ceiling OK to 6ft	[n/a]	{362.30AX2}[39]

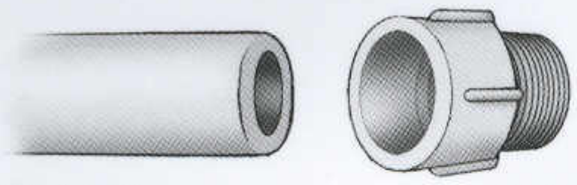


Fig. 61
PVC 80 Conduit & Connector

Fig. 62
ENT & Connector

RNC—Rigid Nonmetallic Conduit—(PVC)

☐ Burial depth	**T4** [300.5A]	{300.5A}
☐ Support to prevent sags & within 3ft of box	[352.30B]	{352.30B}
☐ Expansion joints req if subject to ≥¼in movement OR	[352.44]	{352.44}
If lateral riser is in soil subject to frost or upheaval	[300.5J]	{300.5J}
☐ Not permitted in environments >50°C (122°F)	[352.12D]	{352.12D}

These tables apply if all the conductors in the pipe are the same size. Based on NEC Chapter 9 & Annex C

T12 EMT • Conduit Fill							T13 EMT • Conduit Fill							T14 • Rigid Nonmetallic Conduit PV80							T15 • Rigid Nonmetallic Conduit PV80						
Size AWG kcmil	Number of conductors in THHN,THWN						Size AWG kcmil	Number of Conductors in XHHW						Size AWG kcmil	Number of conductors in THHN,THWN						Size AWG kcmil	Number of Conductors in XHHW					
•	½	¾	1	1¼	1½	2	•	½	¾	1	1¼	1½	2	•	½	¾	1	1¼	1½	2	•	½	¾	1	1¼	1½	2
14	12	22	35	61	84	138	14	8	15	25	43	58	96														
12	9	16	26	45	61	101	12	6	11	19	33	45	74	12	6	12	20	37	51	86	12	5	9	15	27	38	63
10	5	10	16	28	38	63	10	5	8	14	24	33	55														
8	3	6	9	16	22	36	8	2	5	8	13	18	30	8	2	4	7	13	18	31	8	1	3	6	11	15	26
6	2	4	7	12	16	26	6	1	3	6	10	14	22														
4	1	2	4	7	10	16	4	1	2	4	7	10	16	4	1	1	3	6	8	14	4	1	1	3	6	8	14
3	1	1	3	6	8	13	3	1	1	3	6	8	14														
2	1	1	3	5	7	11	2	1	1	3	5	7	11	2	1	1	2	4	6	10	2	1	1	2	4	6	10
1	1	1	1	4	5	8	1	1	1	1	4	5	8														
1/0	1	1	1	3	4	7	1/0	1	1	1	3	4	7	1/0	0	1	1	2	3	6	1/0	0	1	1	2	3	6
2/0	0	1	1	2	3	6	2/0	0	1	1	2	3	6														
3/0	0	1	1	1	3	5	3/0	0	1	1	1	3	5	3/0	0	1	1	1	2	4	3/0	0	1	1	1	2	4
4/0	0	1	1	1	2	4	4/0	0	1	1	1	2	4														
250	0	0	1	1	1	3	250	0	0	1	1	1	3	250	0	0	1	1	1	3	250	0	0	1	1	1	3

Fig. 63 • Too Many Bends

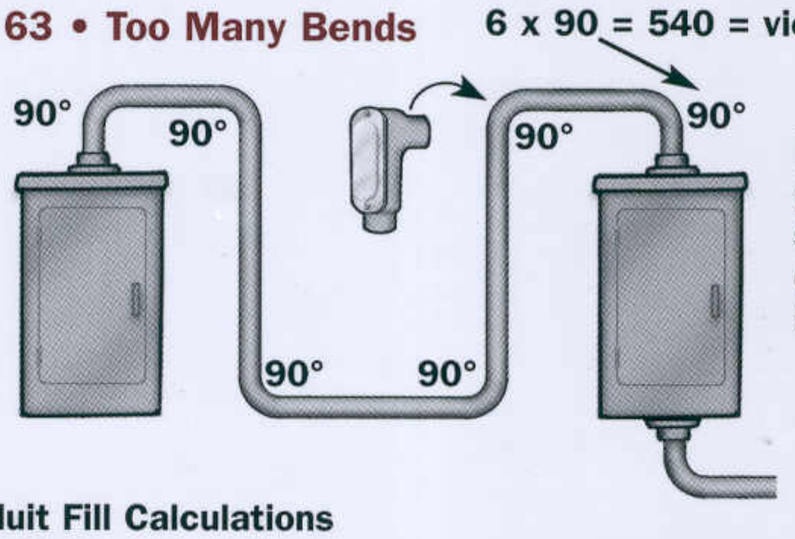
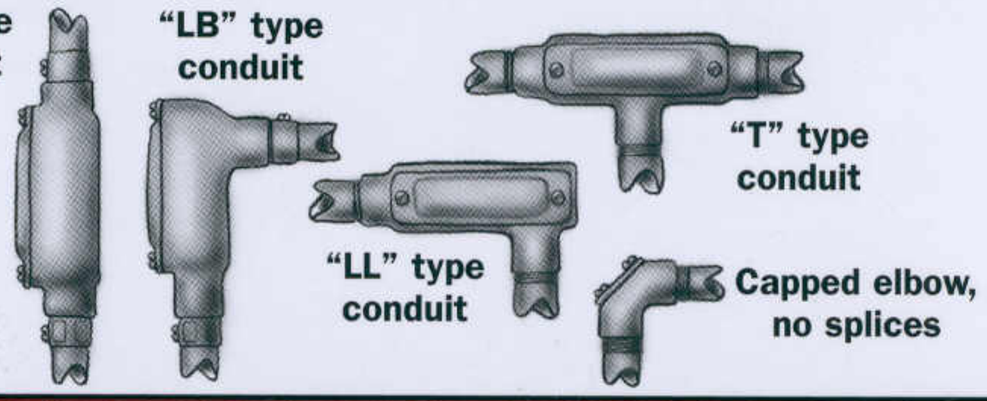


Fig. 64 Conduit Bodies



Conduit Fill Calculations

When different size conductors are used, use **T16** to find the wire areas, add them up, and use **T17** to find the minimum size conduit. Example: 3 2AWG THHN + 3 8AWG XHHW in FMC. (3 x 0.1158) + (3 x 0.0347) = 0.4515, next greater size in 40% column is 0.511. Therefore, a min. 1¼in. size is needed.

Table 16 • Sq. In. Area of Conductors (Based on NEC T5 Chapter 9)

	14	12	10	8	6	4	2	1	1/0	2/0	3/0	4/0	250
TW	.0139	.0181	.0243	.0437	.0726	.0973	.1333	.1901	.2223	.2624	.3117	.3718	.4596
THHN	.0097	.0133	.0211	.0366	.0507	.0824	.1158	.1562	.1855	.2223	.2679	.3237	.3970
XHHW	.0139	.0181	.0243	.0437	.0590	.0814	.0962	.1146	.1534	.1825	.2190	.2642	.3197

Table 17 • Conduit & Tubing Fills (Based on T4 Chapter 9)

Trade Size	Internal Diameter								2 Wire sq.in. Fill 31%								>2 Wire sq.in. Fill 40%							
	EMT	EN	FMC	LTC	IMC	RMC	P80	P40	EMT	EN	FMC	LTC	IMC	RMC	P80	P40	EMT	EN	FMC	LTC	IMC	RMC	P80	P40
⅜	—	.384	.494	—	—	—	—	—	—	—	.036	.059	—	—	—	—	—	—	.046	.077	—	—	—	—
½	.622	.560	.635	.632	.660	.632	.526	.602	.094	.076	.098	.097	.106	.097	.067	.088	.122	.099	.127	.125	.137	.125	.087	.114
¾	.824	.760	.824	.830	.864	.836	.722	.804	.165	.141	.165	.168	.182	.170	.127	.157	.213	.181	.213	.216	.235	.220	.164	.203
1	1.049	1.000	1.020	1.054	1.105	1.063	.936	1.029	.268	.243	.253	.270	.297	.275	.213	.258	.346	.314	.327	.349	.384	.355	.275	.333
1¼	1.380	1.340	1.275	1.395	1.448	1.394	1.255	1.360	.464	.437	.396	.474	.510	.473	.383	.450	.598	.564	.511	.611	.658	.610	.495	.581
1½	1.610	1.570	1.538	1.588	1.683	1.624	1.476	1.590	.631	.600	.576	.614	.689	1.056	.530	.616	.814	.774	.743	.792	.889	.829	.684	.794
2	2.067	2.020	2.040	2.033	2.150	2.083	1.913	2.047	1.040	.994	1.013	1.006	1.125	1.508	.891	1.020	1.342	1.282	1.307	1.298	1.452	1.363	1.150	1.316

Table 18 • Box Fill Worksheet			
Item	**Size**	**#**	**Total**
#14 conductors exiting box	2.00		
#12 conductors exiting box	2.25		
#10 conductors exiting box	2.50		
#8 conductors exiting box	3.00		
#6 conductors exiting box	5.00		
Largest grounding conductor—count only one		1	
Devices—2 per connected conductor size			
Internal clamps—one based on largest wire present		1	
Fixture fittings—one for each type based on largest wire			
TOTAL			

Based on NEC 314.16(B)

Table 19 • Box Fill Example			
Item	**Size**	**#**	**Total**
#14 conductors exiting box	2.00		
#12 conductors exiting box	2.25	6	13.50
#10 conductors exiting box	2.50		
#8 conductors exiting box	3.00		
#6 conductors exiting box	5.00		
Largest grounding conductor—count only one	2.25	1	2.25
Devices—2 per connected conductor size	4.50	1	4.50
Internal clamps—one based on largest wire present	2.25	1	2.25
Fixture fittings—one for each type based on largest wire			
TOTAL			22.5

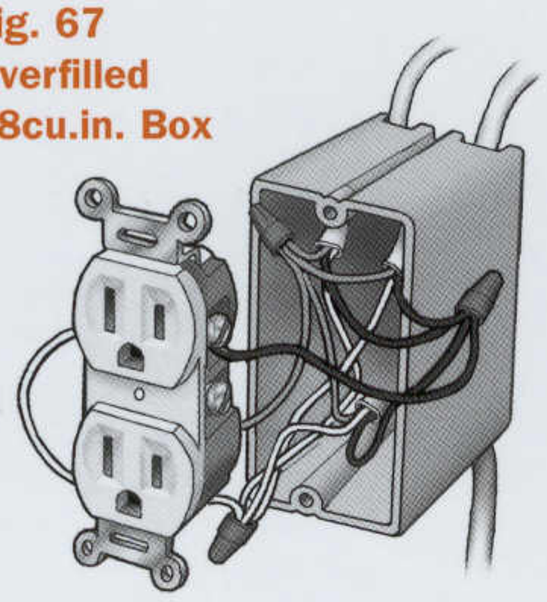
3 12/2+G Romex + device overfills 18cu.in. box.

Boxes

Boxes are necessary to safely enclose and protect wiring splices and to support devices and luminaires (fixtures).

