Bonding Grounding Ampacities & Fill

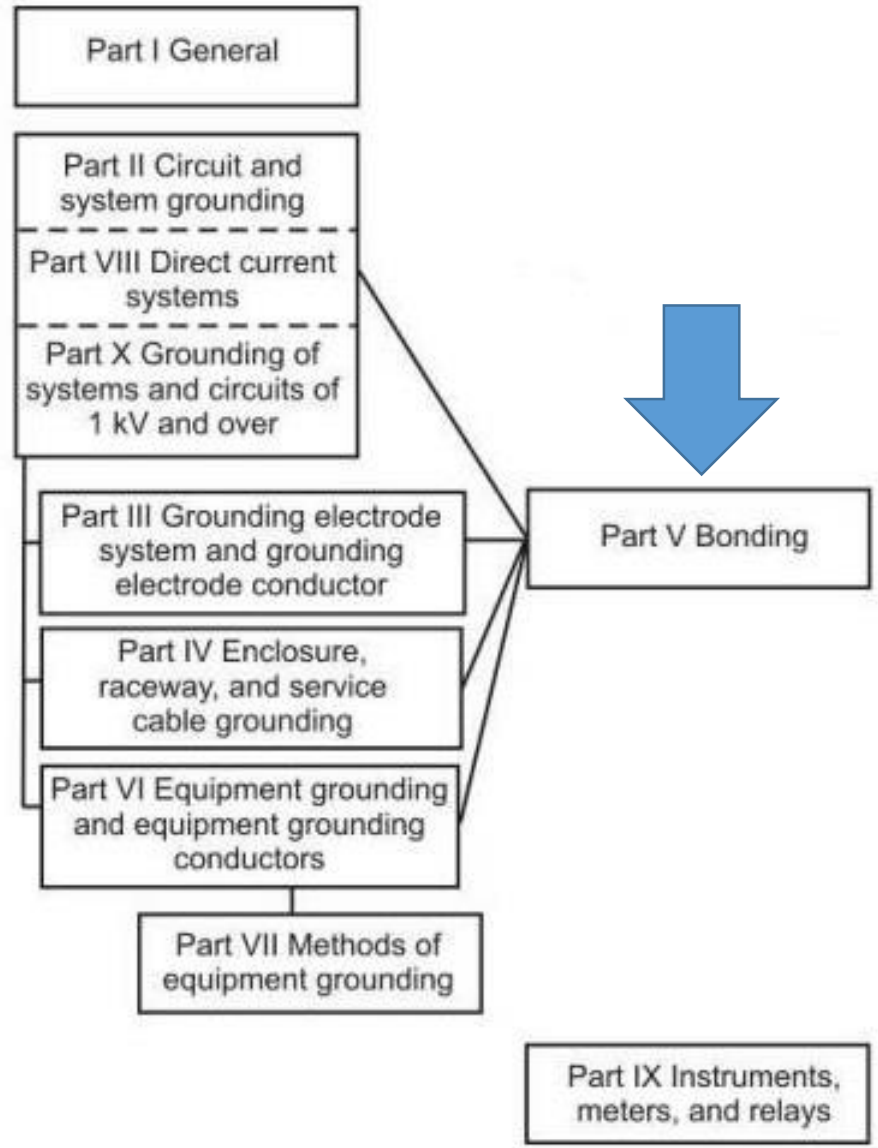
National Electric Code

Bonding & Grounding	9:00 - 9:45
Bonding & Grounding	10:00 - 10:45
Conductor Ampacities Box & Conduit Fill	11:00 - 11:50

Contact Hours: 3hrs

PPP CEU's: 0.30

Figure 250.1


Part I General
Part II Circuit and system grounding
Part VIII Direct current systems
Part X Grounding of systems and circuits of 1 kV and over
Part III Grounding electrode system and grounding electrode conductor
Part IV Enclosure, raceway, and service cable grounding
Part VI Equipment grounding and equipment grounding conductors
Part VII Methods of equipment grounding
Part V Bonding
Part IX Instruments, meters, and relays

NEC Article 250 “Grounding and Bonding”

250.2 Definitions

Bonding Jumpers:

A <u>reliable conductor</u> to ensure the required electrical conductivity <u>between metal parts</u> required to be electrically connected.
(makes no mention of ground)

250.4(A)(1)

Electrical systems that are grounded

shall be connected to earth in a manner that will limit the voltage imposed by

1) lightning,

2) line surges,

3) or unintentional contact with higher-voltage lines

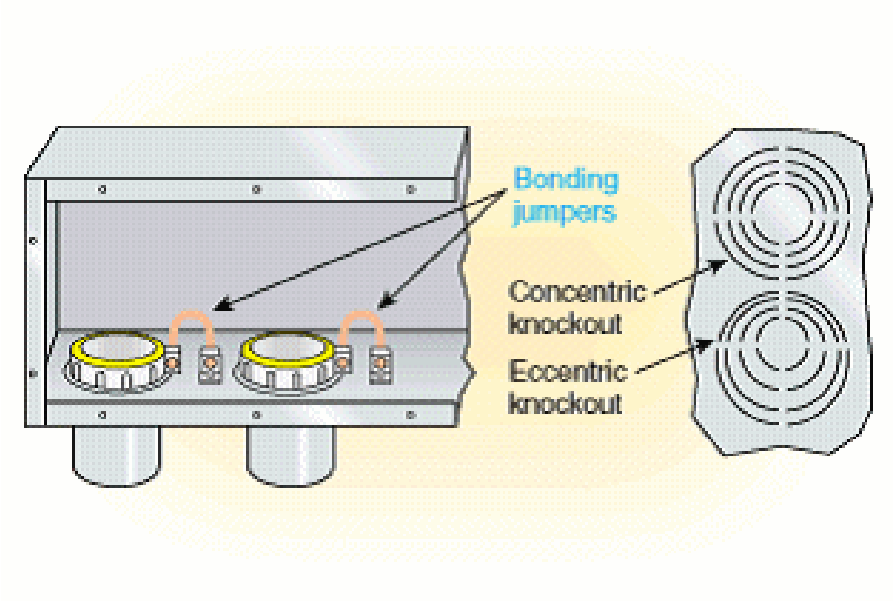
4) and that will stabilize the voltage to Earth during normal operation.

Almost EVERYTHING we inspect is a GROUNDED SYSTEM!

Normally non-current-carrying conductive materials enclosing electrical conductors or equipment, or forming part of such equipment, shall be connected to earth so as to limit the voltage to ground on these materials. 250.4(A)(2)

Normally non-current-carrying conductive materials enclosing electrical conductors or equipment, or forming part of such equipment, shall be connected together and to the electrical supply source in a manner that establishes an effective ground-fault current path.

250.4(A)(3) (Bonding)



Bonding Jumpers installed around concentric or eccentric knockouts

Bonding Jumpers installed around expansion fittings

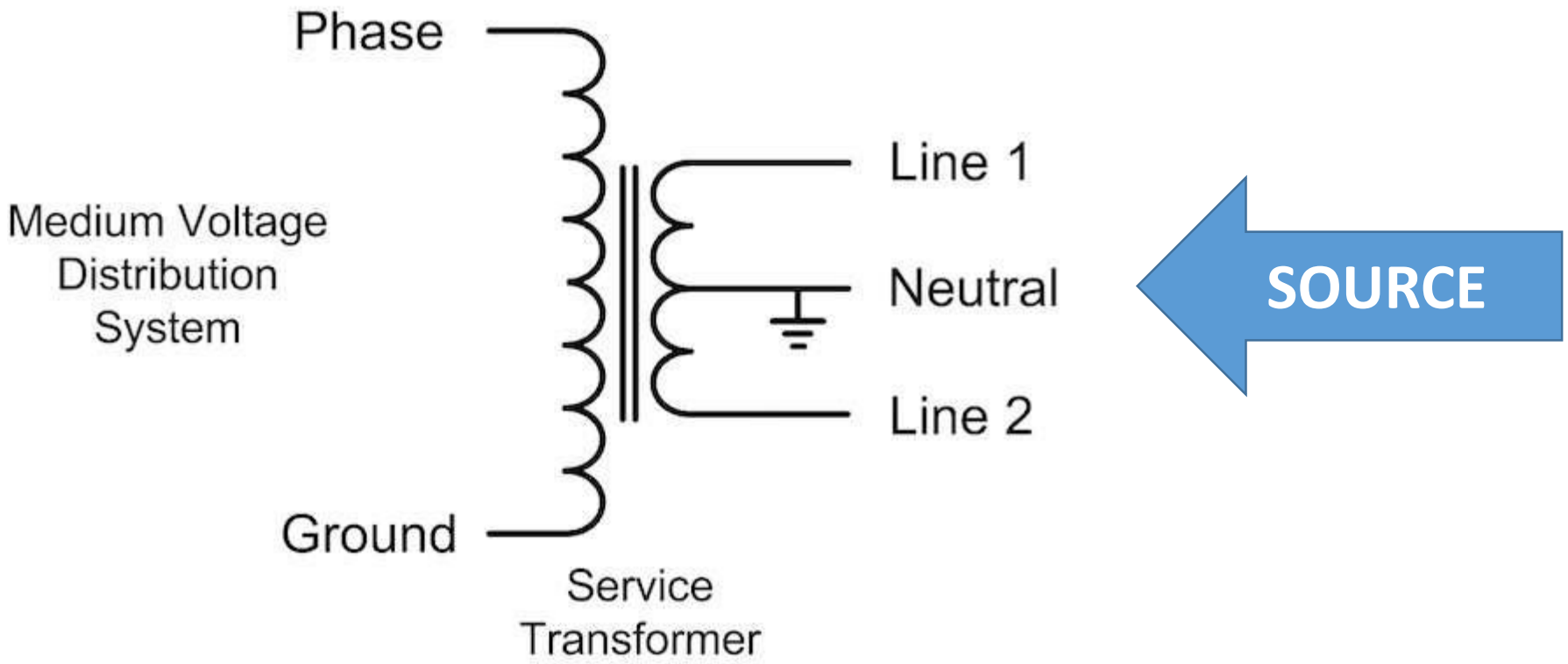
Examples of Bonding Jumpers for loosely joined metal raceways or components where movement is intended or possible.

Normally non-current-carrying conductive materials that are likely to become energized, shall be connected together and to the electrical supply source in a manner that establishes an effective ground-fault current path.

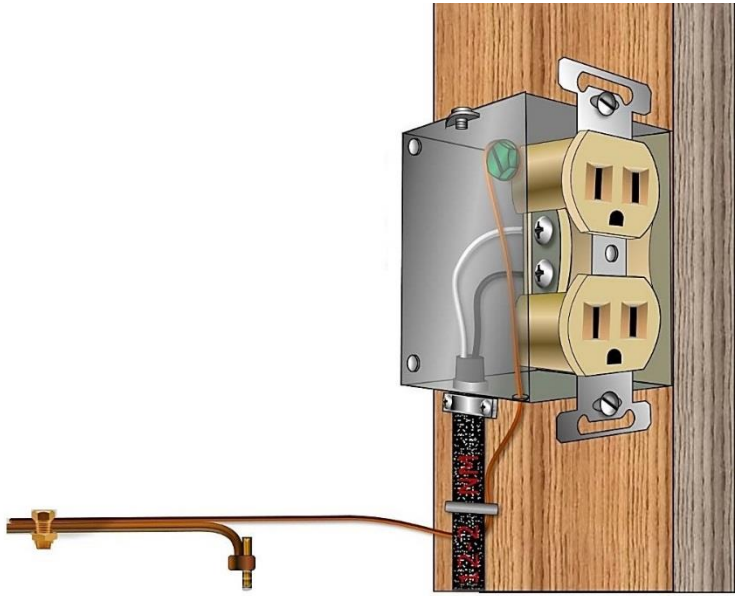
250.4(A)(4) (Bonding of conductive materials)

Electrical equipment & wiring that are likely to become energized, shall be installed in a manner that creates a low-impedence circuit….capable of safely carrying….maximum current where ground-fault to electrical source. The earth shall not be considered as an effective….path.

250.4(A)(5) (Effective….path)


Phase
Line 1
Medium Voltage
Distribution
System
Neutral
SOURCE
Line 2
Ground
Service
Transformer

Not This



or

THE EARTH GROUND IS NOT THE “SOURCE”

250.8 Connection of Grounding and Bonding Equipment

(A) Permitted Methods.
Grounding conductors and bonding jumpers shall be connected by one of the following means:

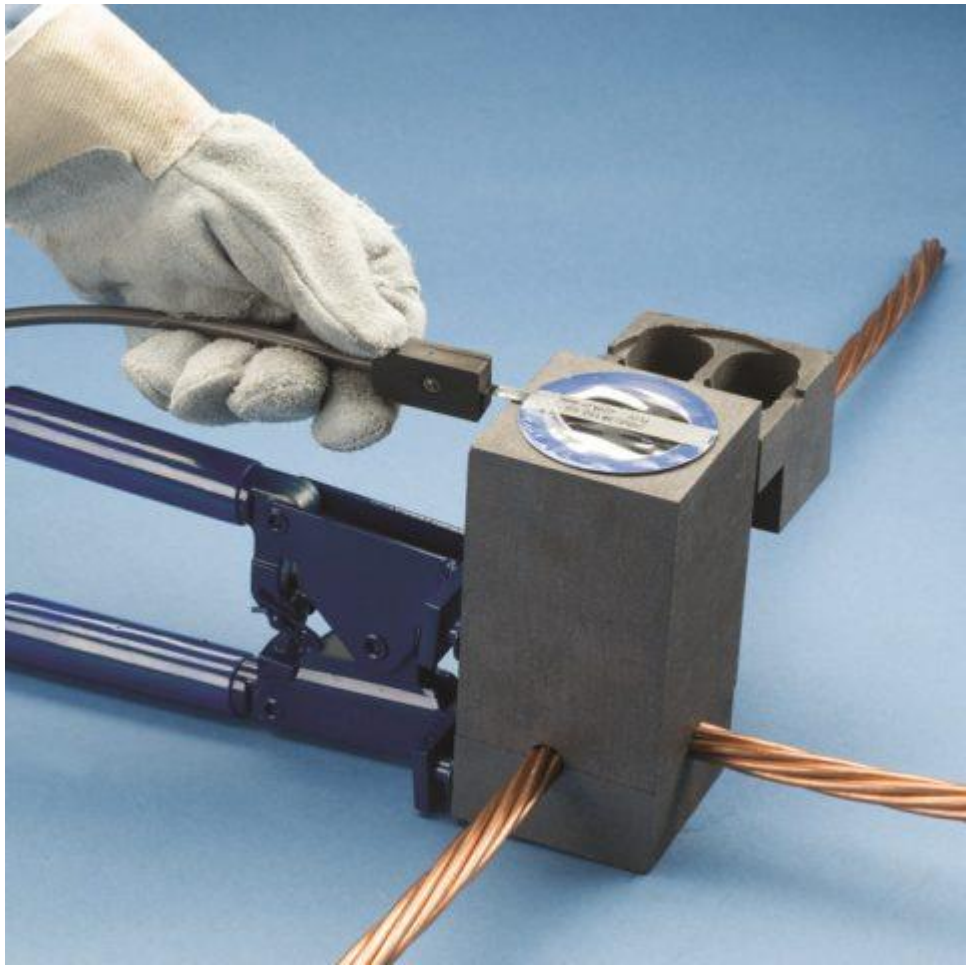
1. Listed pressure connectors
2. Terminal bars
3. Pressure connectors listed as grounding and bonding equipment
4. Exothermic welding process
5. Machine screw-type fasteners that engage not less than two threads or are secured with a nut
6. Thread-forming machine screws that engage not less than two threads in the enclosure
7. Connections that are part of a listed assembly
8. Other listed means

Listed Pressure Connectors

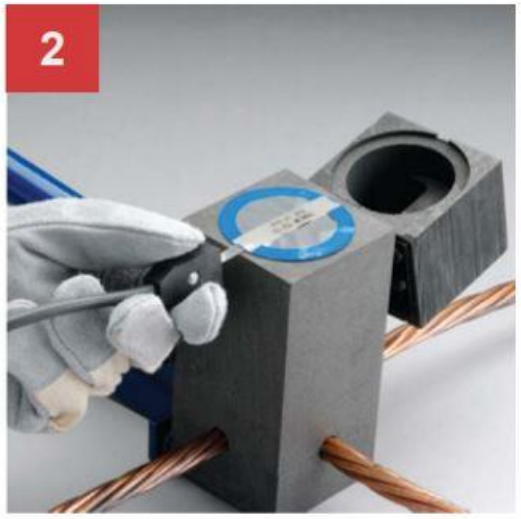
Terminal Bars

Exothermic Welding Process

Exothermic Welding Process



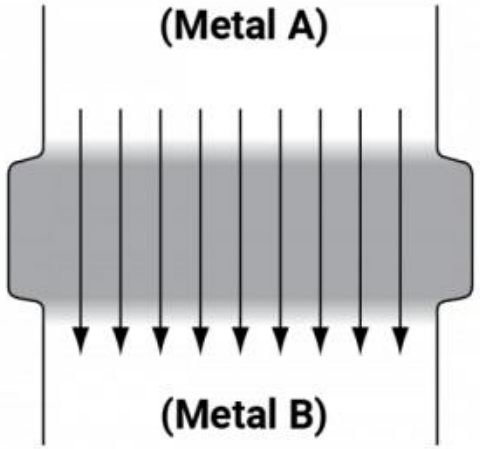
Exothermic Welding Process



Exothermic Welding Process

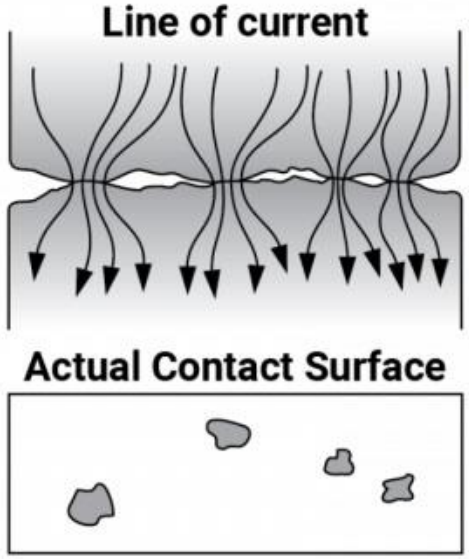
Comparison between nVent ERICO Cadweld Bonded Connection and Mechanical Connection

CADWELD WELD



The Cadweld bonded connection provides conductivity over the whole of the section due to molecular bonding between the metal surfaces.

MECHANICAL CRIMPED CONNECTION



The mechanical connection presents a significant difference between the apparent contact surface and the actual surface.

Exothermic Welding Process

In 1938, Pops **patented the Cadweld process**, and enabled one man with 25 pounds of equipment to replace all of this equipment previously needed. Shortly thereafter, exothermic welding for cathodic protection applications was created, followed by high voltage power transmission and electrical grounding and bonding connections.

Over the last 80 years, the equipment has been greatly enhanced to improve ease-of-use, product safety and weld quality to increasingly justify its use and broaden its applications. Exothermic welding is a significant invention that **has accounted for more than 150 million connections.**

Disadvantages of mechanical connections:

- Cause a point-to-point current flow (i.e. unequal current density).
- **Susceptible to corrosion**, lowering resistance over time.
- Require an anti-oxidant compound in order to prolong the lifetime of the connection.

