

Unit 6

CONDUCTOR SIZING AND PROTECTION CALCULATIONS

Part A—Conductor Requirements

6.1 Conductor Insulation [310.104(A)]

Table 310.104(A) provides information on conductor insulation properties such as letter type, operation temperature, application, insulation, and outer cover properties. Only conductors in Tables 310.104(A) through 310.104(E) can be installed, and only for the application identified in the tables. The following abbreviations and explanations are helpful in understanding Tables 310.13 and 310.16.

Author's Comment:

- The following explains the lettering on conductor insulation [Table 310.104(A)]: **Figure 6–1**
 - No H 60°C insulation rating
 - H 75°C insulation rating
 - HH 90°C insulation rating
 - N Nylon outer cover
 - R Thermoset insulation
 - T Thermoplastic insulation
 - U Underground
 - W Wet or damp locations
 - X Cross-linked polyethylene insulation

➡ See page 139 for Table 310.104(A) Conductor Applications and Insulations.

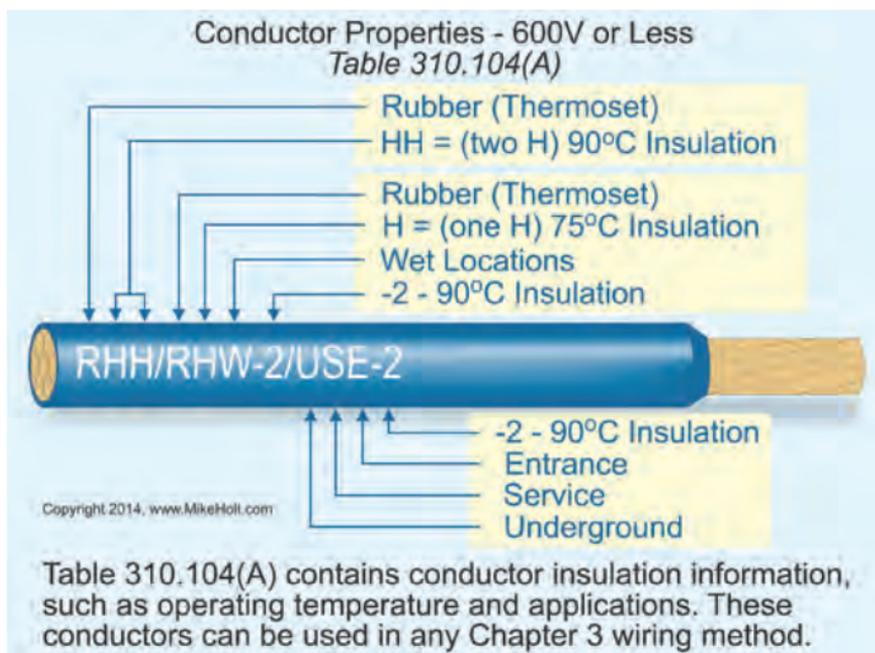


Figure 6-1

Other Conductor Construction and Application

Author's Comment:

- The following abbreviations and explanations will be helpful in understanding Tables 310.15(B)(16) and 310.104(A).
 - -2 Conductor is permitted to be used at a continuous 90°C operating temperature in a wet or dry location [Table 310.15(B)(16)]
 - F Fixture wires (solid or 7 strands) [Table 402.3]
 - FF Flexible fixture wire (19 strands) [Table 402.3]

For more information about fixture wires, see Article 402, Table 402.3, and Table 402.5. For more information on flexible cords and flexible cables, see Article 400, Table 400.4, Table 400.5(A), and Table 400.5(B).

It's common to see conductors with a dual insulation rating, such as THHN/THWN. This type of conductor can be used in a dry location at the THHN 90°C ampacity, or if used in a wet location, the THWN ampacity rating of the 75°C column of Table 310.15(B)(16) for THWN insulation types must be adhered to. When a -2 is added at the end of an insulation type, such as THWN-2, that means that the conductor can be used in a wet or dry location at the 90°C ampacity rating.