General	2002	2005
☐ Metal boxes must be grounded	[314.4]	{314.4}
☐ Box & conduit body covers must remain accessible	[314.29]	{314.29}
☐ Max ¼in setback from noncombustible surface	**F66** [314.20][40]	{314.20}
☐ Box extenders OK to correct excess setback	[local]	{local}
☐ Boxes flush w/ combustible surface	**F66** [314.20]	{314.20}
☐ No wallboard gaps >⅛in {for boxes w/ flush-type covers}	[314.21]	{314.21}[41]
☐ Min 6in free cond in box & min 3in past box face	[300.14]	{300.14}
☐ Boxes must be supported	[314.23]	{314.23}
☐ EMT OK for conduit body support, not for box support	[358.12]	{358.12}
☐ PVC OK for conduit body support, not for box support	[352.12B]	{352.12B}
☐ Outdoor boxes must prevent water entry	**F70** [314.15A]	{314.15A}
☐ Outdoor wet loc recep boxes req in-use covers	**F70** [406.8B1][42]	{406.8B1,2}
Box Fill		
☐ Size must be OK to provide free space for cond	[314.16]	{314.16}
☐ 4in (6cu in) pancake box only OK for end of 14/2 run	**F65** [314.16B]	{314.16B}
☐ 3in (4cu in) pancake box too small for any splices	**T18**,**19** [314.16B]	{314.16B}
☐ 18cu in box too small for 3 12/2 Romex	**T19**,**F67** [314.16B]	{314.16B}
Factors to Consider for Box Fill		
☐ Count number & size of cond exiting box	**T18** [314.16B1]	{314.16B1}
☐ Pigtail cond to devices don't count	[314.16B1]	{314.16B1}
☐ Support fittings count as 1 cond for each fitting type based on largest cond in box	[314.16B3]	{314.16B3}
☐ Internal clamps—count only 1 based on largest cond in box	[314.16B2]	{314.16B2}
☐ Devices = 2 cond per connected wire size	[314.16B4]	{314.16B4}
☐ All EGCs count as only 1 based on largest	[314.16B5]	{314.16B5}

Fig. 67
Overfilled 18cu.in. Box



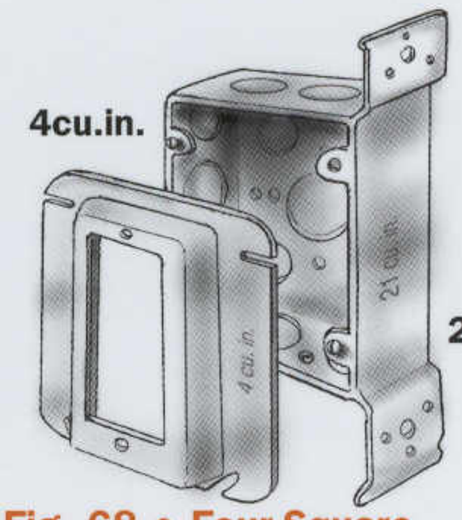


Fig. 68 • Four-Square Steel/Side Bracket

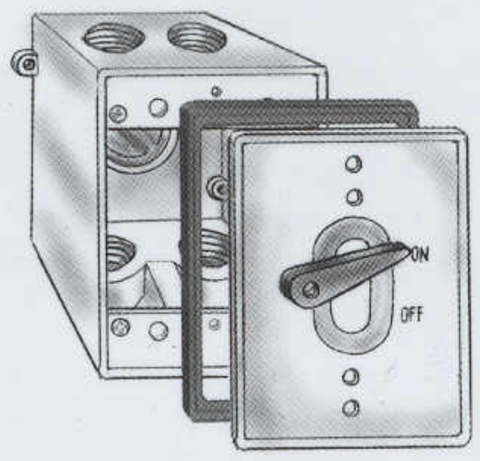
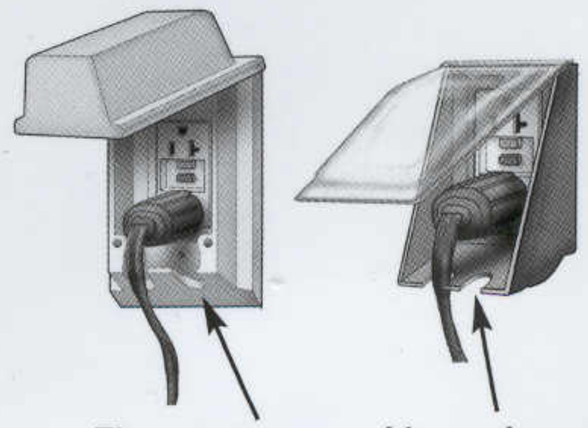


Fig. 69 • Weatherproof Boxes Are Threaded, Switch Covers Raintight

Fig. 70
In-Use Covers



These covers provide cord openings so the covers can shut with the plug inserted

Fig. 65
Pancake Boxes

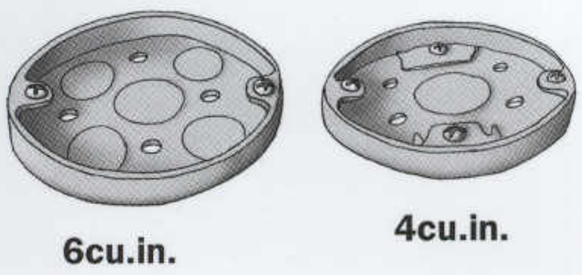


Fig. 66
Improper Box Installation

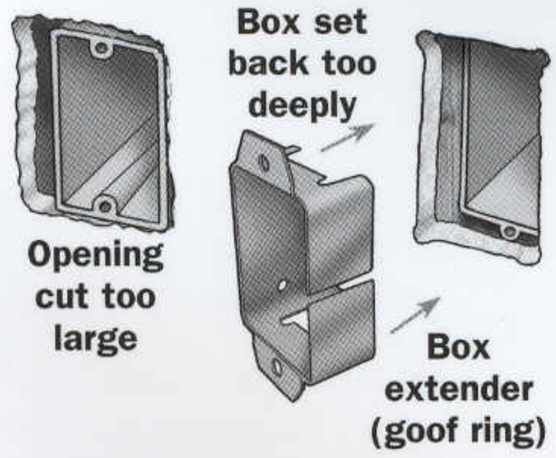


Fig. 71 SSU-Fused Disconnect

Fig. 72 Standard Outdoor Cover Not OK in Wet Locations

Appliances

The term appliances *refers to equipment (other than lighting) that uses electricity. All appliances require some means of disconnecting the hot conductors so they can be safely serviced or replaced.*

Acceptable Disconnecting Devices	**2002**	**2005**
☐ Cord & plug if accessible (behind DW OK)	[422.33A]	{422.33A}
☐ Breaker alone for appls <300VA or ⅛hp	[422.31A]	{422.31A}
☐ In-sight switch or breaker req if ≥300VA or ⅛hp OR Lockable out-of-sight breaker (EXC AC)	**F74** [422.31B]	{422.31B}
☐ 05 req permanent hasp breaker lockouts— no temporary handle locks	**F74** [n/a]	{422.31B}[43]
☐ Unit switch that opens all ungrounded cond	[422.34]	{422.34}

Kitchens

☐ Garbage disposer cord min 18in, max 36in	[422.16B1]	{422.16B1}
☐ DW cord min 3ft, max 4ft measured from back	[422.16B2]	{422.16B2}
☐ Cords must be flexible (no NM cable)	[422.16B1,2]	{422.16B1,2}
☐ Electric range ckt min 40A	[210.19A3]	{210.19A3}
☐ Range hoods (can include microwave) OK for C&P if cord 18in–36in & accessible recep not subject to damage on individual ckt	[n/a]	{422.16B4}[44]

Air-Conditioning

☐ Multimotor eqpmt wiring per nameplate, (ex.—min ckt ampacity & max fuse or breaker)	[440.4B]	{440.4B}
☐ Disc on or in sight of condenser	**F73** [440.14]	{440.14}
☐ Disc not OK on compressor access panel	[440.14][45]	{440.14}
☐ Working space req in front of disc	[110.26A]	{110.26A}
☐ Room AC plug disc OK if controls ≤6ft off floor	[440.63]	{440.63}
☐ Max cord length 120V=10ft, 240V=6ft	[440.64]	{440.64}
☐ AFCI or LCDI protection req for C&P room AC units	[440.65]	{440.65}

Central Fuel-Burning Furnace

☐ In-sight disc req (w/ fuses if req by manu)	**F71** [422.32]	{422.32}
☐ Lighting outlet switched at entry to eqpmt space	[210.70A3]	{210.70A3}
☐ Central furnace must be on individual ckt	[422.12]	{422.12}
☐ 120V recep req within 25ft on same elevation	[210.63][46]	{210.63}

Electric Furnaces & Space Heaters

☐ Branch ckt 125% load (heat watts + motor FLC)	[424.3B]	{424.3B}
☐ Disc in sight or lockable breaker	**F74** [424.19]	{424.19}
☐ Unit switch that opens all ungrounded cond OK as disc for space heater w/ no motor >⅛hp	{424.19C]	{424.19C}

Water Heater

☐ In-sight or lockable breaker or switch OK	**F74** [422.31B]	{422.31B}
☐ Breaker lockout hasp req to remain when not in use	[n/a]	{422.31B}[43]
☐ Bond hot, cold, & gas pipes	[250.104A,B]	{250.104A,B}

Paddle Fans

☐ Listed box for fan support (no standard boxes)	[314.27D]	{314.27D}
☐ Listed boxes or box systems OK to 70lb	**F75** [422.18BX]	{314.27D}[47]
☐ Independent support for fans >70lb	**F75** [422.18B]	{314.27D}[47]
☐ Max weight marked on boxes rated >35lb	[422.18BX]	{314.27D}[48]
☐ Min 7ft clearance above floor	**F75** [manu]	{manu}

Hydromassage Tub (Circulating Bathtub)

☐ GFCI protection req	[680.71]	{680.71}
☐ GFCI protect 125V receps within 5ft horiz of tub	[680.71]	{680.71}
☐ GFCI protect 125V receps in same room as tub	[680.72]	{680.72}
☐ Electrical eqpmt (pump motor) must be accessible	[680.73]	{680.73}
☐ Disconnecting means (C&P OK) req in sight of motor	[430.102B]	{430.102B}
☐ Bond metal circulating piping to motor bond lug w/ solid Cu 8AWG EXC Bonding prohibited if listed double-insulated motor	[680.74]	{680.74}[49]

Outdoor De-icing & Snow-Melting Equipment

☐ GFPE protection req for de-icing eqpmt	[426.28]	{426.28}
☐ AFCIs may be used as GFPE for de-icing eqpmt	[426.28]	{426.28}

