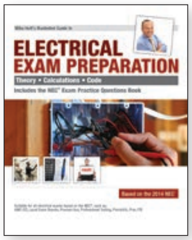
2014

Mike Holt's Illustrated Guide to
Electrical Exam Preparation based on the 2014 NEC®



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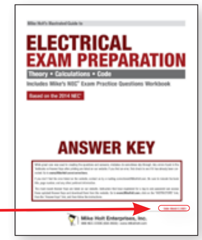

To view the corrected page, click on the Page # in first column. To return to this page, click anywhere within the corrected page.

Page #	Reference	Correction
20	Power Example at 240W	Step 3: The formula $R = E^2/P$ should be $P = E^2/R$.
26	Question 46	Answer choice (d) should be: a or b.
29	Question 10	The formula $P = I^2/R$ should be $P = I^2 \times R$.
29	Question 13	The formula $P = I^2/R$ should be $P = I^2 \times R$.
55	Question 26	The word all was added in answer choice (d).
136	Figure 5-20 Example	The calculation was changed to match the Figure 5-20 graphic.
160	Question 15	Answer choice (a) 7 conductors should be (a) 8 conductors.
175	Table Example	Table 310.15(B)(16) example (below Figure 6-16), the answer should be (d) 4/0 AWG, rated 205A at 90ºC [Table 310.15(B)(16)]
182	Example 1	The ambient temperature of 60˚C used in the solution should be 50˚C
182	Example 3	The correction factor of 0.82 used in the solution should be 0.87. Solution should be 148A.
184	Example 2	Answer choice (c) 56.20A should be (c) 57A. Answer (b) 42.50A should be (c) 57A. 105˚F Ambient + 40˚F Rooftop Adder = 145˚F should be 90˚F Ambient + 40˚F Rooftop Adder = 130˚F Ambient Temperature Correction Factor for 145˚F = 0.58 should be Ambient Temperature Correction Factor for 130˚F = 0.76 Corrected Ampacity = 75A x 0.58 should be Corrected Ampacity = 75A x 0.76 Corrected Ampacity = 43.50A should be Corrected Ampacity = 57A
184	Figure 6-31	Figure was changed to reflect corrections in Example 2 listed above.
185	Ampacity Adjustment Example 2	1 THWN is rated 130A at 90ºC should be 1 THWN is rated 130A at 75ºC.
187	Example 2	The 8 THHN should be rated at 55A, not 40A.
192	Branch Circuit Conductor Sizing Example	Table 310.15(B)(16), the 75ºC column should be 60ºC.
194	Feeder Conductor Sizing Example	The last two paragraphs of the solution for the Feeder Conductor Sizing Example were rewritten to correct errors and improve clarity. Also, the 255A number should be 290A in several places in the example.

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Page #	Reference	Correction
217	Size Conductor Example	In the question portion of the example, 230V was changed to 240V.
218	Size Conductor Example	In the question portion of the example, 460V was changed to 480V.
219	Distance—Three-Phase Example	In the question, the 3 AWG conductors should be 1 AWG conductors. In the solution, the Cmils 83,690, (3 AWG) should be Cmils 83,690, (1 AWG).
220	Maximum Load—Three-Phase Example	The Question answer choices has been changed. The Answer has been changed. The wording on the Note has been changed. Please click here to see specifics.
228	Question 6	In Question "two 4 AWG aluminum" was changed to "two 3 AWG aluminum." The Answer (b) was changed from 5.31V to 4.21V.
231	Several Examples	Description for Single-Phase Alternating Current Example 2: Table 430.247 should be Table 430.248. Description for Single-Phase Alternating Current Example 4: Table 430.247 should be Table 430.248. Description for Three-Phase Alternating Current Example 2: Table 430.247 should be Table 430.250
237	Example 3	In the Feeder Size solution, the third "+22A" will be deleted. There should only be two of them.
255	Example 1	Answer choice (a) should be 12 AWG, not 10 AWG and choice (d) should be 6 AWG, not 8 AWG
255	Example 2	Answer choice (a) should be 12 AWG, not 10 AWG and choice (d) should be 6 AWG, not 8 AWG
276	Dwelling Unit Optional Load Calculation Example	The amperage of the service conductor in the solution for the Dwelling Unit Optional Load Calculation [220.82] Example was incorrect. 3 AWG rated 130A at 75°C should be 3 AWG rated 100A at 75°C
277	Dwelling Unit Optional Load Calculation Example	Section 9.10, Step 2: The Code reference was changed to 220.83(B). Section 9.11, Step 2: The Code reference was changed to 220.83(B) and the text was changed to read: Air-conditioning at 100 percent [220.83(B)(1)] versus electric space-heating at 100 percent [220.83(B)(4)].
279	Neutral Service and Feeder Calculation Example	The neutral conductor size and temperature rating in the solution for the Neutral Service and Feeder Calculation [220.61(B)] example was incorrect. Neutral Conductor = 3 AWG rated 85A at 60°C should be Neutral Conductor = 4 AWG at 75°C
293	Example 1	A *Note: was added for clarification.
294	Example 2	A *Note: was added for clarification.
296	Dryer Demand Ex 3	The Demand Load was changed from 100 kW to 110 kW.
296	Dryer Demand Ex 4	The demand factor percent was changed from 40 percent to 35 percent.
299	Single-Phase, Step 1	The phrase "4 units" was deleted from Example 1, Step 1 and the following calculation was added: 10 ranges/3 (for three-phase) = 3.33 ranges (units) between any two phases Round up since one can't have a partial range; 4 ranges (units) between any two phases.
300	Single-Phase, Step 1	The phrase "7 units" was deleted from Example 2, Step 1 and the following calculation was added: 20 ranges/3 (for three-phase) = 6.67 ranges (units) between any two phases Round up since one can't have a partial range; 7 ranges (units) between any two phases.
303	Step 1, Multifamily Dwelling Calculations	There was a typographical error in step 1 of the solution for the Multifamily Dwelling Calculations—Standard Method Example. Remainder at 2% should be Remainder at 35%.
303	Step 2, Multifamily Dwelling Calculations	There was a typographical error in step 2 of the solution for the Multifamily Dwelling Calculations—Standard Method Example. Connected load multiplier should be 10 units and not 20 units.

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Page #	Reference	Correction
304	Step 6, Standard Method Service Load Calculations Example	The text 7,500 VA x 25 units were removed in Step 5 within STEP 6.
304	Std Method Serv Load Calcs, Three Phase Ex	The Code reference at the end of the question was changed to 210.52(F) Ex 1.
313	Step 1, Service Neutral SIngle-Phase Example	Remainder percentage should be 35% not 25% as shown. However, the calculation is correct as shown.
314	Neutral 1-Ph Example	In Step 3, the number of dryers was corrected from "25" to "10."
314	Neutral 3-Ph Example	The reference to section 220.11(C)(2) was changed to section 210.52(F) Ex 1.
330	Multioutlet Receptacle Assembly...Example	The answer choices were changed to correct a technical error to (a) 9 kVA, (b) 8 kVA, (c) 20 kVA, (d) 23 kVA and the final answer is now (d) 23 kVA.
338	Example 2	Question should read: What size service conductors are required for a 120/208V, three-phase restaurant that isn't all-electric and has a total connected load of 300 kVA if paralleled in two raceways.
342	Example 1	The reference given in the formula in Example 1 for the "Welder Percentage" should be 630.31(B).
343	11.15 Example 1	The air compressor should be 5 hp not 71⁄2 hp in the bullet list and also in Step 1(2)(a). The welder should be 60% duty not 50% in Step 1 (1)(b).
344	Example 2	In the list under the question, the LIghting value was changed from 20,600 VA to 20, 000 VA.
360	Less Than 9A Example	The primary current primary voltage should be 240V and not 480V.
392	Question 10	Answer Choice (c) should be laundry areas and Answer Choice (d) should be b and c
437	Question 2	The question was revised to read: Smooth-sheath Type MC cable with an external diameter not greater than ¾ in. shall have a bending radius not less than ______ times the external diameter of the cable.
498	Question 18	Class I, Division 2, Zone was added to the question and the answer choices were all changed to coincide with the new text.
537	Question 7	The word supply should be inserted in question so it reads: Wiring from an emergency source can supply emergency or other loads, provided the conductors ______.
559	Question 17	Answer Choice (d) should be 22.50.

Step 2: *What do you know about the heat strip?*

E = 208V, R = E^2/P

R = 230V x 230V/9,600W

R = 5.51 ohms

Step 3: *The formula to determine power is:* ***P = E^2/R***.

Step 4: *The answer is:*

P = $208V^2$/5.51 ohms

P = 7,851W or 7.85 kW

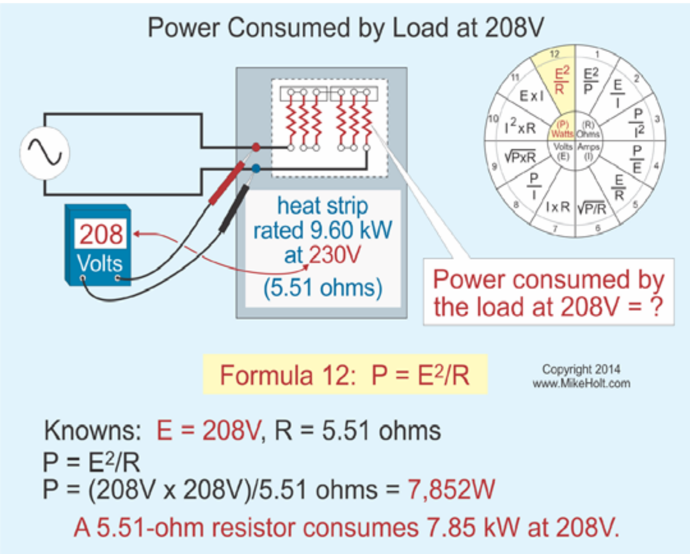

Figure 1–31

Author's Comment:

- It's important to realize that the resistance of the heater unit doesn't change—it's a property of the material through which the current flows and isn't dependent on the voltage applied.

Thus, for a small change in voltage, there's a considerable change in the power consumption by this heater.

Author's Comment:

- The current flow for this heat strip is **I = P/E**.

P = 7,851W

E = 208V

I = 7,851W/208V

I = 38A

▶ Power Example at 240V

Question: *What's the power consumed by a 9.60 kW heat strip rated 230V connected to a 240V circuit?* Figure 1–32

(a) 7.85 kW (b) 9.60 kW (c) 10.45 kW (d) 11.57 kW

Answer: *(c) 10.45 kW*

Step 1: *What's the problem asking you to find?*

The power consumed by the resistance.

Step 2: *What do you know about the resistance?*

*R = 5.51 ohms**

The resistance of the heat strip is determined by the formula* ***R = E^2/P*.

E = Nameplate voltage rating of the resistance, 230V

P = Nameplate power rating of the resistance, 9,600W

R = E^2/P

R = $230V^2$/9,600W

R = 5.51 ohms

Step 3: *The formula to determine power is:* ***P = E^2/R***

Step 4: *The answer is:*

P = 240V x 240V/5.51 ohms

P = 10,454W

P = 10.45 kW

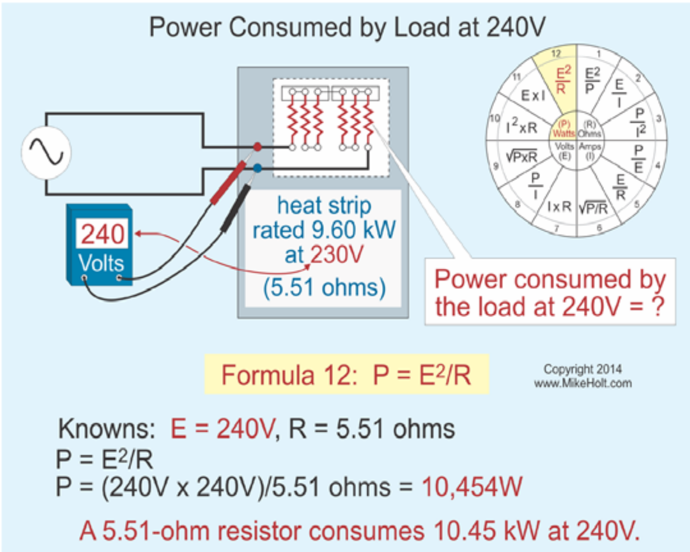

Figure 1–32

1.21 Ohm's Law Formula Circle

43. What's the voltage drop of two 12 AWG conductors (0.40 ohms) supplying a 16A load, located 100 ft from the power supply?

E_{VD} = I x R
E_{VD} = 16A x 0.40 ohms

(a) 1.60V
(b) 3.20V
(c) 6.40V
(d) 12.80V

44. What's the resistance of the circuit conductors when the conductor voltage drop is 7.20V and the current flow is 50A?

R = E/I
R = 7.20V/50A

(a) 0.14 ohms
(b) 0.30 ohms
(c) 3 ohms
(d) 14 ohms

1.22 PIE Formula Circle

45. What's the power loss in watts of a conductor that carries 24A and has a voltage drop of 7.20V?

P = I x E
P = 24A x 7.20V

(a) 175W
(b) 350W
(c) 700W
(d) 2,400W

1.23 Formula Wheel

46. The formulas in the power wheel apply to _____.

(a) direct-current circuits
(b) alternating-current circuits with unity power factor
(c) direct-current circuits or alternating-current circuits
(d) a or b

1.24 Using the Formula Wheel

47. When working any formula, the key to calculating the correct answer is following these four steps:

Step 1: Know what the question is asking you to find.
Step 2: Determine the knowns of the circuit.
Step 3: Select the formula.
Step 4: Work out the formula calculation.

(a) True
(b) False

1.25 Power Losses of Conductors

48. Power in a circuit can be either "useful" or "wasted." Wasted work is still energy used; therefore it must be paid for, so we call wasted work "_____."

(a) resistance
(b) inductive reactance
(c) capacitive reactance
(d) power loss

49. The total circuit resistance of two 12 AWG conductors (each 100 ft long) is 0.40 ohms. If the current of the circuit is 16A, what's the power loss of both conductors?

P = I^2 x R
P = $16A^2$ x 0.40 ohms

(a) 75W
(b) 100W
(c) 300W
(d) 600W

50. What's the conductor power loss for a 120V circuit that has a 3 percent voltage drop and carries a current flow of 12A?

P = I x E
P = 12A x (120V x 3%)

(a) 43W
(b) 86W
(c) 172W
(d) 1,440W

9. The energy consumed by a 5-ohm resistor is _____ than the energy consumed by a 10-ohm resistor, assuming the current in both cases remains the same.

(a) more
(b) less

1.24 Using the Formula Wheel

10. What's the power loss of two 10 AWG conductors when the current through the circuit is 16A and the total resistance is 0.18 ohms?

$P = I^2 \times R$

(a) 2.80W
(b) 3.80W
(c) 46W
(d) 55W

1.27 Power Changes with the Square of the Voltage

11. When a 100W, 115V lamp operates at 230V, the lamp will consume approximately _____ when the total resistance is 132.25 ohms.

$P = E^2/R$

(a) 150W
(b) 300W
(c) 400W
(d) 450W

12. A 1,500W resistive heater is rated 230V and is connected to a 208V supply. The power consumed by this load at 208V will be approximately _____ when the total resistance is 35.27 ohms.

$P = E^2/R$

(a) 1,225W
(b) 1,625W
(c) 1,750W
(d) 1,850W

13. The total resistance of a circuit is 10.20 ohms. The load has a resistance of 10 ohms and the wire has a resistance of 0.20 ohms. If the current of the circuit is 12A, then the power consumed by the circuit conductors (0.20 ohms) is approximately _____.

$P = I^2 \times R$

(a) 8W
(b) 29W
(c) 39W
(d) 45W

23. The product-over-sum method is used to calculate the resistance of ____ resistance(s) at a time.

(a) one
(b) two
(c) three
(d) four

24. The advantage of the reciprocal method is that the formula can be used for as many resistances as the parallel circuit contains.

(a) True
(b) False

2.12 Parallel-Connected Power Supplies

25. When power supplies are connected in parallel, the voltage remains the same, but the current or ampere-hour capacity is increased.

(a) True
(b) False

Part C—Series-Parallel Circuits

Introduction

26. A ____ circuit is a circuit that contains some resistances in series and some resistances in parallel with each other.

(a) parallel
(b) series
(c) series-parallel
(d) all of these

27. That portion of the series-parallel circuit that contains resistances in series must comply with the rules for series circuits.

(a) True
(b) False

28. That portion of the series-parallel circuit that contains resistances in parallel must comply with the rules for parallel circuits.

(a) True
(b) False

2.14 Working With Series-Parallel Circuits

29. When working with series-parallel circuits, it's best to redraw the circuit so you can see the series components and the parallel branches.

(a) True
(b) False

Part D—Multiwire Branch Circuits

Introduction

30. A multiwire branch circuit has two or more ungrounded conductors having a potential difference between them, and having an equal difference of potential between each ungrounded conductor and the grounded conductor.

(a) True
(b) False

2.16 Neutral Conductor

31. A neutral conductor is the conductor connected to the ____ of a system that's intended to carry neutral current under normal conditions.

(a) grounding electrode
(b) neutral point
(c) intersystem bonding termination
(d) earth

32. An ungrounded delta system contains a neutral point.

(a) True
(b) False

33. The common point on a 4-wire, three-phase, 120/208V wye-connected system is defined by the *Code* as the "____ point."

(a) wye
(b) neutral
(c) bridge
(d) ungrounded

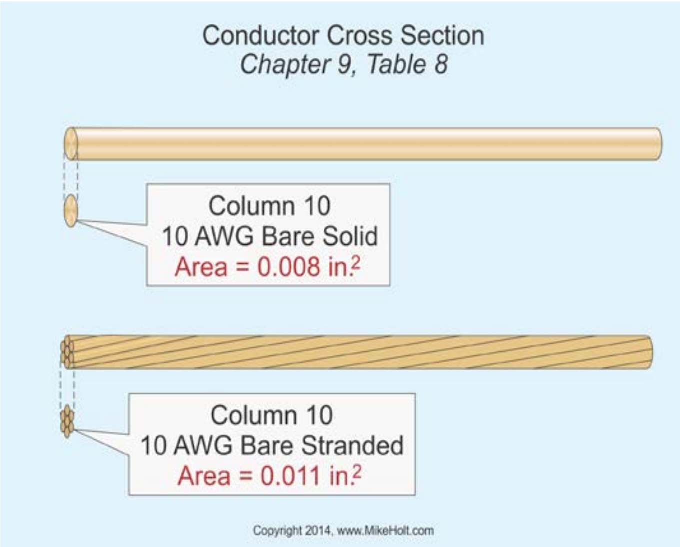

Figure 5–17

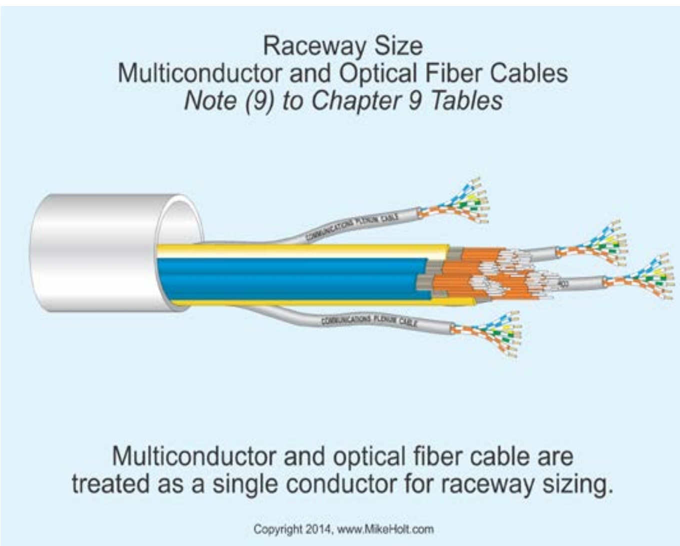

Figure 5–18

For cables with elliptical cross sections, the cable cross-sectional area in sq in. is based on the major diameter of the ellipse as the circle diameter. Figure 5–19

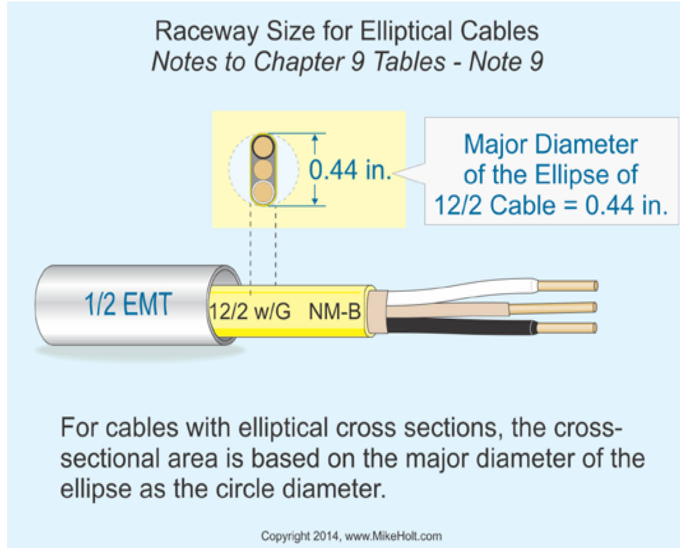

Figure 5–19

Question: *What's the area in sq in. for Type NM cable having a major diameter (ellipse) of 0.44 in. where the area of a circle is calculated using the formula: Area = Pi x r², Pi is equal to 3.14 and "r" (the radius) is equal to ½ of the cable diameter.* Figure 5–20

Area = Pi x r²

Area = 3.14 x (Dia. x ½)²

Area = 3.14 x (0.44 in. x ½)²

Area = 3.14 x (0.22 in.)²

Area = 3.14 x 0.0484

Area = 0.1520 sq in.