Machine screw-type fasteners…. secured with a nut

Thread-forming machine screws….not less than two threads in the enclosure

Question:
What type of screws can be used for panels and junction boxes?

A. Drywall Screw

B. Pan-head Screw

C. Sheet Metal Screw

D. Square/Flat Screw

E. Phillips/Flat Screw

F. All of the Above

Screws for electrical panels and boxes should not have sharp pointed tips nor course threads!

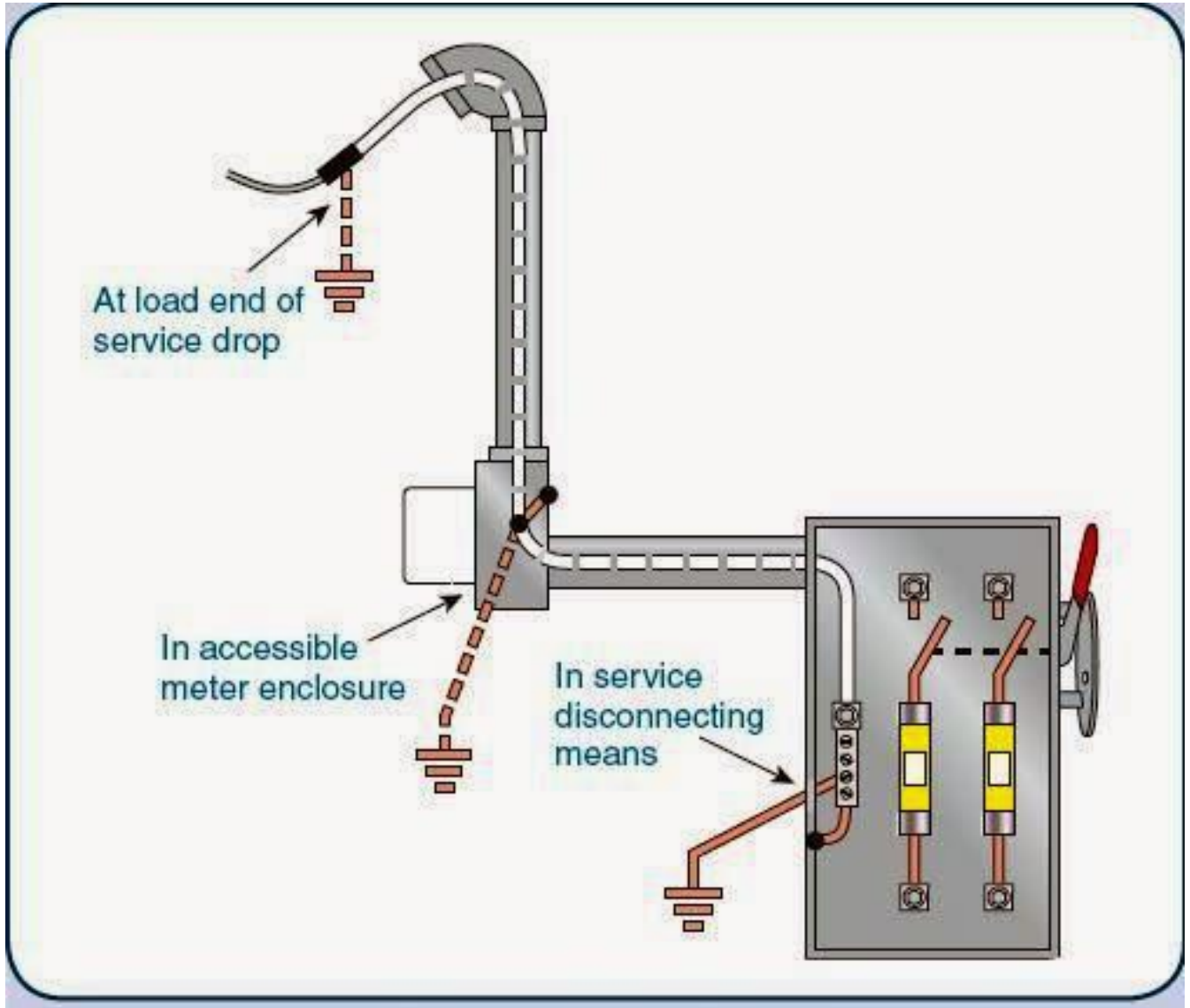
250.22 Circuits Not t Be Grounded

1. Electric cranes operating above combustible fibers…… 503.155
2. Health care facilities as provided in 517.61 & 517.160 (Anesthetizing Locations and Isolated Power Systems)
3. Equipment within electrolytic cell working zone….. 668
4. Secondary lighting circuits…… 411.5(A)
5. Secondary lighting circuits…… 680.23(A)(2)

250.24 Grounding Service-Supplied Alternating-Current Systems

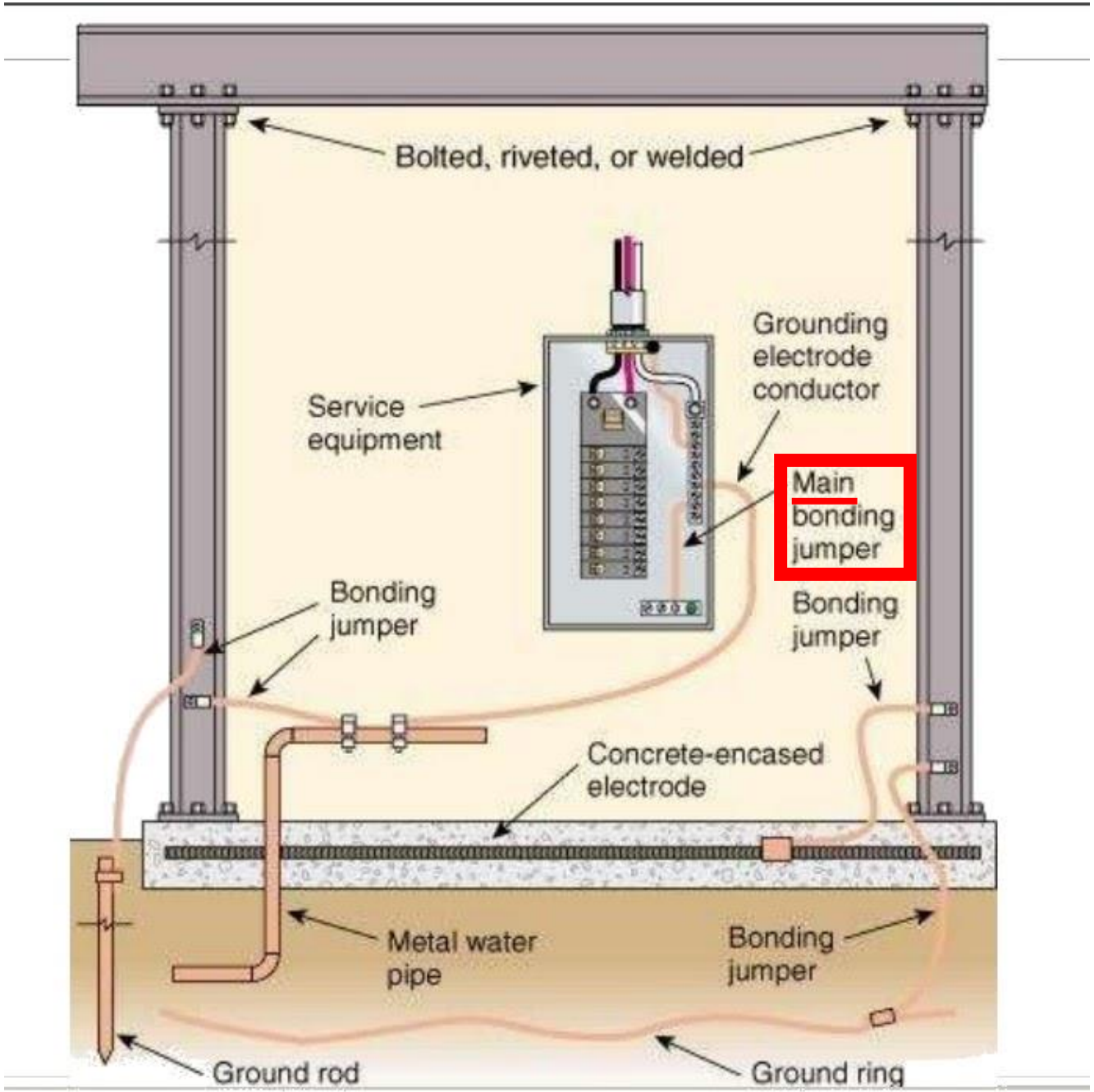
Premise wiring supplied by a grounded AC service shall have a grounding electrode conductor connected to the grounded service conductor.

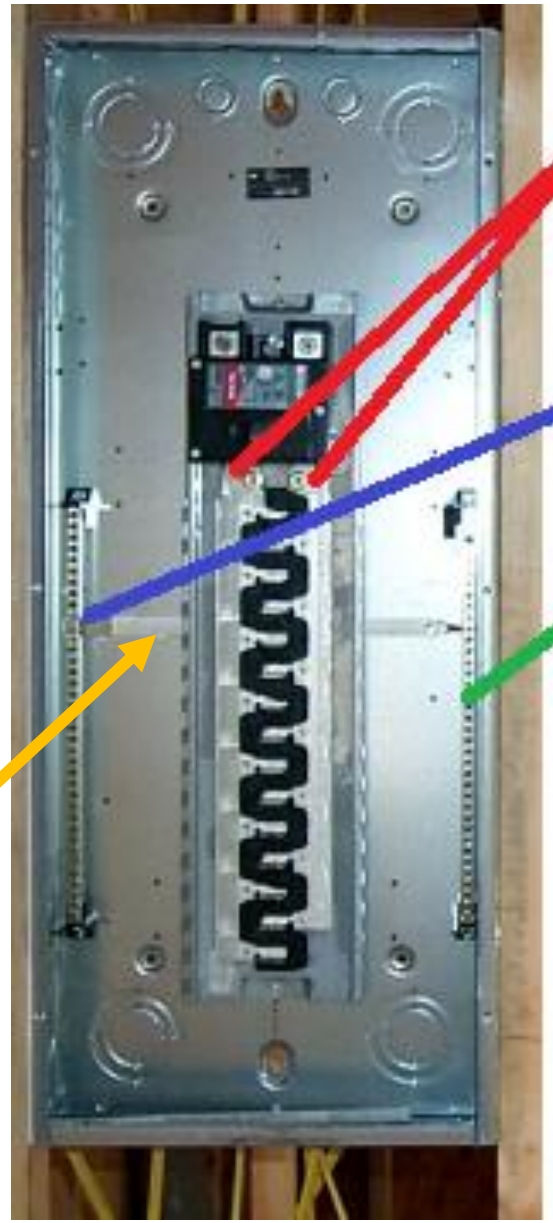
Grounding electrode conductor connection shall be made at any accessible point from the load end of the service drop or service lateral to and including the terminal or bus to which the grounded service conductor is connected at the service disconnecting means.



Three locations where 250.24(A)(1) permits the grounding electrode conductor to be connected to the ground service conductor.

For a grounded system, an unspliced main bonding jumper shall be used to connect the equipment grounding conductor and the service disconnect enclosure to the grounded conductor within the enclosure for each service disconnect…..


Bolted, riveted, or welded
Service equipment
Grounding electrode conductor
Main bonding jumper
Bonding jumper
Bonding jumper
Concrete-encased electrode
Metal water pipe
Bonding jumper
Ground rod
Ground ring



Ungrounded (hot) bus bars

Grounded (neutral) bus bar

Grounding bus bar

Main Bonding Jumper?

250.24 (C)(1) Routing & Sizing.

The grounded conductor (neutral) shall be routed with the phase conductors and shall not be smaller than the required grounding electrode conductor (250.66) but shall not be required to be larger than the largest ungrounded… conductor…..

TABLE 250.66 Grounding Electrode Conductor for Alternating-Current Systems

Size of Largest Ungrounded Service-Entrance Conductor or Equivalent Area for Parallel Conductors[a] (AWG/kcmil)		Size of Grounding Electrode Conductor (AWG/kcmil)	
Copper	Aluminum or Copper-Clad Aluminum	Copper	Aluminum or Copper-Clad Aluminum[b]
2 or smaller	1/0 (or smaller	8 (10mm2)	6
1 (50mm2) or 1/0	2/0 or 3/0	6 (16mm2)	4
2/0 or 3/0	4/0 or 250	4 (25mm2)	2
Over 3/0 through 350 (185mm2)	Over 250 through 500	2 (25mm2)	1/0
Over 350 through 600 (300mm2)	Over 500 through 900	1/0 (70mm2)	3/0
Over 600 through 1100 (650mm2)	Over 900 through 1750	2/0 (70mm2)	4/0
Over 1100	Over 1750	3/0 (95mm2)	250

Notes:

1. Where multiple sets of service-entrance conductors are used as permitted in 230.40, Exception No. 2, the equivalent size of the largest

The grounded conductor (neutral) shall be shall not be smaller than the required grounding electrode in Table 250.66?

The grounded conductor (neutral) routed with the phase conductors shall not be smaller than…

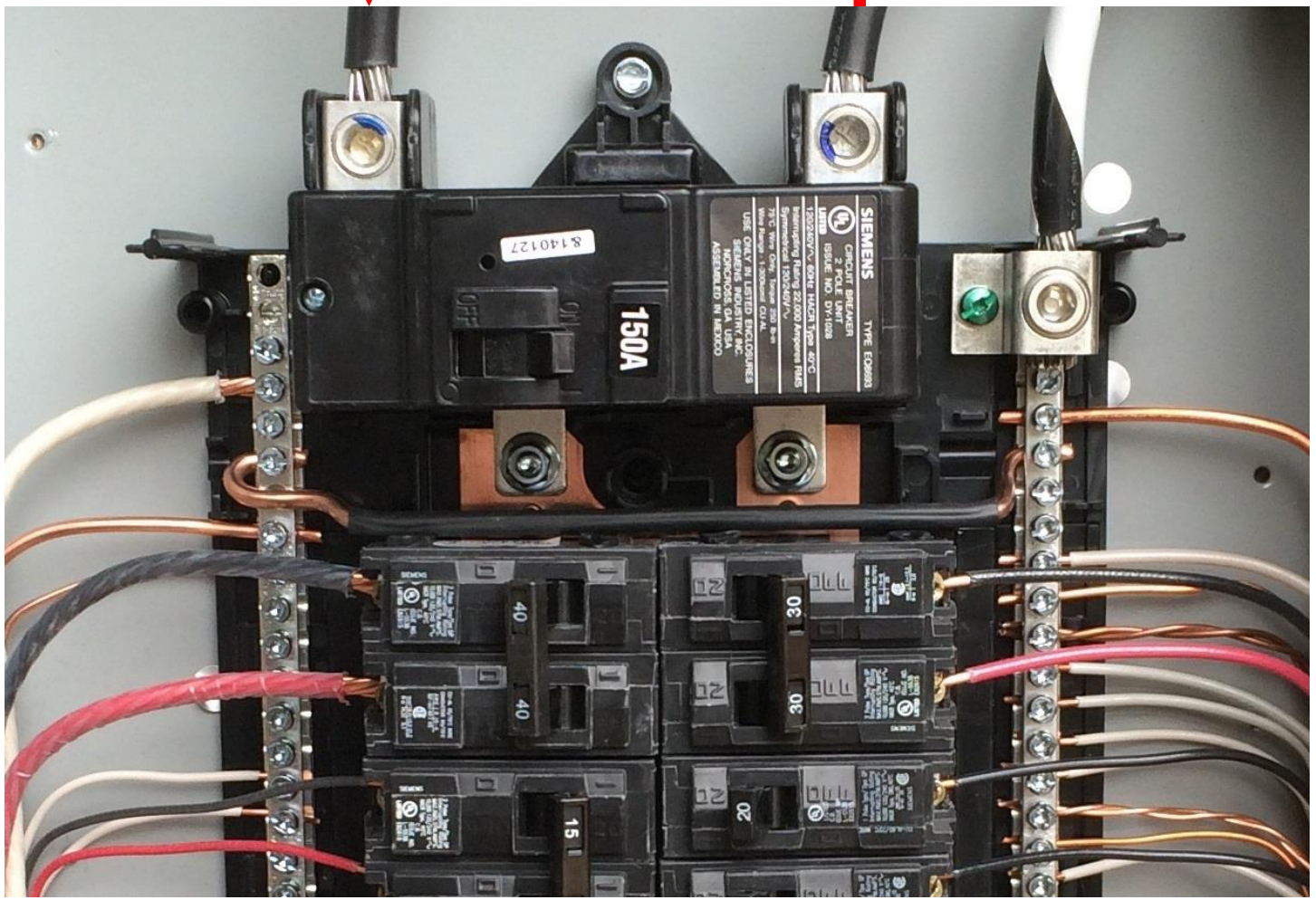
Size of Largest Ungrounded Service-Entrance Conductor or Equivalent Area for Parallel Conductors[a] (AWG/kcmil)		Size of Grounding Electrode Conductor (AWG/kcmil)	
Copper	Aluminum or Copper-Clad Aluminum	Copper	Aluminum or Copper-Clad Aluminum[b]
2 or smaller	1/0 (or smaller	8 (10mm2)	6
1 (50mm2) or 1/0	2/0 or 3/0	6 (16mm2)	4
2/0 or 3/0	4/0 or 250	4 (25mm2)	2

Grounded conductor (neutral) sized by Table 250.66 ????