Fig. 73
Air-Conditioning Condenser

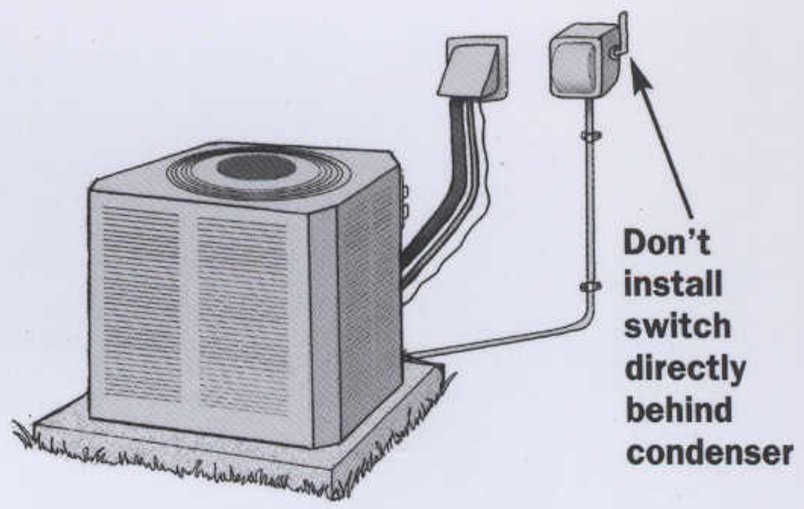


Fig. 74
Breaker Lockout

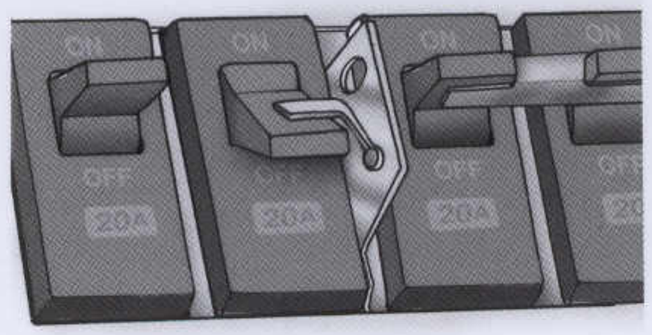


Fig. 75
Paddle Fan Support

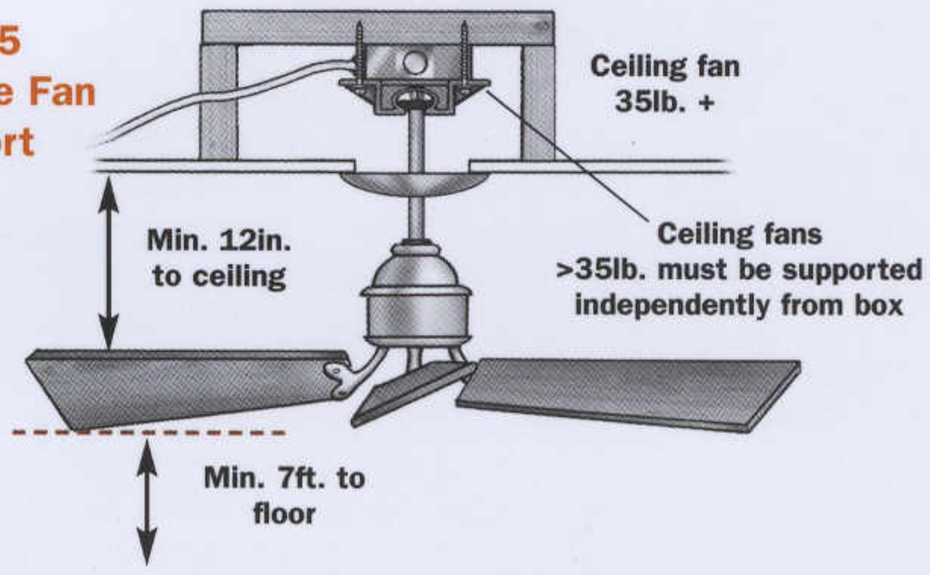
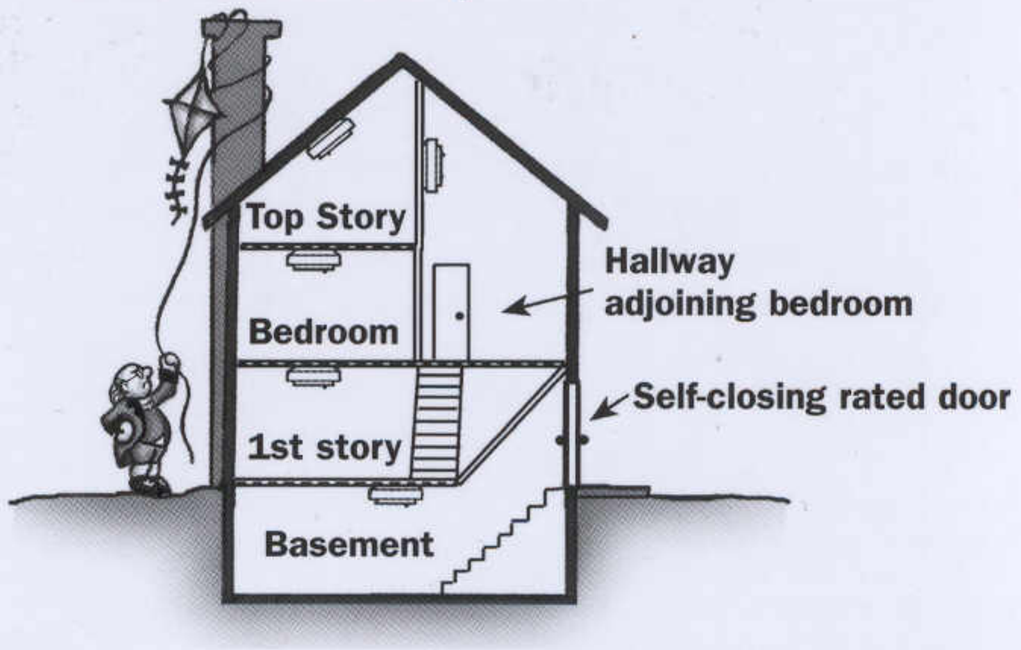


Fig. 76 • Smoke Detectors Required in Each Bedroom



Smoke Detector **03 IRC**

☐ New construction hard wired w/ battery backup		[313.2]
☐ Req in each bedroom & adjoining hall	**F76**	[313.1]
☐ At least one req each story & basement	**F76**	[313.1]
☐ Must be interconnected & audible from sleeping rooms		[313.1]
☐ Compliance req for remodeling req permit		[313.1.1]
☐ Interconnection & hard wire not req on remodel if finishes would have to be removed		[313.1.1X]

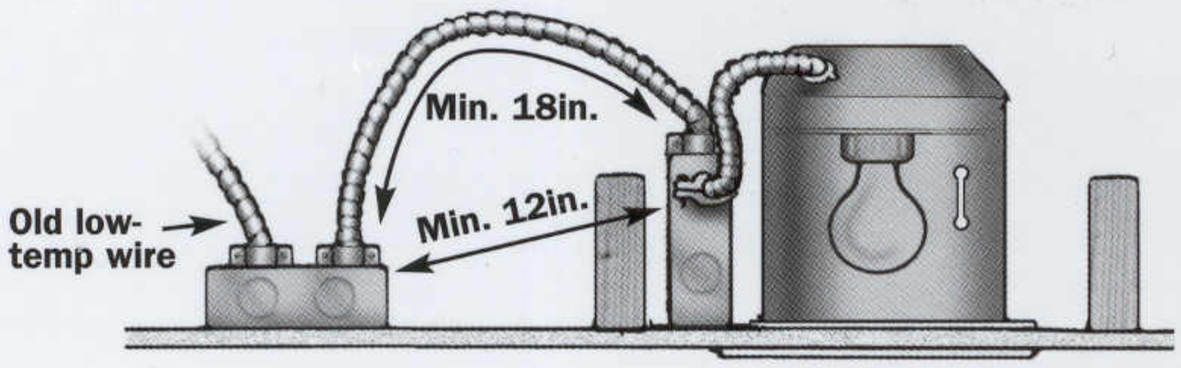
Lighting

Luminaires (lighting fixtures) produce heat, so precautions must be taken in their location and installation to protect combustible materials.

Required Locations	2002	2005
☐ Wall-switched lighting outlets req in all habitable rooms & bathrooms	[210.70A1]	{210.70A1}
☐ Lighting outlet may be switched recep EXC in kitchens & bathrooms	[210.70A1X1]	{210.70A1X1}
☐ Switched lighting outlet on ext side of all grade-level doors EXC garage vehicle door	[210.70A2b]	{210.70A2b}
☐ Switched light in garage, hall, & stairs	[210.70A2b]	{210.70A2b}
☐ Switched outlet at entrance for utility rooms, basements, crawl spaces, or attics containing eqpmt req servicing	[210.70A3]	{210.70A3}

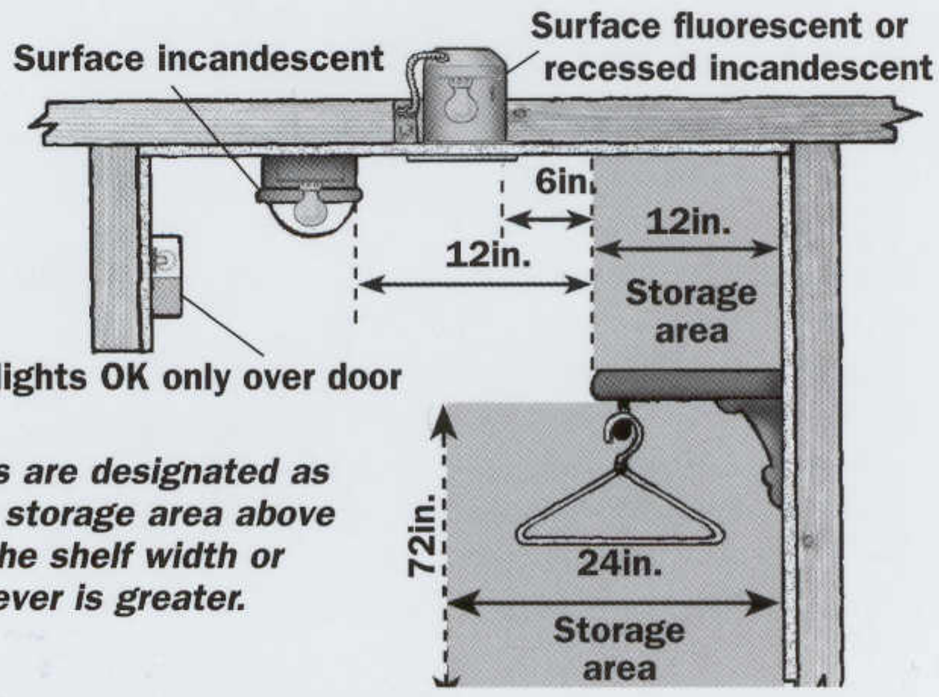
Recessed Light Clearances		
☐ Non-Type IC rated min 3in from insulation.	[410.66B]	{410.66B}
☐ Non-Type IC rated min ½in from combustibles	[410.66A1]	{410.66A1}
☐ IC rated OK in contact w/ combustible material	[410.66A2]	{410.66A2}
☐ IC rated OK in contact w/ insulation	[410.66B]	{410.66B}
☐ Max bulb wattage must be visible when relamping	[410.70]	{410.70}
☐ Isolate old low-temp-rated wiring from fixture **F77**	[410.67B,C]	{410.67B,C}

Fig. 77
Recessed Lighting Distances



Closet Light Clearances **F78**	2002	2005
☐ Incandescent fixtures bulbs req to be fully enclosed	[410.8C]	{410.8C}
☐ Surface incandescent fixtures min 12in from storage	[410.8D1]	{410.8D1}
☐ Surface fluorescent min 6in from storage	[410.8D2]	{410.8D2}
☐ Surface fixtures on wall OK only over door	[410.8D1,2]	{410.8D1,2}
☐ Recessed fixtures (wall or ceiling) min 6in from storage	[410.8D3,4]	{410.8D3,4}

Fig. 78
Closet Lights



Shaded areas are designated as storage. The storage area above the shelf is the shelf width or 12in., whichever is greater.

