Unit 6—Conductor Sizing and Protection Calculations

PART A—General Conductor Requirements

6.1 Conductor Insulation Property

Table 310.13 of the *NEC* provides information on conductor properties such as permitted use, maximum operating temperature, and other insulation details. The following abbreviations and explanations are helpful in understanding Tables 310.13 and 310.16.

-2	Conductor is permitted to be used at a continuous 90ºC operating temperature
F	Fixture wire (solid or 7-strand)
FF	Flexible fixture wire (19-strand)
H	75ºC insulation rating
HH	90ºC insulation rating
N	Nylon outer cover
T	Thermoplastic insulation
W	Wet or damp

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).

6.2 Allowable Conductor Ampacity

The ampacity of a conductor is the current in amperes that a conductor can carry continuously without exceeding its temperature rating under specific conditions of use.

General Requirements

Tables or Engineering Supervision. There are two ways to determine conductor ampacity:

- Tables 310.16
- Engineering formula

AUTHOR'S COMMENT: For all practical purposes, use the ampacities listed in Table 310.16.

Note: The ampacities listed in Table 310.16 are based on temperature alone and don't take voltage drop into consideration. Voltage-drop considerations are for efficiency of operation and

not for safety; therefore, sizing conductors for voltage drop is not a Code requirement in most cases.

Table Ampacity

The ampacity of a conductor is listed in Table 310.16 under the condition of no more than three current-carrying conductors bundled together in an ambient temperature of 86°F. The ampacity of a conductor changes if the ambient temperature is not 86°F or if more than three current-carrying conductors are bundled together.

Table 310.16. Allowable Ampacities of Insulated Conductors
Based On Not More Than Three Current-Carrying Conductors and Ambient Temperature of 30°C (86°F)

Size	Temperature Rating of Conductor, See Table 310.13						Size
	60°C (40°F)	75°C (167°F)	90°C (194°F)	60°C (40°F)	75°C (167°F)	90°C (194°F)	
AWG kcmil	TW UF	THHW THW THWN XHHW Wet Location	THHW XHHW Dry Location	TW UF	THHN THW THWN XHHW Wet Location	THHN THHW XHHN Dry Location	AWG kcmil
	Copper			Aluminum/Copper-Clad Aluminum			
14*	20	20	25				12*
12*	25	25	30	20	20	25	10*
10*	30	35	40	25	30	35	8*
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
300	240	285	320	190	230	255	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

*See 240.4(D)

6.3 Conductor Sizing

Conductors are sized according to the American Wire Gage (AWG) from 40 AWG through 4/0 AWG. The smaller the number, the larger the conductor up to 1 AWG. Conductors larger than 4/0 AWG are identified according to their cross-sectional area in circular mils, such as 250,000 cmil, 300,000 cmil, 500,000 cmil, etc. The circular mil size is usually expressed in kcmil (1,000 circular mils), such as 250 kcmil, 300 kcmil, and 500 kcmil.

Smallest Conductor Size

The smallest size conductor permitted by the *NEC* for branch circuits, feeders, or services is 14 AWG copper or 12 AWG aluminum. Some local codes require a minimum 12 AWG for commercial and industrial installations. Conductors smaller than 14 AWG are permitted for:

- Class 1 remote-control circuits
- Fixture wire
- Flexible cords
- Motor control circuits
- Nonpower-limited fire alarm circuits
- Power-limited fire alarm circuits

6.4 Terminal Ratings

Conductors must be sized in accordance with the lowest temperature rating of any terminal, device, or conductor insulation of the circuit.

Circuits Rated 100A and Less

Equipment terminals rated 100A or less (and pressure connector terminals for 14 AWG through 1 AWG conductors), must have the conductor sized no smaller than the 60°C temperature rating listed in Table 310.16, unless the terminals are marked otherwise.