6.2 Conductor Sizes

Conductor sizes are expressed in American Wire Gauge (AWG), typically from 18 AWG up to 4/0 AWG. Conductor sizes larger than 4/0 AWG are expressed in kcmil (thousand circular mils) [110.6]. *Figure 6-2*

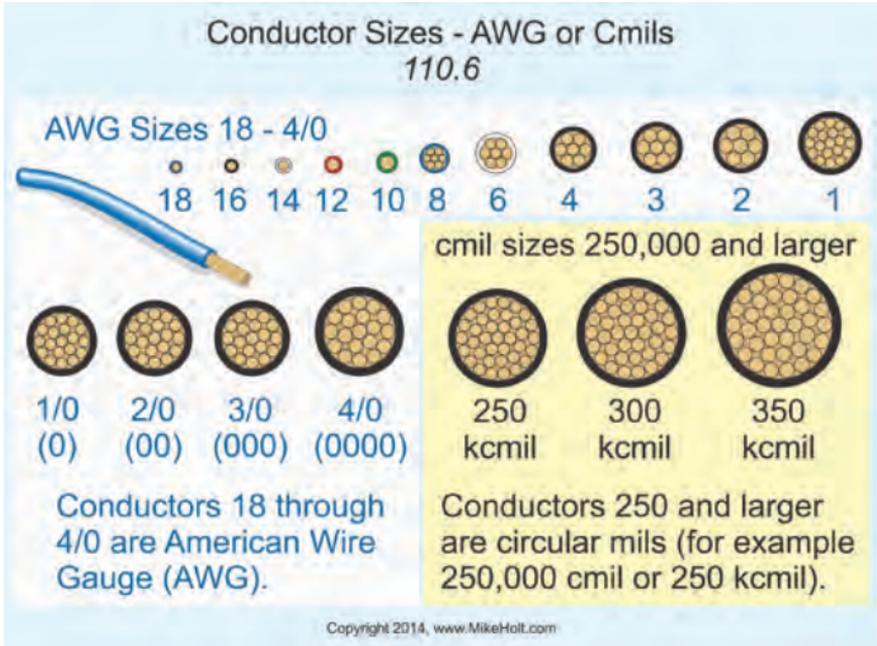


Figure 6-2

6.3 Smallest Conductor Size [310.106]

(A) Minimum Size Conductors. The smallest conductor permitted for branch circuits for residential, commercial, and industrial locations is 14 AWG copper, except as permitted elsewhere in this *Code*.

Author's Comment:

- There's a misconception that 12 AWG copper is the smallest conductor permitted for commercial or industrial facilities. Although this isn't true based on *NEC* rules, it may be a local code requirement.
- Conductors smaller than 14 AWG are permitted for:
 - Class 1 remote-control circuits [725.43]
 - Fixture wire [402.6]
 - Motor control circuits [Table 430.72(B)]

6.4 Conductor Size—Equipment Terminal Rating [110.14(C)]

Temperature Limitations (Conductor Size). Conductors are to be sized using their ampacity from the insulation temperature rating column of Table 310.15(B)(16) that corresponds to the lowest temperature rating of any terminal, device, or conductor of the circuit.

(1) Equipment Temperature Rating Provisions. Unless the equipment is listed and marked otherwise, conductor sizing for equipment terminations must be based on Table 310.15(B)(16) in accordance with 110.14(C)(1)(a) or (b):

Equipment 100A and Less, Conductor Sized to 60°C [110.14(C)(1)(a)(1)]

Equipment terminals rated 100A or less and pressure connector terminals for 14 AWG through 1 AWG conductors, must have the conductor sized to the 60°C temperature rating listed in Table 310.15(B)(16).

Figure 6–3

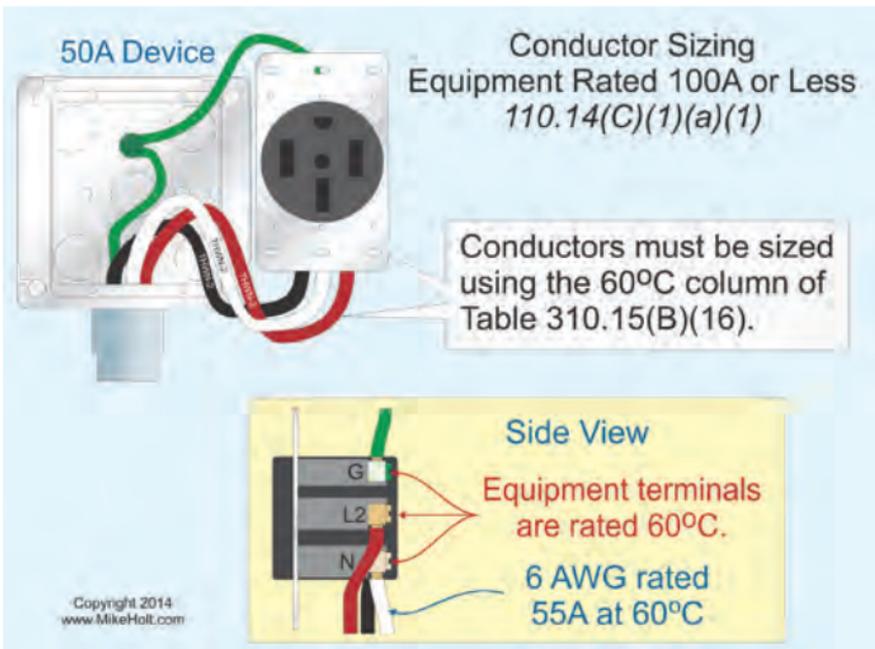


Figure 6–3

Author's Comment:

- Conductors are sized to prevent the overheating of terminals, in accordance with listing standards. For example, a 50A circuit with 60°C terminals requires the circuit conductors to be sized not smaller than 6 AWG, in accordance with the 60°C ampacity listed in Table 310.15(B)(16). An 8 THHN insulated conductor has a 90°C ampacity of 55A in a dry location, but 8 AWG can't be used for this circuit because the conductor's operating temperature at full-load ampacity (55A) will be near 90°C, which is well in excess of the 60°C terminal rating.

Question: According to Table 310.15(B)(16), what size THHN conductor is required for a 50A rated circuit?

Answer: 6 AWG, rated 55A at 60°C [Table 310.15(B)(16)]

➡ See page 141 for Table 310.15(B)(16) Allowable Ampacities of Insulated Conductors Based on Not More Than Three Current-Carrying Conductors and Ambient Temperature of 30°C (86°F)

**Equipment 100A and Less, Conductor Sized to 75°C
[110.14(C)(1)(a)(3)]**

Conductors terminating on equipment rated 75°C can be sized in accordance with the ampacities listed in the 75°C temperature column of Table 310.15(B)(16). **Figure 6–4**

Question: According to Table 310.15(B)(16), what size THHN conductor is required for a 50A circuit where the equipment is listed for use at 75°C?

Answer: 8 AWG, rated 50A at 75°C [Table 310.15(B)(16)]

Conductor Sizing - Equipment Rated 100A or Less
 110.14(C)(1)(a)(3)



Terminals
 Rated 75°C

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Conductors terminating on equipment rated 75°C are sized in accordance with the ampacities listed in the 75°C temperature column of Table 310.15(B)(16), provided the conductors have an insulation rating of at least 75°C.

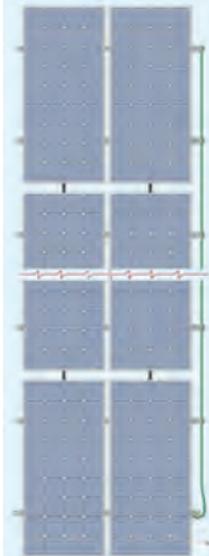
Figure 6-4

Equipment Over 100A, Conductor Sized to 75°C
[110.14(C)(1)(b)(1)]

Terminals for equipment rated over 100A and pressure connector terminals for conductors larger than 1 AWG must have the conductor sized according to the 75°C temperature rating listed in Table 310.15(B)(16).

Figure 6-5

Conductor Sizing - Equipment Over 100A
 110.14(C)(1)(b)(1)



Unless listed and marked otherwise, conductors must be sized using the 75°C column of Table 310.15(B)(16).

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Figure 6-5

Question: According to Table 310.15(B)(16), what size THHN conductor is required to supply a 150A feeder?

Answer: 1/0 AWG, rated 150A at 75°C [Table 310.15(B)(16)]

Terminals Rated 90°C, Conductor Sized to 90°C [110.14(C)(2)]

The 90°C ampacity column of Table 310.15(B)(16) can be used for separately installed connectors if the conductor and terminals are rated at least 90°C. Figure 6–6