220.61 Feeder or service neutral load shall be the maximum unbalance of the load...
The maximum unbalanced load shall be the maximum net calculated load between the neutral conductor and ungrounded conductor

IN OUT

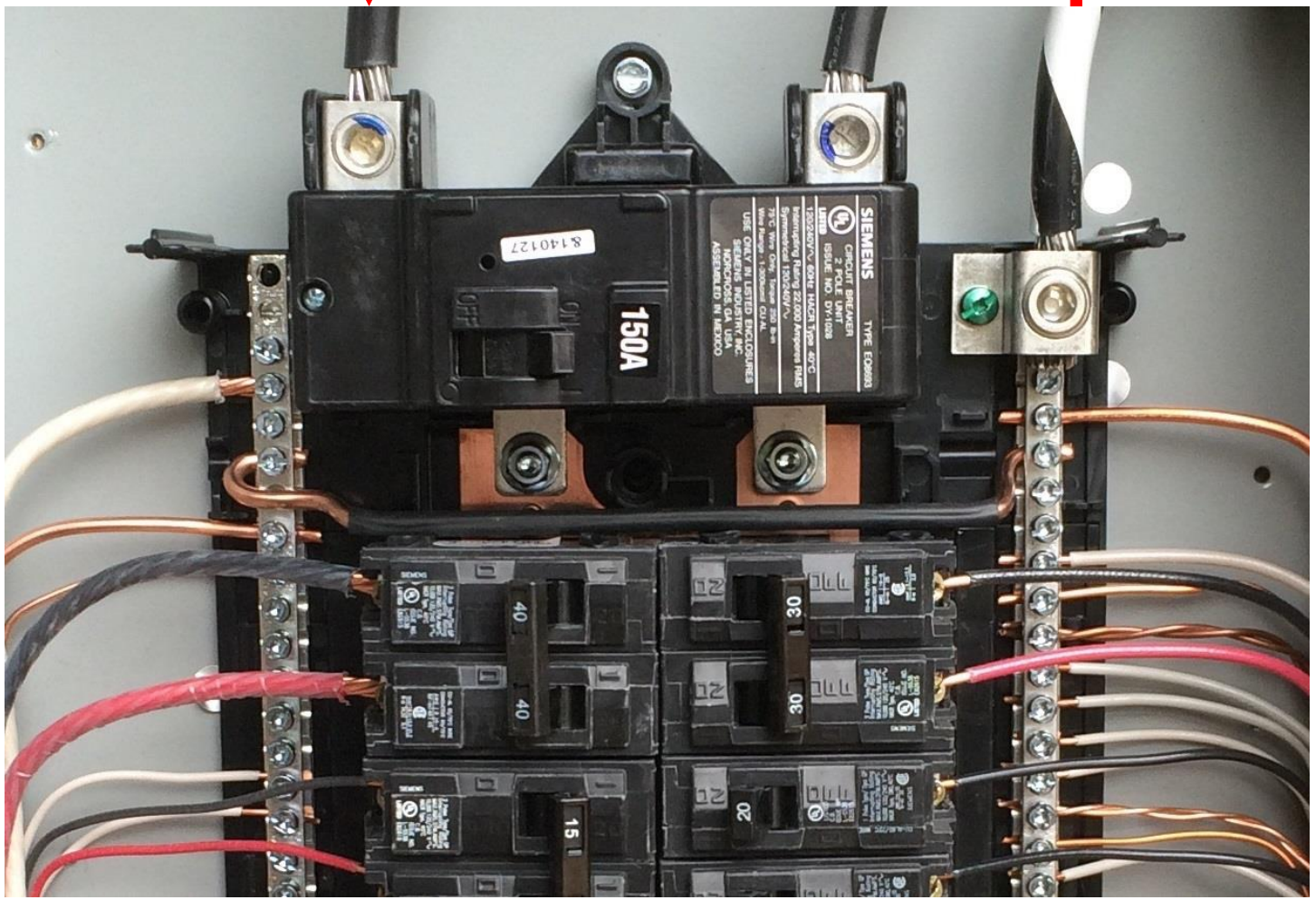
= BALANCED



IN

OUT

= UNBALANCED



250.24 (C)(2) Parallel Conductors

Where the service-entrance phase conductors are installed in parallel, the size of the grounded conductor shall be based on the total circular mil area of the parallel conductors….but not smaller than 1/0 AWG.

Also see:
250.122(F) Where conductors are run parallel…the equipment grounding conductor (EGC)…shall be run parallel in each raceway…
…Each…shall be sized on ampere rating…overcurrent device…in accordance with Table 250.122

Table 250.122 Minimum Size Equipment Grounding Conductors for Grounding Raceway and Equipment

Rating or Setting of Automatic Overcurrent Device in Circuit Ahead of Equipment, Conduit, etc., Not Exceeding (Amperes)	Size (AWG or kcmil)	
	Copper	Aluminum or Copper-Clad Aluminum*
15	14	12
20	12	10
60	10	8
100	8	6
200	6	4
300	4	2
400	3	1
500	2	1/0
600	1	2/0
800	1/0	3/0
1000	2/0	4/0
1200	3/0	250
1600	4/0	350
2000	250	400
2500	350	600
3000	400	600
4000	500	750
5000	700	1200
6000	800	1200

Note: Where necessary to comply with 250.4(A)(5) or (B)(4), the equipment grounding conductor shall be sized larger than given in this table.

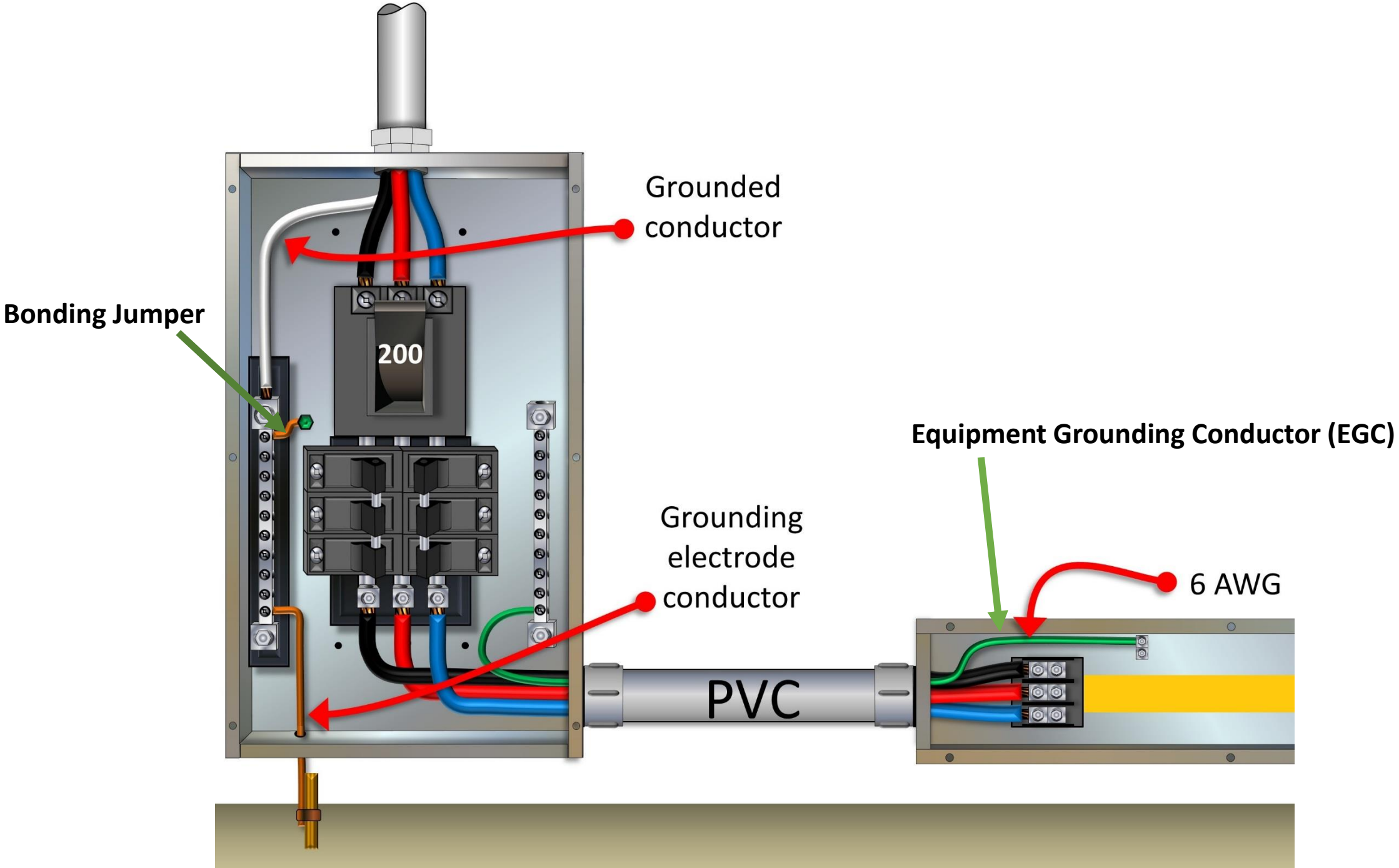
*See installation restrictions in 250.120.

TABLE 250.66 Grounding Electrode Conductor for Alternating-Current Systems

Size of Largest Ungrounded Service-Entrance Conductor or Equivalent Area for Parallel Conductors[a] (AWG/kcmil)		Size of Grounding Electrode Conductor (AWG/kcmil)	
Copper	Aluminum or Copper-Clad Aluminum	Copper	Aluminum or Copper-Clad Aluminum[b]
2 or smaller	1/0 (or smaller	8 (10mm2)	6
1 (50mm2) or 1/0	2/0 or 3/0	6 (16mm2)	4
2/0 or 3/0	4/0 or 250	4 (25mm2)	2
Over 3/0 through 350 (185mm2)	Over 250 through 500	2 (25mm2)	1/0
Over 350 through 600 (300mm2)	Over 500 through 900	1/0 (70mm2)	3/0
Over 600 through 1100 (650mm2)	Over 900 through 1750	2/0 (70mm2)	4/0
Over 1100	Over 1750	3/0 (95mm2)	250

Notes:

1. Where multiple sets of service-entrance conductors are used as permitted in 230.40, Exception No. 2, the equivalent size of the largest


Grounded
conductor
Bonding Jumper
200
Equipment Grounding Conductor (EGC)
Grounding
electrode
conductor
6 AWG
PVC

250.24 (D) Grounding Electrode Conductor (GEC)
….GEC shall connect EGC, service equipment…grounded conductor (neutral) to Electrode(s)…and sized…250.66

250.66 Size of…Grounding Electrode Conductor (GEC)
…size at service…shall not be less than given in Table 250.66 except as permitted in (A) through (C).

Size of Largest Ungrounded Service-Entrance Conductor or Equivalent Area for Parallel Conductors[a] (AWG/kcmil)		Size of Grounding Electrode Conductor (AWG/kcmil)	
Copper	Aluminum or Copper-Clad Aluminum	Copper	Aluminum or Copper-Clad Aluminum[b]
2 or smaller	1/0 (or smaller	8 (10mm2)	6
1 (50mm2) or 1/0	2/0 or 3/0	6 (16mm2)	4
2/0 or 3/0	4/0 or 250	4 (25mm2)	2

2008 NEC

250.66(A) Where the GEC is connected to rod, pipe, or plate electrodes as permitted in 250.52(A)(5) or (A)(7), that portion of the conductor that is the sole connection to the GEC shall not be required to be larger than 6 AWG copper.

2017 NEC

250.66(A) If the GEC or bonding jumper connected to a single or multiple rod, pipe or plate electrode(s), or any combination thereof, as described in 250.52…, does not extend on to other types of electrodes that require a larger size conductor, the GEC shall not be required to be larger than 6 AWG copper.

?

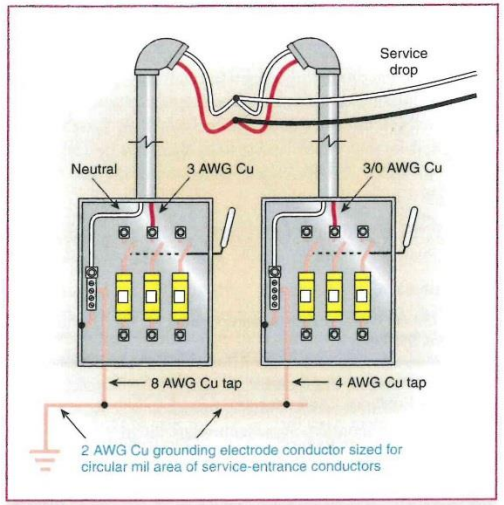


Exhibit 250.30 A grounding electrode conductor with multiple sets of service conductors, sized according to Table 250.66, Note 1.

Solution

STEP 1. Using Table 8 in Chapter 9, calculate the total circular mil area of both grounded service conductors:

3 AWG = 52,620 circular mils
3/0 AWG = 167,800 mils
Total area = 220,420 circular mils

From Table 8, the next larger standard size is 250 kcmil.

STEP 2. Use Table 250.66 to size the grounding electrode conductor. According to the fourth row, "Over 3/0 through 350," the size should be 2 AWG copper or 1/0 AWG aluminum.

Note that the taps to the grounding electrode conductor from each service disconnecting means enclosure in Exhibit 250.30 are sized from Table 250.66 based on the size of the service-entrance conductors supplying the enclosures.

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

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

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

As illustrated in Exhibit 250.31, where a grounding electrode conductor is run from the service equipment or separately derived system to a water pipe or structural metal building member and from that point to one of the electrodes mentioned in 250.66(A), that portion of the grounding electrode between the service equipment or separately derived system and the water pipe or structural metal building member must be a full-size conductor, per Table 250.66. If the grounding electrode conductor from the service equipment is run, for example, to the ground rod first and then to the water pipe, the conductor to the ground rod would also have to be full size, per Table 250.66. Note that Exhibit 250.31 is not intended to show the physical routing and connection of the bonding jumpers. The sizes for the bonding jumpers to the ground rod and the concrete-encased electrode shown in Exhibit 250.31 are the maximum sizes required by the *Code*.

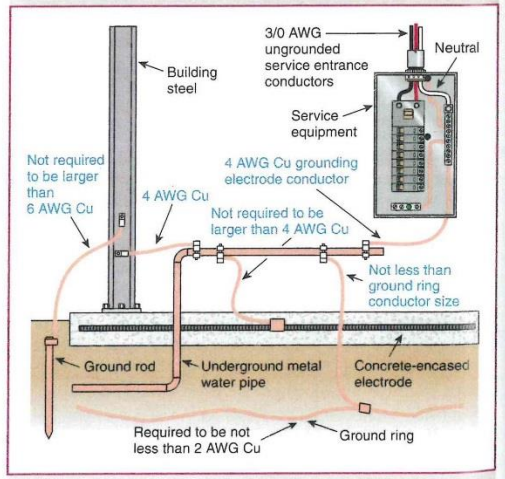


Exhibit 250.31 Grounding electrode conductor and bonding jumpers sized in accordance with 250.66 for a service supplied by 3/0 AWG ungrounded conductors.

As illustrated in Exhibit 250.31, where a grounding electrode conductor is run from the service equipment or separately derived system to a water pipe or structural metal building member and from that point to one of the electrodes mentioned in 250.66(A), that portion of the grounding electrode between the service equipment or separately derived system and the water pipe or structural metal building member must be a full-size conductor, per Table 250.66. If the grounding electrode conductor from the service equipment is run, for example, to the ground rod first and then to the water pipe, the conductor to the ground rod would also have to be full size, per Table 250.66. Note that Exhibit 250.31 is not intended to show the physical routing and connection of the bonding jumpers. The sizes for the bonding jumpers to the ground rod and the concrete-encased electrode shown in Exhibit 250.31 are the maximum sizes required by the *Code*.

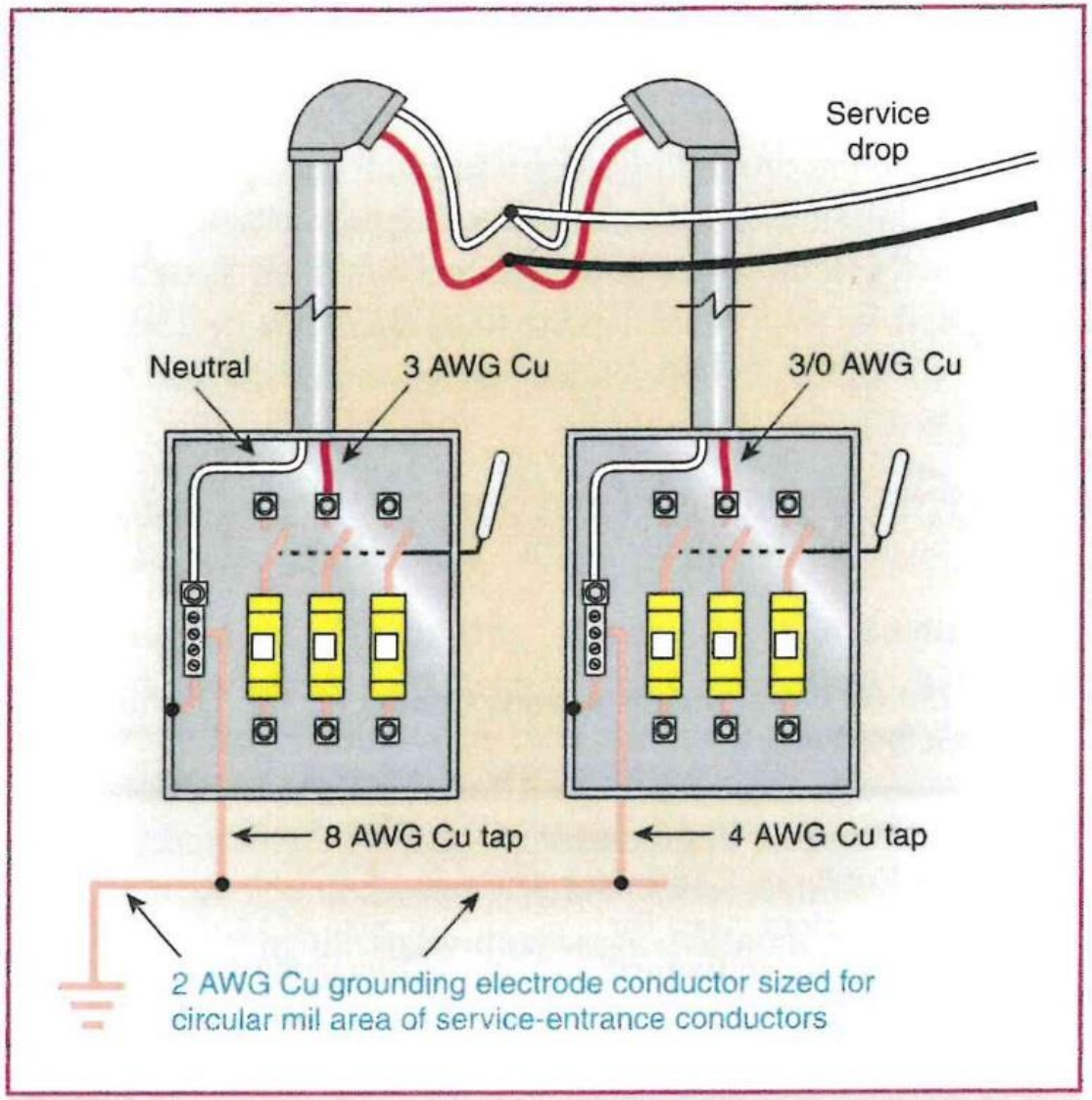


Exhibit 250.30 A grounding electrode conductor with multiple sets of service conductors, sized according to Table 250.66, Note 1.