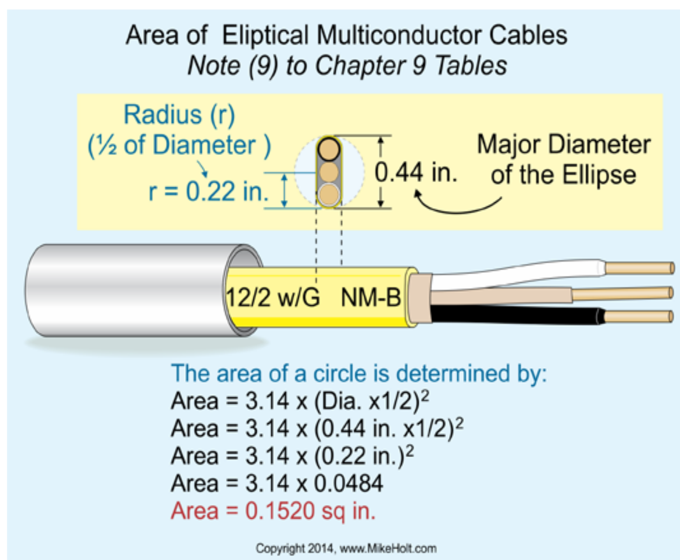

Figure 5–20

8. A 200A feeder installed in Schedule 80 PVC has three 3/0 THHN conductors, one 2 THHN conductor, and one 6 THHN conductor. What size raceway is required?

(a) A trade size 2 raceway.
(b) A trade size 2½ raceway.
(c) A trade size 3 raceway.
(d) A trade size 3½ raceway.

9. What size rigid metal conduit is required for three 4/0 THHN conductors, one 1/0 THHN conductor, and one 4 THHN conductor when the raceway is 24 in. or less in length?

(a) A trade size 1½ rigid metal conduit.
(b) A trade size 2 rigid metal conduit.
(c) A trade size 2½ rigid metal conduit.
(d) A trade size 3 rigid metal conduit.

10. An existing trade size ¾ rigid metal conduit that doesn't exceed 24 in. in length contains four 10 THHN conductors and one 10 AWG (bare stranded) ground wire. How many additional 10 THHN conductors can be installed?

(a) 5 conductors
(b) 7 conductors
(c) 9 conductors
(d) 11 conductors

11. When all the conductors are the same size (total cross-sectional area including insulation), the number of conductors permitted in a raceway can be determined by simply looking at the Tables in ____ of the *NEC*.

(a) Chapter 9
(b) Annex B
(c) Annex C
(d) Annex D

12. When equipment grounding conductors are installed in a raceway, the actual area of the conductor must be used when calculating raceway fill.

(a) True
(b) False

13. When a raceway doesn't exceed 24 in. in length, the raceway is permitted to be filled to ____ percent of its cross-sectional area.

(a) 31
(b) 40
(c) 53
(d) 60

5.4 Sizing Raceways Using Annex C

14. How many 16 TFFN conductors can be installed in trade size ¾ electrical metallic tubing?

(a) 26 conductors
(b) 29 conductors
(c) 30 conductors
(d) 40 conductors

15. How many 6 RHH conductors (without outer cover) can be installed in trade size 1¼ electrical nonmetallic tubing?

(a) 8 conductors
(b) 13 conductors
(c) 16 conductors
(d) 25 conductors

16. How many 1/0 XHHW conductors can be installed in trade size 2 flexible metal conduit?

(a) 6 conductors
(b) 7 conductors
(c) 13 conductors
(d) 16 conductors

17. How many 12 RHH conductors (with outer cover) can be installed in a trade size 1 IMC raceway?

(a) 4 conductors
(b) 5 conductors
(c) 7 conductors
(d) 11 conductors

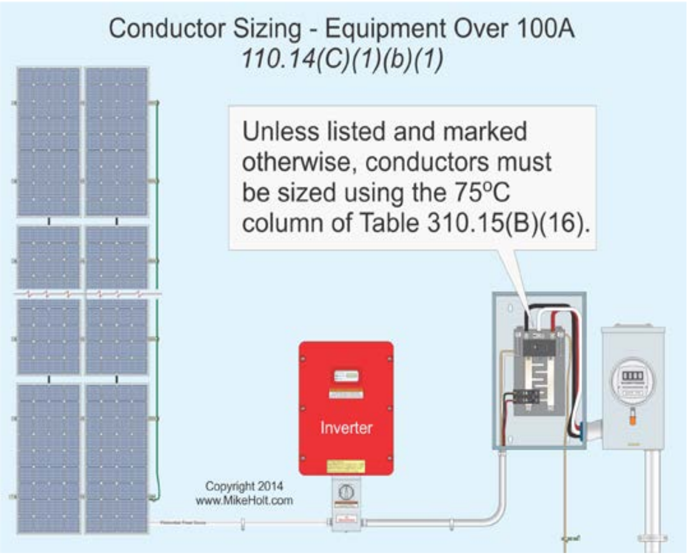

Figure 6–14

Question: *According to Table 310.15(B)(16), what size THHN conductor is required to supply a 150A feeder?* Figure 6–15

(a) 1/0 AWG (b) 2/0 AWG (c) 3/0 AWG (d) 4/0 AWG

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

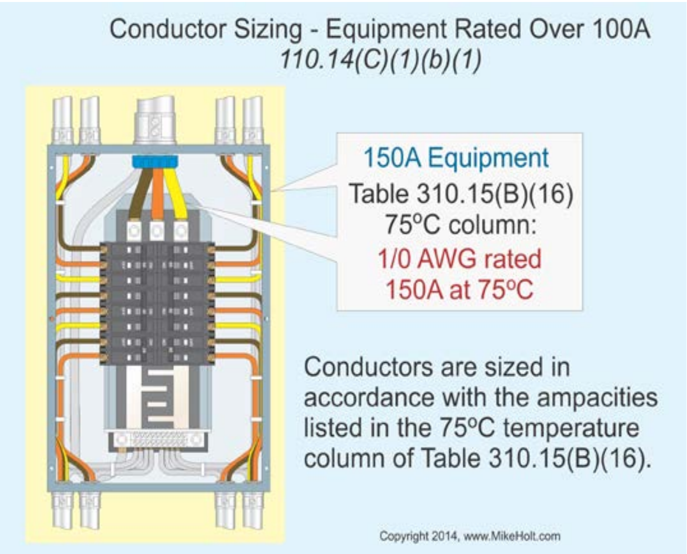

Figure 6–15

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

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

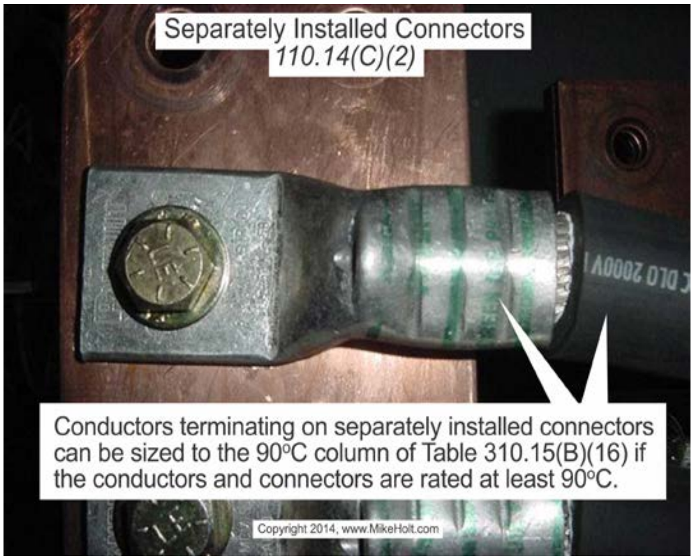

Figure 6–16

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 90ºC?*

(a) 1/0 AWG (b) 2/0 AWG (c) 3/0 AWG (d) 4/0 AWG

Answer: *(d) 4/0 AWG, rated 205A at 90ºC [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).

▶ Ambient Temperature Above 86ºF (30ºC) Example 1

Question: *What's the ampacity of a 6 THWN-2 conductor when installed in an outdoor location that has an ambient temperature of 50ºC?* Figure 6–28

(a) 35A (b) 53A (c) 61.50A (d) 75A

Answer: *(b) 61.50A*

Conductor Ampacity for 6 THWN-2 is 75A, at 90ºC [Table 310.15(B)(16)]

Correction Factor for a 90ºC conductor installed in an ambient temperature of 50ºC is 0.82 [Table 310.15(B)(2)(a)].

Corrected Ampacity = 75A x 0.82
Corrected Ampacity = ***61.50A***

Note: *Ampacity decreases when the ambient temperature is greater than 30ºC/86ºF.*

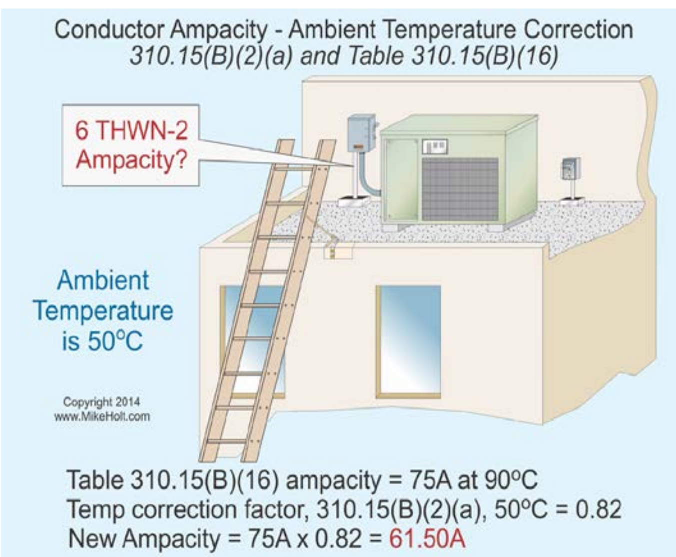

Figure 6–28

▶ Ambient Temperature Above 86ºF (30ºC) Example 2

Question: *What's the ampacity of 3/0 THHN conductors if the ambient temperature is 108°F?*

(a) 173A (b) 196A (c) 213A (d) 241A

Answer: *(b) 196A*

Conductor Ampacity for 3/0 THHN is 225A, at 90ºC [Table 310.15(B)(16)]

Correction Factor for a 90ºC conductor installed in an ambient temperature of 108ºF is 0.87 [Table 310.15(B)(2)(a)].

Corrected Ampacity = 225A x 0.87
Corrected Ampacity = ***196A***

▶ Ambient Temperature Above 86ºF (30ºC) Example 3

Question: *What's the ampacity of 1/0 XHHW-2 conductors if the ambient temperature is 108°F?*

(a) 139A (b) 196A (c) 213A (d) 241A

Answer: *(a) 139A*

Conductor Ampacity for 1/0 XHHW-2 is 170A, at 90ºC [Table 310.15(B)(16)]

Correction Factor for a 90ºC conductor installed in an ambient temperature of 108ºF is 0.87 [Table 310.15(B)(2)(a)].

Corrected Ampacity = 170A x 0.87
Corrected Ampacity = ***148A***

6.10 Rooftop Temperature Adder [310.15(B)(3)(c)]

Scan the QR code for a video clip of Mike explaining this topic; this is a sample from the DVDs that accompany this textbook.

The temperatures contained in Table 310.15(B)(3)(c) are added to the outdoor ambient temperature for ampacity correction for other than XHHW-2 conductors installed in raceways or cables exposed to direct sunlight on or above rooftops. Figure 6–29

▶ Rooftop Temperature Adder Example 2

Question: *What's the ampacity of a 6 THWN-2 conductor installed ¾ in. above the roof, where the ambient temperature is 90ºF?* Figure 6–31

(a) 20A *(b) 43.50A* *(c) 57A* *(d) 65.40A*

Answer: *(c) 57A*

Corrected Ampacity = Table 310.15(B)(16) Amperes x Ambient Temperature Correction Factor from Table 310.15(B)(2)(a)

Ambient Temperature Includes Roof Top Temperature Adder [Table 310.15(B)(3)(c)]

90ºF Ambient + 40ºF Rooftop Adder = 130ºF

Ambient Temperature Correction Factor for 130ºF = 0.76 [Table 310.15(B)(2)(a)]

6 THWN-2, rated 75A 90ºC [Table 310.15(B)(16)]

Corrected Ampacity = 75A x 0.76
Corrected Ampacity = 57A

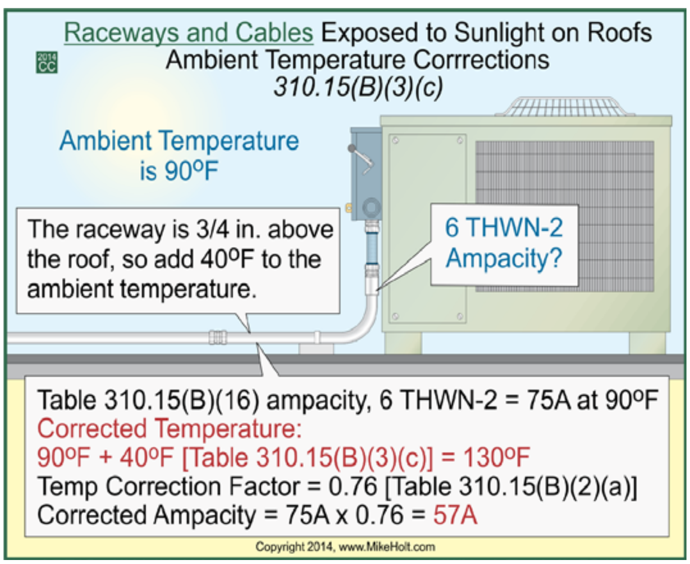

Figure 6–31

6.11 Ampacity Adjustment [310.15(B)(3)(a)]

Conductor Bundle. Where the number of current-carrying conductors in a raceway or cable exceeds three, or where single conductors or multiconductor cables are installed without maintaining spacing for a continuous length longer than 24 in., the allowable ampacity of each conductor, as listed in Table 310.15(B)(16), must be adjusted in accordance with the adjustment factors contained in Table 310.15(B)(3)(a).

Table 310.15(B)(3)(a) Conductor Ampacity Adjustment for More Than Three Current–Carrying Conductors

Number of Conductors[1]	Adjustment
4–6	0.80 or 80%
7–9	0.70 or 70%
10–20	0.50 or 50%
21–30	0.45 or 45%
31–40	0.40 or 40%
41 and above	0.35 or 35%

[1]*Number of conductors is the total number of conductors, including spare conductors, including spare conductors, adjusted in accordance with 310.15(B)(5) and (B)(6). It doesn't include conductors that can't be energized at the same time.*

Author's Comment:

- Conductor ampacity reduction is required when four or more current-carrying conductors are bundled because heat generated by current flow isn't able to dissipate as quickly as when there are three or fewer current-carry conductors. Figure 6–32

Conductor Bundling Ampacity Adjustment Formula:

Adjusted Ampacity = Table 310.15(B)(16) Ampacity x Bundled Ampacity Adjustment Factor from Table 310.15(B)(3)(a)

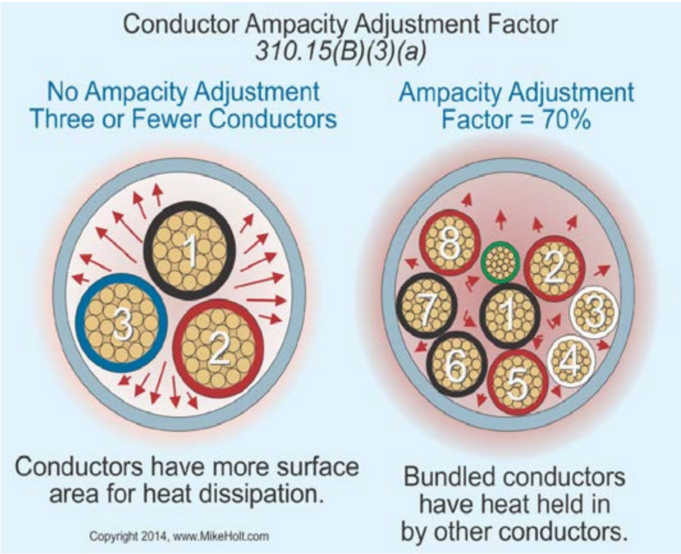

Figure 6–32

Author's Comment:

- The neutral conductor might be a current-carrying conductor, but only under the conditions specified in 310.15(B)(5). Equipment grounding conductors are never considered current carrying [310.15(B)(6)].
- When correcting or adjusting conductor ampacity, the ampacity is based on the temperature insulation rating of the conductor as listed in Table 310.15(B)(16), not the temperature rating of the terminal [110.14(C)].
- Where more than three current-carrying conductors are present and the ambient temperature isn't between 78°F and 86°F, the ampacity listed in Table 310.15(B)(16) must be corrected and adjusted for both conditions.