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 310.16. However, an 8 THHN insulated conductor has a 90°C ampacity of 50A, but 8 AWG cannot be used for this circuit because the conductor's operating temperature at full-load ampacity (50A) will be near 90°C, which is well in excess of the 60°C terminal rating. Figure 6–1

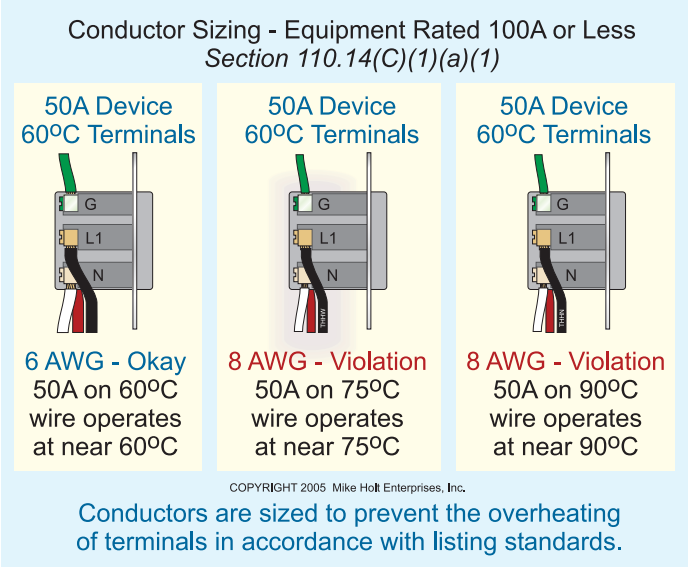

Figure 6–1

▶ Terminal Rated 60ºC

What size THHN conductor is required for a 50A circuit listed for use at 60ºC? Figure 6–2A

- Answer: 6 AWG

Conductors must be sized to the lowest temperature rating of either the equipment or the conductor. THHN insulation can be used, but the conductor size must be selected based on the 60ºC terminal rating of the equipment, not the 90ºC rating of the insulation. Using the 60ºC column of Table 310.16, this 50A circuit requires a 6 THHN conductor (rated 55A at 60ºC).

▶ Terminal Rated 75ºC

What size THHN conductor is required for a 50A circuit listed for use at 75ºC? Figure 6–2B

- Answer: 8 AWG

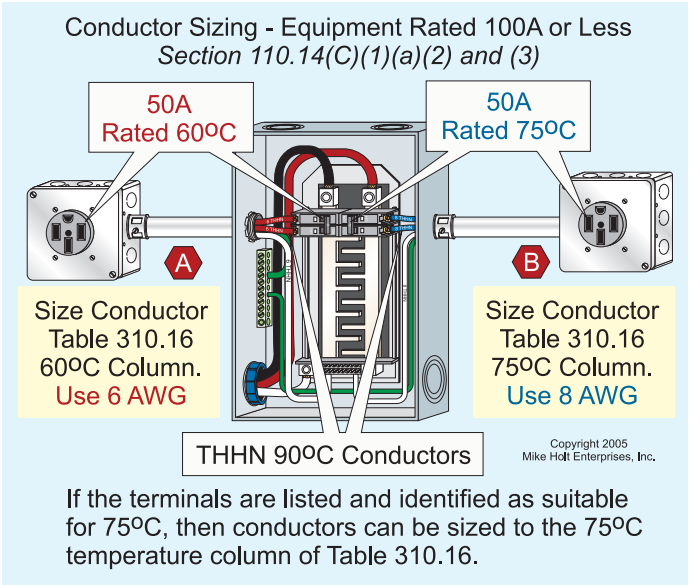

Figure 6–2

Using the 75ºC column of Table 310.16, this installation will permit 8 THHN (rated 50A at 75ºC) to supply the 50A circuit.