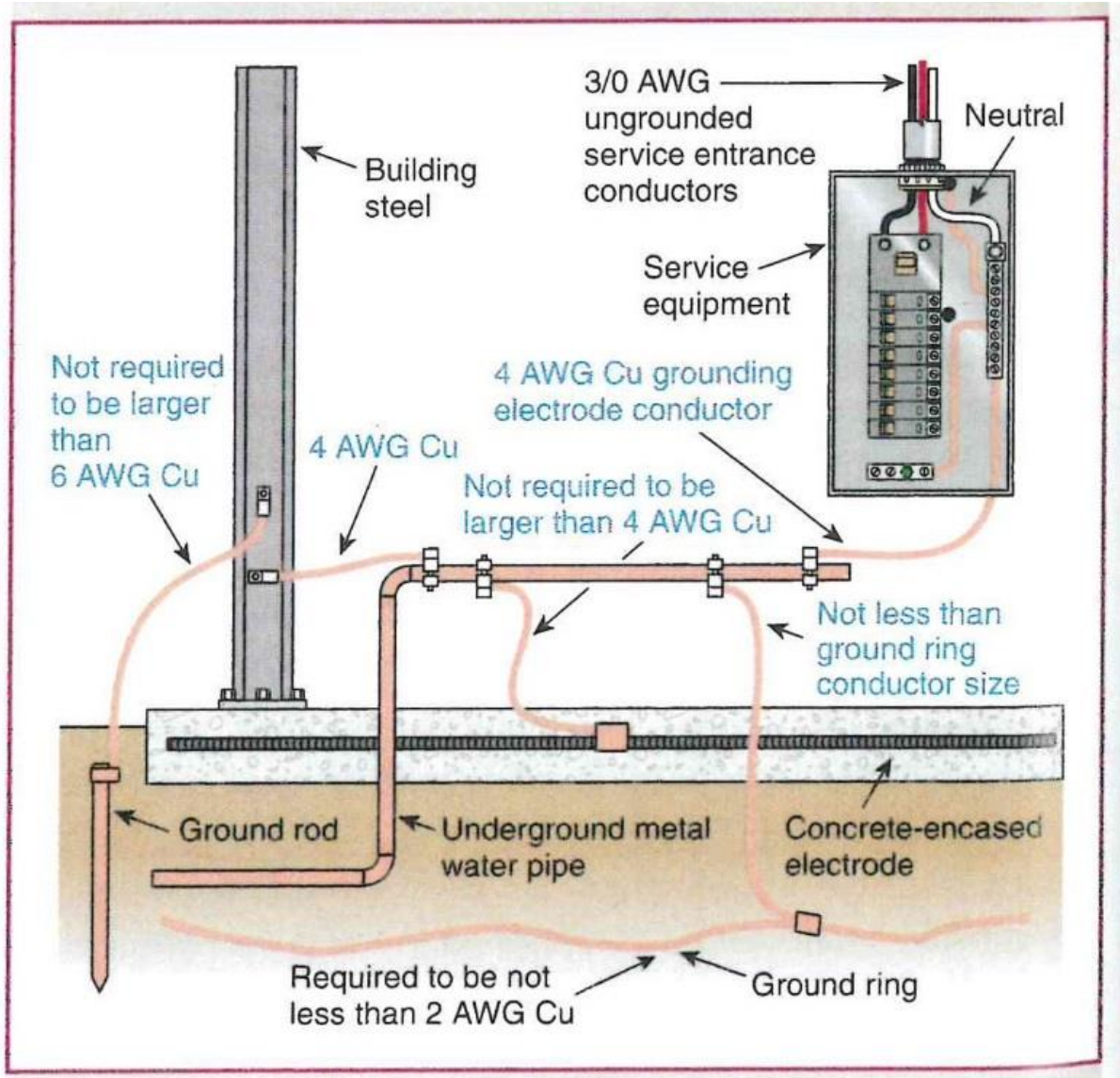


Exhibit 250.31 Grounding electrode conductor and bonding jumpers sized in accordance with 250.66 for a service supplied by 3/0 AWG ungrounded conductors.

2008 NEC HANDBOOK
"The use of bonding jumpers or GEC's larger than required by 250.66 is certainly not prohibited.

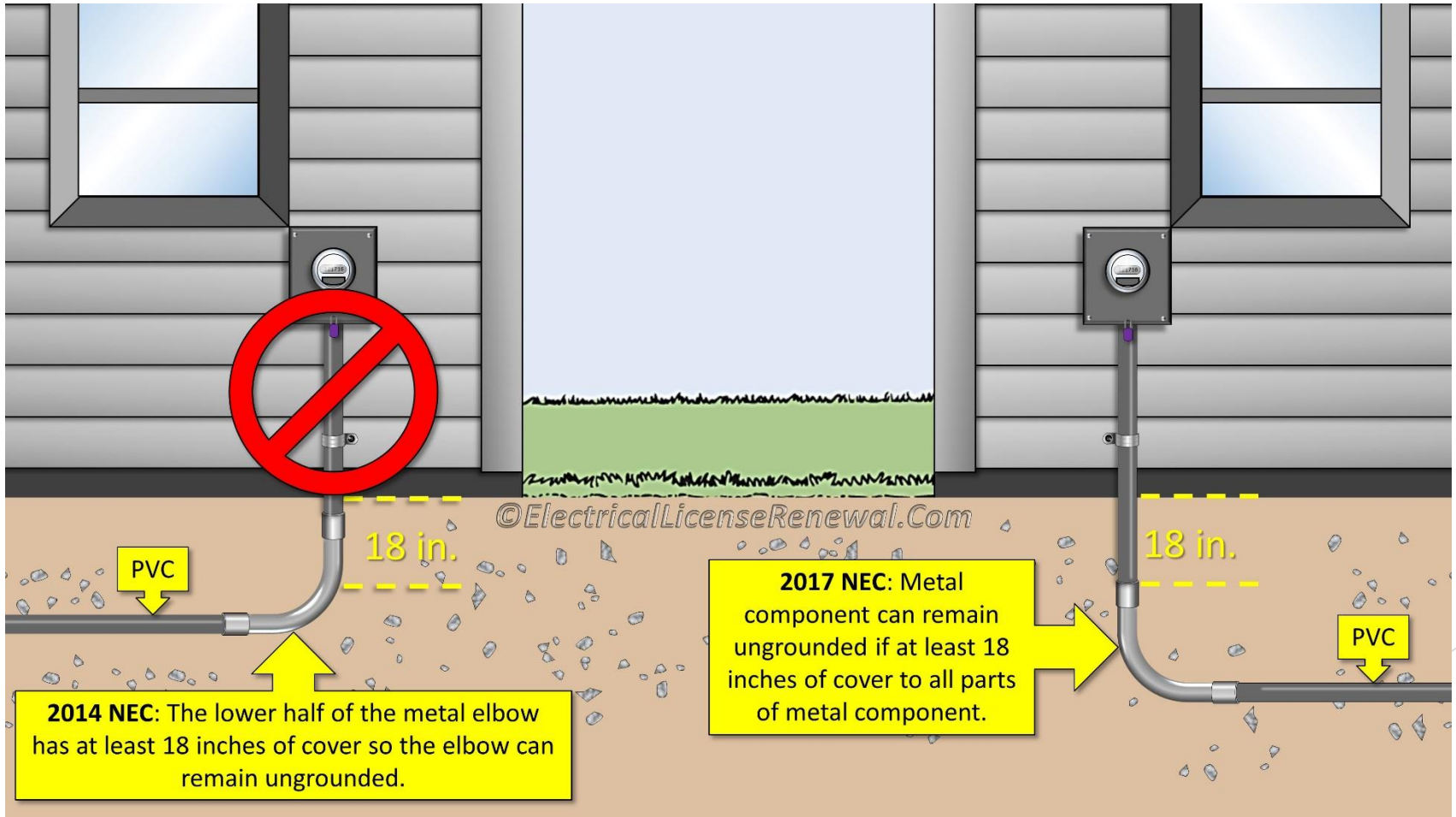
250.68(A) Accessibility
All mechanical elements used to terminate a GEC or bonding jumper to a grounding electrode shall be accessible.
Exception: buried or concrete encased

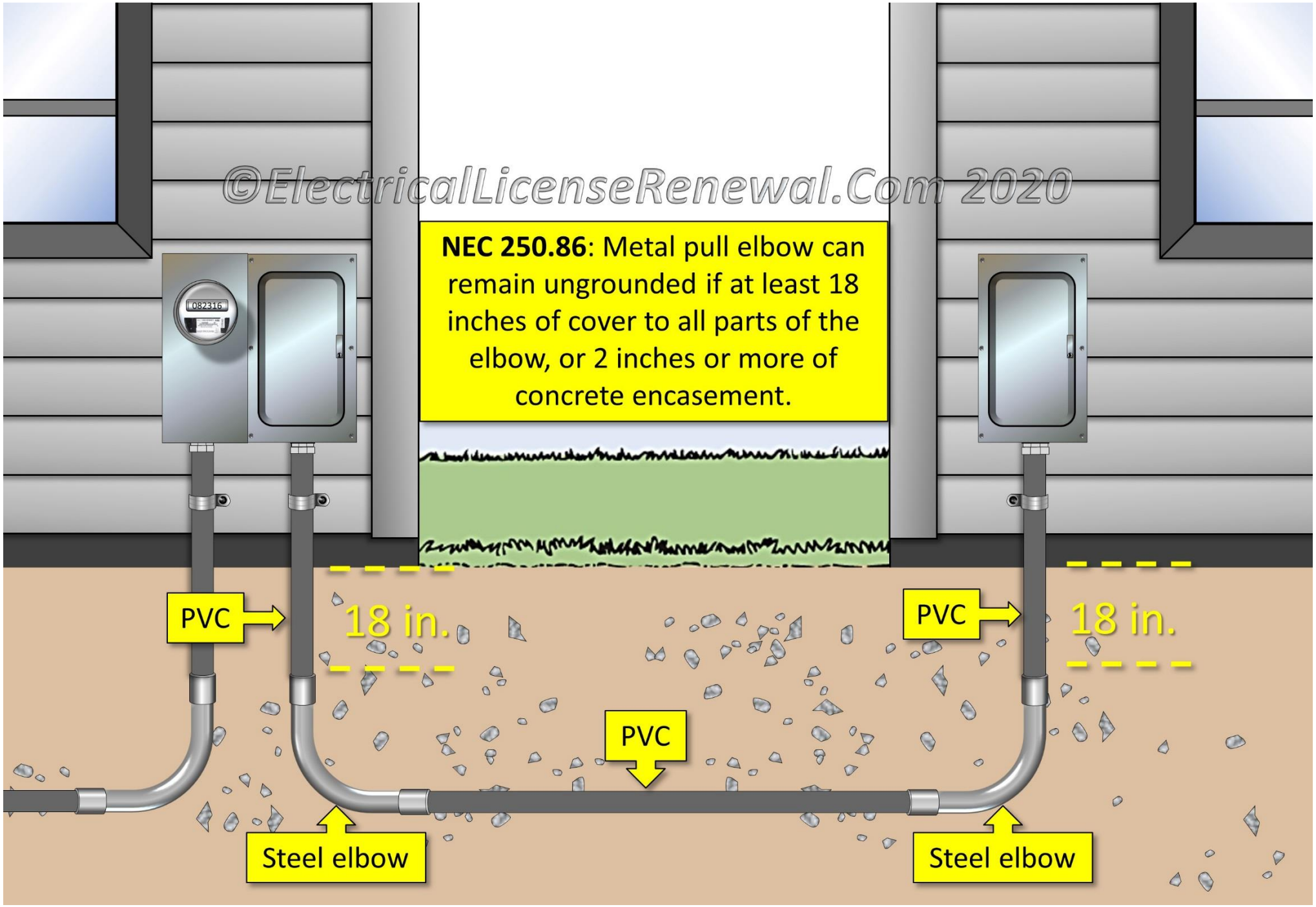
Accessible: Capable of being removed or exposed without damaging the building structure or finish or not permanently closed in by the structure or finish of the building.

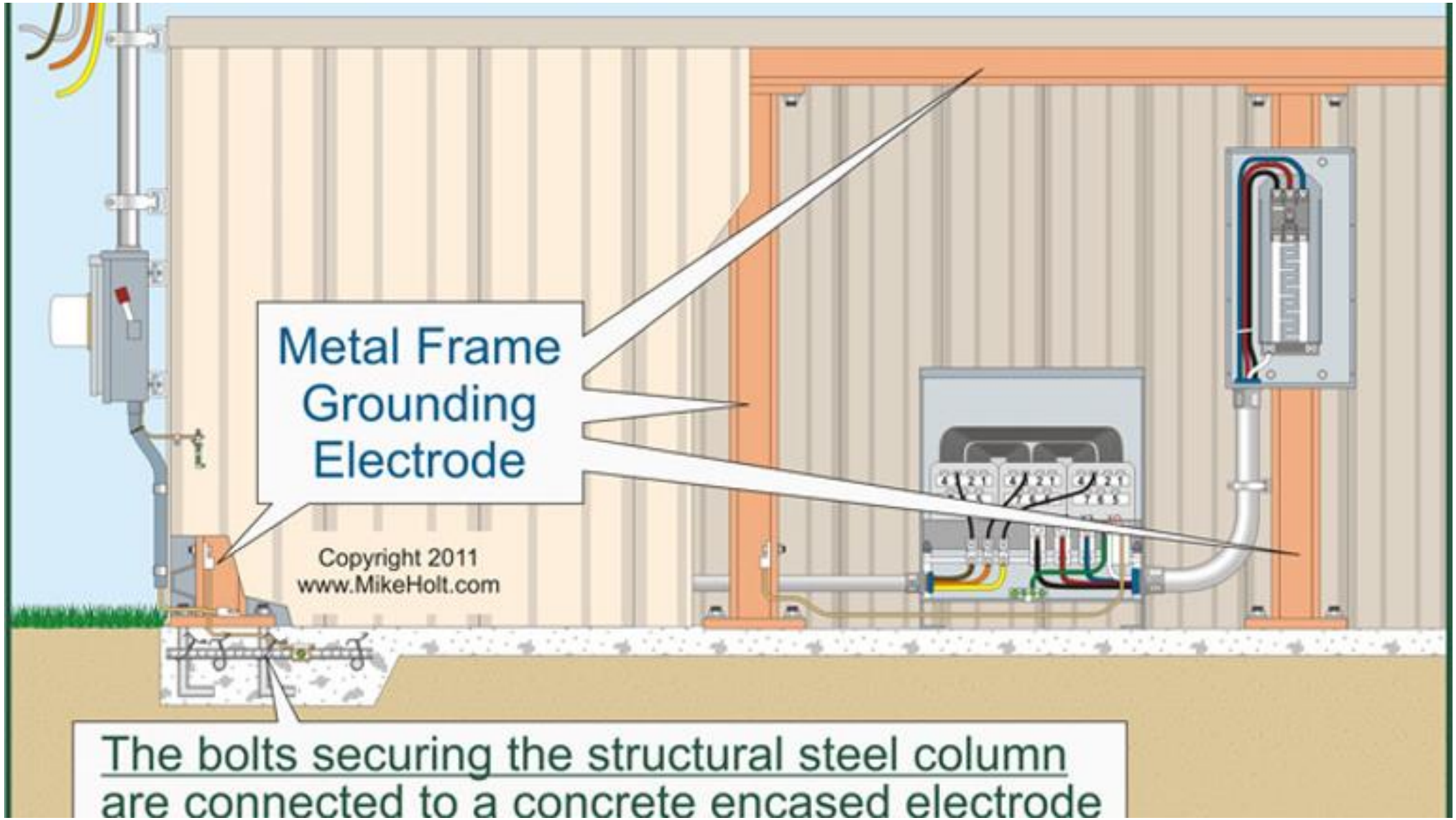
Readily Accessible: Capable of being reached quickly for operation, renewal, or inspections without requiring those to whom ready access is requisite to climb over or remove obstacles or to resort to portable ladders, and so fourth.

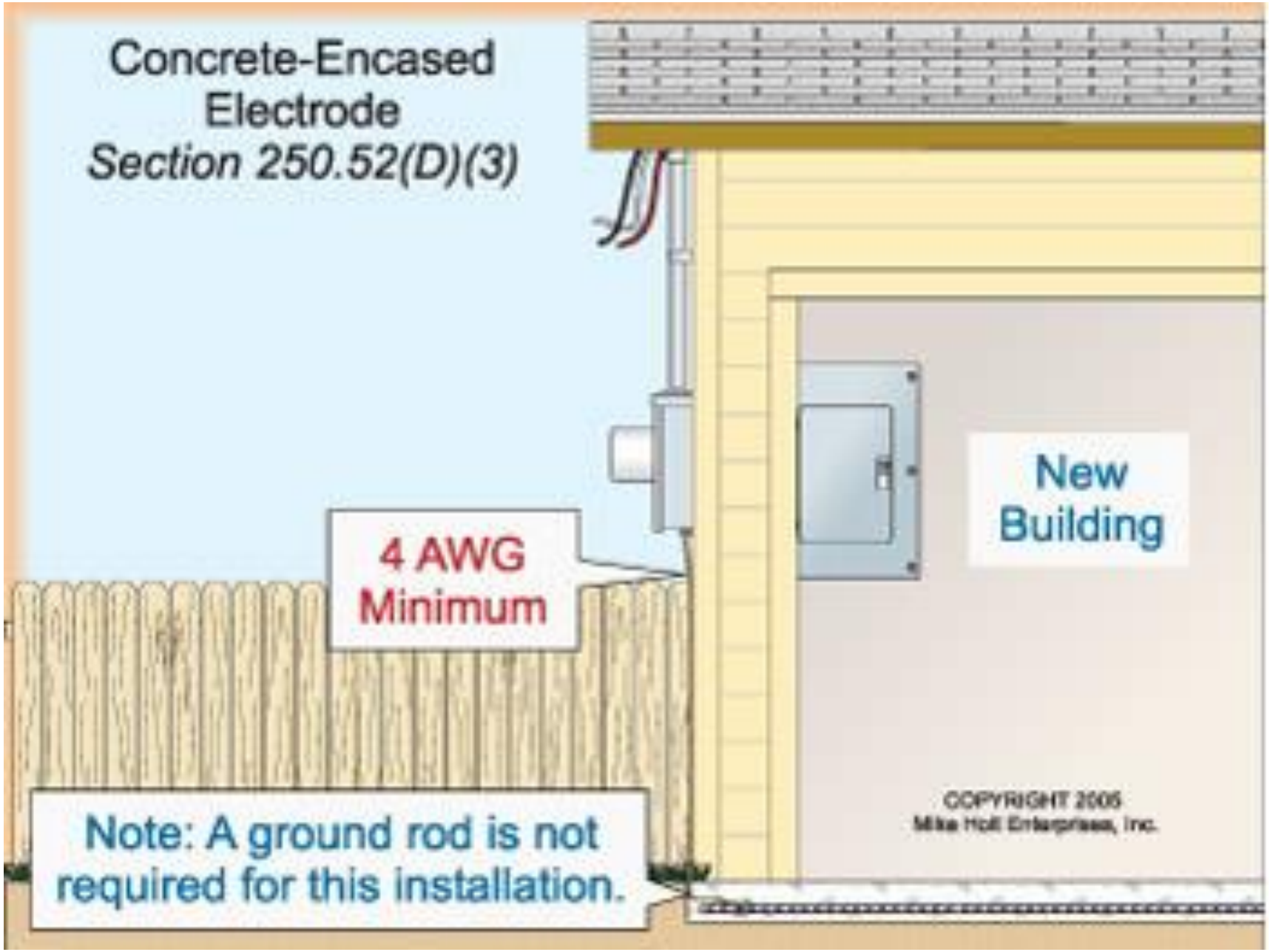
250.80 Service Raceways and Enclosures.
…shall be connected to the grounded system conductor…

Exception: A metal elbow…underground…isolated from possible contact by a minimum of 18 inches…