Switches		
☐ All switching in ungrounded conductors	**F79,80** [404.2A,B]	{404.2A,B}
☐ Switches req grounding EXC		
Replacement switches w/ plastic faceplates OR	[404.9B]	{404.9B}
Provide GFCI protection	[n/a]	{404.9BX}[50]
☐ 3-way switch req at stairs w/ 6 or more risers	[210.70A2c]	{210.70A2c}
☐ Faceplate must completely cover wall opening	[404.9A]	{404.9A}
☐ Dimmers for only incandescent fixtures (not receps)	[404.14E][51]	{404.14E}
☐ Current-carrying cond of ckt grouped	**F79,80** [300.20A]	{300.20A}
☐ Reidentify ungrounded white or gray wires at each box	[200.7C][52]	{200.7C}

3-Way & 4-Way Switches

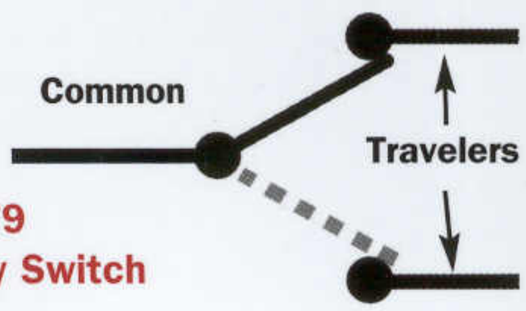
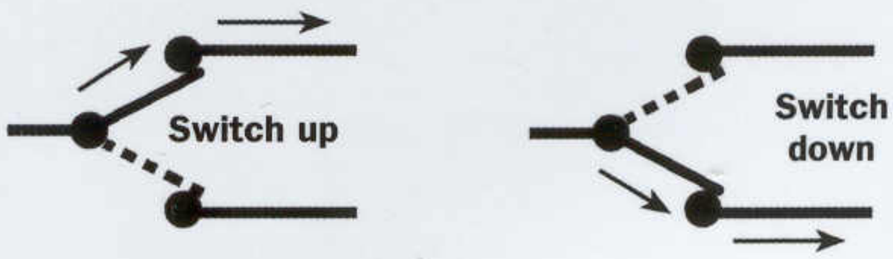
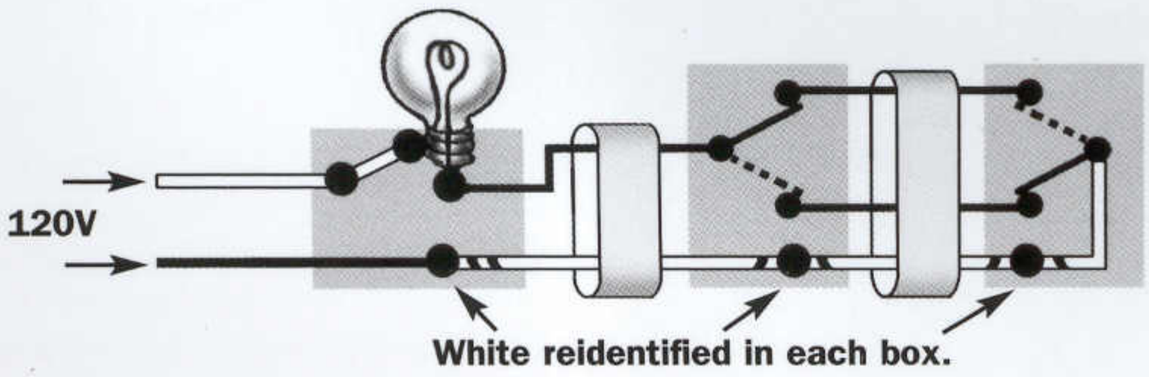
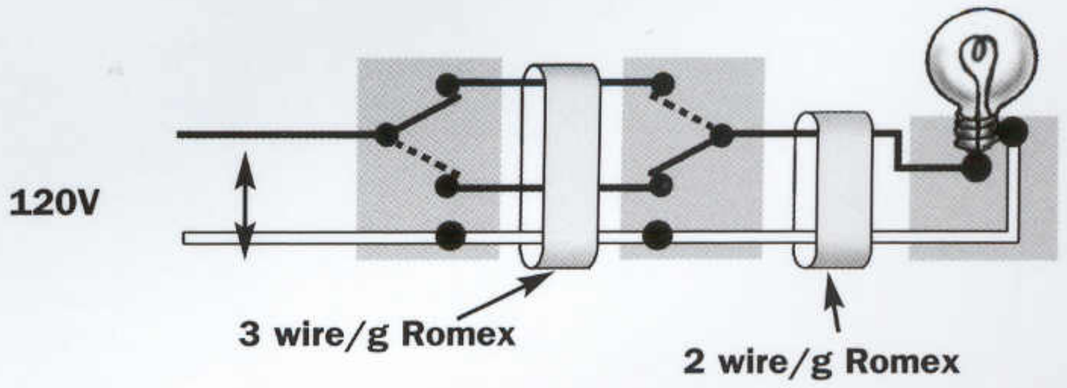


Fig. 79
3-Way Switch

A 3-way switch is a somewhat misleading name for a single-pole double-throw switch. There are actually only two positions. Switching takes place from a common terminal to one or the other "traveler" terminals.







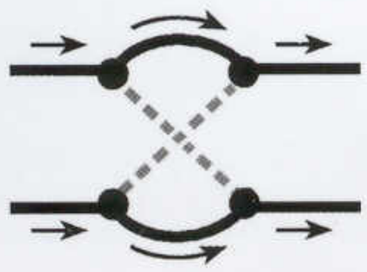
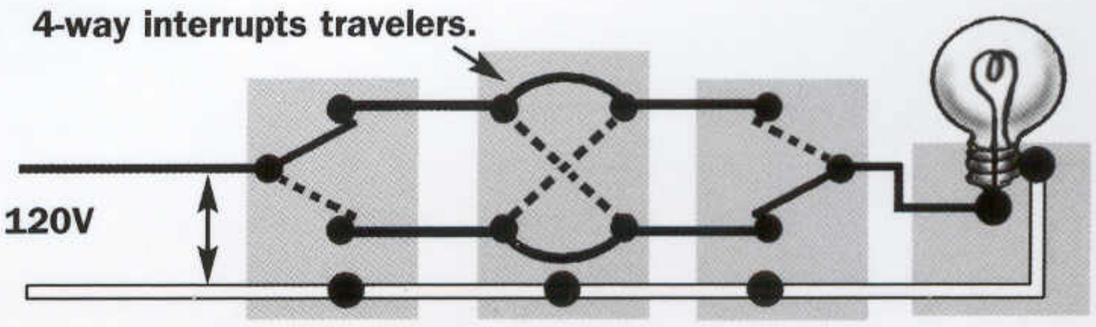


Fig. 80 • 4-Way Switch

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



Swimming Pool

Electricity and water don't mix. Equipment grounding conductors must be insulated to protect them from corrosive chemicals and must land on terminal bars, not on wire nuts. In addition to the hazards created by wiring and equipment, pools also require bonding to eliminate voltage gradients even when there is no electrical equipment in the pool area. For GFCI requirements, see p. 8.

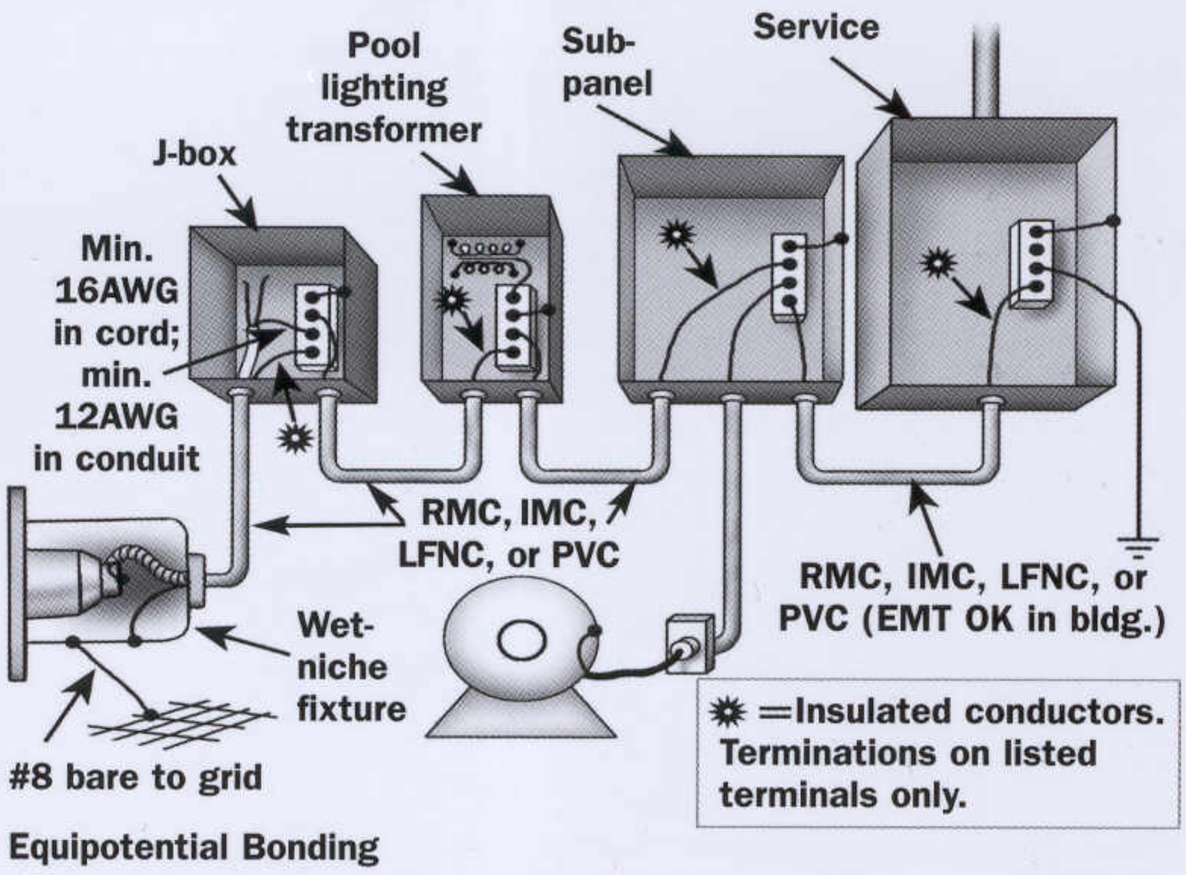
Overhead Clearances	**2002**	**2005**
☐ Triplex service drop above or within 10ft of pool req 22½ft clearance in any direction from water	[680.8A][53]	{680.8A}
☐ Clearance from diving platform 14½ft	[680.8A][54]	{680.8A}

Wiring		
☐ Nonpool underground wiring min 5ft from pool EXC RMC or IMC w/ 6in cover or RNMC w/ 18in cover OK when space limitations leave no choice	[680.10]	{680.10}
☐ Feeder in RMC, IMC, LFNMC, or PVC only	**F81** [680.25A]	{680.25A}
☐ EMT OK only for feeder on or within bldg	[680.25A]	{680.25A}
☐ Motor connection OK in LFMC or LFNMC	[680.21A3]	{680.21A3}
☐ Motors inside SFD any approved wiring method OK	[680.21A4]	{680.21A4}

Equipment Grounded Conductors (EGCs)		
☐ Min size ckt EGC 12AWG	[680.23F2]	{680.23F2}
☐ No splices (must land on terminals)	**F81** [680.23F2]	{680.23F2}
☐ New feeders must be insulated EGC	**F81** [680.25B]	{680.25B}

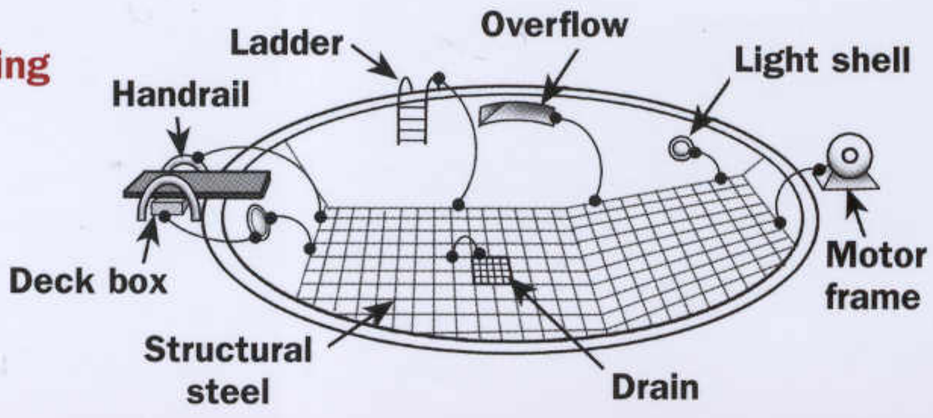
Equipment Grounded Conductors (EGCs)		
☐ Min size ckt EGC 12AWG	[680.23F2]	{680.23F2}
☐ No splices (must land on terminals)	**F81** [680.23F2]	{680.23F2}
☐ New feeders must be insulated EGC	**F81** [680.25B]	{680.25B}