Circuits Over 100A

Terminals for equipment rated over 100A and pressure connector terminals for conductors larger than 1 AWG must have the conductor sized according to the 75ºC temperature rating listed in Table 310.16. Figure 6–3

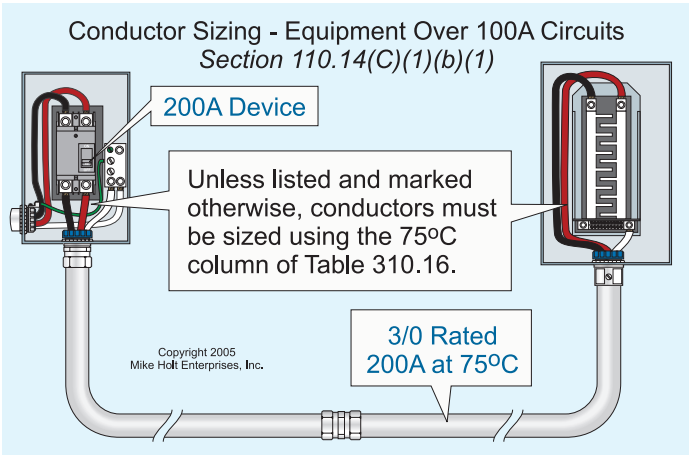

Figure 6–3

▶ Over 100A [110.14(C)(1)(b)]

What size THHN conductor is required to supply a 225A feeder?

- Answer: 4/0 AWG

The conductors in this example must be sized to the lowest temperature rating of either the equipment or the conductor. THHN conductors can be used, but the conductor size must be selected according to the 75°C terminal rating of the equipment when sizing for over 100A. Using the 75°C column of Table 310.16, this will require a 4/0 THHN conductor (rated 230A at 75°C) to supply the 225A circuit. 3/0 THHN is rated 225A at 90°C, but we must size the conductor based on the 75°C terminal rating.

Minimum Conductor Size Table

When sizing conductors, the following table must always be used to determine the minimum size conductor:

Table 310.16 [110.14(C)] Terminal Size and Matching Copper Conductor

Terminal Ampacity	60°C Terminals Wire Size	75° Terminals Wire Size
15	14	14
20	12	12
30	10	10
40	8	8
50	6	8
60	4	6
70	4	4
80	3	4
90	2	3
100	1	3
110	–	2
125	–	1
150	–	1/0
200	–	3/0
225	–	4/0
250	–	250 kcmil
300	–	350 kcmil
400	–	2 – 3/0
500	–	2 – 250 kcmil

What is the purpose of THHN if we can't use its higher ampacity? In general, 90°C rated conductor ampacities cannot be used for sizing circuit conductors. However, THHN offers the opportunity of having a greater conductor ampacity for conductor ampacity adjustment.

6.5 Conductors in Parallel

Parallel conductors permit a smaller cross-sectional area per ampere. This can result in a significant cost savings for circuits over 300A.

Grounding (Bonding) Conductors in Parallel

When equipment grounding (bonding) conductors are installed with circuit conductors that are run in parallel, each raceway must have an equipment grounding (bonding) conductor sized according to the overcurrent protection device rating that protects the circuit.

▶ Sizing Grounding (Bonding) Conductors in Parallel

What size equipment grounding (bonding) conductor is required in each of two raceways for a 400A feeder?

- Answer: 3 AWG

There must be a 3 AWG equipment grounding (bonding) conductor in each of the two raceways.

6.6 Conductor Size—Voltage Drop

The *NEC* generally does not require conductors to be sized to accommodate conductor voltage drop, but 210.19(A)(1) FPN No. 4 and 215.2(A) FPN No. 2 suggest its effects should be considered.

6.7 Overcurrent Protection

Overcurrent protection devices are intended to open the circuit if the current reaches a value that exceeds its rating and to clear ground faults. Overcurrent protection devices have two ratings, overcurrent and ampere interrupting current (AIC).

Overcurrent Rating. Overcurrent protection for conductors and equipment is provided to open the circuit if the current reaches a value that will cause an excessive or dangerous temperature in conductors or conductor insulation. This is the actual ampere rating of the protection device, such as 15A, 20A, or 30A. Figure 6–4