▶ Ampacity Adjustment Example 1

Question: *What's the adjusted ampacity of four 12 THWN-2 conductors in a raceway?* Figure 6–33

(a) 20A *(b) 24A* *(c) 29A* *(d) 32A*

Answer: *(b) 24A*

Adjusted Ampacity = Table 310.15(B)(16) Ampacity x Bundled Ampacity Adjustment Factor from Table 310.15(B)(3)(a)

12 THWN-2 is rated 30A at 90ºC [Table 310.15(B)(16)]

Adjustment factor for four current-carrying conductors is 0.80 [Table 310.15(B)(3)(a)]

Corrected Ampacity = 30A x 0.80
Corrected Ampacity = ***24A***

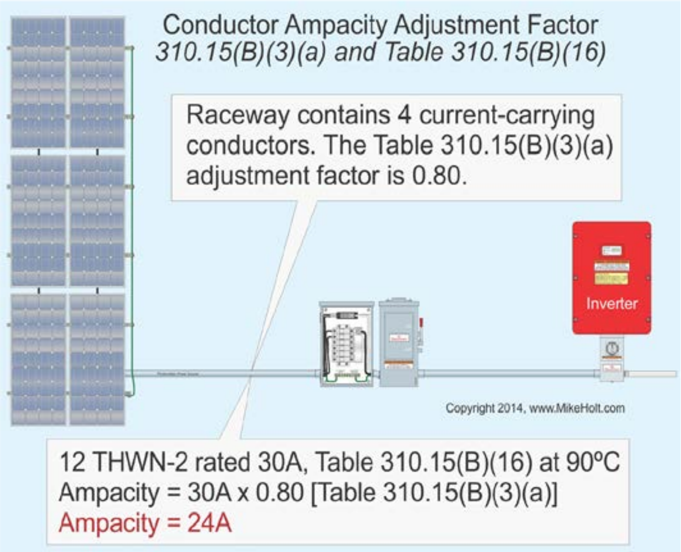

Figure 6–33

▶ Ampacity Adjustment Example 2

Question: *What's the adjusted ampacity of four 1 THWN conductors in a raceway?* Figure 6–34

(a) 120A *(b) 104A* *(c) 29A* *(d) 32A*

Answer: *(b) 104A*

Adjusted Ampacity = Table 310.15(B)(16) Ampacity x Bundled Ampacity Adjustment Factor from Table 310.15(B)(3)(a)

1 THWN is rated 130A at 75ºC [Table 310.15(B)(16)]

Adjustment factor for four current-carrying conductors is 0.80 [Table 310.15(B)(3)(a)]

Corrected Ampacity = 130A x 0.80
Corrected Ampacity = ***104A***

▶ Conductor Ampacity Example 1

Question: *What's the ampacity of four current-carrying 10 THWN-2 conductors installed in a raceway less than ½ in. above a rooftop; ambient temperature 90ºF?* Figure 6–36

(a) 15.30A (b) 18.56A (c) 25.34A (d) 31.25A

Answer: *(b) 18.56A*

Adjusted/Corrected Ampacity = Table 310.15(B)(16) Ampacity x Temperature Factor x Bundled Adjustment Factor

Ambient Temperature Includes Roof Top Temperature Adder [Table 310.15(B)(3)(c)]

90ºF Ambient + 60ºF Rooftop Adder = 150ºF

Ambient Temperature Correction Factor for 150ºF = 0.58 [Table 310.15(B)(2)(a)]

10 THWN-2 is rated 40A at 90ºC [Table 310.15(B)(16)]

Adjustment factor for four current-carrying conductors is 0.80 [Table 310.15(B)(3)(a)]

Adjusted/Corrected Ampacity = 40A x 0.58 x 0.80
Adjusted/Corrected Ampacity = 18.56A

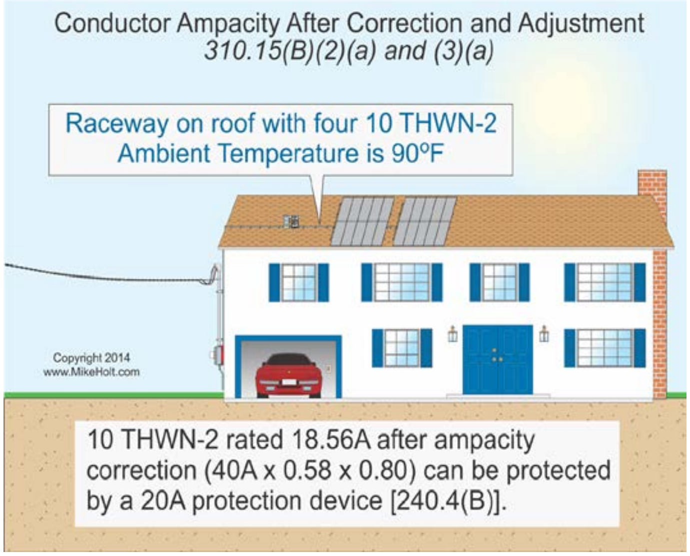

Figure 6–36

▶ Conductor Ampacity Example 2

Question: *What's the ampacity of four current-carrying 8 THHN conductors installed in an ambient temperature of 90ºF?*

(a) 21A (b) 42A (c) 51A (d) 64A

Answer: *(b) 42A*

Adjusted/Corrected Ampacity = Table 310.15(B)(16) Ampacity x Temperature Factor x Bundled Adjustment Factor

Ambient Temperature Correction Factor for 90ºF = 0.96 [Table 310.15(B)(2)(a)]

8 THHN is rated 55A at 90ºC [Table 310.15(B)(16)]

Adjustment factor for four current-carrying conductors is 0.80 [Table 310.15(B)(3)(a)]

Adjusted/Corrected Ampacity = 55A x 0.96 x 0.80
Adjusted/Corrected Ampacity = 42.24A

Lower Ampacity Rule [310.15(A)(2)]

Where more than one ampacity applies for a given circuit length, the lowest ampacity value must be used. Figure 6–37

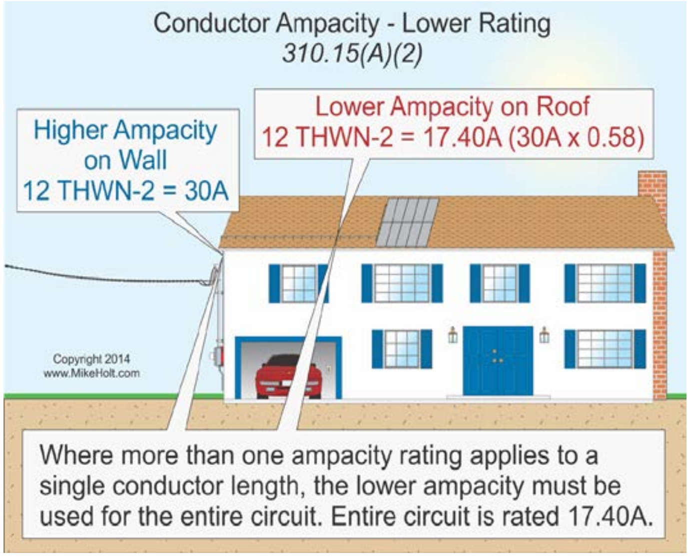

Figure 6–37

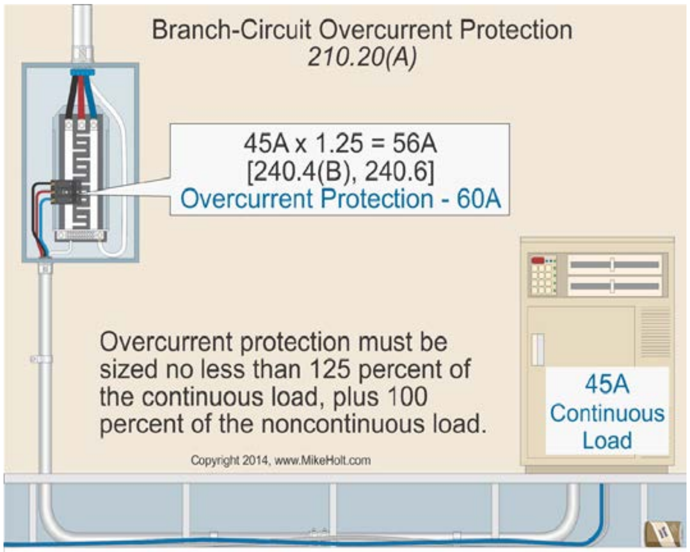

Figure 6–49

Branch Circuits Conductor Sizing [210.19(A)(1)]

Branch-circuit conductors must have an ampacity of not less than the maximum load to be served. The conductor must be the larger of (a) or (b).

(a) Conductors must be sized no less than 125 percent of the continuous loads, plus 100 percent of the noncontinuous loads, based on the terminal temperature rating ampacities as listed in Table 310.15(B)(16). Figure 6–50

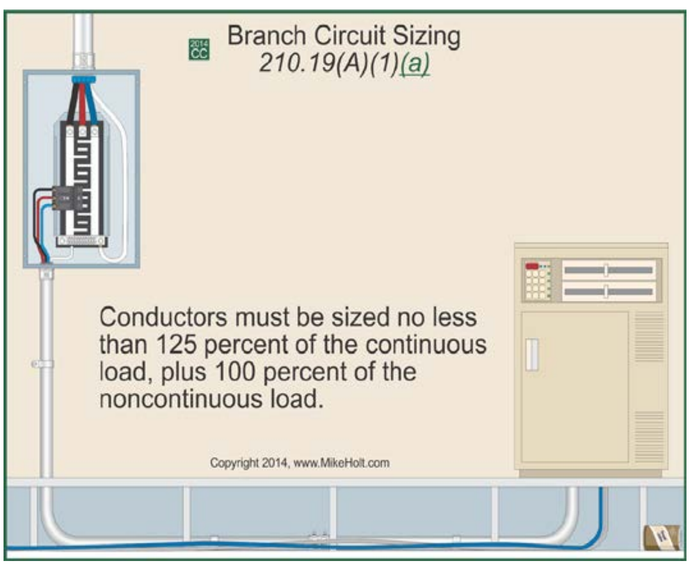

Figure 6–50

(b) Conductors must be sized to carry the load after the application of correction or adjustment factors. Figure 6–51

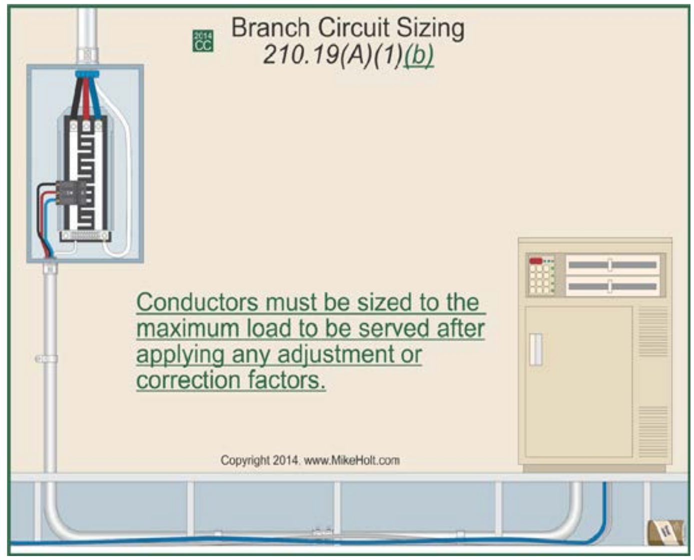

Figure 6–51

▶ Branch Circuit Conductor Sizing Example

Question: *What size branch circuit conductor (THHN) is required for a 45A continuous nonlinear load that requires three ungrounded conductors and a neutral (four current-carrying conductors)?* Figure 6–52

(a) 8 AWG *(b) 6 AWG*
(c) 4 AWG *(d) none of these*

Answer: *(c) 4 AWG*

210.19(A)(1)(a)—Since the load is 45A continuous, the conductor must be sized to have an ampacity of not less than 56A (45A x 1.25). According to Table 310.15(B)(16), 60ºC column, a 4 AWG conductor is suitable, because it has an ampere rating of 70A at 60ºC before any conductor ampacity adjustment and/or correction is applied.

210.19(A)(1)(b)—Because the neutral is considered a current-carrying conductor per 310.15(B)(5)(c), there are four current-carrying conductors. Therefore we must apply Table 310.15(B)(3) adjustment factor of 80%.

4 THHN is 95A at 90ºC [Table 310.15(B)(16)]

Adjustment factor for four current-carrying conductors is 0.80 [Table 310.15(B)(3)(a)].

Corrected Ampacity = 95A x 0.80
Corrected Ampacity = 76A, which is adequate for the 45A load.

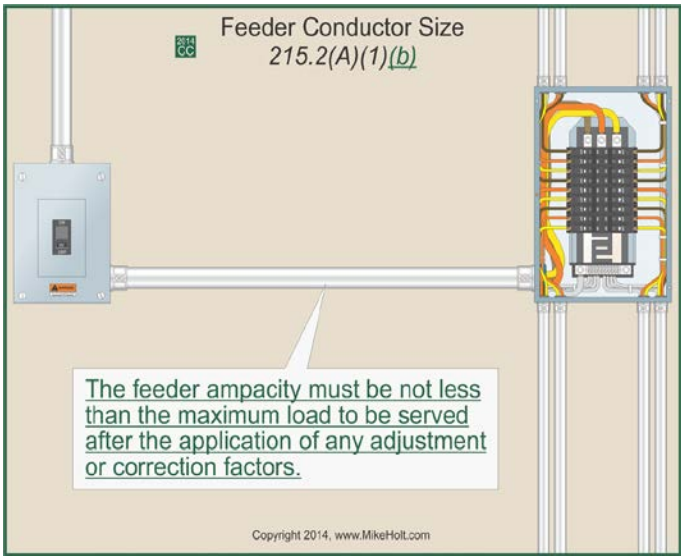

Figure 6–55

▶ Feeder Conductor Sizing Example

Question: *What size feeder conductor (THHN) is required for a 200A continuous nonlinear load at an ambient temperature of 100ºF (four current-carrying conductors)?* Figure 6–56

(a) 2/0 AWG (b) 250 kcmil (c) 4/0 AWG (d) 300 kcmil

Answer: *(d) 300 kcmil*

215.2(A)(1)(a)—Since the load is 200A continuous, the conductors must be sized to have an ampacity of not less than 250A (200A x 1.25). According to Table 310.15(B)(16), 75ºC column, a 250 kcmil conductor is suitable, because it has an ampere rating of 255A at 75ºC before any conductor ampacity adjustment and/or correction is applied.

210.19(A)(1)(b)—Because the ambient temperature is not 86ºC and there are more then three current-carrying conductors we need to determine the corrected ampacity to ensure that it has the ability to supply the 200A load as well as being protected by a 250A protection device.

Ambient Temperature Correction Factor for 100ºF = 0.91 [Table 310.15(B)(2)(a)]

Because the neutral is considered a current-carrying conductor per 310.15(B)(5)(c), there are four current-carrying conductors. Therefore we must apply Table 310.15(B)(3) adjustment factor of 80%.

250 kcmil THHN is rated 290A at 90ºC [Table 310.15(B)(16)]

Corrected Ampacity = 290A x 0.91 x 0.80
Corrected Ampacity = 211A

250 kcmil THHN is rated 211A after ampacity correction and adjustment; it's rated [211A] to supply a 200A continuous load in accordance with 215.2(A)(1)(b), but it's not permitted to be protected by the 250A protection device required by 240.4.

250 kcmil THHN is rated 290A at 90ºC [Table 310.15(B)(16)] before ampacity correction and adjustment.

Corrected/Adjusted Ampacity = 290A x 0.91 x 0.80
Corrected/Adjusted Ampacity = 211A

300 kcmil conductor is rated 233A after ampacity correction and adjustment; it's rated [233A] to supply a 200A continuous load in accordance with 215.2(A)(1)(b), and it's permitted to be protected by the 250A protection device required by 240.4.

300 kcmil THHN is rated 320A at 90ºC [Table 310.15(B)(16)] before ampacity correction and adjustment.

Corrected/Adjusted Ampacity = 320A x 0.91 x 0.80
Corrected/Adjusted Ampacity = 233A

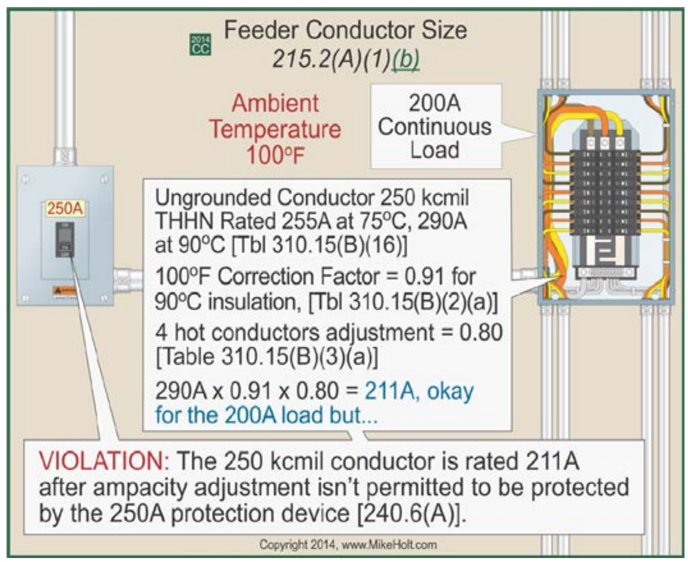

Figure 6–56

6.17 Feeder Tap Rules

Tap. A conductor, other than a service conductor, that has overcurrent protection rated higher than normally allowed in 240.2. Figure 6–57

Feeder Taps Not Over 10' [240.21(B)(1)]

Feeder tap conductors up to 10 ft long are allowed without overcurrent protection at the tap location if installed as follows:

7.9 Sizing Conductors to Account for Voltage Drop

Scan the QR code for a video clip of Mike explaining this topic; this is a sample from the DVDs that accompany this textbook.

The size of a conductor (its resistance) affects voltage drop. If we want to decrease the voltage drop of a circuit, we can increase the cross-sectional area of the conductor (reduce its resistance). When sizing conductors to prevent excessive voltage drop, use the following formulas:

Single-Phase:

Cmils = (2 x K x I x D)/VD

► Size Conductor—Single-Phase Example

Question: *What size conductor should be used to limit the voltage drop to no more than three percent if the single-phase continuous load of 26A at 240V is located 100 ft from the power supply? The terminals are rated 75ºC.* Figure 7–22

(a) 12 AWG (b) 8 AWG (c) 6 AWG (d) 4 AWG

Answer: *(b) 8 AWG*

Cmils = (2 x K x I x D)/VD

K = 12.90 ohms, copper
I = 26A
D = 100 ft

VD = 240V x 0.03
VD = 7.20V

Cmils = (2 x 12.90 ohms x 26A x 100 ft)/7.20V
Cmils = 9,317 cmils, 10 AWG [Chapter 9, Table 8]

Note: *Section 210.19(A)(1) requires that the conductors for a continuous load be sized not less than 125 percent of the continuous load and 210.20(A) requires that the overcurrent protection device must be not less than 125 percent of the continuous load. The continuous load is 26A so the conductor and overcurrent device must be sized at: 26A x 1.25 = 32.50A.*

The 10 AWG conductor required for voltage drop is rated for 30A at 60ºC according to 110.14(C) and Table 310.15(B)(16). However, 240.4(D) limits the overcurrent for 10 AWG to a maximum of 30A, so this won't work. We need to use 8 AWG conductors (rated 40A at 60ºC) for the circuit protected by a 35A device. Figure 7–23

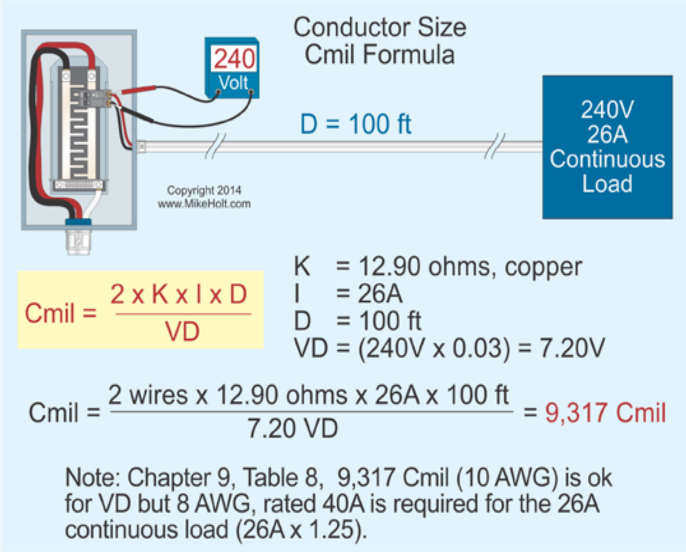

Figure 7–22

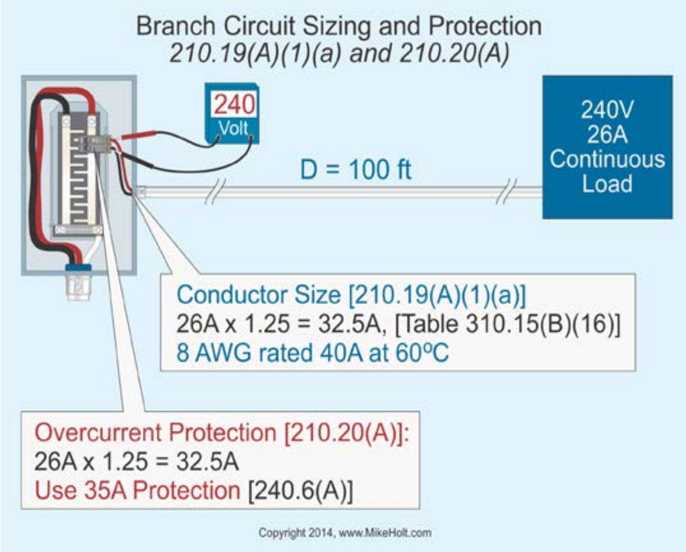

Figure 7–23

Three-Phase:

Cmils = (1.732 x K x I x D)/VD

▶ Size Conductor—Three-Phase Example

Question: *What size conductor should be used to limit voltage drop from exceeding three percent if the equipment nameplate indicates 18A continuous load at 480V, three-phase and its located 300 ft from the power supply?* Figure 7–24

(a) 12 AWG (b) 10 AWG (c) 8 AWG (d) 6 AWG

Answer: *(b) 10 AWG*

Cmils = (1.732 x K x I x D)/VD

K = 12.90 ohms, copper
I = 18A
D = 300 ft
VD = 480V x 0.03 = 14.40V

Cmils = (1.732 x 12.90 ohms x 18A x 300 ft)/14.40V
Cmils = 8,379 cmils, 10 AWG [Chapter 9, Table 8]

Note: *Section 210.19(A)(1) requires that the conductors for a noncontinuous load be sized not less than 125 percent of the continuous load and 210.20(A) requires that the overcurrent protection device must be not less than 125 percent of the continuous load. The continuous load is 18A so the conductor and overcurrent device must be sized at 18A x 1.25 = 22.50A.*

The 10 AWG conductor required for voltage drop is rated for 30A at 60°C according to 110.14(C) and Table 310.15(B)(16). Figure 7–25