Fig. 81 • Pool Equipment Grounding



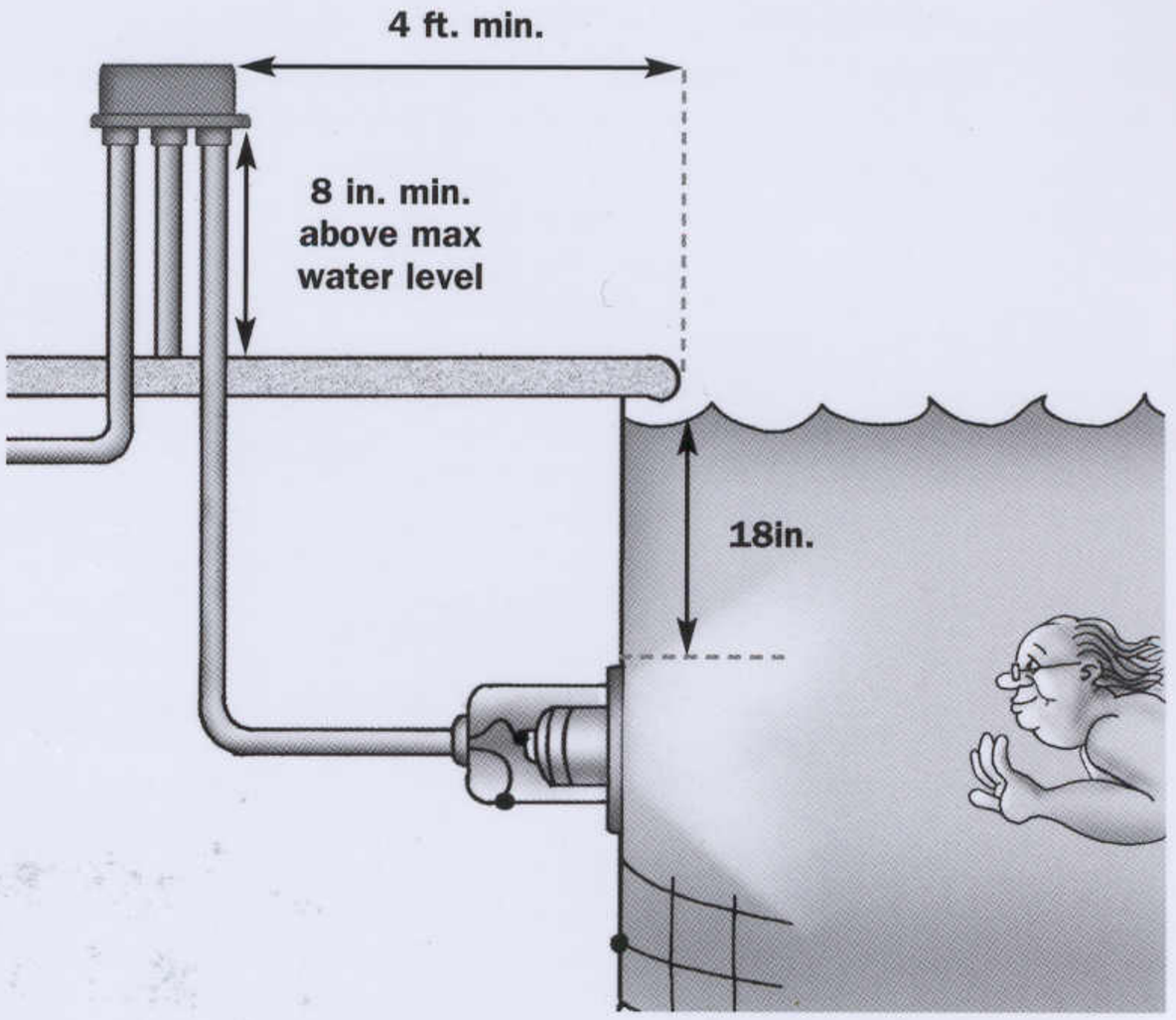
Equipotential Bonding		
☐ Bond all parts of pool structure & eqpmt EXC	**F82** [680.26B]	{680.26B}
Small isolated parts <4in & <1in into plaster	[680.26B3]	{680.26B3}
☐ Bond motors EXC listed & double-insulated type	[680.26B4]	{680.26B4}
☐ Bonding cond min #8 solid Cu	[680.26C]	{680.26C}

Fig. 82 Pool Bonding Grid



Underwater Wet-Niche Lighting	**2002**	**2005**
☐ Min 18in below water level	**F83** [680.23A5]	{680.23A5}
☐ Fixture bonded & secured to shell w/ locking device req a tool for removal	[680.23B5]	{680.23B5}
☐ Low-voltage transformer L&L for pool	[680.23A2]	{680.23A2}
☐ Low-voltage & GFCI wires not in same raceway or box as non-GFCI wires	[680.23F3]	{680.23F3}
☐ 8AWG bonding cond req in LFNMC or RNMC to wet niche	[680.23B2]	{680.23B2}
☐ Bonding connection in wet niche must be potted	[680.23B2]	{680.23B2}
☐ Min 16AWG EGC in cord to wet-niche fixture	**F81** [680.23B3]	{680.23B3}

Fig. 83 Underwater Pool Lighting



Receptacles (see p. 8 for GFCI requirements)	**2002**	**2005**
☐ Min 1 recep <20ft from pool walls	[680.22A3]	{680.22A3}
☐ Min distance from pool wall 10ft EXC	[680.22A3]	{680.22A3}
Reduction to not <5ft horiz OK if space restricted	[680.22A4][55]	{680.22A4}
☐ Pump motor recep not <10ft from pool wall EXC 5ft OK if twist-lock single recep GFCI protected	[680.22A1]	{680.22A1}
☐ Dimensions incl distance around barriers	[680.22A6]	{680.22A6}

Lighting Outlets (see p. 8 for GFCI requirements)		
☐ Outdoors min 5ft from pool unless 12ft above	[680.22B1]	{680.22B1}
☐ Indoors 7ft 6in above water OK if enclosed & GFCI	[680.22B2]	{680.22B2}

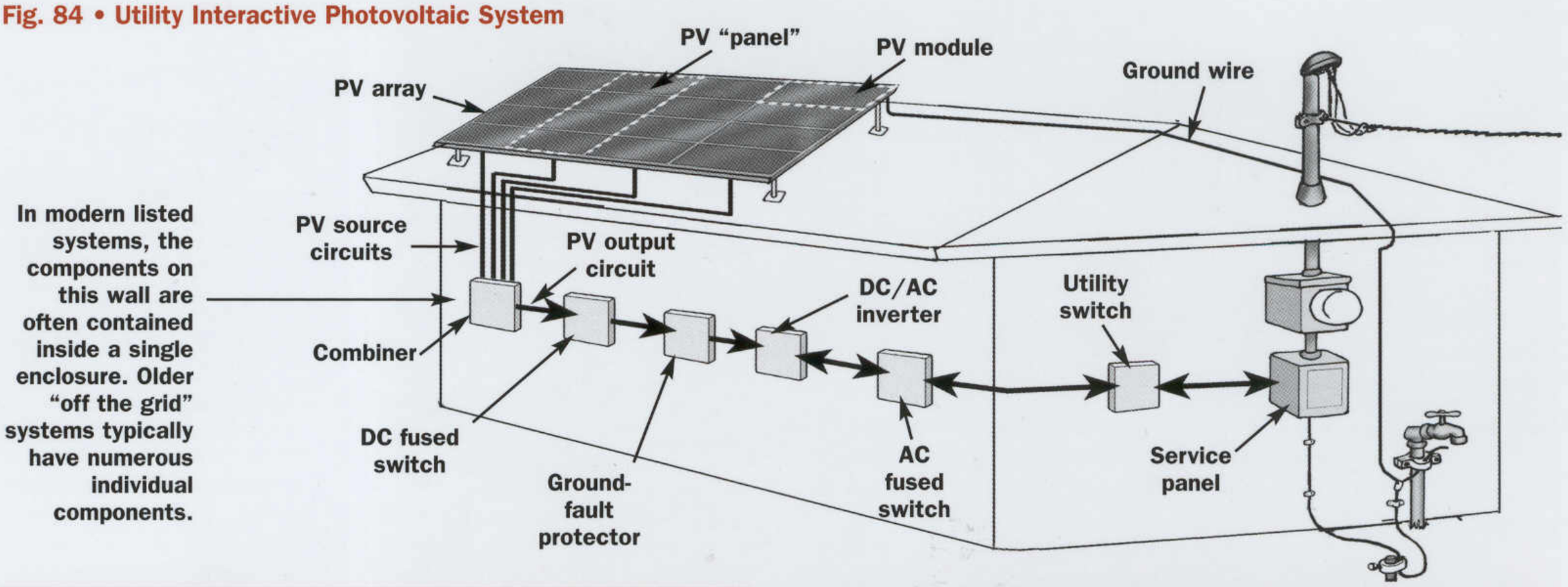
Hot Tub/Spa

Outdoor hot tubs or spas follow the same rules as swimming pools. There are also additional specific rules as shown below for all hot tubs and for indoor hot tubs. A hydromassage tub (p. 24) is not a spa, because it is emptied after each use.

General		
☐ GFCI-protected package unit OK for cord up to 15ft	[680.42A2]	{680.42A2}
☐ Bands to secure hot tub staves exempt from bonding	[680.42B]	{680.42B}

Indoor Spas		
☐ Min one recep 5–10ft from inside wall of spa	[680.43A1]	{680.43A1}
☐ No wall switches <5ft from inside wall of spa	[680.43C]	{680.43C}

Fig. 84 • Utility Interactive Photovoltaic System



Photovoltaics

As energy costs rise, photovoltaic (PV) systems are more popular. They are no longer exclusively used by back-to-the-land homeowners living off the utility grid. Modern utility interactive systems provide a way for consumers to reduce the costs of power consumption while helping the environment. In some states, the utility will rebate a portion of the cost of a PV system. The quality of PV equipment has improved greatly in the last few years, and arrays today have a 30-year expected life. Package systems are now available from major manufacturers. To qualify for utility rebates or be used in an interactive system, equipment should be listed. The standard for modules is ***UL 1703****, and for inverters it is* ***UL 1741****. Contact your utility and building department before beginning any project involving renewable energy sources.*

Definitions

AC Module: A complete unit, including solar cells, inverter, and other components, that produces AC power.*

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

Charge Controller: A device to prevent a battery from being overcharged.

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

DC Ground-Fault Protection: DC GFP is not intended to prevent shock hazards. It is for fire protection when panels are located on dwelling roofs.

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

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

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

Inverter Output Circuit: Change from "load center" to "panelboard" in 2005.

Junction Box: An enclosed terminal block on the back of modules to allow module connection to the electrical system.

Module: A group of PV cells connected together and encapsulated in an environmentally protective laminate—usually tempered glass. Unless otherwise specified, modules have direct current output.

Panel: While this term is more appropriately used for equipment like solar water-heating panels, it is sometimes used to refer to a group of modules that have been preassembled onto a common frame and are designed to be field installed.

Photovoltaic Output Circuit: Conductors between the PV source circuits and the inverter or DC-utilization equipment.

Photovoltaic Source Circuit: Circuits between modules and from modules to the common connection points of the DC system.

Stand-Alone System: A solar PV system that supplies power independent of the utility.

Arrays & Components

The mounting for a photovoltaic array must consider building codes and structural issues, including the weight of the panels and potential wind uplift. The NEC requirements for lightning protection are minimal, and lightning can severely damage PV equipment. Surge suppressors can be permanently installed for component protection. The module frames must also be connected to the earth. In a roof-mounted system, they must be connected to the house GES.