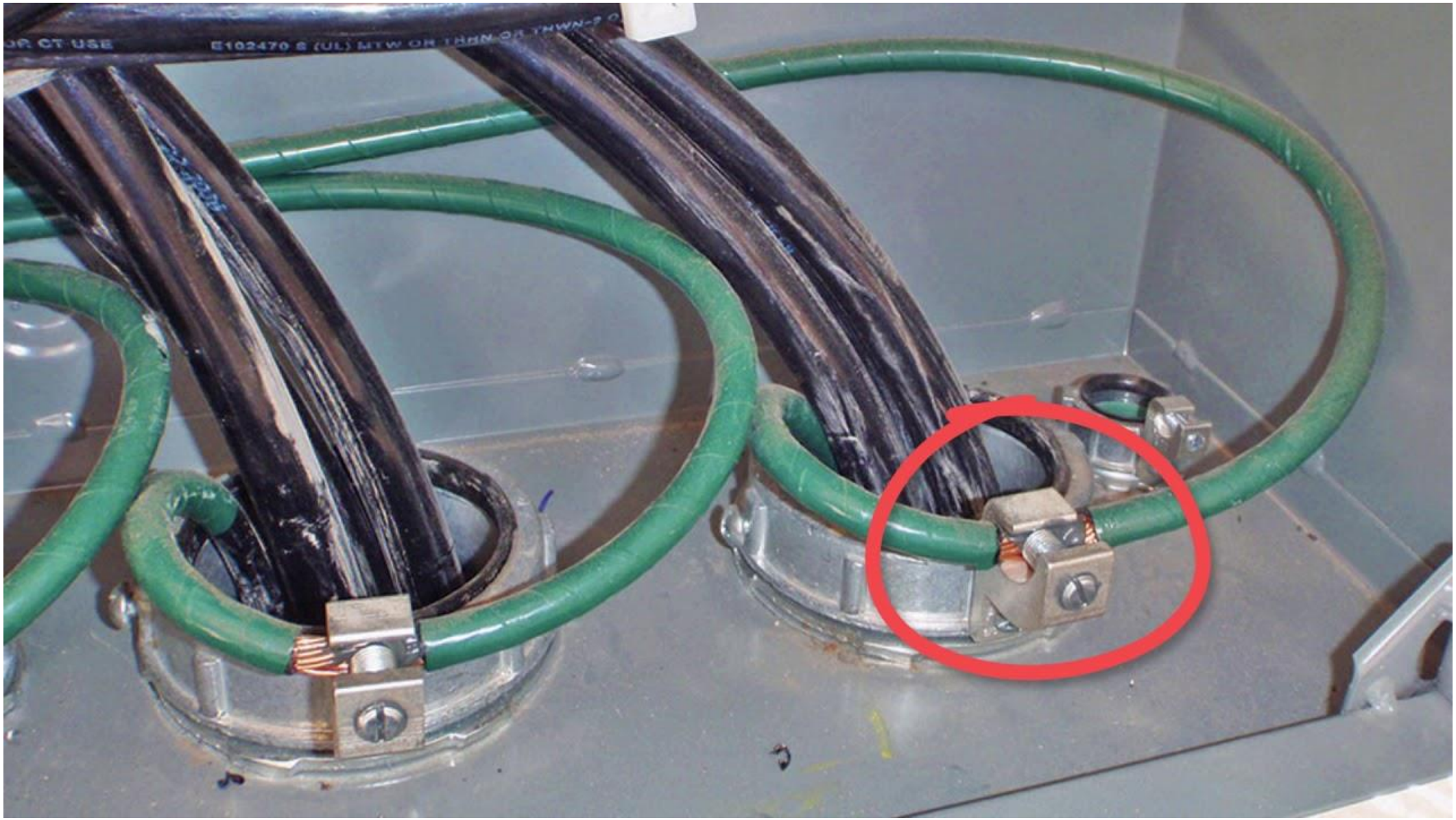

©ElectricalLicenseRenewal.Com 2020
NEC 250.86: Metal pull elbow can remain ungrounded if at least 18 inches of cover to all parts of the elbow, or 2 inches or more of concrete encasement.
PVC
18 in.
PVC
PVC
18 in.
Steel elbow
Steel elbow

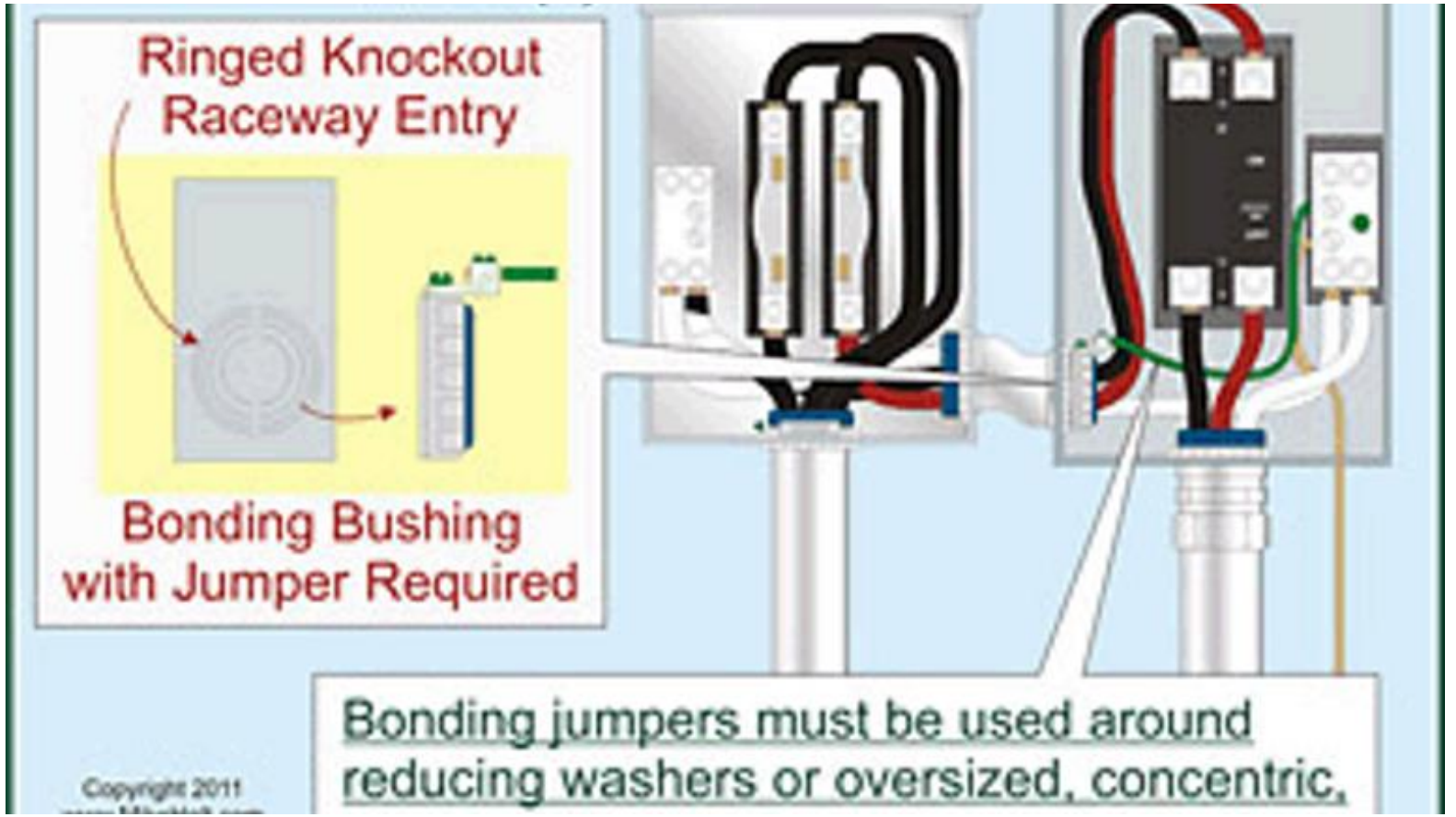

Metal Frame
Grounding
Electrode
Copyright 2011
www.MikeHolt.com
The bolts securing the structural steel column
are connected to a concrete encased electrode


Concrete-Encased
Electrode
Section 250.52(D)(3)
4 AWG
Minimum
New
Building
Note: A ground rod is not
required for this installation.
COPYRIGHT 2005
Mike Holt Enterprises, Inc.


Can be
installed from
the outside or...


...inside of a
metal box or
enclosure


CT USE
E102470 S (UL) MTW OR THHN OR THWN-2


Ringed Knockout
Raceway Entry
Bonding Bushing
with Jumper Required
Bonding jumpers must be used around
reducing washers or oversized, concentric,
Copyright 2011

Why Neutrals and Grounds are Separated in a Sub Panel – YouTube

Why Neutrals & Grounds are Connected in a Main Panel – YouTube

Ground Neutral and Hot wires explained - electrical engineering grounding ground fault - YouTube

Conductor Ampacities

Ampacity is the maximum current that a **conductor** can carry continuously under the conditions of use without exceeding its temperature rating. ...

Current is measured in amperes or “amps.” You must use the correct size **wire** for the current (load) requirement of the circuit to prevent the **wire** from overheating.

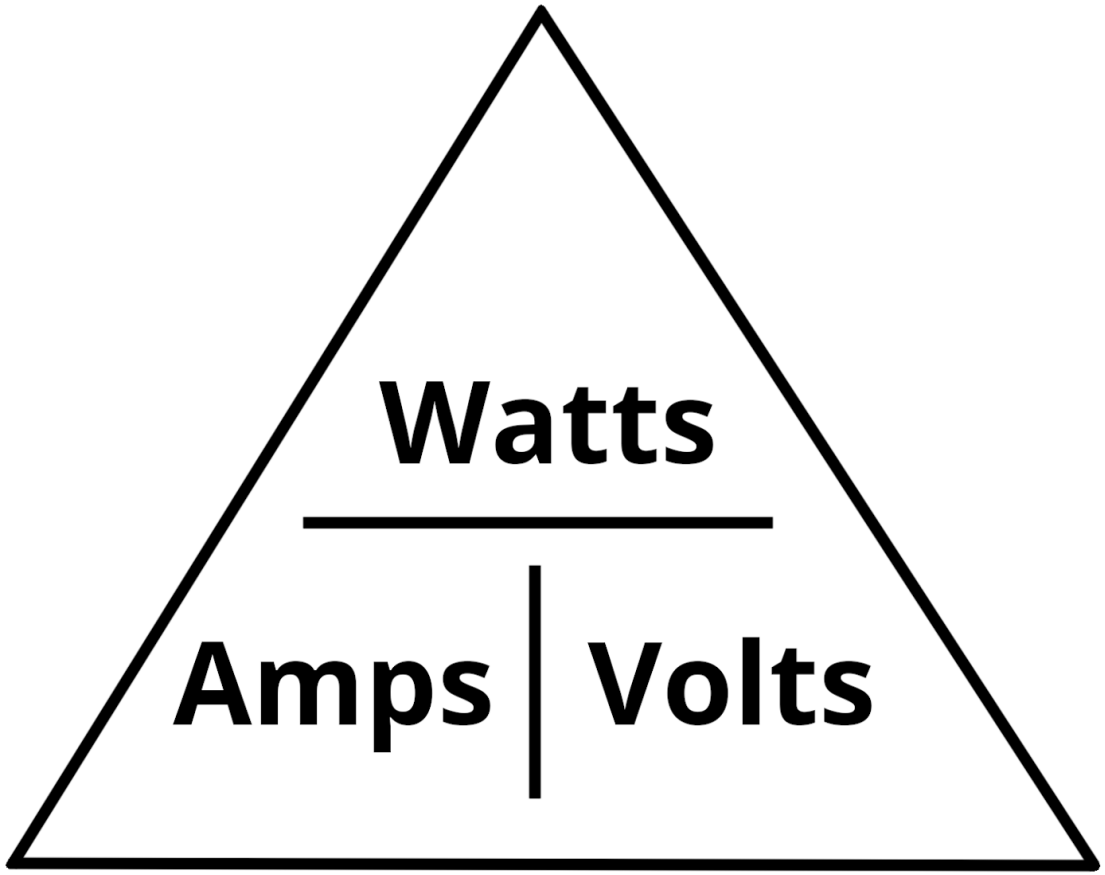
Conductor Ampacities

To obtain **Amps** you need both Watts and Volts:

The **formula** is (W)/(V) =(A).

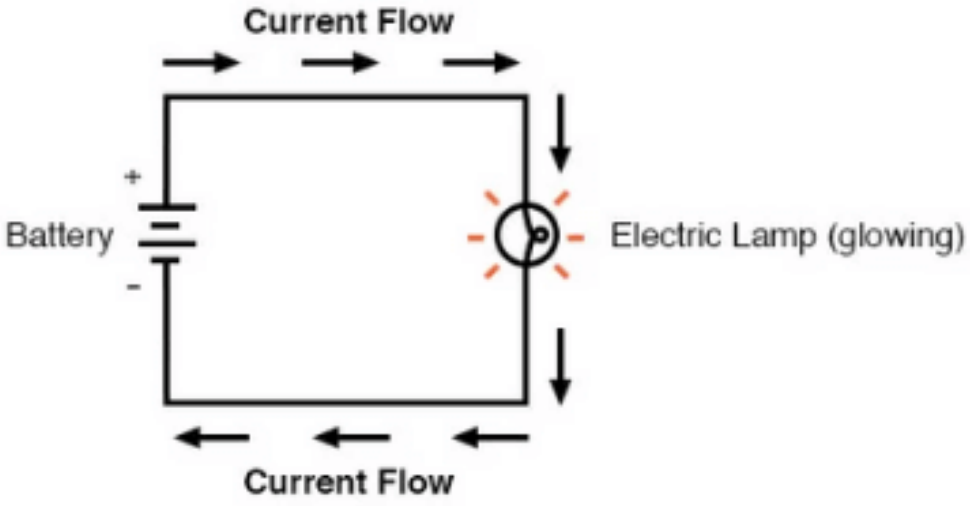
For example, if you have a 1200W toaster running at 120V, the current is 1200W / 120V = 10A.

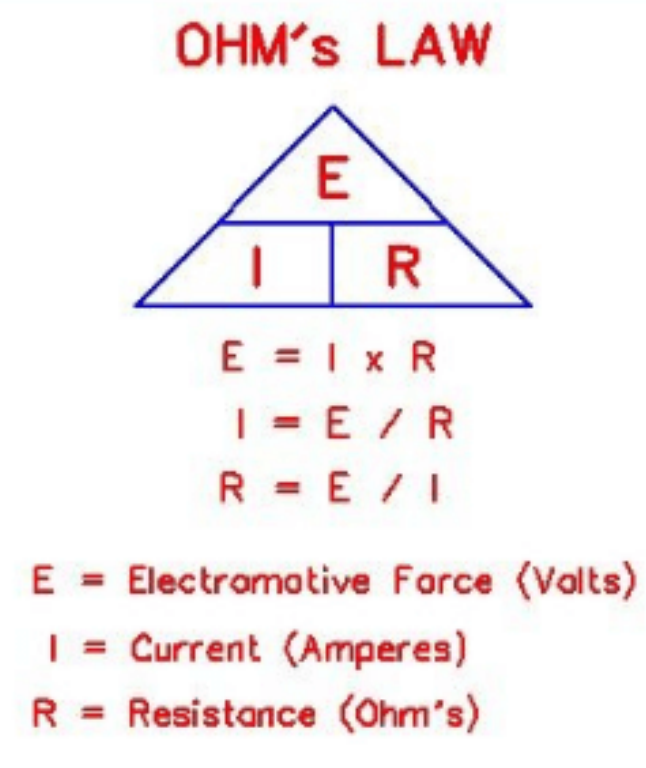
This comes from the equation I = P / V. Where P is the power in Watts, I is the current in **Amps** and V is the voltage in Volts.



amps = watts ÷ volts

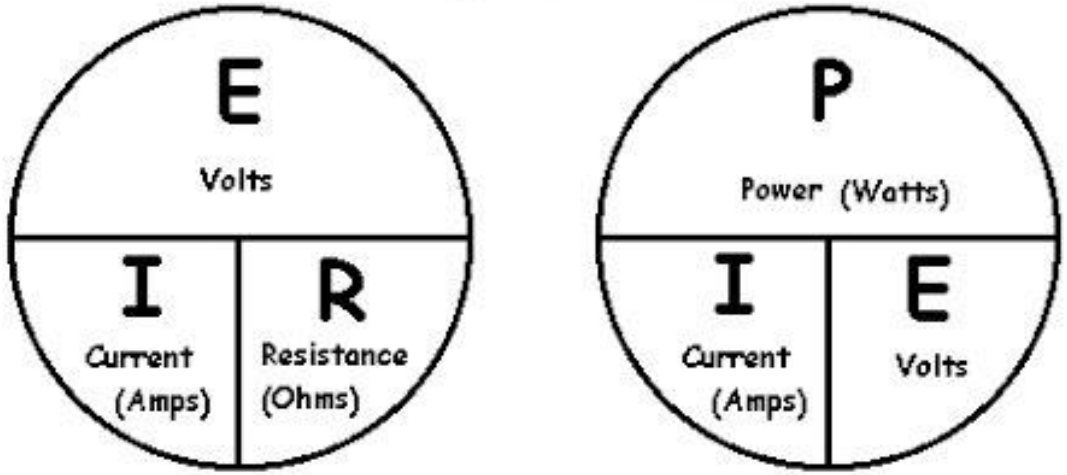
What is Ohm's Law?