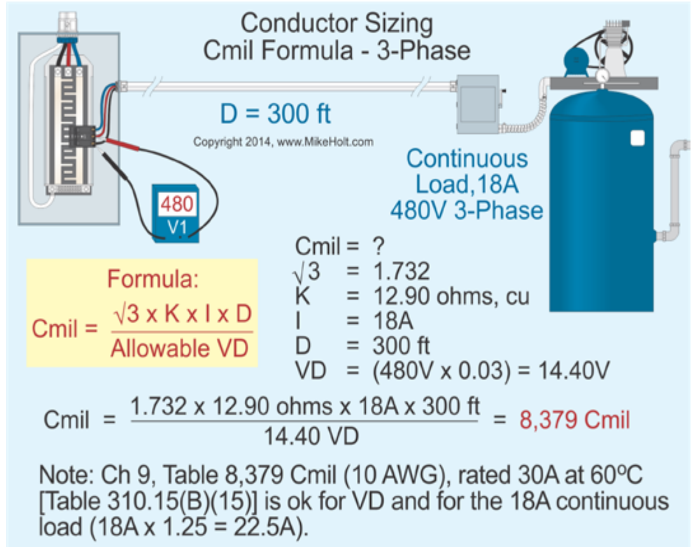

Figure 7–24

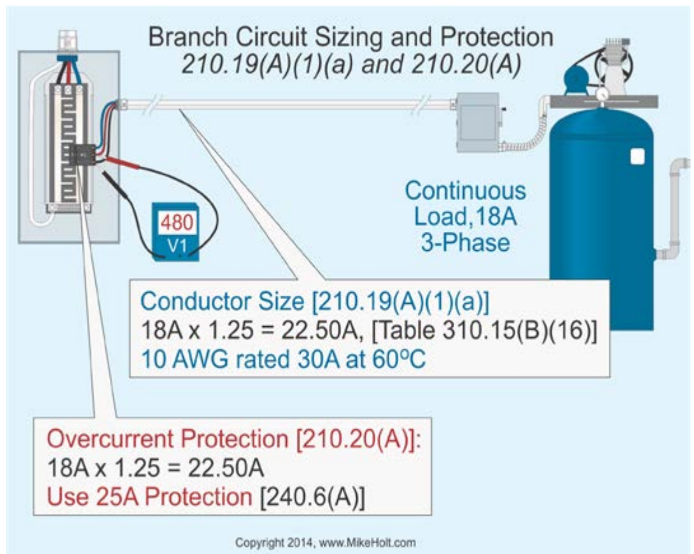

Figure 7–25

7.10 Limiting Conductor Length to Minimize Voltage Drop

Limiting the length of conductors reduces voltage drop. The following formulas can be used to help determine the maximum conductor length needed to limit voltage drop to *NEC* recommendations:

Single-Phase Circuit Voltage Drop:

D = (Cmils x VD)/(2 x K x I)

Three-Phase Circuit Voltage Drop:

D = (Cmils x VD)/(1.732 x K x I)

▶ Distance—Single-Phase Example

Question: *What's the maximum distance a 240V, single-phase, 10A continuous load can be located from the panelboard so the voltage drop doesn't exceed three percent? The load is wired with 12 AWG.* Figure 7–26

(a) 55 ft (b) 110 ft (c) 182 ft (d) 220 ft

Answer: *(c) 182 ft*

D = (Cmils x VD)/(2 x K x I)

Cmils = 6,530 (12 AWG) [Chapter 9, Table 8]

VD = 240V x 0.03
VD = 7.20V

K = 12.90, copper

I = 10A

D = (6,530 cmils x 7.20V)/(2 x 12.90 x 10A)
D = ***182.20 ft***

▶ Distance—Three-Phase Example

Question: *What's the maximum distance a 100A, 208V, three-phase noncontinuous load wired with 1 AWG conductors can be located from the panelboard so the voltage drop doesn't exceed three percent?* Figure 7–27

(a) 75 ft (b) 125 ft (c) 147 ft (d) 234 ft

Answer: *(d) 234 ft*

D = (Cmils x VD)/(1.732 x K x I)

Cmils = 83,690, (1 AWG) [Chapter 9, Table 8]

VD = 208V x 0.03
VD = 6.24V

K = 12.90 ohms, copper

I = 100A

D = (83,690 cmils x 6.24V)/(1.732 x 12.90 ohms x 100A)
D = ***234 ft***

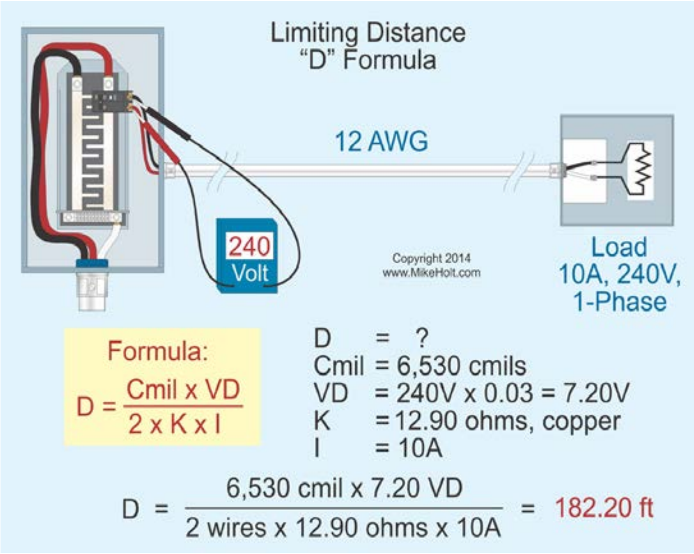

Figure 7–26

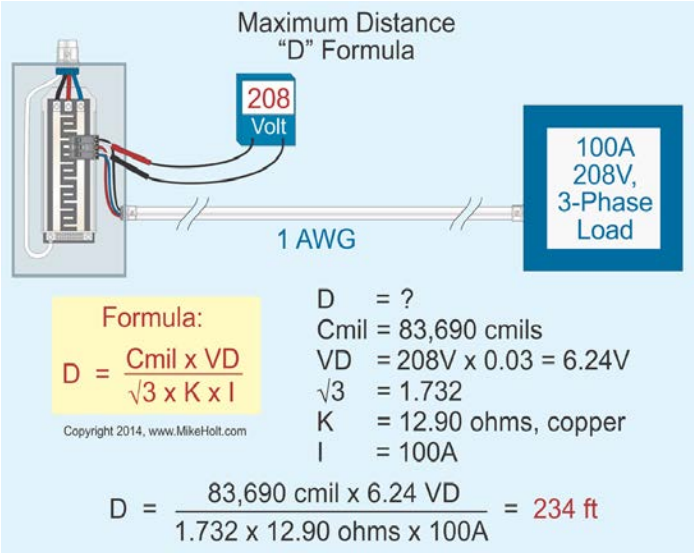

Figure 7–27

7.11 Limiting Current to Limit Voltage Drop

Sometimes the only method of limiting the circuit voltage drop is to limit the load on the conductors. The following formulas can be used to determine the maximum load:

Single-Phase Circuit Voltage Drop:

I = (Cmils x VD)/(2 x K x D)

▶ Maximum Load—Single-Phase Example

Question: *What's the maximum recommended continuous load that should be placed on 1/0 AWG aluminum conductors in a nonmetallic raceway to a panelboard located 200 ft from a 240V single-phase power source so the NEC recommendation for voltage drop isn't exceeded?* Figure 7–28

(a) 51A (b) 90A (c) 94A (d) 115A

Answer: *(b) 90A*

I = (Cmils x VD)/(2 x K x D)

Cmils = 105,600 (1/0 AWG) [Chapter 9, Table 8]

VD = 240V x 0.03
VD = 7.20V

K = 21.20 ohms, aluminum

D = 200 ft

I = (105,600 cmils x 7.20V)/(2 x 21.20 ohms x 200 ft)
I = ***90A***

Note: *The maximum continuous load of 90A Is permitted on 1/0 AWG aluminum, which is rated 120A at 75ºC [Table 310.15(B)(16)].*

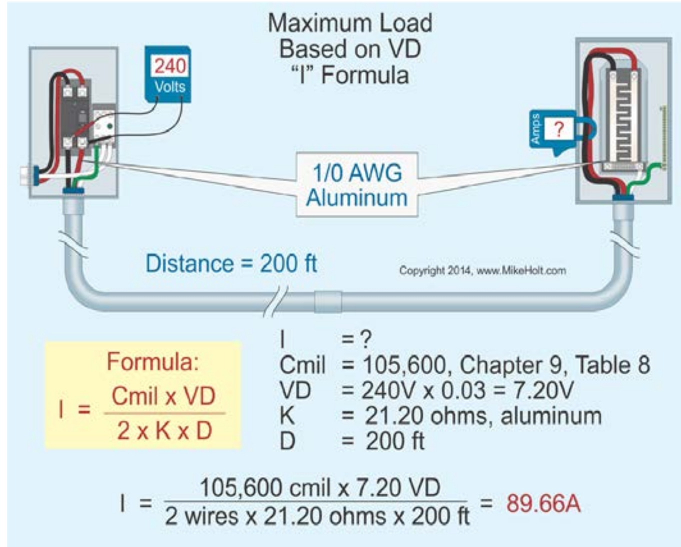

Figure 7–28

Three-Phase Circuit Voltage Drop:

I = (Cmils x VD)/(1.732 x K x D)

▶ Maximum Load—Three-Phase Example

Question: *What's the maximum recommended continuous load that should be placed on a 150A rated feeder containing 1 AWG copper conductors in an aluminum raceway to a panelboard located 150 ft from a 208V, three-phase power source so the NEC recommendation for voltage drop isn't exceeded?* Figure 7–29

(a) 104A (b) 130A (c) 150A (d) none of these

Answer: *(a) 104A*

I = (Cmils x VD)/(1.732 x K x D)

Cmils = 83,690 (1 AWG) [Chapter 9, Table 8]

VD = 208V x 0.03
VD = 6.24V

K = 12.90 ohms, copper

D = 150 ft

I = (83,690 cmils x 6.24V)/(1.732 x 12.90 ohms x 150 ft)
I = 155.80A

Note: *The maximum continuous load on a protection device [215.3] and conductor [215.2(A)(1)(a)] isn't permitted to exceed 80 percent of their rating.*

The maximum continuous load on the overcurrent device: 150A x 80% = 120A. The maximum continuous load on 1 AWG rated 130A at 75°C: 130A x 80% = ***120A****.*

7.8 Determining Circuit Conductors' Voltage Drop—Formula Method

6. What's the voltage drop of two 3 AWG aluminum conductors that supply a 5 hp, 115V, single-phase motor that has a nameplate rating of 55A? The motor is located 95 ft from the power supply.

(a) 3.25V
(b) 4.21V
(c) 6.24V
(d) 7.26V

7.9 Sizing Conductors to Account for Voltage Drop

7. A 240V, 40A, single-phase load is located 150 ft from an existing junction box. The junction box is located 50 ft from the panelboard. When the 40A load is on, the voltage at the junction box is calculated to be 236V. The *NEC* recommends that the voltage drop for this branch circuit not exceed three percent of the 240V source (7.20V). What size copper conductor can be installed from the junction box to the load and still meet the *NEC* recommendations for branch circuits?

(a) 6 AWG
(b) 3 AWG
(c) 1 AWG
(d) 1/0 AWG

8. An existing junction box is located 65 ft from the panelboard and contains 4 AWG aluminum conductors. What size copper conductor can be used to extend this circuit 85 ft and supply a 50A, 208V load?

Note: Apply the *NEC* recommended voltage-drop limits.

(a) 10 AWG
(b) 8 AWG
(c) 6 AWG
(d) 4 AWG

7.10 Limiting Conductor Length to Minimize Voltage Drop

9. How far can a 230V, 50A, three-phase load be located from a panelboard if it's fed with 3 AWG conductors and still meet the *NEC* recommendations for voltage drop for branch circuits?

(a) 275 ft
(b) 300 ft
(c) 325 ft
(d) 350 ft

7.11 Limiting Current to Limit Voltage Drop

10. Two 8 AWG copper conductors supply a 120V load that's located 225 ft from the panelboard. What's the maximum load in amperes that can be applied to these conductors without exceeding the *NEC* recommendation on conductor voltage drop?

(a) 0A
(b) 5A
(c) 10A
(d) 15A

▶ Table FLC Direct-Current Example

Question: *According to Table 430.247, what's the FLC from the NEC Tables for a 5 hp 120V dc motor?*

(a) 28A *(b) 32.20A* *(c) 40A* *(d) 56A*

Answer: *(c) 40A*

5 hp, 120V, dc motor = ***40A*** *[Table 430.247]*

▶ Table FLC Single-Phase Alternating Current Example 1

Question: *According to Table 430.248, what's the FLC for a 5 hp 115V single-phase motor?*

(a) 28A *(b) 32.20A* *(c) 40A* *(d) 56A*

Answer: *(d) 56A*

5 hp, 125V, ac motor = ***56A*** *[Table 430.248]*

▶ Table FLC Single-Phase Alternating Current Example 2

Question: *According to Table 430.248, what's the FLC for a 5 hp 200V single-phase motor?*

(a) 28A *(b) 32.20A* *(c) 40A* *(d) 56A*

Answer: *(b) 32.20A*

5 hp, 200V, ac motor = ***32.20A*** *[Table 430.248]*

▶ Table FLC Single-Phase Alternating Current Example 3

Question: *According to Table 430.248, what's the FLC for a 5 hp 208V single-phase motor?*

(a) 30.80A *(b) 32.20A* *(c) 40A* *(d) 56A*

Answer: *(a) 30.80A*

5 hp, 208V, ac motor = ***30.80A*** *[Table 430.248]*

▶ Table FLC Single-Phase Alternating Current Example 4

Question: *According to Table 430.248, what's the FLC for a 5 hp 230V single-phase motor?*

(a) 28A *(b) 31A* *(c) 39A* *(d) 52A*

Answer: *(a) 28A*

5 hp, 230V, ac motor = ***28A*** *[Table 430.248]*

▶ Table FLC Three-Phase Alternating Current Example 1

Question: *According to Table 430.250, what's the FLC for a 5 hp 230V three-phase motor?*

(a) 11A *(b) 15.20A* *(c) 40A* *(d) 56A*

Answer: *(b) 15.20A*

5 hp, 230V, three-phase ac motor = ***15.20A*** *[Table 430.250]*

▶ Table FLC Three-Phase Alternating Current Example 2

Question: *According to Table 430.250 what's the FLC for a 25 hp 230V three-phase motor?*

(a) 28A *(b) 35.20A* *(c) 40A* *(d) 68A*

Answer: *(d) 68A*

5 hp, 230V, three-phase ac induction motor = ***68A*** *[Table 430.250]*

8.3 Motor Nameplate Full Load Amperes (FLA) [430.6(A)(2)]

Overload devices must be sized based on the motor nameplate current rating in accordance with 430.31.

► Feeder Conductor Size Example 2

Question: *What size feeder conductor is required for two 7½ hp, three-phase, 230V motors, terminals rated 75ºC?* Figure 8–15

(a) 10 AWG (b) 8 AWG (c) 6 AWG (d) 4 AWG

Answer: *(b) 8 AWG*

7½ hp FLC = 22A [Table 430.250]

Feeder Size = (22A x 1.25) + 22A
Feeder Size = 49.50A, 8 AWG rated 50A at 75ºC [Table 310.15(B)(16)]

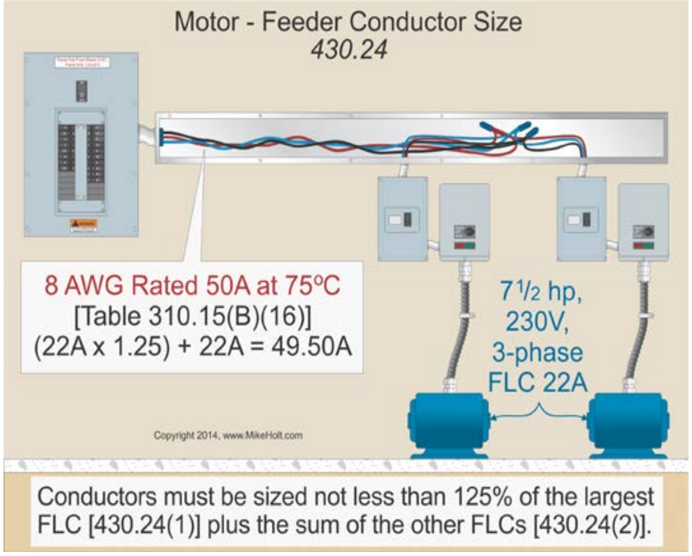

Figure 8–15

► Feeder Conductor Size Example 3

Question: *What size feeder conductor is required for two 7½ hp and one 15 hp, three-phase, 230V motors, terminals rated 75ºC?* Figure 8–16

(a) 10 AWG (b) 8 AWG (c) 3 AWG (d) 4 AWG

Answer: *(c) 3 AWG*

7½ hp FLC = 22A [Table 430.250]
15 hp FLC = 42A [Table 430.250]

Feeder Size = (42A x 1.25) + 22A + 22A
Feeder Size = 96.50A, 3 AWG rated 100A at 75ºC [Table 310.15(B)(16)]

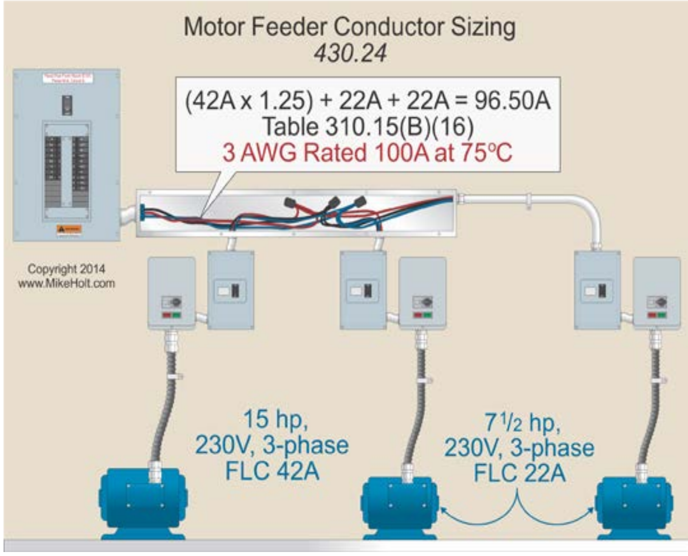

Figure 8–16

8.6 Overcurrent Protection

Overcurrent is current, in amperes, greater than the rated current of the equipment or conductors resulting from an overload, short circuit, or ground fault. Figure 8–17

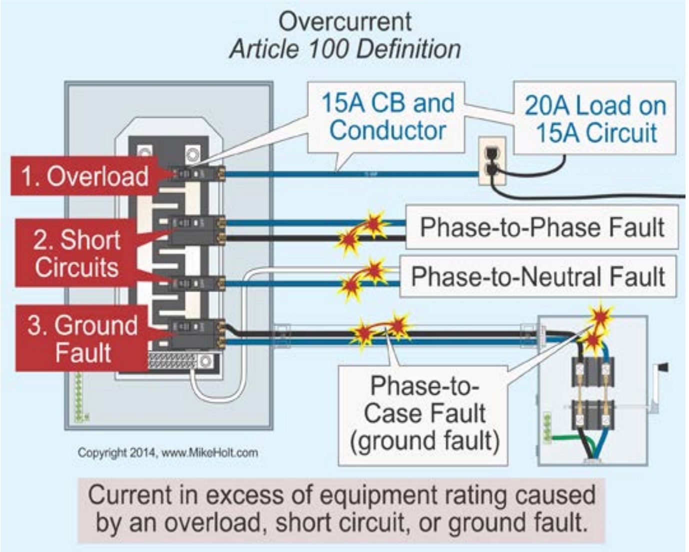

Figure 8–17

Author's Comment:

- These conductors must be protected against short circuits and ground faults in accordance with 440.22(B)(1).