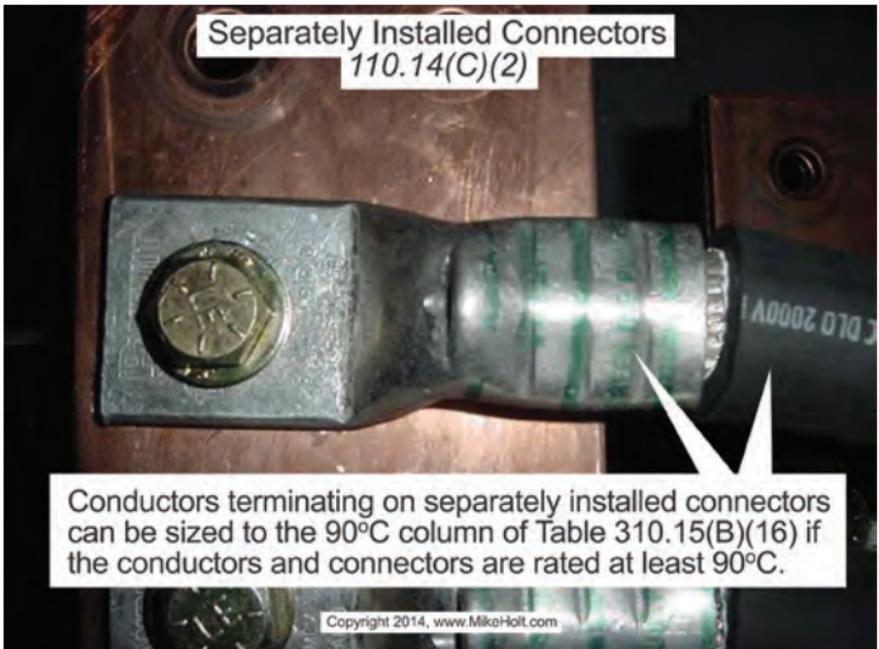


Figure 6–6

Question: According to Table 310.15(B)(16), what size 200A aluminum compact conductor can be used to interconnect busbars protected by a 200A overcurrent protection device if all terminals are rated 90°C?

Answer: 4/0 AWG, rated 205A at 90°C [Table 310.15(B)(16)]

Minimum Conductor Size Table

When sizing conductors, the following table can be used to determine the minimum size conductor to meet the requirements of 110.14(C).

Circuit Rating	60°C	75°C
50A	6 AWG	8 AWG
60A	4 AWG	6 AWG
70A	4 AWG	4 AWG
100A	1 AWG	3 AWG
125A	—	1 AWG
150A	—	1/0 AWG
200A	—	3/0 AWG
225A	—	4/0 AWG

What's the Value of 90°C Conductor Insulation?

The advantage of THHN insulated conductors is that the 90°C insulation rating allows for a higher conductor ampacity for conductor ampacity “adjustment” and/or “correction” in accordance with 310.15(B)(2) (a) and 310.15(B)(3)(a). The higher ampacity of THHN, as compared to the terminal temperature rating, will often permit the use of a conductor without having to increase its size because of conductor ampacity adjustment or correction. The advantage of THHN isn't that it allows a smaller circuit conductor, but that you might not have to install a larger conductor because of ampacity adjustments or corrections.



CAUTION: *Conductor voltage drop, ambient temperature correction, and conductor bundle adjustment factors are additional elements that must be considered in sizing conductors. These subjects are covered elsewhere in this textbook.*

6.5 Overcurrent Protection [Article 240]

Article 240 covers the general requirements for overcurrent protection and the installation requirements of overcurrent devices.

Author's Comment:

- Overcurrent is a condition where the current exceeds the rating of equipment or ampacity of a conductor due to overload, short circuit, or ground fault [Article 100].

An overcurrent device protects the circuit by opening the device when the current reaches a value that will cause excessive or dangerous temperature rise (overheating) in conductors. Overcurrent devices must have an interrupting rating sufficient for the maximum possible fault current available on the line-side terminals of the equipment [110.9]. Electrical equipment must have a short-circuit current rating that permits the circuit's overcurrent device to clear short circuits or ground faults without extensive damage to the circuit's electrical components [110.10 Note].

There are many different rules for protecting conductors and equipment. It's not simply 12 AWG wire and a 20A breaker. The general rule is that conductors must be protected at the point where they receive their supply in accordance with their ampacities, as listed in Table 310.15(B)(16).

Except as permitted by 240.4(A) through (G), conductors must be protected against overcurrent in accordance with their ampacity after ampacity correction and adjustment required in 310.15.

Overcurrent Devices Rated 800A or Less [240.4(B)]

The next higher standard rating of overcurrent device listed in 240.6(A) (above the ampacity of the ungrounded conductors being protected) is permitted, provided all of the following conditions are met:

- (1) The conductors aren't part of a branch circuit supplying more than one receptacle for cord-and-plug-connected loads.
- (2) The ampacity of a conductor, after the application of ambient temperature correction [310.15(B)(2)(a)], conductor bundling adjustment [310.15(B)(3)(a)], or both, doesn't correspond with the standard rating of a fuse or circuit breaker in 240.6(A).
- (3) The overcurrent device rating doesn't exceed 800A.

► Overcurrent Protection 800A and Less Example

Question: *What's the maximum size overcurrent device that can be used to protect 500 kcmil conductors, where each conductor has an ampacity of 380A at 75°C, in accordance with Table 310.15(B)(16) and the calculated load is 370A?*

Answer: 400A