Why "**I**" for current (Amps)?
From the French phrase "intensité du courant" (current intensity)
1820 Ampère's force law

Ohm's Law


E
Volts
I
Current
(Amps)
R
Resistance
(Ohms)

P
Power (Watts)
I
Current
(Amps)
E
Volts

Ohm's Law Triangle

$$V = I \times R \qquad I = \frac{V}{R} \qquad R = \frac{V}{I}$$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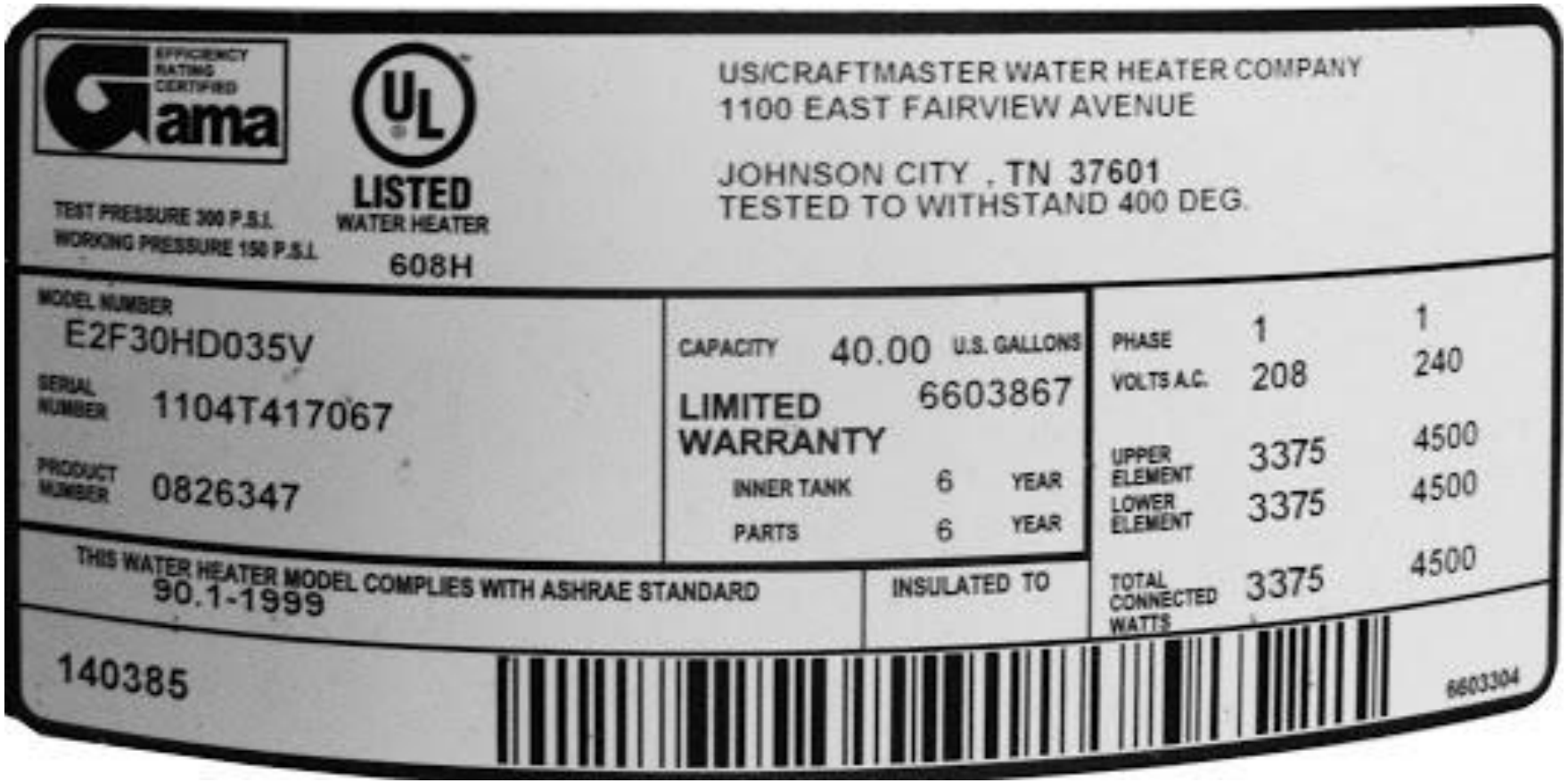
COFFEE BREWER
EXTRACTOR™
Model No.:
CBS-2052e
Serial No.: 480138030002B
THIS EQUIPMENT IS TO BE INSTALLED TO COMPLY WITH THE
APPLICABLE FEDERAL, STATE, OR LOCAL PLUMBING CODES
Electrical Configuration:
*** SINGLE OR 3 PHASE. SEE INSTRUCTIONS INSIDE LOWER COVER ***
VAC: 120/208-240
Phase: 1 or 3
Wires: 3 or 4 + grnd
Amps: 19.5 - 25.8
KW: 4.6 - 9.1
Heaters: 3 X 3 KW
USE ONLY COPPER WIRE FOR POWER SUPPLY CONNECTION
c UL us LISTED
94U1
Made in USA
September, 2003
NSF Certified to ANSI/NSF 4
COVERED BY ONE OR MORE OF THE FOLLOWING PATENTS: 5,000,082; 5,331,885; 5,943,944;
5,953,991; 6,035,761; 6,044,753; 6,135,009; 6,148,71
OTHER PATENTS MAY BE PENDING


LG
REFRIGERATOR-FREEZER
MODEL No.: GR-B472Q
CLASS Tropical
RATING 127V~ 60Hz
RATED CURRENT 2.4A
DEFROSTING INPUT 205W
RATED INPUT OF HEATER CORD 150W
RATED MAX INPUT OF LAMP
REFRIGERATOR 20W
FREEZER 15W
REFRIGERANT R134a 150g
INSULATION BLOWING GAS Cyclopentane
DIMENSIONS 680(W) × 708(D) × 1725(H) mm
SERIAL No.: Refer to bar code label.
MADE IN KOREA
3850JZ2161F


EFFICIENCY RATING CERTIFIED
Gama
UL
LISTED
WATER HEATER
608H
TEST PRESSURE 300 P.S.I.
WORKING PRESSURE 150 P.S.I.
US/CRAFTMASTER WATER HEATER COMPANY
1100 EAST FAIRVIEW AVENUE
JOHNSON CITY , TN 37601
TESTED TO WITHSTAND 400 DEG.
MODEL NUMBER
E2F30HD035V
SERIAL NUMBER
1104T417067
PRODUCT NUMBER
0826347
CAPACITY 40.00 U.S. GALLONS
6603867
LIMITED WARRANTY
INNER TANK 6 YEAR
PARTS 6 YEAR
PHASE 1 1
VOLTS A.C. 208 240
UPPER ELEMENT 3375 4500
LOWER ELEMENT 3375 4500
TOTAL CONNECTED WATTS 3375 4500
THIS WATER HEATER MODEL COMPLIES WITH ASHRAE STANDARD 90.1-1999
INSULATED TO
140385
6603304

The current rating of a cable or wire indicates the current capacity that the wire or cable can safely carry continuously.

If this limit, or current rating, is exceeded for a length of time, the heat generated may burn or melt the insulation.

The current rating of a wire is used to determine what size is needed for a given load, or current drain.

The factors that determine the current rating of a wire are:

1) **conductor size,**
2) **the location of the wire in a circuit,**
3) **the type of insulation,**
4) **the safe current rating,**
5) **the material the wire is made of.**

These factors also affect the resistance (in ohms) of a wire-carrying current.

WIRE LOCATION:

The location of a wire in a circuit determines the temperature under which it operates.

Wire may be located in a conduit or laced with other wires in a cable.

When confined in conduit, wire operates at a higher temperature than if it were open to the free air.

The higher the temperature under which a wire is operating, the greater its resistance.

When resistance is higher, current capacity is lowered.

In each case, the resistance of a wire determines its current-carrying capacity.

The greater the resistance, the more power it dissipates in the form of heat energy.

Insulation

Different types of insulation will burn or melt at different temperatures.
Therefore, the type of insulation used is the third factor that determines the current rating of a conductor.

Rubber insulation will begin deteriorating at relatively low temperatures, whereas varnished cloth insulation retains its insulating properties at higher temperatures. Other types of insulation are fluorinated ethylene propylene (FEP), silicone rubber, or extruded polytetrafluoroethylene. They are effective at still higher temperatures.

Southwire®

SIMPULL®

THHN CABLE

SOLD BY-THE-FOOT (CONTINUOUS)

QUANTITY OF 1 = 1 FOOT
QUANTITY OF 10 = 10 FEET

Thermoplastic:

This material is one that will soften and even melt when exposed to a sufficiently high temperature.

In other words, when the material is originally compounded, it becomes relatively hard yet pliable, much like most plastics we encounter in our daily lives.

However, if it is exposed to high temperature at some future time, it *softens and melts*.

The major reason for selecting a thermoplastic material is because it is the most economical type of insulation.

Some of the commonly used thermoplastic insulations used nowadays:

- PVC (Polyvinyl Chloride)
- PE (Polyethylene)
- ECTFE
- PVDF
- Nylon

Thermoset:

This material, on the other hand, *does not soften* when exposed to high temperatures.

Once it's compounded and cured, it becomes "rubbery" and retains its properties even when exposed to high temperatures.

Thermoset insulations are *usually used where the wire or cable will be exposed to high temperatures.*

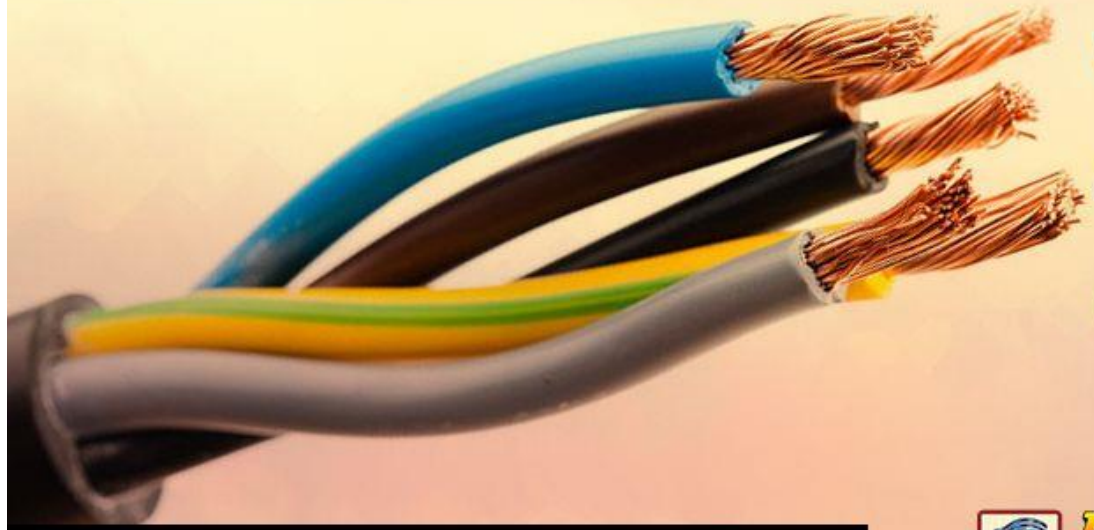
Some thermoset insulations often used are:

- XLPE
- CPE
- EPR

THW	**THHN / THWN**	**XLP-XHHW**	**EPR HYPALON**
Supply Problem	Stock	Stock	Stock
Lowest Cost	Low Cost-Circuit Sizes	Low Cost-Large Sizes	Highest Cost
75°C	90°C / 75°C	90°C	90°C / 75°C
Colors	Colors	Colors	Black Only
Larger OD	Small OD	Small OD	Larger OD
Fair Electricals	Fair Electricals	Good Electricals	Good Electricals
Good Moisture Res.	Good Moisture Res.	Excellent Moisture Res.	Excellent Moisture Res.
Pulls Easy	Pulls Easy	Pulls Easy	Pulls Harder
Good Flame Res.	Good Flame Res.	Poor Flame Res.	Good Flame Res.
Good Oil Res.	Good Oil Res.	Poor Oil Res.	Good Oil Res.
Good Chemical	Good Chemical	Good Chemical	Good Chemical
Poor Low Temp. -10°C(+14°)	Poor Low Tep. -10°C (+14°)	Excellent Low Temp.	Good Low Temp.

WIRE LETTERING

The letters THHN, THWN, THW and XHHN represent the main insulation types of individual wires. These letters depict the following NEC requirements:



- **T** Thermoplastic Insulation
- **H** Heat Resistance
- **HH** High Heat Resistance (up to 194°F)
- **W** Suitable For Wet Locations
- **N** Nylon coating, resistant to damage by oil or gas
- **X** Synthetic polymer that is flame-resistant

Toll Free No: 180030005331

www.plazacables.com

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AN ISO 9001 & 14001 CERTIFIED COMPANY
Your Powerful partner

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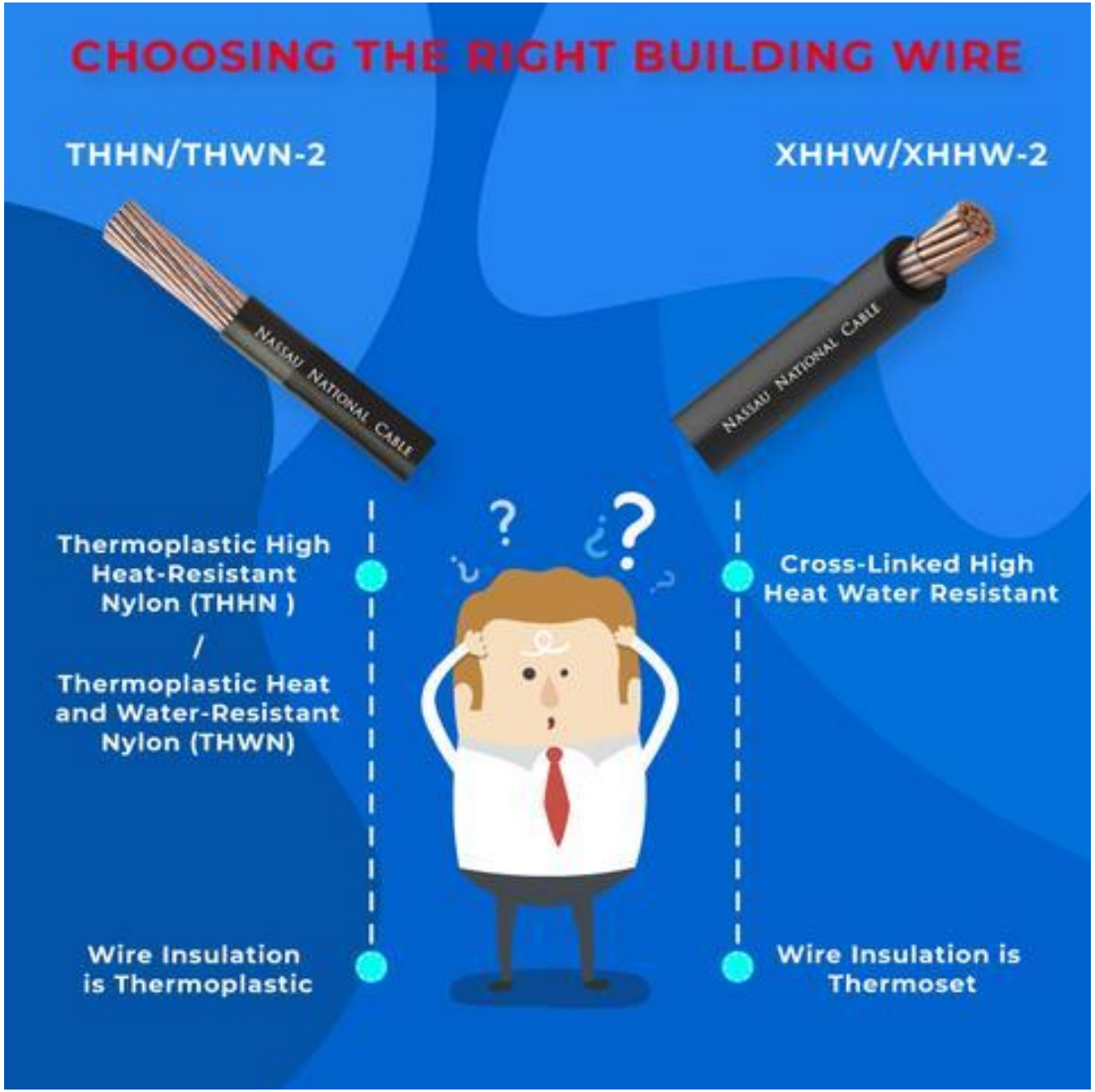
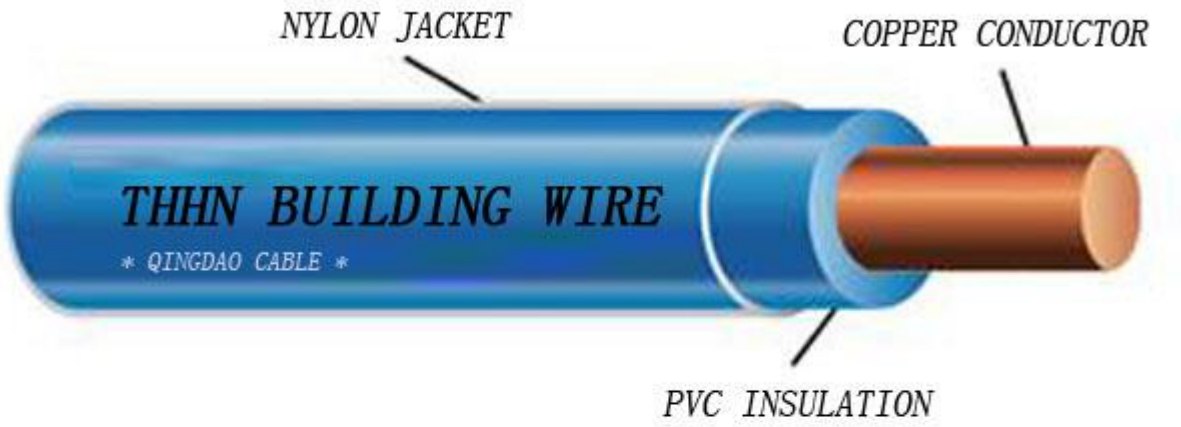
if exposed to high temperature at some future time, it *softens and melts*.

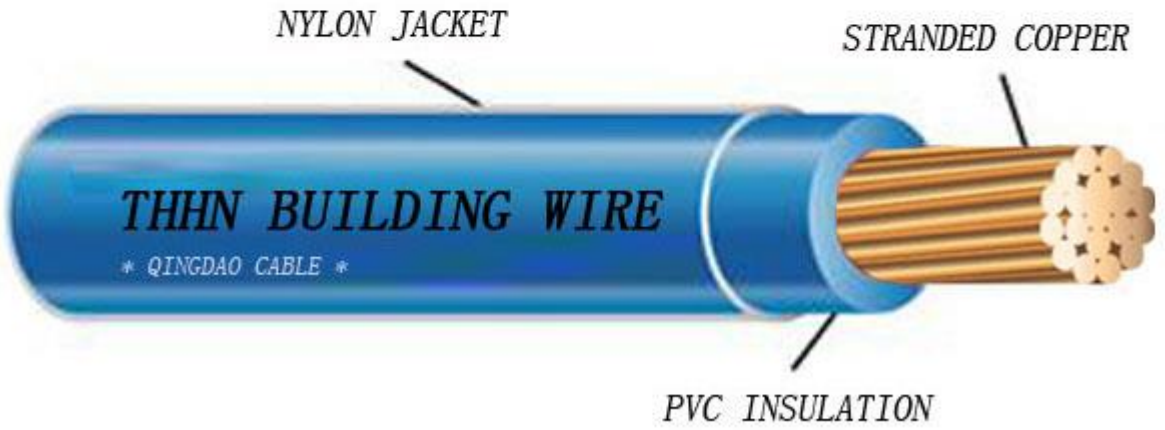
Most Economical



does not soften when exposed to high temperatures.



14-10 AWG
Flexible when smaller



14-4/0 AWG
Flexible when larger


AARGH!!