▶ Motor-Compressor and Other Motors—Conductor Size Example 1

Question: *What size conductor is required for a 16.70A motor-compressor with a 1.20A fan at 60ºC?* Figure 8–58

(a) 12 AWG *(b) 10 AWG* *(c) 8 AWG* *(d) 6 AWG*

Answer: *(b) 10 AWG*

Conductor Size = (16.70A x 1.25) + 1.20A
Conductor Size = 22.08A, 10 AWG rated 30A at 60°C [Table 310.15(B)(16)]

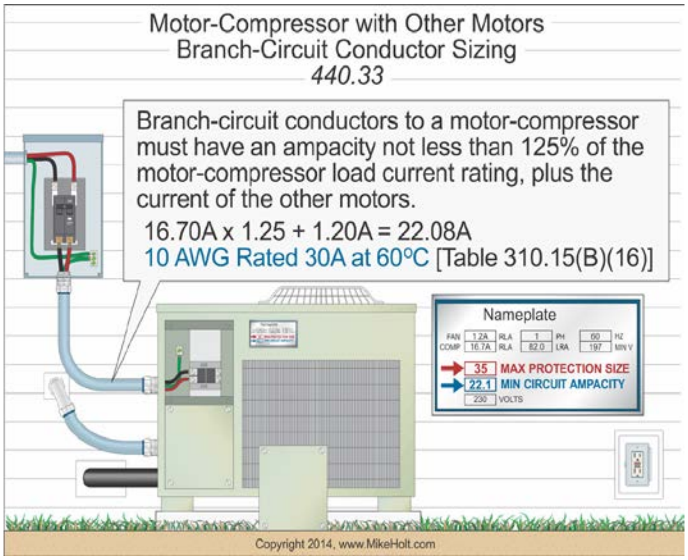

Figure 8–58

▶ Motor-Compressor and Other Motors—Conductor Size Example 2

Question: *What size conductor is required for a 23A motor-compressor with a 1.30A fan at 60ºC?* Figure 8–59

(a) 12 AWG *(b) 10 AWG* *(c) 8 AWG* *(d) 6 AWG*

Answer: *(b) 10 AWG*

Conductor Size = 23A x 1.25 + 1.30A
Conductor Size = 30.05A, 10 AWG rated 30A at 60°C [Table 310.15(B)(16)]

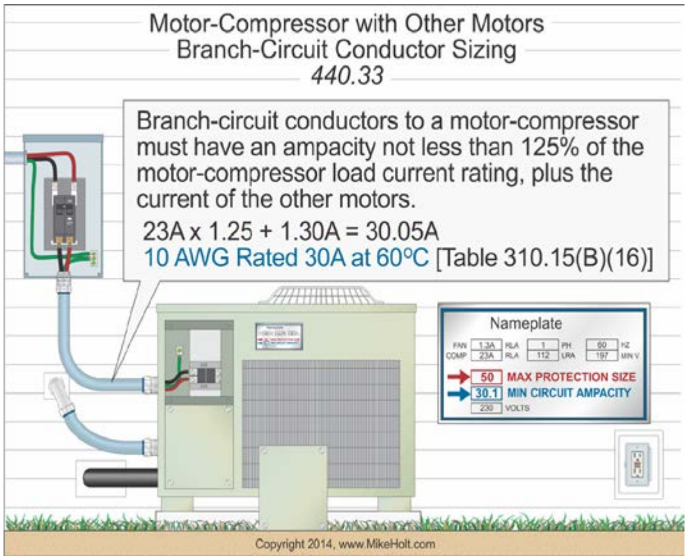

Figure 8–59

Question: *What size service is required for a 1,500 sq ft dwelling unit containing the following loads?* Figure 9–26

Dishwasher	*1,500 VA*
Disposal	*1,000 VA*
Water Heater	*4,500 W*
Dryer	*4,000 W*
Range	*14,000 W*
Air-Conditioning	*17A, 240V*
Electric Heating (one control unit)	*8,000 W*

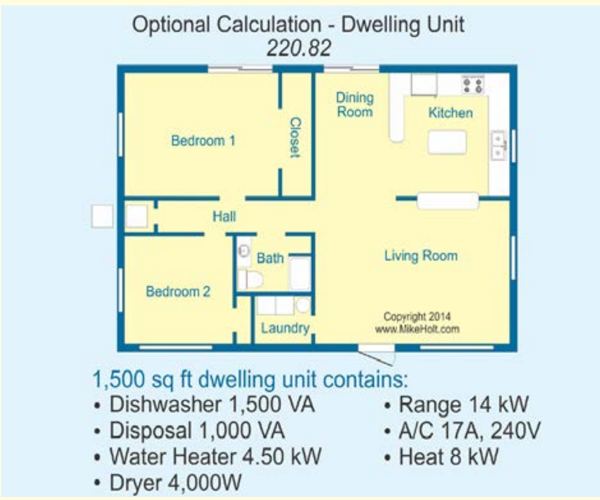

Figure 9–26

Step 1: General Loads [220.82(B)]

General Lighting			
(1,500 sq ft x 3 VA)	*4,500 VA*		
Small-Appliance Circuits			
(1,500 VA x 2 circuits)	*3,000 VA*		
Laundry Circuit	*1,500 VA*		
Appliance (name plate)			
Dishwasher	*1,500 VA*		
Disposal	*1,000 VA*		
Water Heater	*4,500 W*		
Dryer	*4,000 W*		
Range	*+14,000 W*		
Connected Load	*34,000 VA*		
First 10 kW at 100%	*– 10,000 VA*	*x 1.00*	*10,000 VA*
Remainder at 40%	*24,000 VA*	*x 0.40*	*+ 9,600 VA*
Calculated General Load			***19,600 VA***

Step 2: Air-Conditioning versus Heat [220.82(C)]

Air-conditioning at 100 percent [220.82(C)(1)]
versus electric space heating at 65 percent [220.82(C)(4)]

Air Conditioner [Table 430.248]:
A/C VA = Volts x Amperes
A/C VA = 240V x 17A
A/C VA = 4,080 VA, omit [220.60]

Electric Space Heat = 8,000 W x 0.65
Electric Space Heat = 5,200 W ***5,200 W***

Step 3: Service Size and Feeder/Service Conductors [310.15(B)(7)]

Step 1. Calculated General Load	*19,600 VA*	
Step 2. Heat Demand Load	*+ 5,200 W*	
Total Demand Load	*24,800 VA*	***24,800 VA***

Service Size in Amperes = VA Demand Load/System Volts

Figure 9–27
Service Size in Amperes = 24,800 VA/240V
Service Size in Amperes = 103A, 110A service [240.6(A)]

Service Conductor =83% of Service Rating [310.15(B)(7)]
91A x 83%, 3 AWG rated 100A at 75ºC [Table 310.15(B)(16)]

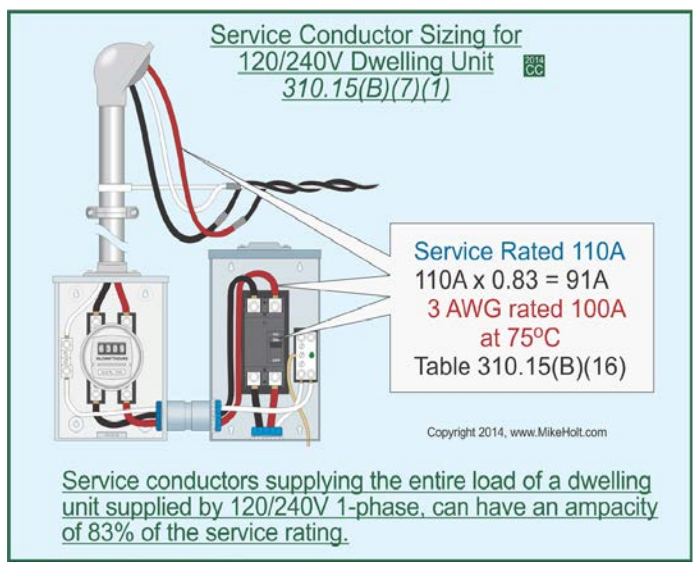

Figure 9–27

9.10 Existing Dwelling Unit Optional Load Calculation [220.83]

The following steps can be used to determine if the existing service or feeder is of sufficient capacity to serve additional loads using the optional method contained in Article 220, Part IV:

Author's Comment:

- The calculation of a feeder or service load for existing installations can be also be in accordance with the actual maximum demand in accordance with 220.87.

Step 1: General Loads [220.83(B)]

The demand load must not be less than 100 percent for the first 8 kVA, plus 40 percent of the remainder of the following loads:

(1) ***General Lighting and Receptacles:*** 3 VA per sq ft

(2) ***Small-Appliance and Laundry Branch Circuits:*** 1,500 VA for each 20A small-appliance and laundry branch circuit specified in 220.52.

(3) ***Appliances:*** The nameplate VA rating of all appliances and motors that are fastened in place (permanently connected) or located on a specific circuit, except heating and air-conditioning.

Note: Be sure to calculate the range and dryer at their nameplate ratings!

Step 2: Largest of Air-Conditioning versus Heating [220.83(B)]

Include the larger of air-conditioning equipment versus space-heating.

Step 3: Service Size [310.15(B)(7)]

For one-family dwellings and for individual dwelling units of two-family and multifamily dwellings, service and feeder conductors supplied by a single-phase, 120/240V system can be sized in accordance with 310.15(B)(7)(1) through (4).

9.11 Existing Dwelling Unit Optional Load Calculation [220.83] Example

Question: *What size service is required for a 1,500 sq ft dwelling unit containing the following loads?*

Dishwasher	*1,500 VA*
Disposal	*1,000 VA*
Water Heater	*4,500 W*
Dryer	*4,000 W*
Range	*14,000 W*
Air-Conditioning	*17A, 240V*
Electric Heating	*8,000 W*

Step 1: General Loads [220.83(B)]

General Lighting			
(1,500 sq ft x 3 VA)	*4,500 VA*		
Small-Appliance Circuits			
(1,500 VA x 2 circuits)	*3,000 VA*		
Laundry Circuit	*1,500 VA*		
Appliances (nameplate)			
Dishwasher	*1,500 VA*		
Disposal	*1,000 VA*		
Water Heater	*4,500 W*		
Dryer	*4,000 W*		
Range	*+14,000 W*		
Connected Load	*34,000 VA*		
First 8 kW at 100%	*– 8,000 VA*	*x 1.00 =*	*8,000 VA*
Remainder at 40%	*26,000 VA*	*x 0.40 =*	*+10,400 VA*
Calculated General Load			*18,400 VA*

Step 2: Air-Conditioning versus Heat [220.83(B)]

Air-conditioning at 100 percent [220.83(B)(1)] versus electric space-heating at 100 percent [220.83(B)(4)]

Air Conditioner [Table 430.248]:

A/C VA = VA x Volts
A/C VA = 240V x 17A
A/C VA = 4,080 VA, omit

Electric Space-Heat: 8,000 W	*8,000 W*

(continued)

9.13 Neutral Service and Feeder Calculation [220.61(B)]

Question: *What's the neutral demand load for a 1,500 sq ft dwelling unit containing the following loads?* Figure 9–29

Dishwasher	*1,500 VA*
Disposal	*1,000 VA*
Water Heater	*4,500 W*
Dryer	*4,000 W*
Range	*14,000 W*
Air-Conditioning	*17A, 240V*
Electric Heating (one control unit)	*8,000 W*

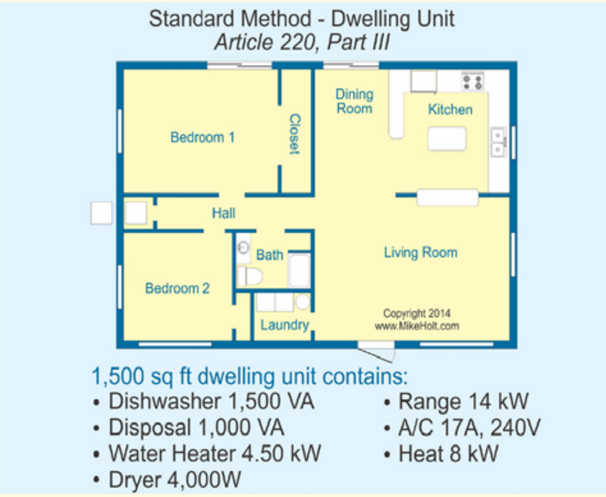

Figure 9–29

Step 1: General Lighting and Receptacles

(1,500 sq ft x 3 VA) [220.12]	*4,500 VA*		
Small-Appliance Circuits (1,500 VA x 2) [220.52(A)]	*3,000 VA*		
Laundry Circuit (1,500 VA x 1) [220.52(B)]	*+1,500 VA*		
Total Connected Load	*9,000 VA*		
First 3,000 VA at 100% [Table 220.42]	*–3,000 VA*	*x 1.00 =*	*3,000 VA*
Remainder at 35%	*6,000 VA*	*x 0.35 =*	*+2,100 VA*
Demand Load			***5,100 VA***

Step 2: Appliance Demand Load [220.53]

Dishwasher	*1,500 VA*	
Waste Disposal	*+1,000 VA*	
Demand Load	*2,500 VA*	***2,500 VA***

Step 3: Dryer Demand Load [220.54]

5,000 W x 0.70 = 3,500 W ***3,500 W***

Step 4: Cooking Equipment Demand Load [220.55]

Step a: *Since the range exceeds 12 kW, we must comply with Note 1 of Table 220.55. The first step is to determine the demand load as listed in Column C of Table 220.55 for one unit = 8 kW.*

Step b: *We must increase the Column C value (8 kW) by 5% for each kVA that the range exceeds 12 kW [Table 220.55, Note 1], 14 kW –12 kW = 2 kW.*

2 x 5% = 10% increase of the Column C value, resulting in 110%, or a 1.10 multiplier.

Range Demand Load = 8 kW x 1.10
Range Demand Load = 8.80 kW

Step c: *Neutral demand load sized to 70% of Table 220.55 value.*

Neutral Demand Load = 8,800 W x 0.70
Neutral Demand Load = 6,160 W ***6,160 W***

Step 5: Neutral Conductor Size [220.61 and Table 310.15(B)(16)]

Step 1. General Lighting Demand Load	*5,100 VA*
Step 2. Appliance Demand Load	*2,500 VA*
Step 3. Dryer Demand Load	*3,500 W*
Step 4. Cooking Equipment Demand Load	*+6,160 W*
Total Demand Load	***17,260 VA***

Neutral Amperes = Neural Demand Load/System Voltage

Neutral Amperes = 17,260 VA/240V
Neutral Amperes = 72A

Neutral Conductor = 4 AWG rated 85A at 75ºC [Table 310.15(B)(16)]

10.1 General Lighting and General-Use Receptacle Demand Load [220.42]

The *NEC* recognizes that the general lighting and receptacle, small-appliance, and laundry circuits won't all be on at full load at the same time, so it allows a demand factor to be applied to the total connected load [220.52]. To determine the feeder demand load for these circuits, use the following steps:

Step a: *Total Connected Load.* Determine the total connected load for:

(1) General lighting and receptacles at 3 VA per sq ft [220.12],

(2) Two small-appliance circuits each at 1,500 VA [220.52(A)], and Figure 10–2

(3) One laundry circuit at 1,500 VA [220.52(B)]. See Figure 10–2.

Step b: *Demand Factor.* Apply the Table 220.42 demand factors to the total connected load.

Step c: First 3,000 VA at 100 percent demand; remaining VA at 35 percent demand.

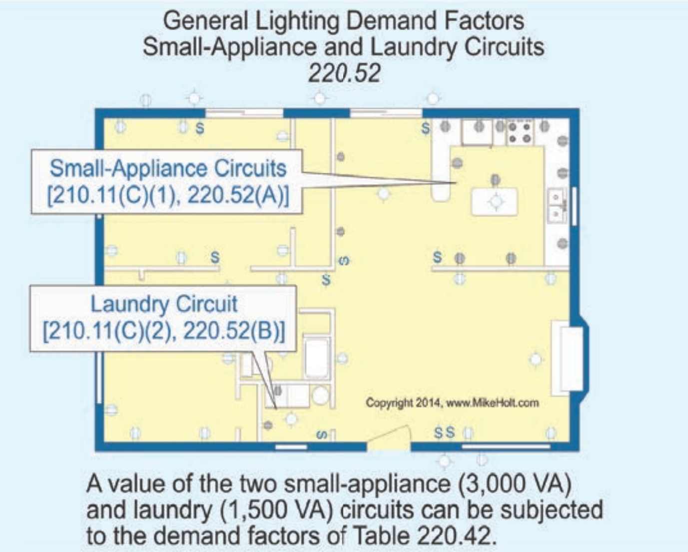

Figure 10–2

Lighting and General-Use Receptacles [220.12]

The *NEC* requires a minimum of 3 VA per sq ft for the general lighting and general-use receptacles for the purpose of determining branch circuits and feeder/service calculations.

Author's Comment:

- The 3 VA per sq ft rule for general lighting includes all 15A and 20A general-use receptacles, but it doesn't include the small-appliance or laundry circuit receptacles. See 220.14(J) for details.

► General Lighting Demand Load Example 1

Question: *What's the general lighting and receptacle demand load for a 10-unit apartment building? Each unit is 1,000 sq ft.* Figure 10–3

(a) 51,300 VA (b) 74,700 VA (c) 105,600 VA (d) 28,200 VA

Answer: *(d) 28,200 VA*

General Lighting			
(1,000 sq ft x 3 VA)	*3,000 VA*		
Small-Appliance Circuits	*3,000 VA*		
Laundry Circuit	*+1,500 VA*		
Connected Load for one unit	*7,500 VA*		
Connected Load			
(7,500 VA x 10 units)	*75,000 VA*		
First 3,000 VA at 100%			
[Table 220.42]	*– 3,000 VA*	*x 1.00 =*	*3,000 VA*
Next 117,000 VA at 35%*	*72,000 VA*	*x 0.35 =*	*+25,200 VA*
Total Demand Load			*28,200 VA*

**Note: Remember to subtract 3,000 VA from 120,000 VA when using Table 220.42 since the 35% only applies to 3,001 VA to 120,000 VA.*

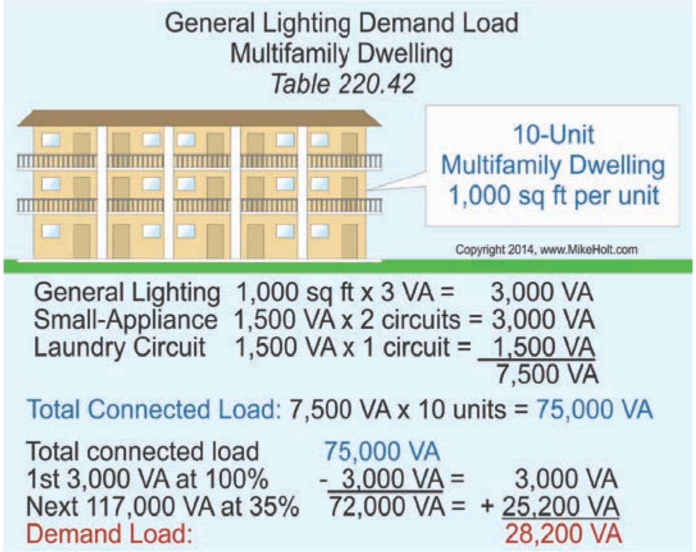

Figure 10–3

▶ General Lighting Demand Load Example 2

Question: *What's the general lighting and receptacle (including small-appliance circuits) demand load for an apartment building that contains 20 units? Each apartment is 1,500 sq ft.* Figure 10–4

Note: *Laundry facilities are provided on the premises for all tenants [210.52(F) Ex 1].*

(a) 5,200 VA (b) 25,500 VA (c) 40,590 VA (d) 51,450 VA

Answer: *(d) 51,450 VA*

General Lighting			
(1,500 sq ft x 3 VA)	*4,500 VA*		
Small-Appliance Circuits			
2 x 1,500 VA	*3,000 VA*		
Laundry Circuit	*+ 0 VA*		
Connected Load for One Unit	*7,500 VA*		
Connected Load [Table 220.42]			
(7,500 VA x 20 units)	*150,000 VA*		
First 3,000 VA at 100%	*– 3,000 VA*	*x 1.00 =*	*3,000 VA*
	147,000 VA		
Next 117,000 VA at 35%*	*117,000 VA*	*x 0.35 =*	*40,950 VA*
Remainder at 25%	*30,000 VA*	*x 0.25 =*	*+ 7,500 VA*
Total Demand Load			*51,450 VA*

**Note: Remember to subtract 3,000 VA from 120,000 VA when using Table 220.42 since the 35% only applies to 3,001 VA to 120,000 VA.*

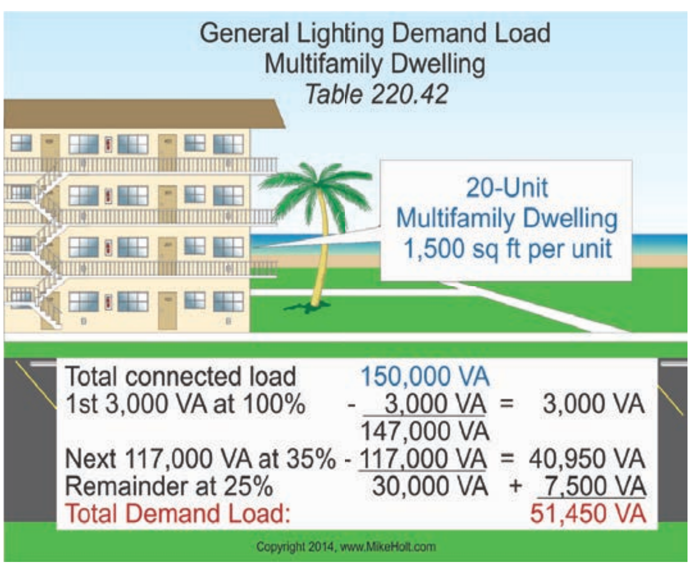

Figure 10–4

10.2 Appliance Demand Load [220.53]

Add the nameplate ratings of all appliances fastened in place. If there are four or more appliances, apply a 75 percent demand factor to determine the demand load.