Modules	**2002**	**2005**
☐ Modules req marking of polarity, max OCPD rating for module protection, open ckt voltage, operating voltage, max system voltage, operating current, sc current, and max power	[690.51]	{690.51}
☐ AC modules req marking of nominal voltage, frequency, max power, max current, and max OCPD rating for module protection	[690.52]	{690.52}
Photovoltaic Arrays & Inverters		
☐ PV ckt must be isolated from other systems	[690.4B]	{690.4B}
☐ Rooftop arrays must be DC ground-fault protected	[690.5]	{690.5}
☐ Inverter must be listed if used in interactive system	[690.60]	{690.60}
☐ Roof-mounted inverters OK in not readily accessible loc (AC output modules) if warning plaque at service	[Ø]	{690.14D}[56]
☐ Interactive systems must automatically disconnect from service in grid outage EXC OK to feed subpanel through transfer switch during outage	[690.61]	{690.61}
Grounding		
☐ Module frames & all metal parts must be grounded	[690.43]	{690.43}
☐ DC 2-wire system >50V must have grounded cond	[690.41]	{690.41}
☐ DC GEC to same electrode as AC system OR	[n/a]	{690.47C2}[57]
to separate electrodes that are bonded together	[n/a]	{690.47C1}[57]
☐ Size EGCs of PV output ckt same as ckt cond OR Size EGCs to **T2** if GFP protected	**T2** [690.45][58]	{690.45}
Overcurrent Protection & Wiring		
☐ Max voltage = sum of rated open-ckt voltage of series connected modules times correction factors for cold temp	**T20** [690.7A]	{690.7A}
☐ DC ckt overcurrent protection must be DC rated	[690.9D]	{690.9D}
☐ Single OCPD OK for series-connected string	[690.9E][59]	{690.9E}
☐ OCPD at each source for components with >1 source	[690.9A]	{690.9A}
☐ OCPDs <15A, sized in 1A increments	[690.9C][60]	{690.9C}
☐ Rating of PV breakers + util main breaker ≤120% of panel rating	[690.64B2X]	{690.64B2X}
☐ All currents considered continuous	[690-8b]	{690.8}
☐ PV source ckt currents = sum of parallel module sc currents times 125%	[690.8A1]	{690.8A1}

Overcurrent Protection & Wiring (cont.)	2002	2005
☐ Size cond for 125% of max PV source sc currents	[690.8B1]	{690.8B1}
☐ Consider high ambient temp (use 90° wire)	[310.15B]	{310.15B}
☐ No multiwire ckt on 120V supply	[690.10C]	{690.10C}
☐ Single-cond cables type SE, UF, USE, & USE-2 OK in PV source ckt, exposed cables sunlight resistant	[690.31B]	{690.31B}
☐ PV source ckt may pass through bldg interior if in metal conduit	[Ø]	{690.31E}[61]
Disconnects		
☐ Req for inverters, batteries, charge controllers	[690.15]	{690.15}
☐ Fuses in PV source ckt req individual disc	[690.16]	{690.16}
☐ Ungrounded cond disc must be switch or breaker	[690.17]	{690.17}
☐ Disc energized from two directions req warning label	[690.17]	{690.17}
☐ Array must be capable of being disabled	[690.18]	{690.18}
☐ Backfed connection to load center—breaker not req to be secured in place unless acting as main breaker	[Ø]	{690.64B5}[62]
☐ Don't disconnect grounded cond	[n/a]	{690.13}[63]

Table 20 • Voltage Correction Factors (Based on NEC T690.7)

Multiply Rated Open-Circuit Voltage by the Correction Factor Shown Below	Ambient Temperature (in °F)	Ambient Temperature (in °C)
1.06	77 to 50	25 to 10
1.10	49 to 32	9 to 0
1.13	31 to 14	–1 to –10
1.17	13 to –4	–11 to –20
1.25	–5 to –40	–21 to –40

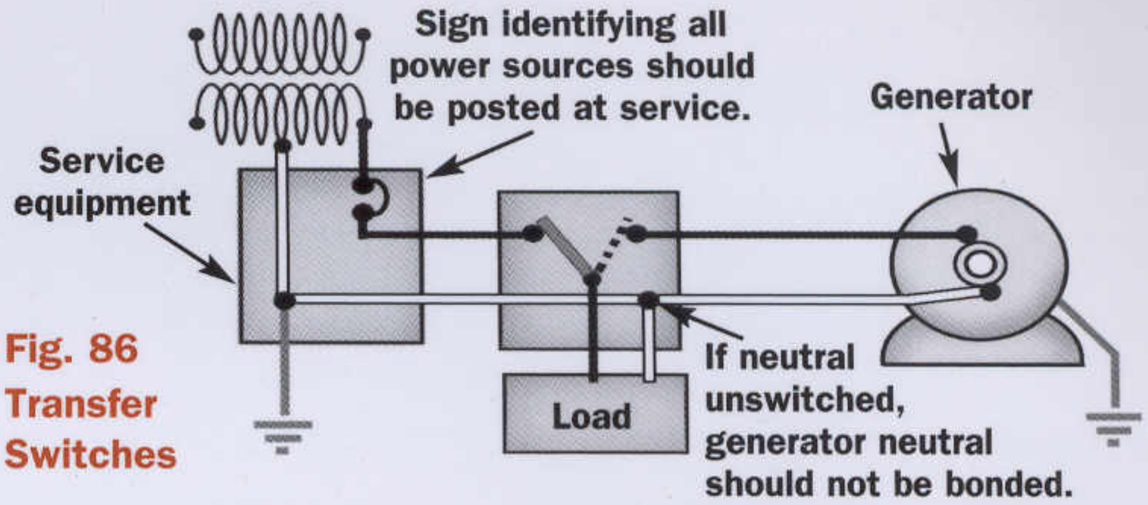


Fig. 86 Transfer Switches

Generators

Generators provide a source of emergency power during a utility outage. Care must be taken to ensure that the two 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	2002	2005
☐ Must be suitable for environment, i.e., type 3 if outdoors	[445.10]	{445.10}
☐ Rainproof generators *not* to be enclosed indoors	[110.3B]	{110.3B}
☐ Cond sized 115% of nameplate current rating	[445.13]	{445.13}
☐ GEC req for permanently installed generators	[250.30A2]	{250.30A3}
☐ Must have sufficient capacity for all connected loads	[702.5]	{702.5}
☐ Remove bonding jumper if transfer switch does not switch neutral	F86 [250.24A5]	{250.24A5}
Transfer Switches		
☐ Sign req at service indicating generator loc	F86 [702.8A]	{702.8A}
☐ Transfer eqpmt must prevent simultaneous connection of generator & util service	[702.6]	{702.6}
☐ Elec vehicle OK as standby power source through listed util interactive connection	[n/a]	{625.26}[64]

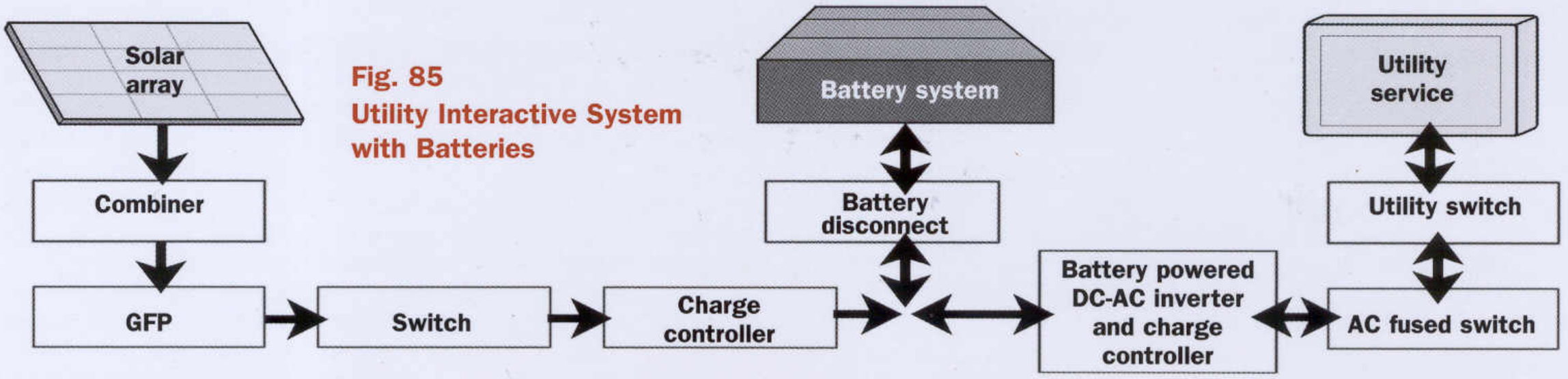


Fig. 85 Utility Interactive System with Batteries

Batteries

Batteries are a dangerous portion of on-site power systems due to exposed contacts, off-gassing, chemical spills, and large amounts of stored energy. Most interactive utility systems do not include batteries. Off-grid systems and most hybrid systems do use batteries. It is important that they be kept at a proper temperature (70°F–80°F). At too low a temperature, they lose some of their capacity; and if too warm, they will self-discharge and eventually be damaged.

Location Requirements	2002	2005
☐ Racks to be rigid & substantial	[480.8A]	{480.8A}
☐ Trays to be nonconductive & resist deterioration	[480.8B]]	{480.8B}
☐ Working space (min 3ft deep 30in wide) for batteries	[480.9C]	{480.9C}
☐ Working space measured from edge of battery rack	[480.9C]	{480.9C}
☐ No eqpmt above battery rack	[110.26A3]	{110.26A3}
☐ Segregate other eqpmt from battery off-gas area	[110.11]	{110.11}
☐ Ventilation to prevent gas buildup	[480.9A]	{480.9A}
☐ Live parts >50V req guarding	[480.9B]	{480.9B}
☐ PV battery systems to operate <50V nominal	[690.71B1]	{690.71B1}
☐ Guard all live parts of PV battery systems	[690.71B2]	{690.71B2}

Wiring	2002	2005
☐ Flex cables ≥2/0AWG OK from battery to junction box	[690.74]	{690.74}
☐ Other wiring from batteries in approved wiring method	[480.3]	{480.3}
Charge Controllers		
☐ Should be listed (some are not)	[110.3B]	{110.3B}
☐ Current limiting OCPDs req *if* output exceeds sc rating of other eqpmt in ckt	[690-71c]	{690.71C}
☐ Series type fused on both input & output sides	[manu]	[manu]

A charge controller prevents a battery from being overcharged and damaged. In a system such as the one in **F85**, *the batteries could be charged from either the PV source or the utility source, so a charge controller is needed at each source. Recombinant-type battery caps will greatly reduce the free hydrogen in the air but may need to be removed during equalization. Placing the batteries in plastic trays helps for this procedure. This problem usually occurs only during a very heavy charge or discharge. When doing an equalization charge (controlled overcharge to prevent sulfation buildup), open a window or door.*

Fuses

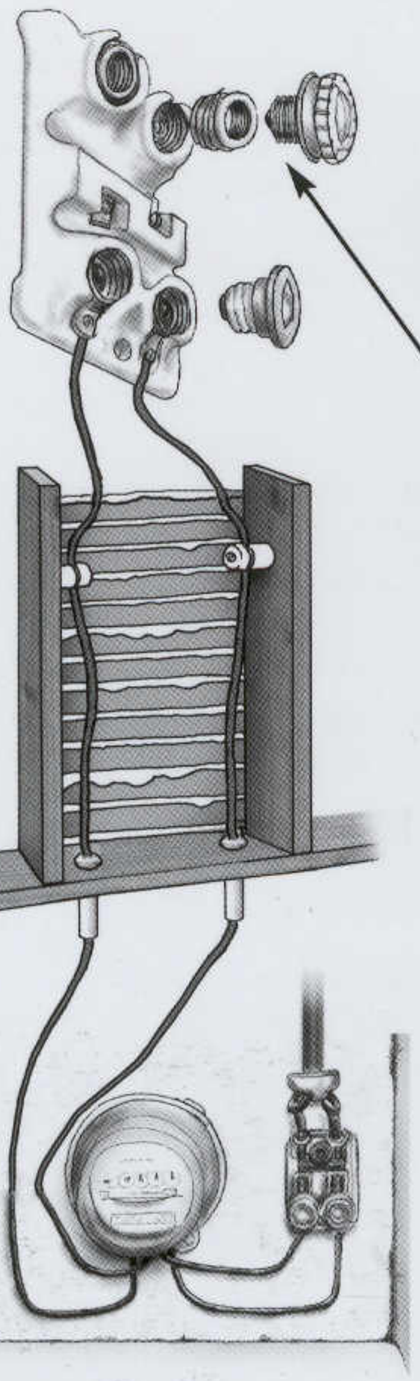
Fuses provide excellent overcurrent protection if the right size fuse is in place. Unfortunately, they are often sized incorrectly, allowing the wiring to be overloaded or shunted (a penny behind the fuse). Older ceramic fuse panels, and panels with cartridge fuses, also pose a risk of electrocution because of exposed electrical contacts.