Table 3.10.1.16 Allowable Ampacities of Insulated Conductors Rated 0 Through 2000 Volts, 60°C Through 90°C (140°F Through 194°F), Not More Than Three Current-Carrying Conductors in Raceway, Cable, or Earth (Directly Buried), Based on Ambient Temperature of 30°C (86°F)

Size mm²(mm dia.)	Temperature Rating of Conductor (See Table 3.10.1.13.)						Size mm²(mm dia.)
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	
	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, USE, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, USE, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	
	COPPER			ALUMINUM OR COPPER-CLAD ALUMINUM			
2.0(1.6)*	20	20	25	—	—	—	2.0(1.6)*
3.5(2.0)*	25	25	30	20	20	25	3.5(2.0)*
5.5(2.6)*	30	35	40	25	30	35	5.5(2.6)*
8.0(3.2)	40	50	55	30	40	45	8.0(3.2)
14	55	65	70	40	50	60	14
22	70	85	90	55	65	80	22
30	90	110	115	65	80	90	30
38	100	125	130	75	90	105	38
50	120	145	150	95	110	125	50
60	135	160	170	100	120	135	60
80	160	195	205	120	145	165	80
100	185	220	225	140	170	190	100
125	210	255	265	165	200	225	125
150	240	280	295	185	225	250	150
175	260	305	345	205	245	275	175
200	280	330	355	220	265	300	200
250	315	375	400	255	305	345	250

Table 3.10.1.16 Allowable Ampacities of Insulated Conductors Rated 0 Through 2000 Volts, 60°C Through 90°C (140°F Through 194°F), Not More Than Three Current-Carrying Conductors in Raceway, Cable, or Earth (Directly Buried), Based on Ambient Temperature of 30°C (86°F)

Size mm²(mm dia.)	Temperature Rating of Conductor (See Table 3.10.1.13.)						Size mm²(mm dia.)
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	
	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, USE, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, USE, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	
	COPPER			ALUMINUM OR COPPER-CLAD ALUMINUM			
2.0(1.6)*	20	20	25	—	—	—	2.0(1.6)*
3.5(2.0)*	25	25	30	20	20	25	3.5(2.0)*
5.5(2.6)*	30	35	40	25	30	35	5.5(2.6)*
8.0(3.2)	40	50	55	30	40	45	8.0(3.2)
14	55	65	70	40	50	60	14
22	70	85	90	55	65	80	22
30	90	110	115	65	80	90	30
38	100	125	130	75	90	105	38
50	120	145	150	95	110	125	50
60	135	160	170	100	120	135	60
80	160	195	205	120	145	165	80
100	185	220	225	140	170	190	100
125	210	255	265	165	200	225	125
150	240	280	295	185	225	250	150
175	260	305	345	205	245	275	175
200	280	330	355	220	265	300	200
250	315	375	400	255	305	345	250

CORRECTION FACTORS

Ambient Temp. (°C)	For ambient temperatures other than 30°C (86°F), multiply the allowable ampacities shown above by the appropriate factor shown below.						Ambient Temp. (°F)
21–25	1.08	1.05	1.04	1.08	1.05	1.04	70–77
26–30	1.00	1.00	1.00	1.00	1.00	1.00	78–86
31–35	0.91	0.94	0.96	0.91	0.94	0.96	87–95
36–40	0.82	0.88	0.91	0.82	0.88	0.91	96–104
41–45	0.71	0.82	0.87	0.71	0.82	0.87	105–113
46–50	0.58	0.75	0.82	0.58	0.75	0.82	114–122
51–55	0.41	0.67	0.76	0.41	0.67	0.76	123–131
56–60	—	0.58	0.71	—	0.58	0.71	132–140

CORRECTION FACTORS

Ambient Temp. (°C)	For ambient temperatures other than 30°C (86°F), multiply the allowable ampacities shown above by the appropriate factor shown below.						Ambient Temp. (°F)
21–25	1.08	1.05	1.04	1.08	1.05	1.04	70–77
26–30	1.00	1.00	1.00	1.00	1.00	1.00	78–86
31–35	0.91	0.94	0.96	0.91	0.94	0.96	87–95
36–40	0.82	0.88	0.91	0.82	0.88	0.91	96–104
41–45	0.71	0.82	0.87	0.71	0.82	0.87	105–113
46–50	0.58	0.75	0.82	0.58	0.75	0.82	114–122
51–55	0.41	0.67	0.76	0.41	0.67	0.76	123–131
56–60	—	0.58	0.71	—	0.58	0.71	132–140
61–70	—	0.33	0.58	—	0.33	0.58	141–158
71–80	—	—	0.41	—	—	0.41	159–176

***See 240.4(D)**

240.4 “Protection of Conductors”

240.4(D) Small Conductors
Unless specifically permitted in (E) or (G), the overcurrent protection shall not exceed that required by (1) through (7) after any correction factors… have been applied.

(1) 18 AWG Copper 7 amps, 5.6 amps continuous…

(2) 16 AWG Copper 10 amps, 8 amps continuous…

(3) 14 AWG Copper 15 amps

(4) 12 AWG Aluminum & Copper-Clad Aluminum 15 amps

(5) 12 AWG Copper 20 amps

(6) 10 AWG Aluminum & Copper-Clad Aluminum 25 amps

(7) 10 AWG Copper 30 amps

240.4(B) Devices Rated 800 Amps of Less

The next higher standard overcurrent device rating (above the ampacity of the conductors being protected) shall be permitted to be used, provided all of the following conditions are met:

(1) … not part of multi-outlet branch circuit…

(2) … ampacity of conductor does not correspond with standard breaker or fuse rating…

(3) … next higher standard rating…does not exceed 800 amps

What wire size may be on this breaker (15 amp)?

12 AWG Copper ? ✓

14 AWG Copper ? ✓

16 AWG Copper ? ⊘

What wire size may be on this breaker (25 amp)?

12 AWG Copper ? ⊘

10 AWG Copper ? ✓

8 AWG Copper ? ✓

(2) … ampacity of conductor does not correspond with standard breaker or fuse rating…

What wire size may be on this breaker (25 amp)?

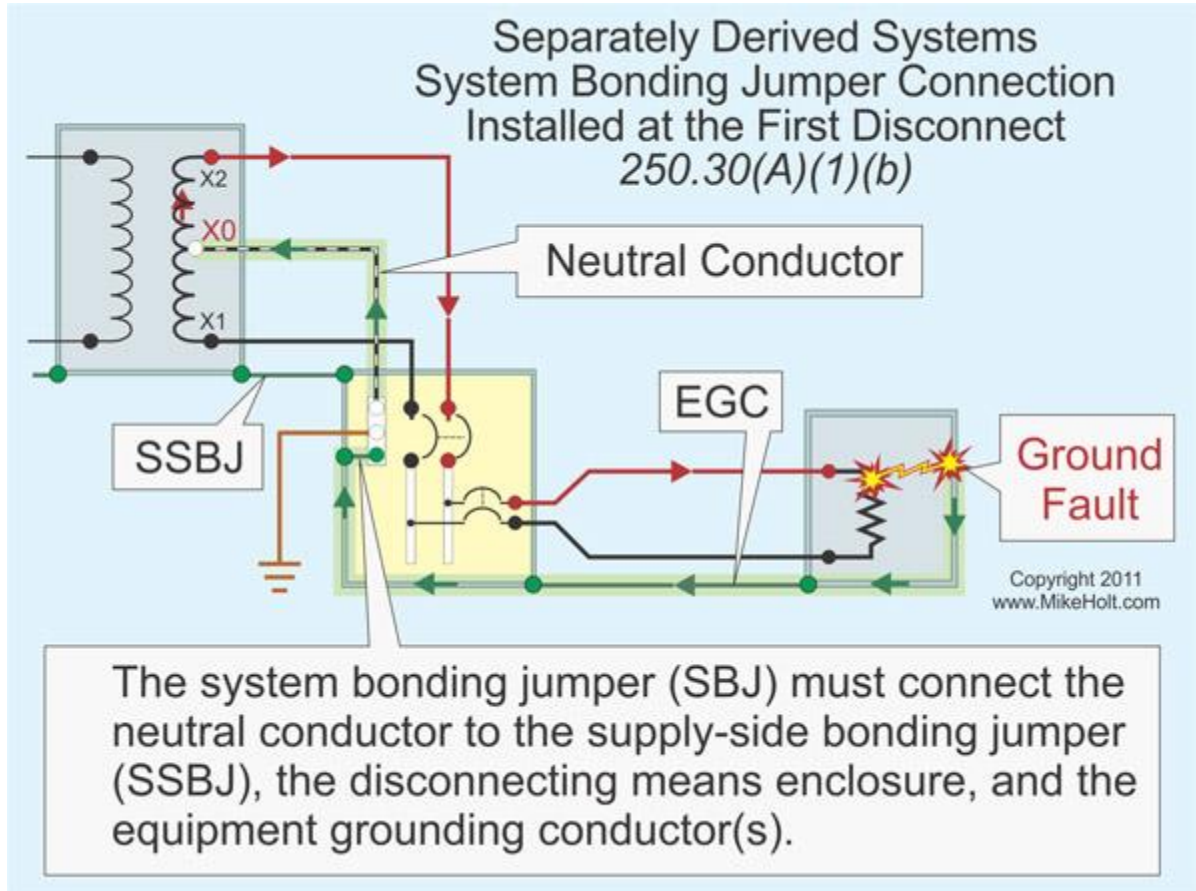
12 AWG Copper ? ⊘

10 AWG Copper ? ⊘

8 AWG Copper ? ⊘

Why not?

It’s a F.P.E. That’s why.
“F…in Poor Equipment”


Separately Derived Systems
System Bonding Jumper Connection
Installed at the First Disconnect
250.30(A)(1)(b)
X2
X0
X1
Neutral Conductor
EGC
SSBJ
Ground Fault
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www.MikeHolt.com
The system bonding jumper (SBJ) must connect the neutral conductor to the supply-side bonding jumper (SSBJ), the disconnecting means enclosure, and the equipment grounding conductor(s).

TABLE 310.15(B)(7) Conductor Types and Sizes for 120/240-Volt, 3-Wire, Single-Phase Dwelling Services and Feeders. Conductor Types RHH, RHW, RHW-2, THHN, THHW, THW, THW-2, THWN, THWN-2, XHHW, XHHW-2, SE, USE, USE-2

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

TABLE 310.15(B)(16) *(formerly Table 310.16) Allowable Ampacities of Insulated Conductors Rated Up to and Including 2000 Volts, 60°C Through 90°C (140°F Through 194°F), Not More Than Three Current-Carrying Conductors in Raceway, Cable, or Earth (Directly Buried), Based on Ambient Temperature of 30°C (86°F)**

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

*Refer to 310.15(B)(2) for the ampacity correction factors where the ambient temperature is other than 30°C (86°F). Refer to 310.15(B)(3)(a) for more than three current-carrying conductors.

**Refer to 240.4(D) for conductor overcurrent protection limitations.

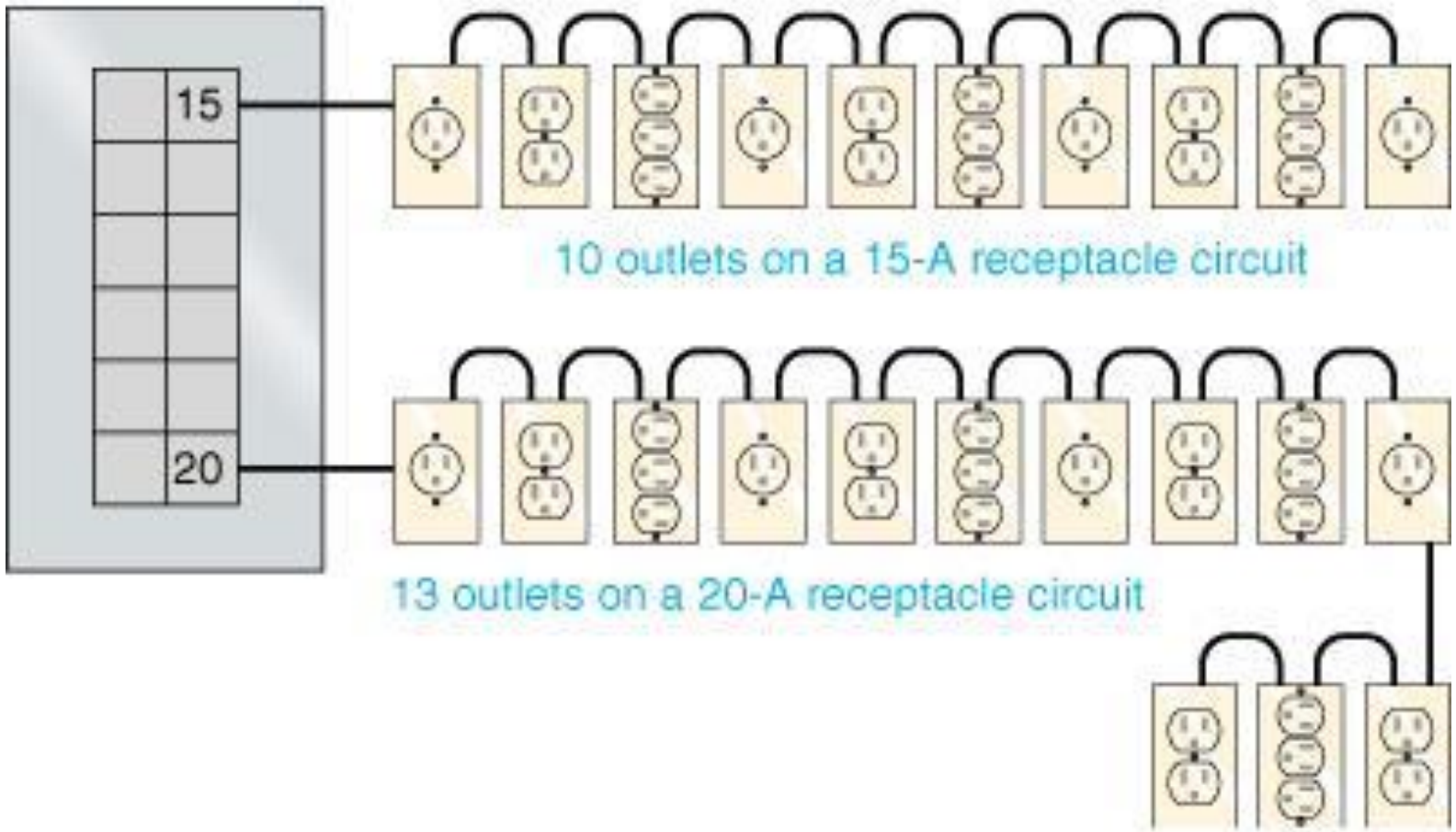
Size AWG or kcmil	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, USE, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, USE	Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	Size AWG or kcmil
	COPPER			ALUMINUM OR COPPER-CLAD ALUMINUM			
18**	—	—	14	—	—	—	—
16**	—	—	18	—	—	—	—
14**	15	20	25	—	—	—	—
12**	20	25	30	15	20	25	12**
10**	30	35	40	25	30	35	10**
8	40	50	55	35	40	45	8
6	55	65	75	40	50	55	6
4	70	85	95	55	65	75	4
3	85	100	115	65	75	85	3
2	95	115	130	75	90	100	2
1	110	130	145	85	100	115	1
1/0	125	150	170	100	120	135	1/0
2/0	145	175	195	115	135	150	2/0
3/0	165	200	225	130	155	175	3/0
4/0	195	230	260	150	180	205	4/0

Trivia Time:

How many duplex receptacles can be on a single 20 amp breaker?

Answer: 13

220.14(I) …outlets shall be calculated at not less than 180 volt-amperes…on one yoke…
180 volt-amperes / 120 volts
= 1.5 amps X 13 = 19.5 amps



Picture from Handbook

Box & Conduit Fill

314.16 Number of Conductors in Outlet Device, Junction Boxes and Conduit Bodies

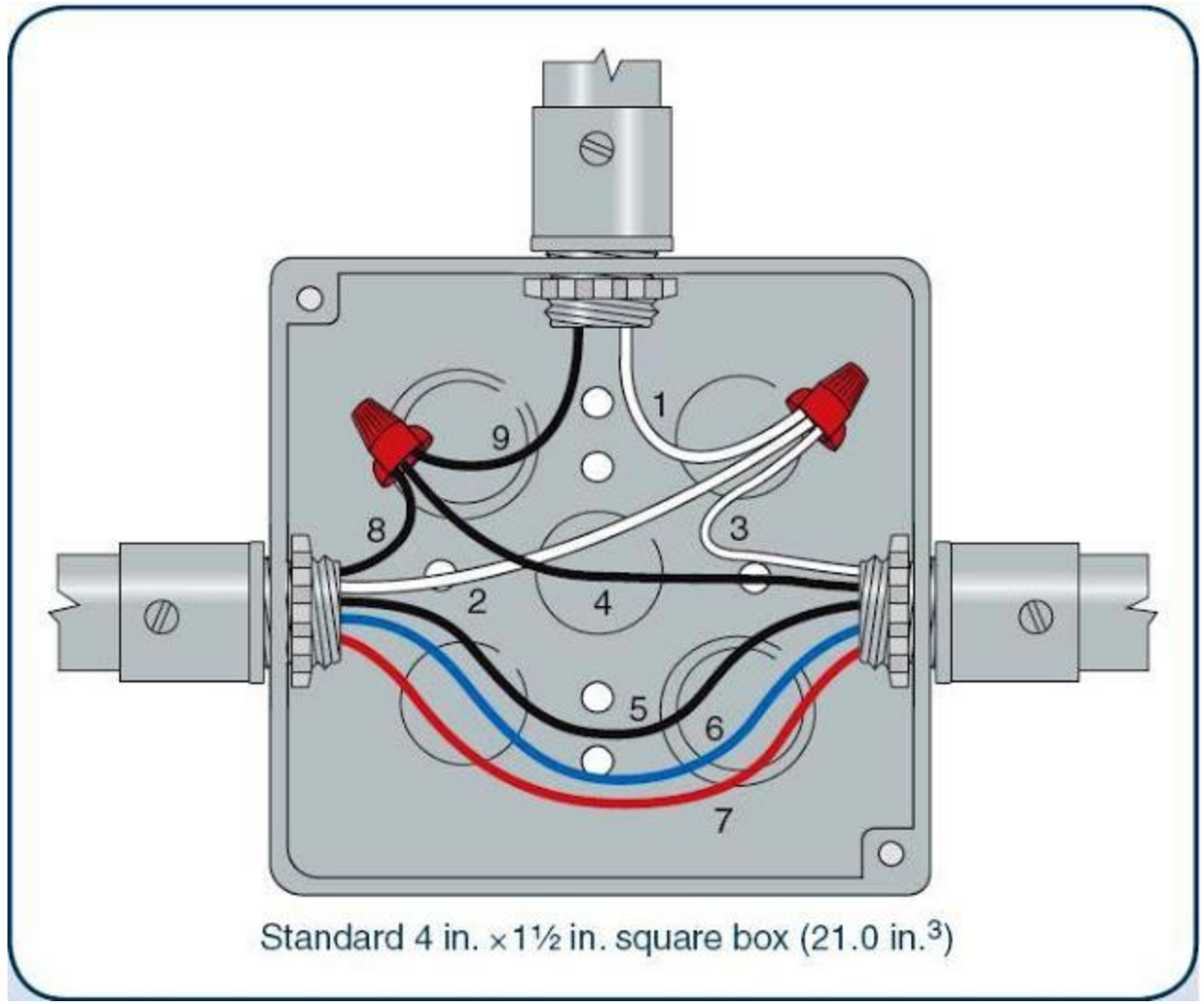
TABLE 314.16(A) Metal Boxes

Box Trade Size			Minimum Volume		Maximum Number of Conductors* (arranged by AWG size)						
mm	in.		cm^3	$in.^3$	18	16	14	12	10	8	6
100 × 32	(4 × 1¼)	round/octagonal	205	12.5	8	7	6	5	5	5	2
100 × 38	(4 × 1½)	round/octagonal	254	15.5	10	8	7	6	6	5	3
100 × 54	(4 × 2⅛)	round/octagonal	353	21.5	14	12	10	9	8	7	4
100 × 32	(4 × 1¼)	square	295	18.0	12	10	9	8	7	6	3
100 × 38	(4 × 1½)	square	344	21.0	14	12	10	9	8	7	4
100 × 54	(4 × 2⅛)	square	497	30.3	20	17	15	13	12	10	6
120 × 32	(4 11/16 × 1¼)	square	418	25.5	17	14	12	11	10	8	5
120 × 38	(4 11/16 × 1½)	square	484	29.5	19	16	14	13	11	9	5
120 × 54	(4 11/16 × 2⅛)	square	689	42.0	28	24	21	18	16	14	8
75 × 50 × 38	(3 × 2 × 1½)	device	123	7.5	5	4	3	3	3	2	1
75 × 50 × 50	(3 × 2 × 2)	device	164	10.0	6	5	5	4	4	3	2
753 50 × 57	(3 × 2 × 2¼)	device	172	10.5	7	6	5	4	4	3	2
75 × 50 × 65	(3 × 2 × 2½)	device	205	12.5	8	7	6	5	5	4	2
75 × 50 × 70	(3 × 2 × 2¾)	device	230	14.0	9	8	7	6	5	4	2
75 × 50 × 90	(3 × 2 × 3½)	device	295	18.0	12	10	9	8	7	6	3
100 × 54 × 38	(4 × 2⅛ × 1½)	device	169	10.3	6	5	5	4	4	3	2
100 × 54 × 48	(4 × 2⅛ × 1⅞)	device	213	13.0	8	7	6	5	5	4	2
100 × 54 × 54	(4 × 2⅛ × 2⅛)	device	238	14.5	9	8	7	6	5	4	2
95 × 50 × 65	(3¾ × 2 × 2½)	masonry box/gang	230	14.0	9	8	7	6	5	4	2
95 × 50 × 90	(3¾ × 2 × 3½)	masonry box/gang	344	21.0	14	12	10	9	8	7	4
min. 44.5 depth	FS — single cover/gang (1¾)		221	13.5	9	7	6	6	5	4	2
min. 60.3 depth	FD — single cover/gang (2⅜)		295	18.0	12	10	9	8	7	6	3
min. 44.5 depth	FS — multiple cover/gang (1¾)		295	18.0	12	10	9	8	7	6	3
min. 60.3 depth	FD — multiple cover/gang (2⅜)		395	24.0	16	13	12	10	9	8	4