Author's Comment:

- This demand factor doesn't apply to space-heating equipment [220.51], clothes dryers [220.54], electric ranges [220.55], or air-conditioning equipment.

▶ Appliance Demand Load Example 1

Question: *What's the appliance demand load for the feeder/service to a 10-unit multifamily building that contains a 1,200 VA dishwasher, a 900 VA waste disposal, and a 4,500 W water heater in each unit?* Figure 10–5

(a) 15 kVA (b) 30 kVA (c) 50 kVA (d) 60 kVA

Answer: *(c) 50 kVA*

Dishwasher	*1,200 VA*		
Disposal	*900 VA*		
Water Heater	*+ 4,500 W*		
Connected Load per Unit	*6,600 VA*		
Total Connected Load	*6.600 VA*	*x 10 units =*	*66,000 VA*
Total Demand Load	*66,000 VA*	*x 0.75* =*	*49,500 VA*

**Use the total number of appliances to determine if the 75 percent demand factor applies. In this case, there are 30 appliances on the feeder/service conductors [220.53].*

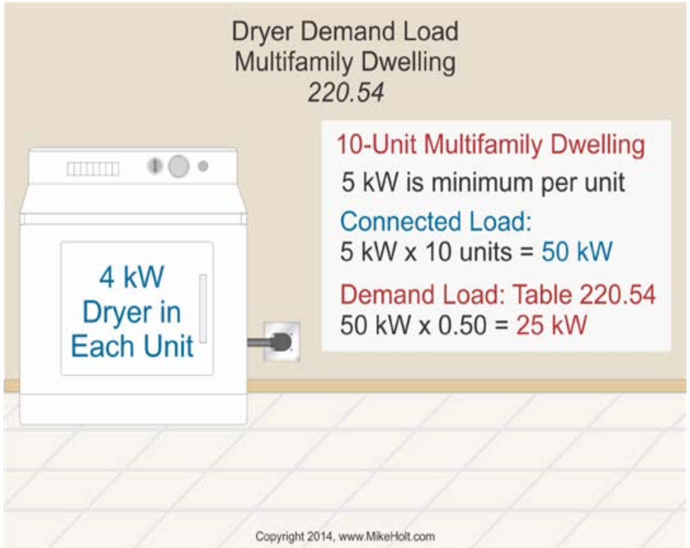

Figure 10–8

▶ Dryer Demand Load [220.54] Example 2

Question: *What's the demand load for ten 5.50 kW dryers?* Figure 10–9

(a) 5 kW (b) 27.50 kW (c) 45 kW (d) 60 kW

Answer: *(b) 27.50 kW*

Connected Load = 5.50 kW x 10 Units
Connected Load = 55 kW

Demand Load = 55 kW x 0.50
Demand Load = 27.50 kW

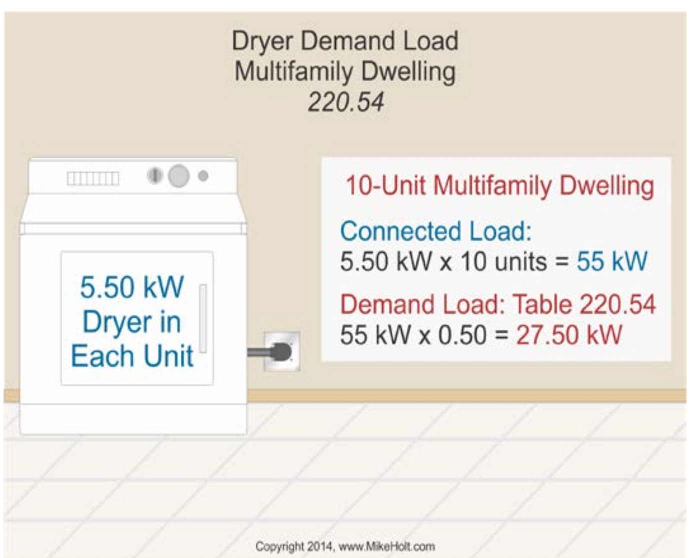

Figure 10–9

▶ Dryer Demand Load [220.54] Example 3

Question: *What's the demand load for twenty 5.50 kW dryers?* Figure 10–10

(a) 23 kW (b) 37 kW (c) 42 kW (d) 60 kW

Answer: *(c) 42 kW*

Percent = 47% – [1% x (Number of Dryers Exceeding 11)]
Percent = 47% – [1% x (20 Dryers – 11 Dryers)]
Percent = 47% – (1% x 9 Dryers)
Percent = 47% – 9%
Percent = 38% or 0.38 [Table 220.54]

Connected Load = 5.50 kW x 20 Units

Demand Load = 5.50 kW x 20 Units x 0.38
Demand Load = 110 kW x 0.38
Demand Load = 41.80 kW

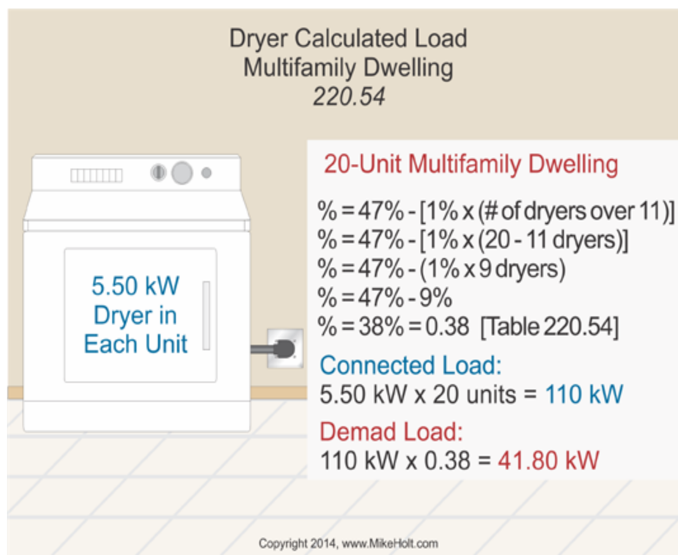

Figure 10–10

▶ Dryer Demand Load Example 4

Question: *Question: What's the demand load for forty 5 kW dryers?* Figure 10–11

(a) 5 kW (b) 27 kW (c) 39.90 kW (d) 53 kW

Answer: *(d) 53 kW*

For 40 dryers, the demand factor percent is 35 percent minus 0.50 percent for each dryer over 23 units [Table 220.54]:

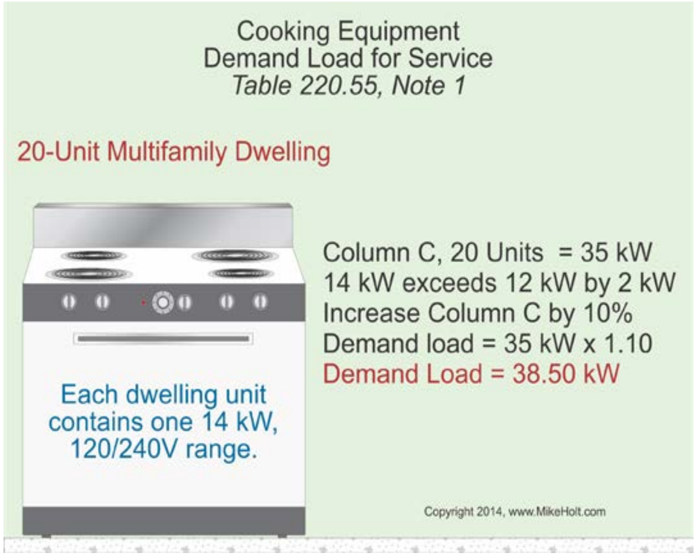

Figure 10–15

▶ Table 220.55, Note 1—Over 12 kW with Equal Ratings Example 2

Question: *What's the demand load for forty 14 kW ranges?*

(a) 28 kW (b) 30 kW (c) 38 kW (d) 61 kW

Answer: *(d) 61 kW*

Step 1: *Table 220.55 Column C Demand Load.*

Total Demand Load Two Phases = 15 kW + 40 kW
Total Demand Load Two Phases = 55 kW

Step 2: *14 kW range exceeds 12 kW by 2 kW.*

Increase Column C Load 5% for each kW in excess of 12 kW.

Step 3: *Increase Column C value by 10%.*

Demand Load = 55 kW x 1.10
Demand Load = 60.50 kW

▶ Table 220.55, Note 2—Over 12 kW with Unequal Ratings Example

Question: *What's the demand load for ten 10 kW and ten 14 kW ranges?*

(a) 22 kW (b) 37 kW (c) 42 kW (d) 78 kW

Answer: *(b) 37 kW*

Step 1: *Determine the total connected load.*

10 kW (min. 12 kW)	*10 ranges x 12 kW =*	*120 kW*
14 kW	*10 ranges x 14 kW =*	*+140 kW*
Total Connected Load		*260 kW*

Step 2: *Determine the average of range ratings.*

260 kW/20 units = 13 kW average rating

Step 3: *Demand Load – Table 220.55 Column C.*

20 ranges = 35 kW

Step 4: *The 13 kW average exceeds 12 kW by 1 kW.*

Increase the Column C Demand Load (35 kW) by 5%.
Demand Load = 35 kW x 1.05
Demand Load = 36.75 kW

Single-Phase Cooking Equipment on Three-Phase Service

Where single-phase ranges are supplied by a 3-phase, 4-wire service, the total load is based on twice the maximum number of cooking equipment connected between any two phases [220.55].

▶ Single-Phase Cooking Equipment on Three-Phase Service Example 1

Question: *What's the demand load for ten single-phase 12 kW 208V ranges on a three-phase service?* Figure 10–16

(a) 28.50 kW (b) 30.50 kW (c) 34.50 kW (d) 42.50 kW

Answer: *(c) 34.50 kW*

Step 1: *Determine the maximum number or ranges between any two phases:*

10 ranges/3 (for three-phase) = 3.33 ranges (units) between any two phases

Round up since one can't have a partial range; 4 ranges (units) between any two phases.

Step 2: *Apply Table 220.55 demand for twice the maximum number or ranges between any two phases:*

4 units x 2 = 8 units
Table 220.55 Column C demand load for 8 units = 23 kW

Step 3: *Demand Load Per Phase: 23 kW/2 phases = 11.50 kW*

Demand Load for Three Phases = 11.50 kW x 3
Demand Load for Three Phases = 34.50 kW

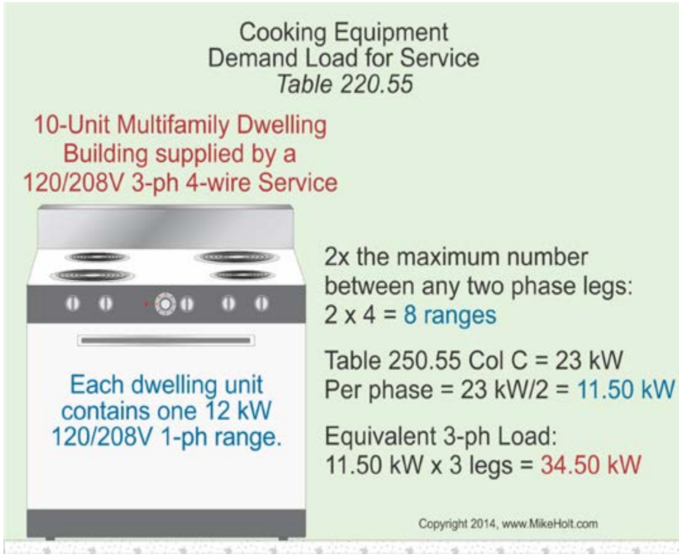

Figure 10–16

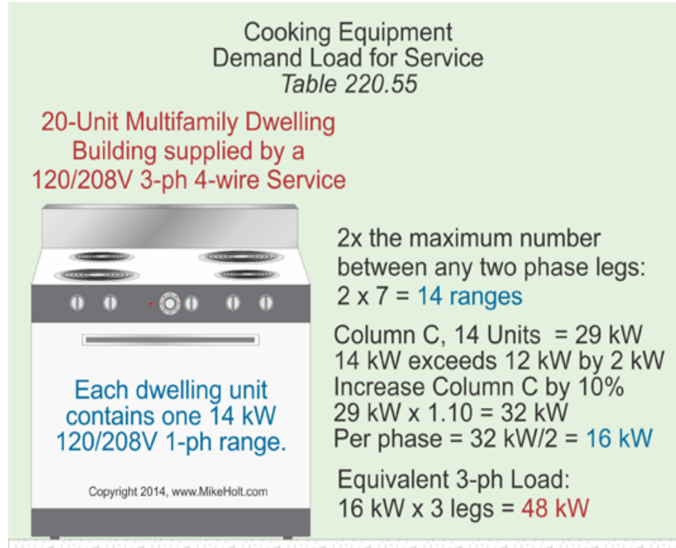

Figure 10–17

▶ Single-Phase Cooking Equipment on Three-Phase Service Example 2

Question: *What's the demand load for twenty single-phase 14 kW 208V ranges on a three-phase service?* Figure 10–17

(a) 28.50 kW (b) 30.50 kW (c) 34.50 kW (d) 48 kW

Answer: *(d) 48 kW*

Step 1: *Determine the maximum number or ranges between any two phases:*

20 ranges/3 (for three-phase) = 6.67 ranges (units) between any two phases

Round up since one can't have a partial range; 7 ranges (units) between any two phases.

Step 2: *Apply Table 220.55 demand for twice the maximum number or ranges between any two phases:*

7 units x 2 = 14 units: 29 kW
14 kW range exceeds 12 kW by 2 kW

Increase the Column C 29 kW by 5% for each kW in excess of 12 kW.

Demand Load = 29 kW x 1.10
Demand Load = 32 kW

Step 3: *Demand Load Per Phase: 32 kW/2 phases = 16 kW*

Demand Load for Three Phases = 16 kW x 3
Demand Load for Three Phases = 48 kW

10.5 Air-Conditioning versus Heat Demand Load [220.60]

The air-conditioning load is calculated at 100 percent [220.50] and the fixed electric heating load is calculated at 100 percent [220.51].

▶ Air-Conditioning versus Heat Example 1

Question: *What's the demand load for a ten-unit multifamily building; each unit has a 16.70A a/c compressor with a 1.20A fan, as compared to 6 kW heat? The system voltage is 120/240V single-phase.* Figure 10–18

(a) 50 kVA (b) 60 kVA (c) 160 kVA (d) 250 kVA

Answer: *(b) 60 kVA*

Air-Conditioning VA = Volts x Amperes

Air-Conditioning VA = 240V x (16.70A + 1.20A)
Air-Conditioning VA = 240V x (17.90A)
Air-Conditioning VA = 4,300 VA x 10 Units
Air-Conditioning VA = 43,000 VA (omit) [220.60]

Heat = 6 kW x 10 Units
Heat = 60,000 W

Step 1: General Lighting and Receptacle Demand [Table 220.42]

General Lighting (1,000 sq ft x 3 VA) [220.12] 3,000 VA
Small-Appliance Circuits [220.52(A)] 3,000 VA
Laundry Circuit [220.52(B)] +1,500 VA
7,500 VA
Total Connected Load (7,500 VA x 10 units) 75,000 VA
First 3,000 VA at 100% [Table 220.42] – 3,000 VA x 1.00 = 3,000 VA
Remainder at 35% 72,000 VA x 0.35 = +25,200 VA
Total Demand Load 28,200 VA

Step 2: Appliance Demand Load [220.53]

Figure 10–22

Dishwasher 1,200 VA
Waste Disposal 900 VA
Water Heater +4,500 W
Connected Load 6,600 VA x 10 units = 66,000 VA
Demand Load 66,000 VA x 0.75 = 49,500 VA*

**Use the total number of appliances to determine if the 75 percent demand factor applies. In this case, there are 30 appliances on the feeder/service conductors [220.53].*

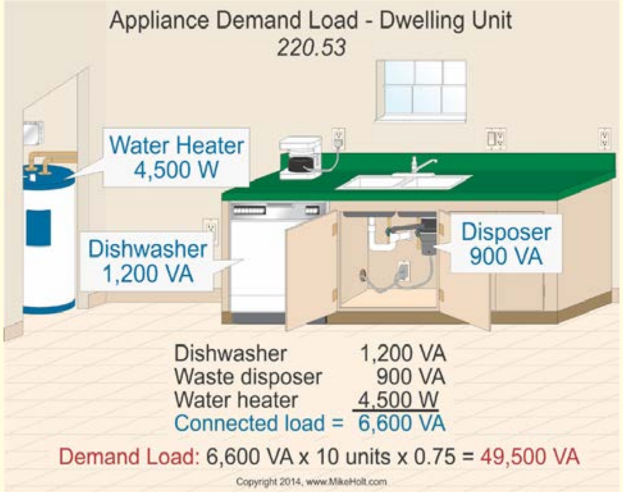

Figure 10–22

Step 3: Dryer Demand Load [220.54]

Dryers must be calculated at a minimum of 5,000 W or the nameplate, whichever is larger [220.54].

Total Connected Load = 5 kW x 10 units
Total Connected Load = 50,000 W

Dryer Demand Factor for 10 dryers (Percent) = 50%

Dryer Demand Load = 50,000 W x 0.50
Dryer Demand Load = 25,000 W

Step 4: Cooking Equipment Demand Load [220.55]

Table 220.55, Column B demand factor for ten units is 34%.
Figure 10–23

Demand Load = (8 kW x 10 Units) x 0.34
Demand Load = 80 kW x 0.34
Demand Load = 27.20 kW

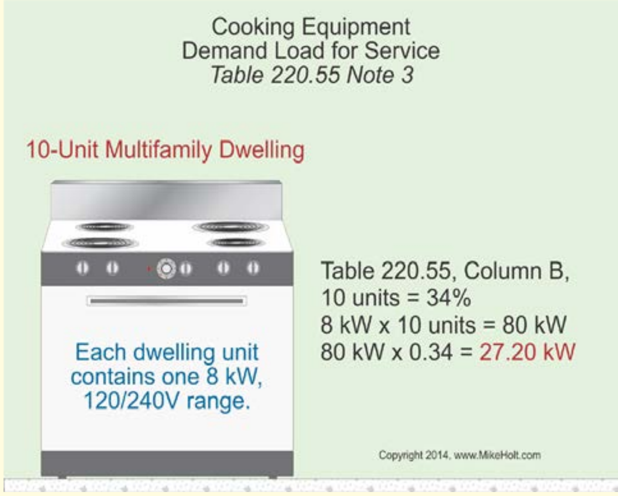

Figure 10–23

Step 5: Air-Conditioning versus Heat Demand Load [220.60]

Figure 10–24

Air-Conditioning VA = Volts x Amperes

Air-Conditioning VA = 240V x (16.70A + 1.20A)
Air-Conditioning VA = 240V x (17.90A)
Air-Conditioning VA = 4,300 VA x 10 Units
Air-Conditioning VA = 43,000 VA, Omit [220.60]

Heat = VA x Number of Units [220.51]
Heat = 6 kW x 10 Units
Heat = 60,000 VA

(continued)

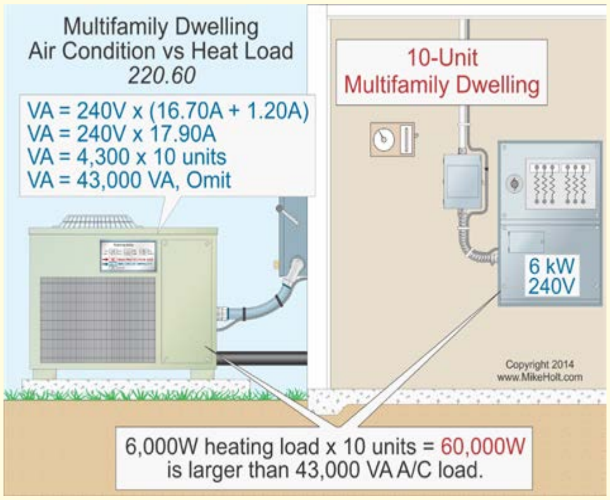

Figure 10–24

Step 6: Service and Service Conductor Size [310.15(B)(16)]

Step 1. General Lighting, Small-Appliance, and Laundry Demand Load	*28,200 VA*
Step 2. Appliance Demand Load	*49,500 VA*
Step 3. Dryer Demand Load	*25,000 W*
Step 4. Range Demand Load	*27,200 W*
Step 5. Heat Demand Load [220.51]	*+ 60,000 W*
Total Demand Load	*189,900 VA*

Service Size = Demand Load VA/System Volts

Figure 10–25

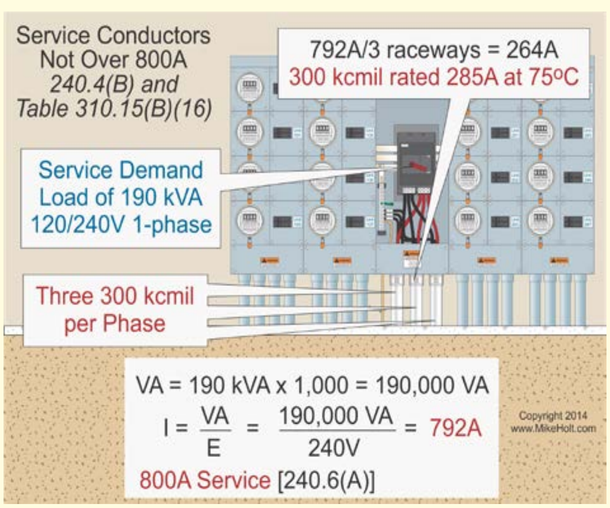

Figure 10–25

Service Size = 389,900 VA/240V
Service Size = 791A, 800A [240.6(A)]

Service Conductor per Raceway = 791A/3 raceways
Service Conductor per Raceway = 264A

300 kcmil rated 285A at 75°C, Table 310.15(B)(16)

▶ Standard Method Service Load Calculations—Three Phase Example

Question: *What size service and service conductors are required for a twenty-unit multifamily building having the following loads in each 1,500 sq ft unit? Laundry facilities are provided on the premises [210.52(F) Ex 1].* Figure 10–26

Dishwasher	*1,200 VA*
Waste Disposal	*900 VA*
Water Heater	*4,500 W*
Range	*12,000 W*
Air-Conditioning (208V), 23.10A + 1.30A Fan	
Electric Space-Heating	*6,000 W*

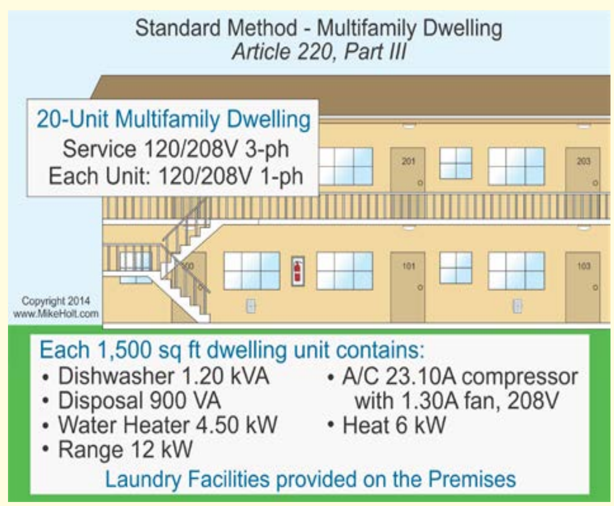

Figure 10–26

Step 2: *14 kW range exceeds 12 kW by 2 kW.*

Increase Column C Demand Load by 5% for each kW in excess of 12 kW.