	2002	2005
☐ No exposed contacts in fuse panel (must be dead front)	[240.50D]	{240.50D}
☐ Type S req if tampering or overfusing exists **F87**	[240.51B]	{240.51B}
☐ S type adapter sized to wire per T7 . . . . . **F87**	[240.4D]	{240.4D}
☐ No fuses in grounded cond (neutral) **F87**	[240.22]	{240.22}
☐ No plug fuses for 240V circuits	[240.51A]	{240.51A}

Knob & Tube (K&T)

K&T wiring is the oldest wiring method found in American homes. When left in its original state it has proven to be reliable and safe. Electrical 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. The knobs of K&T maintain 1in. clearance to wood framing and tubes isolate conductors when passing through wood. Unfortunately, when modified by unqualified persons the inherent safety of K&T is dangerously compromised.

☐ No new K&T	[394.10]	{394.10}
☐ OK to extend to other wire method w/ proper splices	[394.10]	{394.10}
☐ Splices to other methods must be in box EXC	[300.16A]	{300.16A}
Bushing OK at termination of raceway to open eqpmt	[300.16B]	{300.16B}
☐ Must be protected w/ loom where entering box . .	[314.17B,C]	{314.17B,C}
☐ Do not envelop w/ thermal insulation	[394.12]	{394.12}
☐ 3in min between wires, 1in to surfaces **F89**	[394.19A1]	{394.19A1}
☐ Provide protection where exposed <7ft above floor	[398.15C]	{398.15C}
☐ Protect w/ running boards up to 7ft high in attics w/ stairs or permanent ladder **F53**	[394.23A]	{394.23A}



A properly sized type S adapter is required when a fuse has been tampered with or improperly sized. Open ceramic fuse panels such as these are no longer allowed because they have exposed contacts.

Fig. 87 • Old Knob & Tube with Fuses

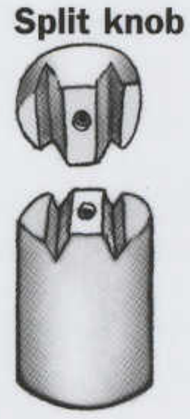


Fig. 88 Porcelain Knob

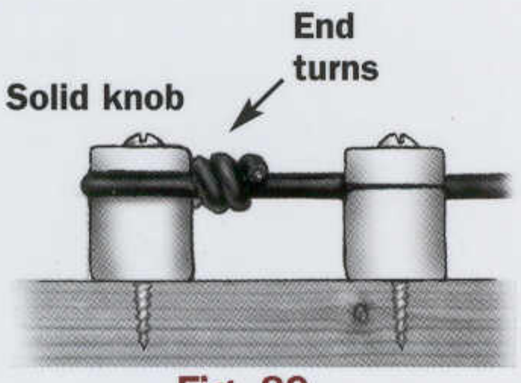


Fig. 89 Splice Wrap

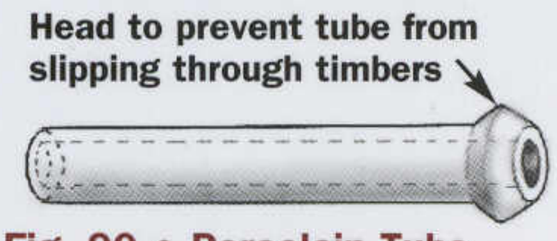
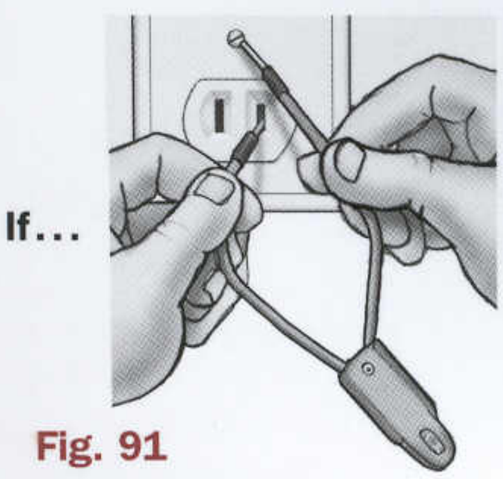


Fig. 90 • Porcelain Tube

Replacement Receptacles

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. Old 2-prong receptacles may be replaced with a GFCI receptacle whether or not an EGC is present and will provide shock protection.

	2002	2005
☐ 2-hole OK if no ground present & no GFCI req **F92**	[406.3D3a]	{406.3D3a}
☐ OK to install GFCI where no ground present . . . **F93**	[406.3D3c]	{406.3D3c}
☐ Sep EGC OK from box to service or GEC or ground bar of panel where ckt originates **F94**	[250.130C]	{250.130C}
☐ Not OK to jumper neutral & EGC **F95**	[250.142B]	{250.142B
☐ If loc where GFCI now req, must use GFCI **F93**	[406.3D2]	{406.3D2}
☐ Replacements must be 3-hole if EGC present . . **F98**	[406.3D1]	{406.3D1}
☐ Bond 3-hole recep to grounded box w/ wire OR . **F98,9**	[250.146]	{250.146}
Use grounding-type recep **F97**	[250.146B]	{250.146B}



If...

Fig. 91

Fig. 92

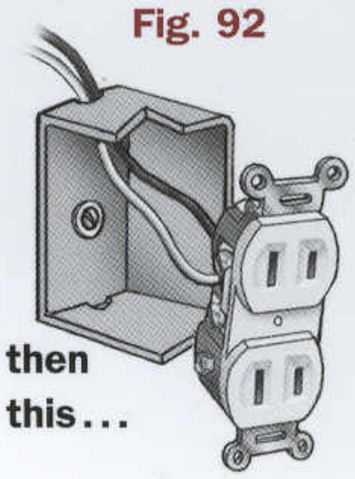


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Fig. 93

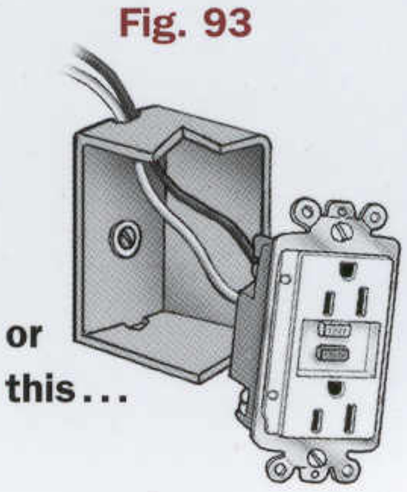

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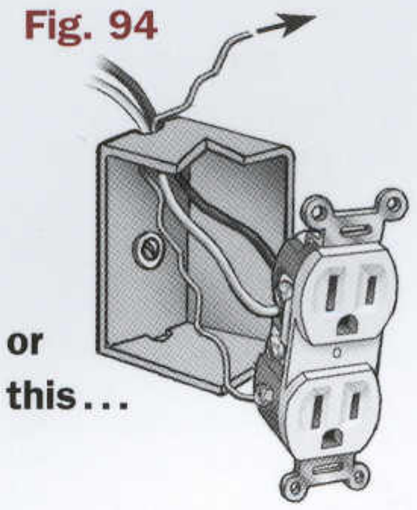
Fig. 94



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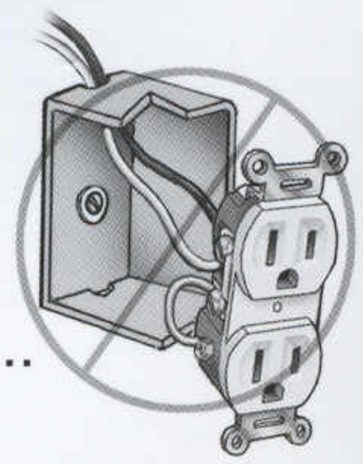
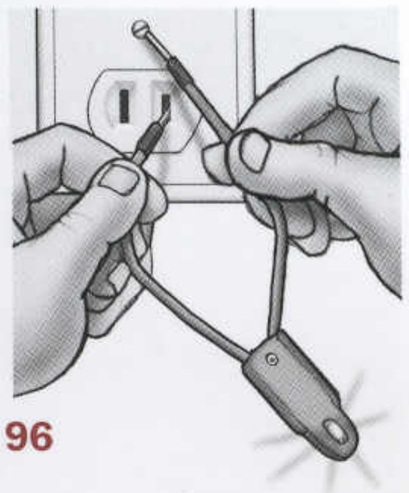


but *not* this...



If...

Fig. 96

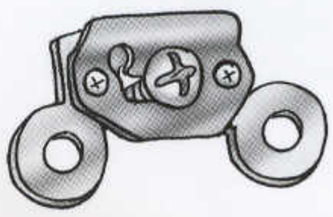


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Fig. 97

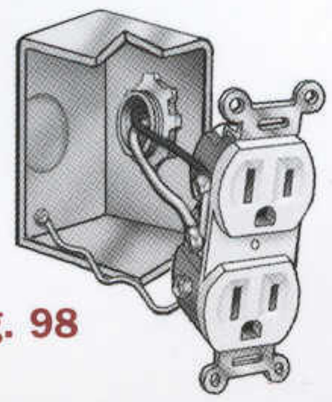

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Fig. 98

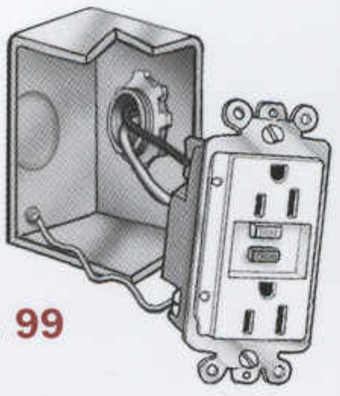

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Fig. 99

Code Change Summary

The National Electrical Code is revised on a 3-year cycle. Thousands of public proposals are distilled into the changes in each new edition. We have enclosed the following summary of major residential changes to aid our readers in the transition to the newer code editions.

The 2002 edition adopted a decimal numbering system. Measurements were shown with the metric designation first, followed by the hard conversion numbers to feet and inches. A "hard conversion" is an approximation to the nearest equivalent feet and inch numbers; a "soft conversion" would be an exact conversion necessitated by safety considerations.

In 2002, the articles for wire, cable, and raceways in chapter 3 were reorganized. The articles for cable, conduit, and tubing were grouped by type and renumbered to follow a parallel system. The suffix numbers (those that follow the article number and the period, e.g. the "10" in 334.10) always cover the same topic regardless of which article they are found in. Numbers ending in ".10" are always the sections dealing with "Uses Permitted" and so on.

A summary of these parallel suffix numbers is listed in **T21**.