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

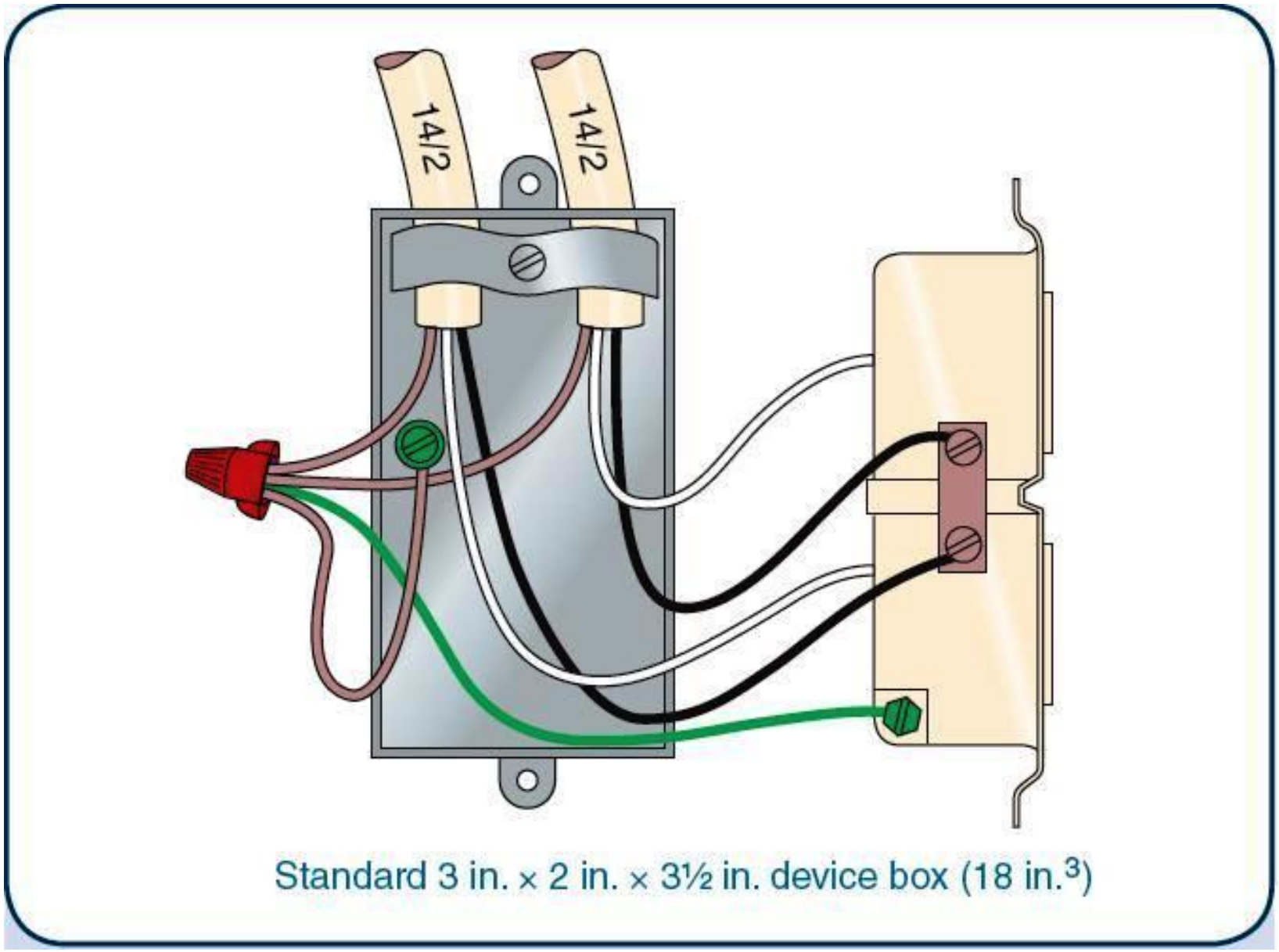
TABLE 314.16(B) Volume Allowance Required per Conductor

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

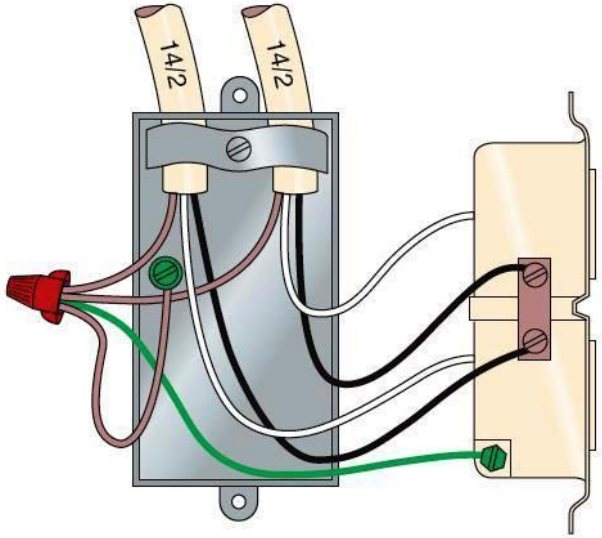


Standard 4 in. ×1½ in. square box (21.0 in.^{3})

Items Contained in Box	Volume Allowance	Based on (see Table)
Conductors that originate outside box	1 for each conductor	based on conductor size
Conductors that pass through box without splice	1 for each conductor	based on conductor size
Conductors 12 inch or greater looped inside box	2 for single	based on conductor size
Conductors that originate and don’t leave box	None, not counted	
Fixture wires	None, not counted	
Internal clamps	1 for each	based on largest conductor
Receptacle & switches on same yoke	2 for each yoke	based on largest conductor
Equipment Grounding Conductor (EGC)	1 only	based on largest EGC



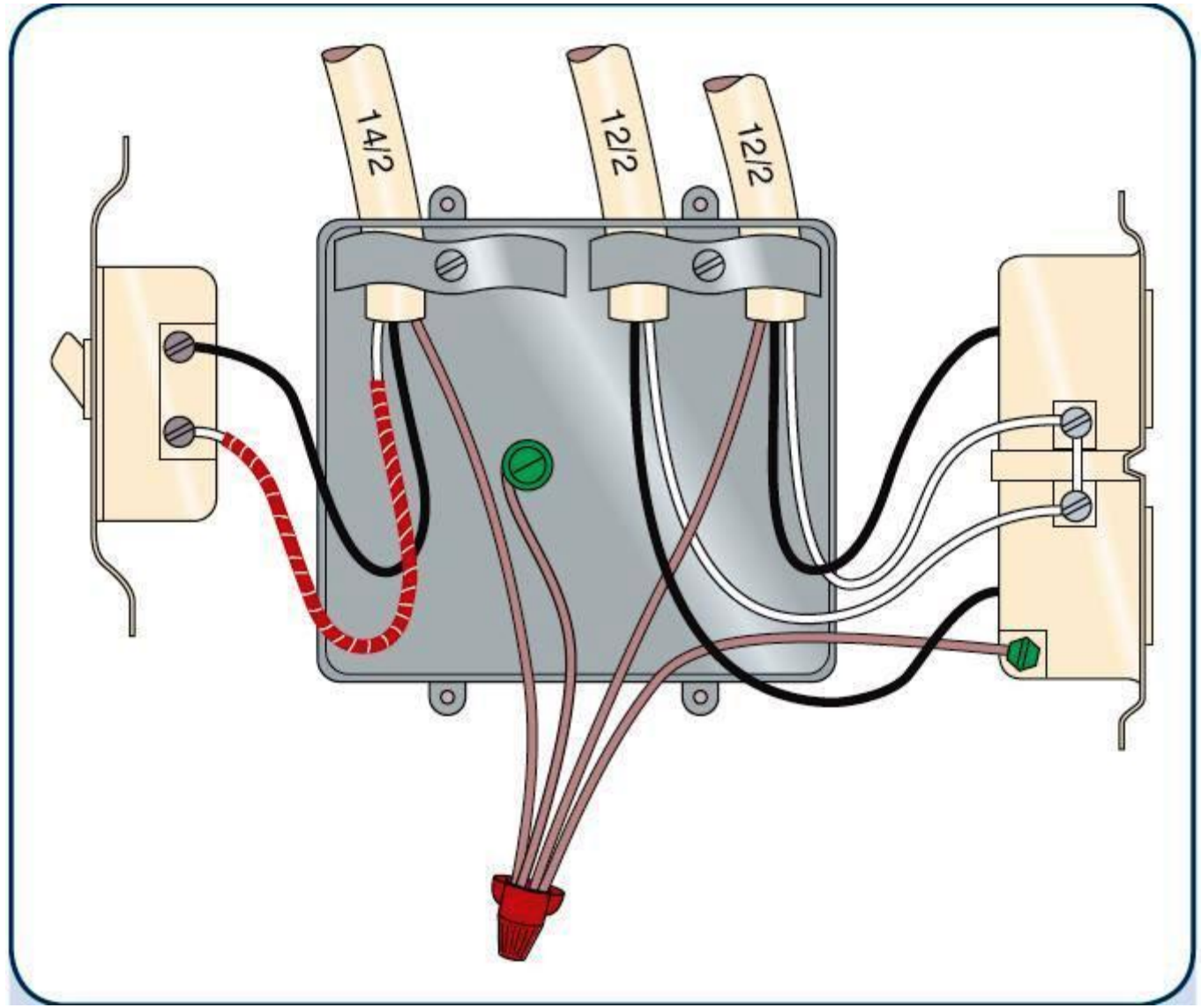
Standard 3 in. × 2 in. × 3½ in. device box (18 in.^{3})

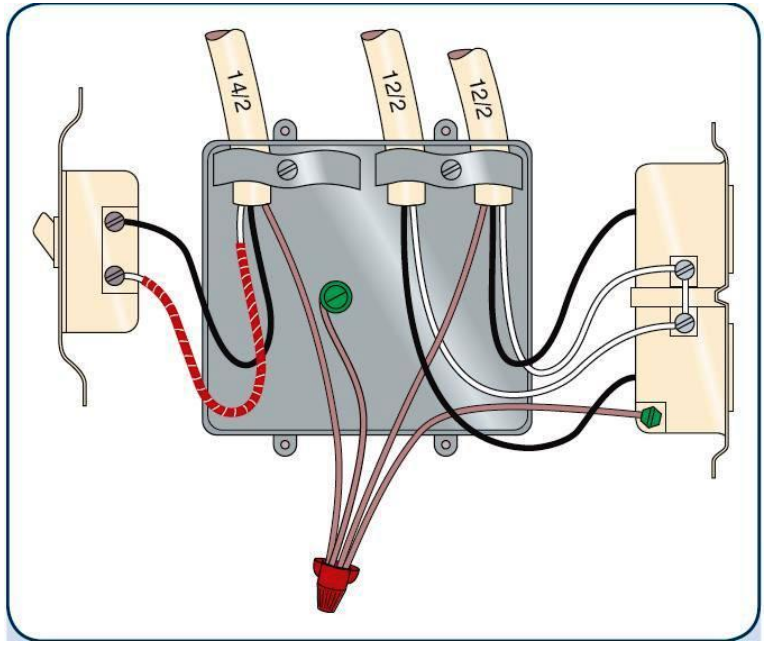


Standard 3 in. × 2 in. × 3½ in. device box (18 in.^{3})

Commentary Table 314.2 Total Box Fill for Example 2

Items Contained Within Box	Volume Allowance	Unit Volume Based on Table 314.16(B) (in.^{3})	Total Box Fill (in.^{3})
4 conductors	4 volume allowances for 14 AWG conductors	2.00	8.00
1 clamp	1 volume allowance (based on 14 AWG conductors)	2.00	2.00
1 device	2 volume allowances (based on 14 AWG conductors)	2.00	4.00
Equipment grounding conductors (all)	1 volume allowance (based on 14 AWG conductors)	2.00	2.00
Total			16.00


14/2
12/2
12/2



Commentary Table 314.3 Total Box Fill for Example 3

Items Contained Within Box	Volume Allowance	Unit Volume Based on Table 314.16(B) (in.³)	Total Box Fill (in.³)
6 conductors	2 volume allowances for 14 AWG conductors	2.00	4.00
	4 volume allowances for 12 AWG conductors	2.25	9.00
2 clamps	1 volume allowance (based on 12 AWG conductors)	2.25	2.25
2 devices	2 volume allowances (based on 14 AWG conductors)	2.00	4.00
	2 volume allowances (based on 12 AWG conductors)	2.25	4.50
Equipment grounding conductors (all)	1 volume allowance (based on 12 AWG conductors)	2.25	2.25
Total			26.00

TABLE 314.16(A) Metal Boxes

Box Trade Size			Minimum Volume		Maximum Number of Conductors* (arranged by AWG size)						
mm	in.		cm^3	$in.^3$	18	16	14	12	10	8	6
100 × 32	(4 × 1¼)	round/octagonal	205	12.5	8	7	6	5	5	5	2
100 × 38	(4 × 1½)	round/octagonal	254	15.5	10	8	7	6	6	5	3
100 × 54	(4 × 2⅛)	round/octagonal	353	21.5	14	12	10	9	8	7	4
100 × 32	(4 × 1¼)	square	295	18.0	12	10	9	8	7	6	3
100 × 38	(4 × 1½)	square	344	21.0	14	12	10	9	8	7	4
100 × 54	(4 × 2⅛)	square	497	30.3	20	17	15	13	12	10	6
120 × 32	(4 11/16 × 1¼)	square	418	25.5	17	14	12	11	10	8	5
120 × 38	(4 11/16 × 1½)	square	484	29.5	19	16	14	13	11	9	5
120 × 54	(4 11/16 × 2⅛)	square	689	42.0	28	24	21	18	16	14	8
75 × 50 × 38	(3 × 2 × 1½)	device	123	7.5	5	4	3	3	3	2	1
75 × 50 × 50	(3 × 2 × 2)	device	164	10.0	6	5	5	4	4	3	2
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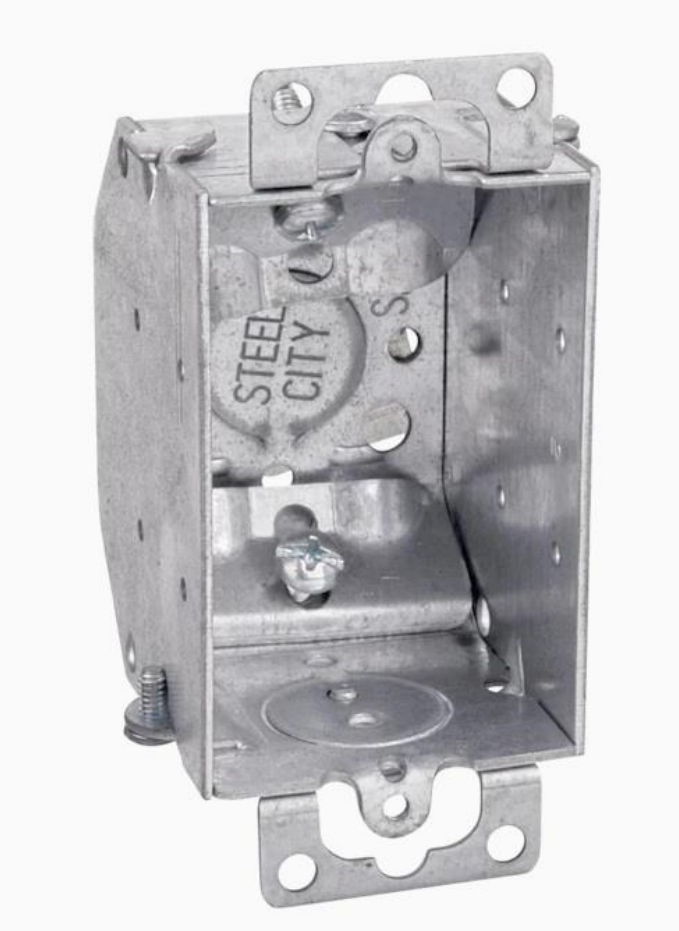
75 × 50 × 70	(3 × 2 × 2¾)	device	230	14.0	9	8	7	6	5	4	2
75 × 50 × 90	(3 × 2 × 3½)	device	295	18.0	12	10	9	8	7	6	3
100 × 54 × 38	(4 × 2⅛ × 1½)	device	169	10.3	6	5	5	4	4	3	2
100 × 54 × 48	(4 × 2⅛ × 1⅞)	device	213	13.0	8	7	6	5	5	4	2
100 × 54 × 54	(4 × 2⅛ × 2⅛)	device	238	14.5	9	8	7	6	5	4	2
95 × 50 × 65	(3¾ × 2 × 2½)	masonry box/gang	230	14.0	9	8	7	6	5	4	2
95 × 50 × 90	(3¾ × 2 × 3½)	masonry box/gang	344	21.0	14	12	10	9	8	7	4
min. 44.5 depth	FS — single cover/gang (1¾)		221	13.5	9	7	6	6	5	4	2
min. 60.3 depth	FD — single cover/gang (2⅜)		295	18.0	12	10	9	8	7	6	3
min. 44.5 depth	FS — multiple cover/gang (1¾)		295	18.0	12	10	9	8	7	6	3
min. 60.3 depth	FD — multiple cover/gang (2⅜)		395	24.0	16	13	12	10	9	8	4

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



Metal box 10.5 cubic inches

Thomas & Betts B118 Box
= 18 cubic inch

Carlon A122 Box = 22 cubic inch

How many 12-2 with ground NM wires can be crammed in a box?

12 AWG = 2.25 cu. in. each

Metal box 10.5 cubic inch
18 cubic inch
22 cubic inch

4 volume allowances for 12 AWG conductor	9.00
1 volume allowances for device 12 AWG conductor	2.25
1 volume allowances for EGC 12 AWG conductor	2.25
	13.5

https://www.constructionmonkey.com/calculations/electrical/boxfill