Step 3: *Increase Column C value by 10%.*

Demand Load = 35 kW x 1.10
Demand Load = 38.50 kW

Neutral Demand Load = Service Demand Load x 70%

Neutral Demand Load = 38.50 kW x 0.70
Neutral Demand Load = 26.95 kW

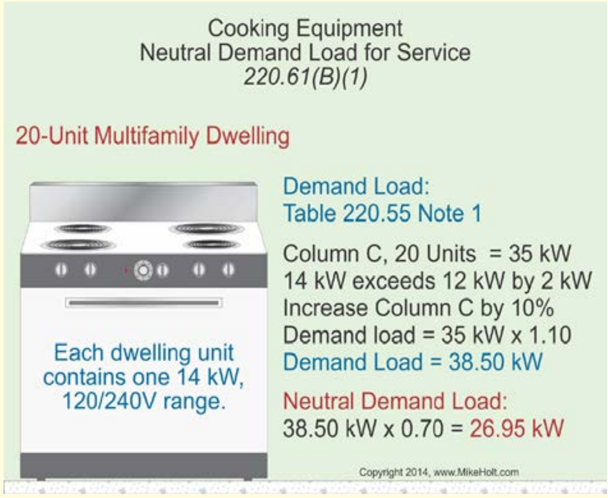

Figure 10–42

10.12 Service Neutral [220.61(B)]

The neutral load is the maximum unbalanced calculated load between the neutral conductor and any ungrounded conductor as determined by Article 220 Part III, as adjusted in accordance with 220.61(B).

Neutral Reduction Over 200A [220.61(B)(2)]

A demand factor of 70 percent can be applied to that portion of the unbalanced load exceeding 200 amperes.

▶ Service Neutral Single-Phase Example

Question: *What's the service neutral demand load for a ten-unit multifamily building having the following loads in each 1,000 sq ft unit?* Figure 10–43

Dishwasher	*1,200 VA*
Waste Disposal	*900 VA*
Water Heater	*4,500 W*
Dryer	*4,000 W*
Range	*8,000 W*
Air-Conditioning (230V), 16.70A + 1.20A Fan	
Electric Space-Heating	*6,000 W*

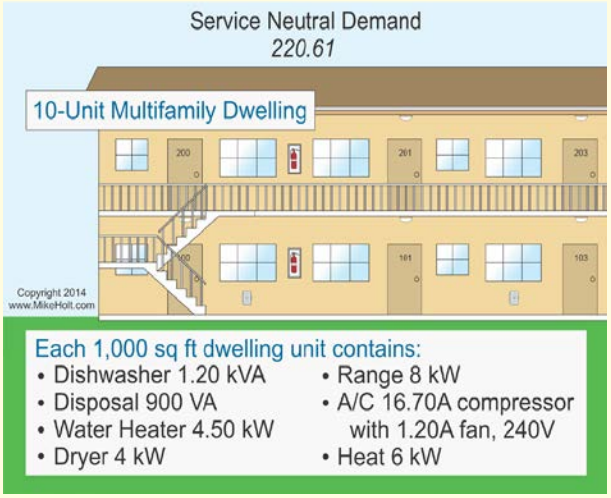

Figure 10–43

Step 1: General Lighting and Receptacle Demand [Table 220.42]

General Lighting (1,000 sq ft x 3 VA) [220.12]	*3,000 VA*		
Small-Appliance Circuits [220.52(A)]	*3,000 VA*		
Laundry Circuit [220.52(B)]	*+1,500 VA*		
	7,500 VA		
Total Connected Load (7,500 VA x 10 units)	*75,000 VA*		
First 3,000 VA at 100% [Table 220.42]	*– 3,000 VA*	*x 1.00 =*	*3,000 VA*
Remainder at 35%	*72,000 VA*	*x 0.35 =*	*+25,200 VA*
Total Demand Load			*28,200 VA*

(continued)

Step 2: Appliance Demand Load [220.53]

Dishwasher	1,200 VA	
Waste Disposal	+ 900 VA	
Connected Load	2,100 VA x 10 units = 21,000 VA	
Demand Load	21,000 VA x 0.75* =	15,750 VA

**Use the total number of appliances to determine if the 75 percent demand factor applies. In this case, there are 20 appliances on the feeder/service conductors [220.53]. The water heaters aren't included because they're a line-to-line load (no neutral).*

Step 3: Dryer Demand Load [220.54]

Dryers must be calculated at a minimum of 5,000 W or the nameplate, whichever is larger [220.54].

Total Connected Load = 5 kW x 10 units
Total Connected Load = 50 kVA

Dryer Demand Factor for 10 dryers (Percent) = 50%

Dryer Demand Load = 50 kVA x 0.50
Dryer Demand Load = 25 kVA

Neutral Demand Load = 25 kVA x 0.70
Neutral Demand Load = 17.50 kVA — 17,500 VA

Step 4: Cooking Equipment Demand Load [220.55]

Table 220.55, Column B demand factor for ten units is 34%

Range Demand Load = (8 kW x 10 Units) x 0.34
Range Demand Load = 80 kW x 0.34
Range Demand Load = 27.20 kW

Neutral Demand Load = Range Demand Load x 0.70
Neutral Demand Load = 27.20 kVA x 0.70
Neutral Demand Load = 19 kVA — 19,040 VA

Step 5: Service Neutral Demand Load

Step 1. General Lighting, Small-Appliance, and Laundry Neutral Demand Load	28,200 VA
Step 2. Appliance Neutral Demand Load	15,750 VA
Step 3. Dryer Neutral Demand Load	17,500 W
Step 4. Range Neutral Demand Load	+19,040 W
Total Neutral Demand Load	80,490 VA

Neutral Load in Amperes = 80,490 VA/240V
Neutral Load in Amperes = 335A

Step 6: Neutral Reduction Over 200A [220.61(B)(2)]

A demand factor of 70 percent is permitted to be applied to that portion of the unbalanced load in excess of 200 amperes.

Service Neutral Demand Load	335A	
First 200A at 100%	–200A x 100% =	200A
Remainder 135A at 70%	135A x 70% =	+ 95A
Service Neutral Size		295A

▶ Service Neutral Three-Phase Example

Question: *What size service and service conductors are required for a twenty-unit multifamily building having the following loads in each 1,500 sq ft unit? A separate laundry facility is provided on the premises [210.52(F) Ex 1].* Figure 10–44

Dishwasher	1,200 VA
Waste Disposal	900 VA
Water Heater	4,500 W
Dryer	4,000 W
Range	12,000 W
Air-Conditioning (230V), 16.70A + 1.20A Fan	
Electric Space-Heating	6,000 W

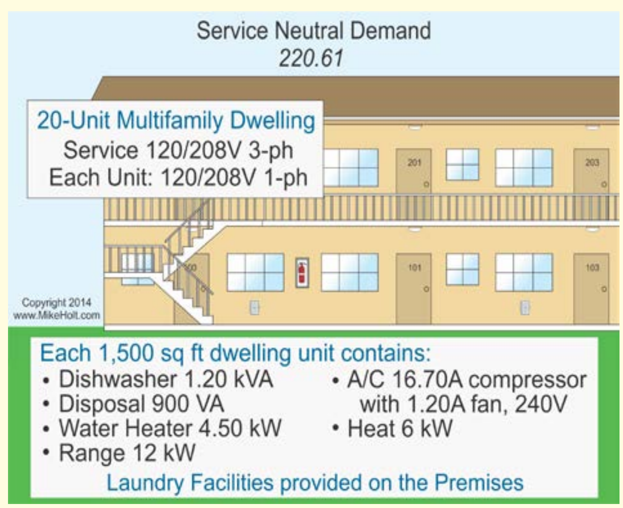

Figure 10–44

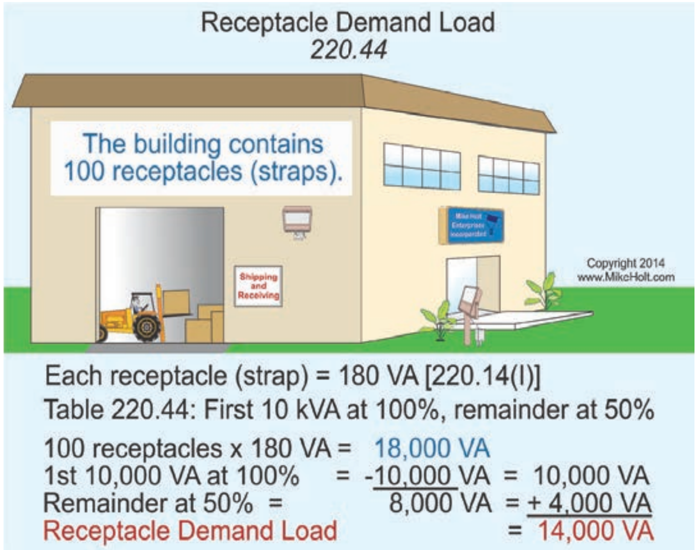

Figure 11–11

► Receptacle Demand Load—Table 220.44 Example 2

Question: *What's the load for one-hundred and fifty 15A/20A, 125V duplex receptacles in a nondwelling occupancy after applying Table 220.44 demand factors?* Figure 11–12

(a) 10 kVA (b) 14 kVA (c) 19 kVA (d) 27 kVA

Answer: *(c) 19 kVA*

Total Receptacle Load

150 receptacles x 180 VA	27,000 VA		
First 10 kVA at 100%	–10,000 VA	x 1.00	10,000 VA
Remainder at 50%	17,000 VA	x 0.50	+ 8,500 VA
Total Receptacle Demand Load			18,500 VA

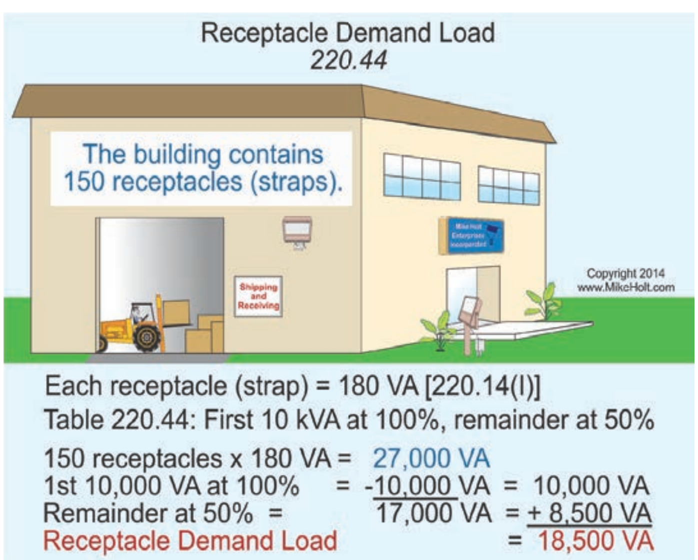

Figure 11–12

► Multioutlet Receptacle Assembly and Receptacle Example

Question: *What's the load for 10 work stations, each of which has 6 ft of multioutlet receptacle assembly not used simultaneously, and 3 ft of multioutlet receptacle assembly simultaneously used, and one-hundred and fifty 15A/20A, 125V duplex receptacles in a nondwelling occupancy after applying Table 220.44 demand factors?*

(a) 9 kVA (b) 18 kVA (c) 20 kVA (d) 23 kVA

Answer: *(d) 23 kVA*

Multioutlet Assembly Load

Nonsimultaneous sections:	
2 sections x 180 VA x 10 stations	3,600 VA
Simultaneously used sections:	
3 sections x 180 VA x 10 stations =	+5,400 VA
Demand Load	9,000 VA

Receptacle Load

150 receptacles x 180 VA	+27,000 VA
Total of Multioutlet Assemblies and Receptacles	36,000 VA

Total of Multioutlet Assemblies and Receptacles	36,000 VA		
First 10 kVA at 100%	–10,000 VA	x 1.00	10,000 VA
Remainder at 50%	26,000 VA	x 0.50	+13,000 VA
Total Receptacle Demand Load			23,000 VA

11.7 Banks and Offices—Receptacle Demand Load [220.14(K)]

The receptacle load is calculated at 180 VA for each receptacle yoke [220.14(I)] if the number of receptacles is known. For banks or office buildings, 1 VA for each square foot of the building is used for the receptacle load if the actual number of receptacles is unknown [220.14(K)(2)]. If the receptacle count is known, the demand factors from Table 220.44 are applied to the total of 180 VA per receptacle yoke, and this is compared to the 1 VA per square foot figure, then the larger of the two is used.

Part C—Optional Method—Feeder/Service Load Calculations

Introduction

An optional method of calculating the service load is permitted for a new restaurant that has electric space heating or electric air-conditioning, or both.

11.12 New Restaurant—Optional Method [220.88]

The following steps can be used to determine the service size for a new restaurant using the optional method described in 220.88:

Step 1: Determine the total connected load. Add the nameplate rating of all loads at 100 percent and include both the air-conditioning and heat load [Table 220.88 Note].

Step 2: Apply the demand factors from Table 220.88 to the total connected load calculated in Step 1.

All-Electric Restaurant Examples

► All-Electric Restaurant Example 1

Question: *What size service conductors are required for an all-electric restaurant (120/208V, three-phase) that has a total connected load of 200 kVA?*

(a) 420A (b) 444A (c) 520A (d) 600A

Answer: *(b) 444A*

Total Connected Load 200 kVA
Total Demand Load 200 kVA x .80 =160 kVA
Total Demand Load 160 kVA

I = VA/(E x 1.732)

I = 160,000 VA/(208V x 1.732)
I = 160,000 VA/360V
I = 444A

Parallel two conductors per phase: 444A/2 raceways = 222A

4/0 AWG rated 230A at 75ºC, Table 310.15(B)(16)

► All-Electric Restaurant Example 2

Question: *What size service conductors are required for an all-electric restaurant (120/208V, three-phase) that has a total connected load of 300 kVA if paralleled in two raceways?*

(a) 420A (b) 472A (c) 520A (d) 600A

Answer: *(b) 472A*

Total Connected Load 300 kVA
Total Demand Load [(300 kVA – 200 kVA) x 0.10] + 160 kVA
Total Demand Load (100 kVA x 0.10) + 160 kVA
Total Demand Load 10 kVA + 160 kVA = 170 kVA
Total Demand Load 170 kVA

I = VA/(E x 1.732)

I = 170,000 VA/(208V x 1.732)
I = 170,000 VA/360V
I = 472A

Parallel two conductors per phase: 72A/2 raceways = 236A

250 kcmil rated 255A at 75ºC [Table 310.15(B)(16)]

► All-Electric Restaurant Example 3

Question: *What size service conductors are required for an all-electric restaurant (120/208V, three-phase) that has a total connected load of 400 kVA if paralleled in two raceways?*

(a) 420A (b) 472A (c) 520A (d) 586A

Answer: *(d) 586A*

Total Connected Load 400 kVA
Total Demand Load [(400 kVA – 325 kVA) x 0.50] + 172.50 kVA
Total Demand Load (75 kVA x 0.50) + 172.50 kVA
Total Demand Load 37.50 kVA + 172.50 kVA 210 kVA
Total Demand Load 210 kVA

I = VA/(E x 1.732)

I = 210,000 VA/(208V x 1.732)
I = 210,000 VA/360V
I = 583.33A

Parallel two conductors per phase: 583.33A/2 raceways = 291.67A

350 kcmil rated 310A at 75ºC [Table 310.15(B)(16)]

▶ Individual Welders Example 2

Question: *What size branch-circuit conductors are required for a 50A resistance welder having a duty cycle of 50 percent?* Figure 11–22

(a) 8 AWG (b) 6 AWG (c) 4 AWG (d) 2 AWG

Answer: *(a) 8 AWG*

Demand Load = Primary Rating x Multiplier [Table 630.31(A)(2)]

Demand Load = 50A x 0.71
Demand Load = 35.50A

8 AWG rated 40A at 60ºC [Table 310.15(B)(16)]

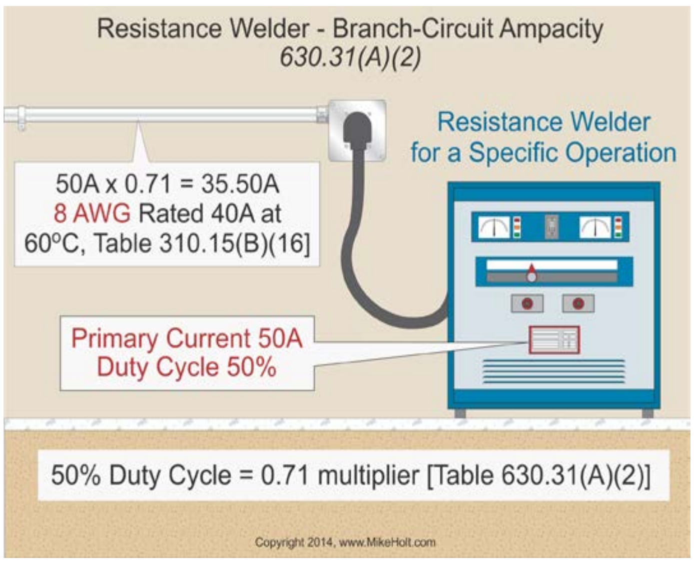

Figure 11–22

Ampacity of Supply Conductors—Group of Welders

Feeder conductors that supply a group of resistance welders must have an ampacity not less than the sum of the value determined using 630.31(A)(2) for the largest welder in the group, plus 60 percent of the values determined for all remaining welders [630.31(B)].