Page 3

1 2005 clarified when Ufer was considered present and req to be used

2 2005 added unbonded metal well casings to GEC

3 2005 spec when bldg steel was considered effectively grounded

Page 4

4 2002 clarified that GEC(s) could go to any part(s) of GES

Page 5

5 2005 forbids use of sheet metal screws to attach grounding lugs

6 2002 did not spec intersystem bonding was for GEC of other system

Page 8

7 2005 added receps within 6ft of utility & laundry sinks & expanded wet bar sink req to incl receps that are not serving countertop area

8 2002 did not req GFCIs in outdoor areas accessible to public, except residential

9 2002 was first to req GFCI protection in nondwelling kitchens

10 2005 clarified that above rule applies to institutional & commercial kitchens & defined kitchen as an area w/ permanent facilities for food preparation & cooking

11 2005 added rule for GFCI protection of the req receps near commercial HVAC eqpmt

12 2002 added rule for GFCI protection of all pool pump motor recepts

13 1999 req protection only for bedroom receptacles outlet ckt—2002 entire ckt

14 2002 did not spec combination type—only "branch feeder" types were available

15 2002 did not allow anything other than ckt breaker type AFCIs

Page 9

16 2002 raised clearance from 22ft to 22½ft when metric numbers took precedence

17 2005 spec that measurement is taken from max water level

18 2002 first to prohibit trees from supporting service conductors

Page 10

19 2002 allowed bldg management to have only access to guest suite OCPDS

20 2002 only specified max height of breakers used as switches

Page 11

21 2005 coordinated w/ definition of number of supply sources in 225.30

Page 12

22 2005 limits height of all breakers, 2002 limited height only when used as switch

23 2005 first to spec plaster gap for panelboard cabinets is same as for boxes

24 2002 allowed labeling that was generic, 2005 req more specificity

25 2002 first to spec handle tie for two ckt to single device

26 2002 first to spec each neutral to have individual terminal—synchronizes with UL

Page 13

27 2005 dropped rule for min 30A feeder

Page 15

28 2005 first to allow bath receptacles on side of vanity rather than wall

29 2002 extended rule against face-up countertop receps to include all countertops & work surfaces, not just baths, wet bars, & kitchens

30 2005 clarified that bonding req only for metal in contact w/ circulating piping

Page 16

31 2005 first to spec when receps are req behind sinks

Page 16 (cont.)

32 2002 raised max height of receps above counters from 18in to 20in

33 2002 clarified that receps below counter not allowed if overhead cabinet available for receptacle mounting

Page 19

34 2005 allows protective plates <1/16in thick if L&L

35 2002 first to req steel framing grommets & bushings to be listed

36 2005 req derating bundles <24in when passing through firestop or insulation

Page 21

36 2002 first to spec that threadless couplers not OK on threaded conduit ends

37 2002 did not permit end of run of FMC to have 6ft unsupported to lum

38 2002 limited unsupported FMC length to 3ft for flexibility for all sizes of FMC

39 2002 did not permit end of run of ENT to have 6ft unsupported to lum

Page 23

40 2002 clarified that gypsum is considered a noncombustible surface

41 2005 specified that side gap rule on boxes only for flush-type covers/faceplates

42 2002 req in-use covers for all outdoor wet-loc boxes, not just unattended cords

Page 24

43 2002 did not address cord plug range hoods or combo microwave

44 1999 did not specifically prohibit installing switch on AC access panel

45 2002 did not specifically prohibit temporary (handle only) lockout devices

46 2002 req service receptacle for HVAC to be on same elevation

47 2005 includes editorial clarification for listed box systems over 35lb

48 2005 clarified that marking is req for boxes rated over 35lb

49 2005 clarified that tubs w/ plastic circulating pipe do not req bonding

Page 25

50 2005 introduced alternative of GFCI protection for ungrounded switches

51 1999 did not specifically prohibit dimmers on receps except PMI

52 1999 did not recognize the color gray for insulation on grounded conductors

Page 26

53 2002 raised min service height from 22ft to 22½ft (metrification)

54 2002 raised min height over diving platform from 14ft to 14½ft (metrification)

55 2002 allowed receps 5ft from pool when space restricted

Page 27

56 2002 did not acknowledge rooftop modules w/ AC output

57 2005 clarified need to either bond sep AC & DC electrodes or to share a common electrode

58 2002 first req sizing EGCs to 125% of SC rating (same as ckt wiring)

59 2002 first to accept single OCPD for series connected string

60 2002 first to req 1A increment ratings on supplementary OCPDs

Page 28

61 2002 did not allow cond to pass through bldg before disc

62 2002 req all backfed breakers to be secured in place

63 2002 did not specifically prohibit disc in grounded cond

64 2002 prohibited using an elec vehicle as a backup power source

Table 21 • Common Numbering System for Wire, Cable, and Raceway Articles (based on NEC Chapter 3)

I. GENERAL		II. INSTALLATION				III. CONSTRUCTION SPECIFICATIONS	
xxx.1	Scope	xxx.10	Uses Permitted	xxx.26	Bends: Number in 1 Run	xxx.44	Expansion Fittings	xxx.100	Construction
xxx.2	Definitions	xxx.12	Uses Not Permitted	xxx.28	Reaming & Threading	xxx.46	Bushings	xxx.110	Corrosion Protection
xxx.3	Other Articles	xxx.14	Dissimilar Metals	xxx.28	Trimming	xxx.48	Joints	xxx.120	Marking
xxx.4	Listing Requirements	xxx.16	Temperature Limits	xxx.30	Securing & Supporting	xxx.50	Conductor Terminations	xxx.130	Standard Length
		xxx.20	Size	xxx.40	Boxes & Fittings	xxx.56	Splices & Taps	xxx.140	Conductors & Cable
		xxx.22	Number of Conductors	xxx.42	Couplings & Connectors	xxx.60	Grounding	xxx.150	Conductor Fill
		xxx.24	Bends: How Made						

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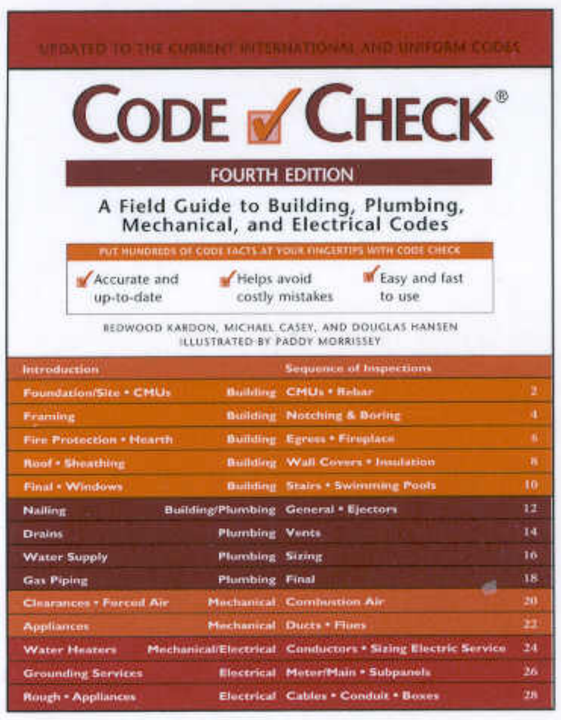

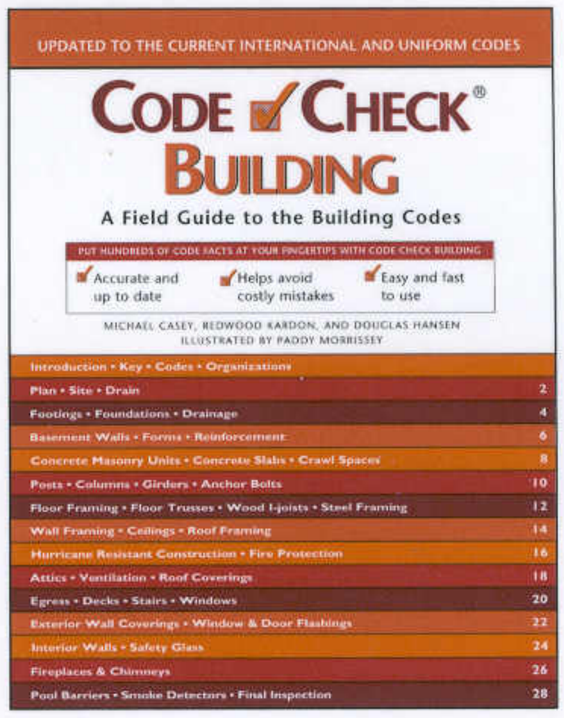

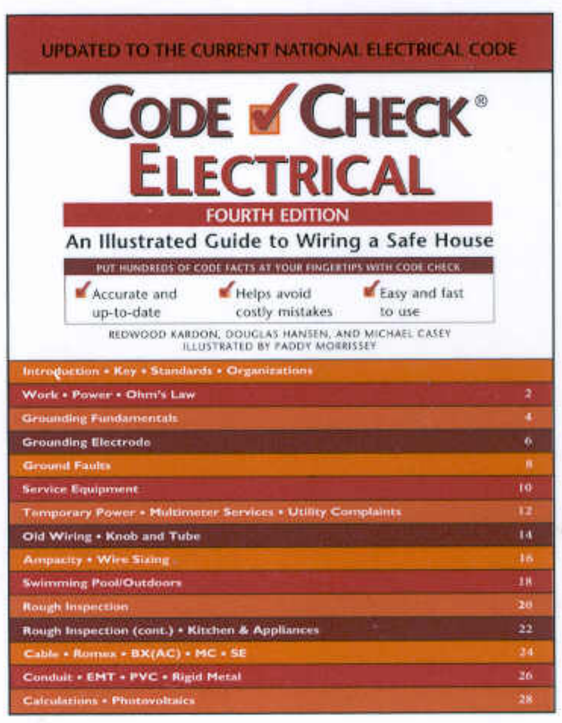

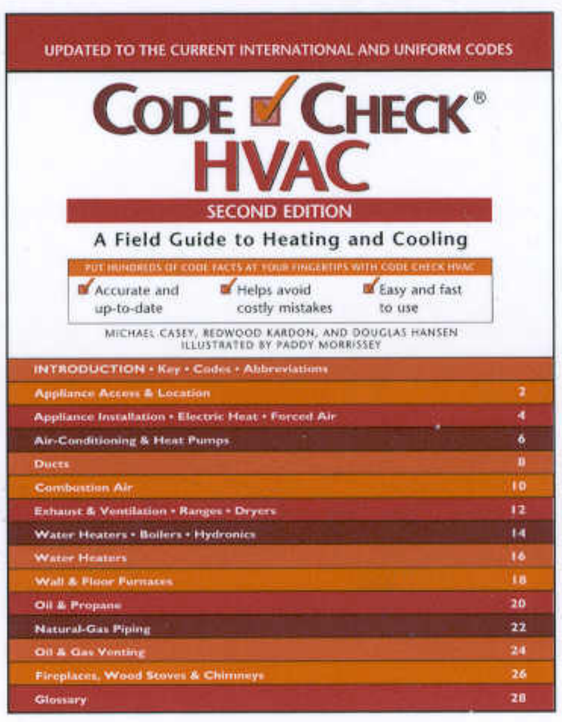

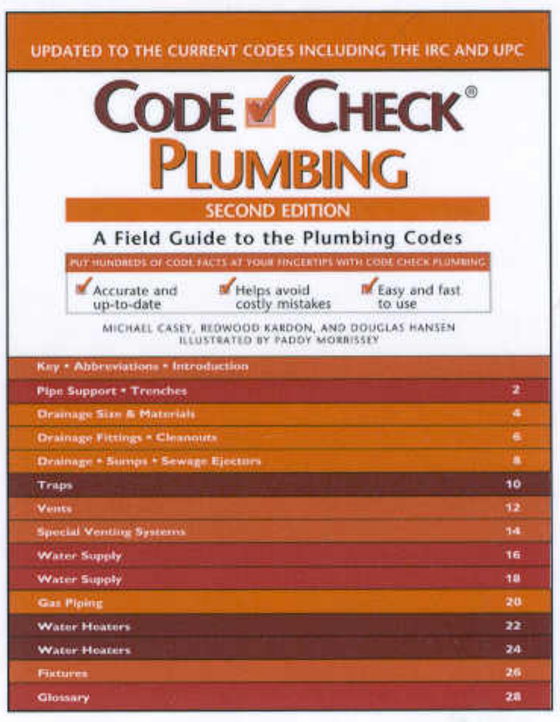

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