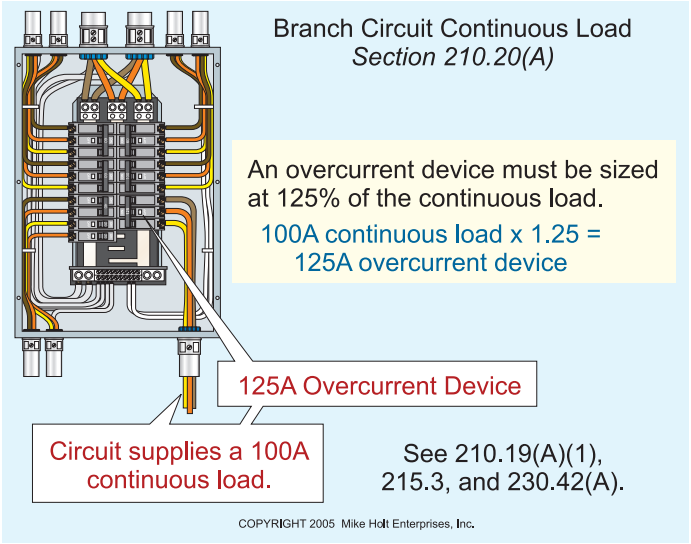

Figure 6–6

Next Higher Overcurrent Rating. The next higher protection device is permitted if all of the following conditions are met:

• Conductors do not supply multioutlet receptacle branch circuits for portable cord-and-plug connected loads.

• The ampacity of a conductor does not correspond with the standard ampere rating of a fuse or circuit breaker.

• The next size up breaker or fuse does not exceed 800A.

▶ Overcurrent Protection of Conductors

What size conductor is required for a 104A continuous load?

• Answer: 1 AWG

The conductor must be sized no less than 125 percent of the continuous load: 104A x 1.25 = 130A. 1 THHN is rated 130A at 75°C and can be protected by a 150A protection device.

Circuits with Overcurrent Protection Over 800A. If the circuit overcurrent protection device exceeds 800A, the circuit conductor ampacity must not be less than the rating of the overcurrent protection device as listed in 240.6.

Where the overcurrent device is over 800A, the conductors must have ampacity equal to or greater than the rating of the overcurrent device. For example, the conductors for a 1,200A feeder paralleled in three raceways must be no smaller than 600 kcmil.

Ampere per parallel conductor = 1,200A/3 raceways
Ampere per parallel conductor = 400A minimum per raceway

Conductor size 600 kcmil rated 420A at 75°C [Table 310.16 and 110.14(C)]

Total parallel ampacity = 420A x 3 conductors
Total parallel ampacity = 1,260A

Small Conductors. Unless specifically permitted in 240.4(E) or 240.4(G), overcurrent protection must not exceed 15A for 14 AWG, 20A for 12 AWG, and 30A for 10 AWG copper conductors; or 15A for 12 AWG, and 25A for 10 AWG aluminum and copper-clad aluminum conductors after ampacity correction. Figure 6–7

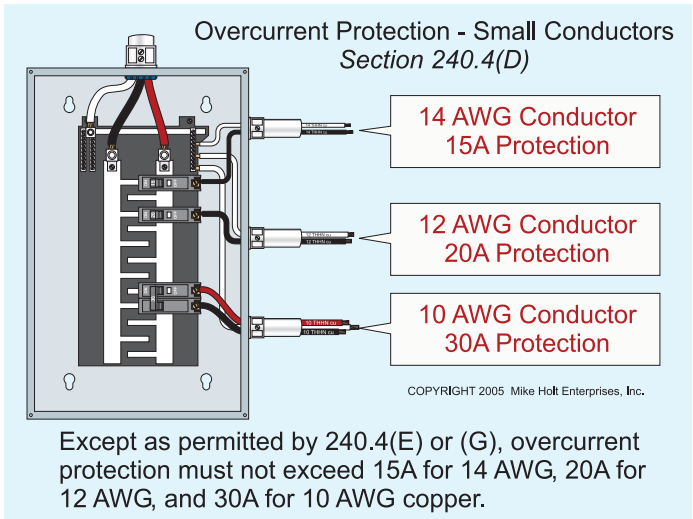

Figure 6–7

6.9 Overcurrent Protection of Conductors—Specific Requirements

When sizing and protecting conductors for equipment, be sure to apply the specific *NEC* requirement from the Article that deals with that particular type of equipment.