▶ Group of Welders Example 1

Question: *What's the minimum size feeder conductor for five 30A resistance welders with a duty cycle of 30 percent?*

(a) 4 AWG (b) 3 AWG (c) 2 AWG (d) 1 AWG

Answer: *(a) 4 AWG*

Demand Load = Primary Rating x Multiplier [Table 630.31(A)(2)] x Welder Percentage [630.31(B)]

Welder 1: 30A x 0.55 = 16.50A x 100%	*16.50A*
Welder 2: 30A x 0.55 = 16.50A x 60%	*9.90A*
Welder 3: 30A x 0.55 = 16.50A x 60%	*9.90A*
Welder 4: 30A x 0.55 = 16.50A x 60%	*9.90A*
Welder 5: 30A x 0.55 = 16.50A x 60%	*+ 9.90A*
Total Demand Load	*56.10A*

Conductor size: 4 AWG rated 70A at 60ºC [Table 310.15(B)(16)]

▶ Group of Welders Example 2

Question: *What's the minimum size feeder conductor for five 50A resistance welders with a duty cycle of 50 percent?*

(a) 4 AWG (b) 3 AWG (c) 2 AWG (d) 1 AWG

Answer: *(d) 1 AWG*

Demand Load = Primary Rating x Multiplier [Table 630.31(A)(2)] x Welder Percentage [630.31(B)]

Welder 1: 50A x 0.71 = 35.50A x 100%	*35.50A*
Welder 2: 50A x 0.71 = 35.50A x 60%	*21.30A*
Welder 3: 50A x 0.71 = 35.50A x 60%	*21.30A*
Welder 4: 50A x 0.71 = 35.50A x 60%	*21.30A*
Welder 5: 50A x 0.71 = 35.50A x 60%	*+21.30A*
Total Demand Load	*120.70A*

Conductor Size: 1 AWG rated 130A at 75ºC [Table 310.15(B)(16)]

Overcurrent Protection

Where the calculated overcurrent protection value dœsn't correspond with the standard overcurrent device ratings in 240.6(A), the next higher standard rating is permitted.

Welders. Each welder must have an overcurrent device set at not more than 300 percent of the rated primary current [630.32(A)].

Conductors. Branch-circuit conductors must be protected by an overcurrent device rated at not more than 300 percent of the conductor rating [630.32(B)].

Disconnecting Means

A switch or circuit breaker is required to disconnect each resistance welder and its control equipment from the supply circuit [630.33].

11.15 Light Industrial Calculation

► **Example 1**

Question: *Calculate the service size for a light industrial manufacturing building with the following loads:*

- *Lighting, 11,600 VA, comprised of electric-discharge luminaries operating at 277V*
- *Twenty-two 20A, 125V receptacle outlets on general-purpose branch circuits, supplied by a separately derived system*
- *Three Welders, ac transformer type (23A, 480V, 60% duty)*
- *Air compressor, 460V, three-phase, 5 hp*
- *Grinder, 460V, three-phase, 1½ hp*
- *Three continuous use industrial process dryers, 480V, three-phase, 15 kVA each*

(a) 100A (b) 110A (c) 125A (d) 150A

Answer: *(d) 150A*

Step 1: Determine the noncontinuous loads and motor loads.
The noncontinuous and motor loads can be combined [430.24].

(1) Noncontinuous Loads

(a) Receptacle Load [220.44]
22 receptacles at 180 VA 3,960 VA

(b) Welder Load [630.11(A) and Table 630.11(A)]

A multiplication factor of 0.78 is allowed for 60% duty cycle welders.

Each welder: 480V x 23A x 0.78 = 8,600 VA

Welder demand factors for 3 welders: [630.11(B)]

First welder	*100%*
Second welder	*100%*
Third welder	*85%*

8,600 VA x 100%	*8,600 VA*
8,600 VA x 100%	*8,600 VA*
8,600 VA x 85%	*+7,320 VA*
	24,500 VA

Total Welder Demand Load +24,500 VA

Total Noncontinuous Loads (receptacles and welders) ***28,460 VA***

(2) Motor Loads [430.24 and Table 430.250]

(a) Air Compressor: 5 hp FLC = 7.60A	
[Table 430.250] 480V x 7.60A x 1.732 =	*6,310 VA*
(b) Grinder: 1½ hp FLC = 3A	
[Table 430.250] 3A x 480V x 1.732 =	*2,490 VA*
(c) Largest Motor, Additional 25 percent:	
6,310 VA x 25% =	*+ 1,580 VA*
Total Motor Loads	***10,400 VA***

Total Noncontinuous Loads and the Motor Loads [430.24] *38,860 VA*

Step 2: Determine the continuous loads.

(1) General Lighting	*11,600 VA*	*11,600 VA*
(2) Three Industrial Process		
Dryers,15 kVA each	*+45,000 VA*	
Total Load	*56,600 VA*	
Continuous Load	*56,600 VA x 1.25 =*	*+14,200 VA*
Total Continuous Load		*70,800 VA*

Step 3: Determine the overcurrent protection [215.3].
The overcurrent device must be sized at 125 percent of the continuous loads, plus the noncontinuous loads:

(1) Noncontinuous Loads		*38,860 VA*
(2) Continuous Loads	*56,600 VA x 1.25 =*	*+70,800 VA*
Total VA		*109,660 VA*

(continued)

Step 4: Convert to amperes to size the overcurrent device:

I = VA/(E x 1.732)

I = 109,660 VA/(480V x 1.732)

I = 109,660 VA/831V

I = 132A

Overcurrent Device = 150A [240.6]

Conductors = 1/0 AWG has an ampacity of150A at 75ºC [110.14(C)(1)(b) and Table 310.15(B)(16)].

▶ Example 2

Question: *Calculate the service size for a light industrial manufacturing building with the following loads:*

- *Lighting, 20,000 VA, comprised of electric-discharge luminaries operating at 277V*
- *One hundred and fifty 20A, 125V receptacle outlets on general-purpose branch circuits, supplied by a separately derived system*
- *Five Welders, nonmotor-generator arc type (50A, 480V, 50% duty)*
- *Air compressor, 460V, three-phase, 10 hp*
- *Grinder, 460V, three-phase, 2 hp*
- *Three continuous use industrial process dryers, 480V, three-phase, 10 kVA each*

(a) 150A (b) 175A (c) 200A (d) 225A

Answer: *(d) 225A*

Step 1: Determine the noncontinuous loads and motor loads.

The noncontinuous and motor loads can be combined [430.24].

(1) Noncontinuous Loads

(a) Receptacle Load [220.44]

150 receptacles x 180 VA	27,000 VA	
First 10 kVA at 100%	–10,000 VA x 1.00	10,000 VA
Remainder at 50%	17,000 VA x 0.50	+ 8,500 VA
Total Receptacle Demand Load		**18,500 VA**

(b) Welder Load [630.11(A) and Table 630.11(A)]

A multiplication factor of 0.71 is allowed for 50% duty cycle welders.

Each welder: 480V x 50A x 0.71 = 17,040 VA

Welder demand factors for 5 welders: [630.11(B)]

First welder	100%
Second welder	100%
Third welder	85%
Fourth welder	70%
Fifth welder	60%

17,040 VA x 100%	17,040 VA
17,040 VA x 100%	17,040 VA
17,040 VA x 85%	14,484 VA
17,040 VA x 70%	11,928 VA
17,040 VA x 60%	+10,224 VA
Total Welder Demand Load	70,716 VA

Total Welder Demand Load	+70,716 VA
Total Noncontinuous Loads (receptacles and welders)	**89,212 VA**

(2) Motor Loads [430.24 and Table 430.250]

(a) Air Compressor: 10 hp FLC = 14A [Table 430.250] 480V x 14A x 1.732 =	11,639 VA
(b) Grinder: 2 hp FLC = 3.40A [Table 430.250] 3.40A x 480V x 1.732 =	2,827 VA
(c) Largest Motor, Additional 25%: 11,639 VA x 25% =	+ 2,910VA
Total Motor Loads	**17,376 VA**

Total Noncontinuous Loads and the Motor Loads [430.24]	106,588 VA

Step 2: Determine the continuous loads.

(1) General Lighting	20,000 VA	
(2) Three Industrial Process Dryers 3 x 15 kVA each	+30,000 VA	
Total Load	50,000 VA	50,000 VA
Continuous Load	50,000 VA x 1.25	+12,500 VA
Total Continuous Load		62,500 VA

Part B–*NEC* Requirements

12.6 Transformer Overcurrent Protection

To protect the windings of a transformer against overcurrent, use the percentages listed in Table 450.3(B) and its applicable notes.

Remember that Article 450 is only for the protection of the transformer windings, and not the conductors supplying the transformer or leaving it. Where 125 percent of the primary current doesn't correspond to a standard fuse or nonadjustable circuit breaker, you can use the next higher rating of overcurrent device, as listed in 240.6(A). This note only applies to currents of 9A or more, however. Figure 12–24

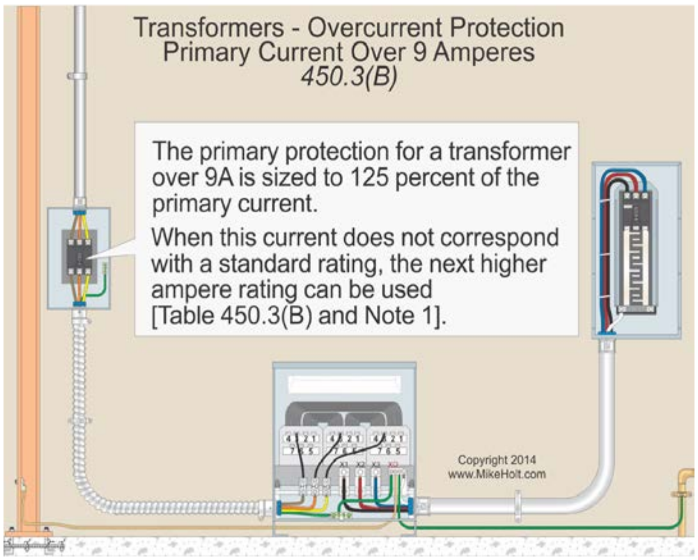

Figure 12–24

Table 450.3(B) Primary Protection Only	
Primary Current Rating	Maximum Protection
9A or More	125%, Note 1
Less Than 9A	167%
Less Than 2A	300%

Note 1. Where 125 percent of the primary current doesn't correspond to a standard rating of a fuse or nonadjustable circuit breaker, the next higher rating is permitted [240.6(A)].

► Primary Overcurrent Protection—Less than 2A Example

Question: *What's the maximum primary overcurrent device rating for a 750 VA continuous loaded, single-phase, 480V transformer?*

(a) 2A (b) 4A (c) 6A (d) 10A

Answer: *(b) 4A*

Primary Current = Transformer VA Rating/Primary Voltage

Primary Current = 750 VA/480V
Primary Current = 1.56A

Primary Protection = Primary Current x Table 430.3(B) Percentage

Primary Protection = 1.56A x 3.00
Primary Protection = 4.68A, 4A [240.6(A)]

Table 450.3(B) Note 1 for rounding only applies to primary currents over 9A.

► Primary Overcurrent Protection—Less than 9A Example

Question: *What's the maximum primary overcurrent device rating for a 2 kVA continuous loaded, single-phase, 240V transformer?*

(a) 4A (b) 5A (c) 13A (d) 17A

Answer: *(c) 13A*

Primary Current = Transformer VA Rating/Primary Voltage

Primary Current = 2,000 VA/240V
Primary Current = 8.33A

Primary Protection = Primary Current x Table 430.3(B) Percentage

Primary Protection = 8.33A x 1.67
Primary Protection = 13.92A

Table 450.3(B) Note 1 for rounding only applies to primary currents over 9A.

7. A three-phase, 4-wire, _____ power system used to supply power to nonlinear loads may necessitate that the power system design allow for the possibility of high harmonic currents on the neutral conductor.

(a) wye-connected
(b) delta-connected
(c) wye/delta-connected
(d) none of these

8. In dwelling units, the voltage between conductors that supply the terminals of _____ shall not exceed 120V, nominal.

(a) luminaires
(b) cord-and-plug-connected loads of 1,440 VA or less
(c) cord-and-plug-connected loads of more than ¼ hp
(d) a and b

9. The GFCI protection required by 210.8(A), (B), (C), and (d) must be _____.

(a) the circuit breaker type only
(b) accessible
(c) readily accessible
(d) concealed

10. GFCI protection shall be provided for all 15A and 20A, 125V receptacles installed in a dwelling unit _____.

(a) attic
(b) garage
(c) laundry areas
(d) b and c

11. GFCI protection shall be provided for all 15A and 20A, 125V receptacles in dwelling unit accessory buildings that have a floor located at or below grade level not intended as _____ and limited to storage areas, work areas, or similar use.

(a) habitable rooms
(b) finished space
(c) a or b
(d) none of these

12. All 15A and 20A, 125V receptacles installed in crawl spaces at or below grade level of dwelling units shall have GFCI protection.

(a) True
(b) False

13. All 15A and 20A, 125V receptacles installed in _____ of dwelling units shall have GFCI protection.

(a) unfinished attics
(b) finished attics
(c) unfinished basements and crawl spaces
(d) finished basements

14. GFCI protection shall be provided for all 15A and 20A, 125V receptacles installed within 6 ft of all dwelling unit sinks located in _____.

(a) laundry rooms
(b) bathrooms
(c) dens
(d) all of these

15. All 15A and 20A, 125V receptacles installed in dwelling unit boathouses shall have GFCI protection.

(a) True
(b) False

16. In other than dwelling units, GFCI protection shall be provided for all outdoor 15A and 20A, 125V receptacles.

(a) True
(b) False

17. All 15A and 20A, 125V receptacles installed in locker rooms with associated showering facilities must be GFCI protected.

(a) True
(b) False

18. There shall be a minimum of one _____ branch circuit for the laundry outlet(s) required by 210.52(F).

(a) 15A
(b) 20A
(c) 30A
(d) b and c

PRACTICE QUIZ 9

STRAIGHT ORDER [ARTICLES 328–398]

Please use the 2014 *Code* book to answer the following questions.

1. Type MV cable is defined as a single or multiconductor solid dielectric insulated cable rated ____ volts or higher.

   (a) 601
   (b) 1,001
   (c) 2,001
   (d) 6,001

2. Smooth-sheath Type MC cable with an external diameter not greater than ¾ in. shall have a bending radius not less than _____ times the external diameter of the cable.

   (a) five
   (b) 10
   (c) 12
   (d) 13

3. Bends made in interlocked or corrugated sheath Type MC cable shall have a radius of at least ____ times the external diameter of the metallic sheath.

   (a) 5
   (b) 7
   (c) 10
   (d) 12

4. Type MC cable can be unsupported where the cable is ____.

   (a) fished between concealed access points in finished buildings or structures and support is impracticable
   (b) not more than 2 ft in length at terminals where flexibility is necessary
   (c) not more than 6 ft from the last point of support within an accessible ceiling for the connection of luminaires or other electrical equipment
   (d) a or c

5. The minimum size copper conductor permitted for Type MC cable is ____.

   (a) 18 AWG
   (b) 16 AWG
   (c) 14 AWG
   (d) 12 AWG

6. Type MI cable shall be supported and secured at intervals not exceeding ____ ft.

   (a) 3
   (b) 3½
   (c) 5
   (d) 6

18. The space between 5 ft and 10 ft from the open end of a vent, discharging upward extending in all directions, shall be classified as Class I, Division 2, Zone _____ in a bulk storage plant.

(a) 0
(b) 1
(c) 2
(d) 3

19. Locations where flammable paints are dried, and provided with adequate positive ventilation, and the ventilating equipment is interlocked with the electrical equipment, may be designated _____ locations by the authority having jurisdiction.

(a) Class I, Division 2
(b) unclassified
(c) Class II, Division 2
(d) Class II, Division 1

20. Article 517 applies to electrical construction and installation criteria in health care facilities that provide services to _____.

(a) human beings
(b) animals
(c) a and b
(d) none of these

21. The patient care space is any space within a health care facility where patients are intended to be _____.

(a) examined
(b) treated
(c) registered
(d) a or b

22. The patient care space of a health care facility does not typically include business offices, corridors, lounges, day rooms, dining rooms, or similar areas.

(a) True
(b) False

23. Wiring methods used in health care locations must comply with the *NEC* Chapter 1 through 4 provisions, except as modified by Article 517.

(a) True
(b) False

24. In patient care areas, the grounding terminals of all receptacles, metal boxes and enclosures containing receptacles, and all non-current-carrying conductive surfaces of fixed electric equipment _____ shall be directly connected to an insulated copper equipment grounding conductor.

(a) operating at over 100V
(b) likely to become energized
(c) subject to personal contact
(d) all of these

25. In health care facilities, receptacles with insulated grounding terminals, as described in 250.146(d) shall be permitted in a patient care vicinity.

(a) True
(b) False

26. Each general care area patient bed location shall be provided with a minimum of _____ receptacle(s), which can be single, duplex, or any combination of these.

(a) two
(b) four
(c) six
(d) eight

27. Which of the following shall not be connected to the life safety branch in a hospital?

(a) exit signs
(b) elevators
(c) general illumination
(d) communications systems

28. Which of the following wiring methods are permitted in an assembly occupancy of fire-rated construction?

(a) metal raceways
(b) Type MC cable
(c) Type AC cable
(d) all of these

7. Wiring from an emergency source can supply emergency or other loads, provided the conductors _____.

(a) terminate in separate vertical sections of a switchboard
(b) terminate in the same vertical section of a switchboard
(c) terminate in a junction box identified for emergency use
(d) are identified as emergency conductors

8. Emergency systems circuit wiring shall be designed and located to minimize the hazards that might cause failure because of _____.

(a) flooding
(b) fire
(c) icing
(d) all of these

9. In the event of failure of the normal supply to the building/structure, emergency power shall be available within _____ seconds.

(a) 5
(b) 10
(c) 30
(d) 60

10. If a generator for emergency system power located outdoors is equipped with a readily accessible disconnecting means in accordance with 445.18, and the disconnecting means is located within sight (within 50 ft) of the building/structure, an additional disconnecting means isn't required on or at the building/structure for the generator feeder conductors that serve or pass through the building/structure.

(a) True
(b) False

11. Unit equipment for emergency systems shall be on the same branch circuit that serves the normal lighting in the area and connected _____ any local switches.

(a) with
(b) ahead of
(c) after
(d) downstream of

12. In emergency systems, only appliances and lamps required for emergency use, shall be supplied by _____.

(a) emergency circuits
(b) multiwire branch circuits
(c) HID-rated circuit breakers
(d) a and b

13. Where batteries are used for _____ of prime movers of legally required standby systems, the authority having jurisdiction shall require periodic maintenance.

(a) control
(b) starting or ignition
(c) a and b
(d) none of these

14. A written record shall be kept of required tests and maintenance on legally required standby systems.

(a) True
(b) False

15. Testing legally required standby system lighting and power systems during maximum anticipated load conditions shall be avoided so as not to tax the standby system unnecessarily.

(a) True
(b) False

16. A legally required standby system shall have adequate capacity and rating for _____ that are expected to operate simultaneously on the standby system.

(a) all of the loads
(b) 80% of the loads
(c) 125% of the loads
(d) none of these

17. A sign shall be placed at the service equipment indicating the _____ of on-site legally required standby power sources.

(a) type
(b) location
(c) manufacturer
(d) a and b

17. Overhead network-powered broadband communications systems conductors shall be located no less than _____ ft from the water's edge of swimming and wading pools, or the base of diving structures.

(a) 10
(b) 12
(c) 18
(d) 22.50

18. A separate branch circuit shall supply elevator machine room/machinery space lighting and receptacle(s). The required lighting shall not be connected to the load side of a(n) _____.

(a) local subpanel
(b) SWD-type circuit breaker
(c) HID-type circuit breaker
(d) GFCI

19. Where run vertically, nonmetallic wireways shall be securely supported at intervals not exceeding _____ ft, unless listed otherwise, with no more than one joint between supports.

(a) 4
(b) 6
(c) 8
(d) 10

20. In a dwelling unit, each wall space _____ or wider requires a receptacle.

(a) 2 ft
(b) 3 ft
(c) 4 ft
(d) 5 ft

21. The voltage drop on technical power systems for sensitive electronic equipment shall not exceed _____ percent for feeder and branch-circuit conductors combined.

(a) 1.50
(b) 2
(c) 2.50
(d) 3

22. Type CMX communications cables can be installed in _____.

(a) one- or two-family dwellings
(b) multifamily dwellings in nonconcealed spaces
(c) a or b
(d) none of these

23. Where a generator for an optional standby system is installed outdoors and equipped with a readily accessible disconnecting means located _____, an additional disconnecting means is not required where ungrounded conductors serve or pass through the building or structure.

(a) inside the building or structure
(b) within sight of the building or structure
(c) inside the generator enclosure
(d) a or c

24. Conductors larger than that for which the wireway is designed can be installed in any wireway.

(a) True
(b) False

25. Article 760 covers the requirements for the installation of wiring and equipment of _____.

(a) communications systems
(b) antennas
(c) fire alarm systems
(d) fiber optics

26. Overcurrent devices for nonpower-limited fire alarm circuits shall be located at the point where the conductor to be protected _____.

(a) terminates at the load
(b) is spliced to any other conductor
(c) receives its supply
(d) none of these

27. Neon tubing which is readily accessible to pedestrians shall be protected from physical damage, other than _____.

(a) Class I, Division 1 locations
(b) listed dry-location portable signs
(c) fixed equipment
(d) wet-location portable signs