

Chapter 12

Branch Circuits and Feeders



Technical Terms

Branch circuit	Show-window lighting load
Continuous load	Track lighting
Feeders	
General lighting load	

Objectives

After completing this chapter, you will be able to:

- Identify the feeder and branch circuit portions of a distribution system.
- Describe the various types of branch circuits.
- Define the functions of a feeder and the functions of branch-circuit conductors.
- Calculate lighting and receptacle loads using *Code* requirements.
- Size branch circuits in accordance with the *Code*.
- Determine branch circuit overcurrent protection required by the *Code*.
- Use the *Code* to size feeder conductors.

In an electrical system, power must be transferred from the service equipment to the lights, machines, and outlets. Regardless of the wiring methods used, the conductors carrying the power fall into one of two categories: feeders or branch-circuit conductors. This chapter will explore the characteristics of these two conductor types.

Definitions

Several definitions are essential to understanding branch circuits and feeders. The following items are illustrated in **Figure 12-1**:

- **Service conductors**—These conductors extend from the power company terminals to the main service disconnect.

- **Feeder**—A conductor that originates at the main distribution or main disconnect device and terminates at another distribution center, panelboard, or load center.
- **Subfeeders**—These conductors originate at distribution centers other than the main distribution center and extend to panelboards, load centers, and disconnect switches that supply branch circuits.
- **Panelboard**—This can be a single panel or multiple panels containing switches, fuses, and circuit breakers for switching, controlling, and protecting circuits.
- **Branch circuits**—The portion of the wiring system extending past the final overcurrent device. These circuits usually originate at a panel and transfer power to load devices.

Branch Circuits

Any circuit that extends beyond the final overcurrent protective device is called a **branch circuit**. This includes circuits servicing single motors (individual) and circuits serving many lights and receptacles (multiwire). Branch circuits are usually low current (30 amps or less), but can also supply high currents.

A basic branch circuit is made up of conductors extending from the final overcurrent protective device to the load. Some branch circuits originate at safety switches (disconnects), but most originate at a panelboard. The following are several branch circuit classifications (**Figure 12-2**):

- **Individual branch circuit**—A branch circuit that supplies a single load.
- **Multioutlet branch circuit**—A branch circuit with multiple loads.
- **General purpose branch circuit**—A multi-outlet branch circuit that supplies multiple outlets for appliances and lighting.

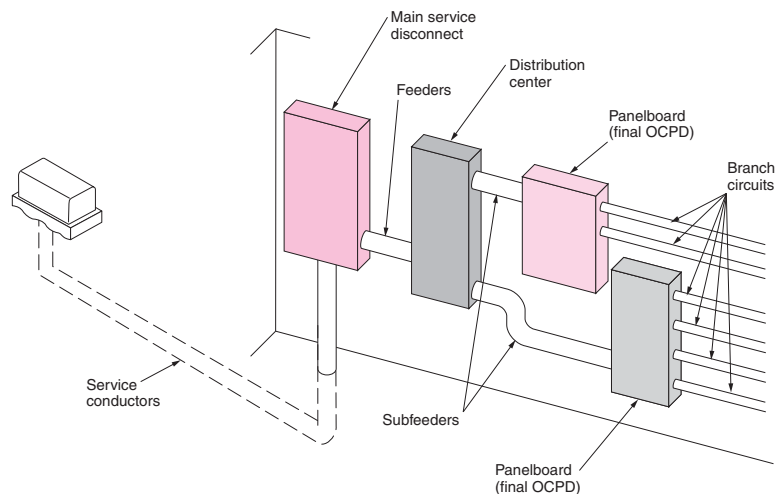


Figure 12-1. Conductors are classified based on their location in the electrical supply system.

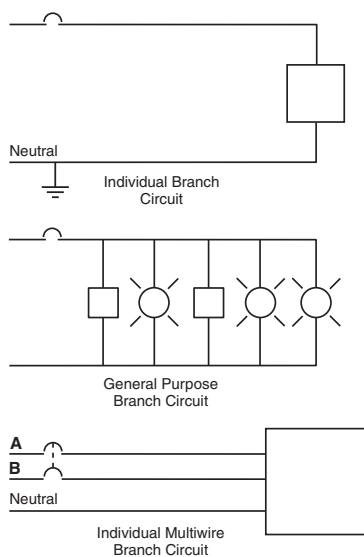


Figure 12-2. Branch circuits are classified as individual or multioutlet, appliance or general.

- **Appliance branch circuit**—A branch circuit that supplies a single appliance load.
- **Multiwire branch circuit**—A branch circuit with two or more ungrounded conductors and one grounded conductor.

Branch-Circuit Rating

A branch circuit is sized for the load it will supply. Sizing the circuit for additional future loads is good practice. The rating of a branch circuit depends on the rating of the overcurrent device protecting the circuit.

Branch circuits serving only one device can have any rating, while a circuit supplying more than one load is limited to ratings of 15, 20, 30, 40, or 50 amps.

Branch-Circuit Voltage

Branch-circuit voltage limits are contained in *Section 210.6* of the *Code*. These limits are based on the equipment being supplied by the circuit:

- In residences and hotel rooms, circuits supplying lighting fixtures and small receptacle loads cannot exceed 120 volts.
- Circuits that are 120 volts and less may be used to supply lampholders, auxiliary equipment of electric-discharge lamps, receptacles, and permanently wired equipment.

- Branch circuits exceeding 120 volts but not exceeding 277 volts may supply mogul-base screw-shell lampholders, ballasts for fluorescent lighting, ballasts for electric-discharge lighting, plug-connected appliances, and hard-wired appliances. Incandescent lighting operating over 150 volts is permitted in commercial construction.
- Circuits exceeding 277 volts and up to 600 volts can supply mercury-vapor and fluorescent lighting, provided the lighting units are installed at heights not less than 22' above grade and in tunnels at heights no less than 18'.

Conductor Size and Ampacity

The ampere rating of branch-circuit conductors must be greater than the maximum load the circuit will provide. For multiple-load branch circuits, the conductor ampacity must correspond to the rating of the overcurrent protective device. However, for circuits supplying hard-wired devices (such as electric heaters, air-conditioning units, and water heaters), the fuse or circuit breaker can be rated at the next higher rating. The conductor is acceptable if its rating is at least that of the load current, even if the overcurrent protective device rating is higher.

The smallest general-purpose conductor for branch circuits is 14 AWG. Tap conductors can be smaller. See *Section 210.19* for more information.

Multiwire Branch Circuits

A branch circuit can be either a two-wire or multiwire branch circuit. A multiwire branch circuit consists of a grounded conductor and two or more ungrounded conductors. A multiwire circuit can be an individual circuit or a multioutlet circuit.

Conductor Color Code

Grounded conductors of branch circuits are identified by color. If the grounded conductor is 6 AWG or smaller, it is white, gray, white with a color stripe, or has three continuous white stripes on other than green insulation. If wires from different systems are contained in the same raceway, the neutrals of different systems are distinguished from one another. For example, the neutral of one system would be white, the neutral of another system would be gray, and the neutral of a third system would be white with a colored stripe. The equipment grounding conductor must be green, green with yellow stripes, or bare (without any insulation).

Hot conductors can be any color except white, gray, green, and white with a color stripe. Normally, hot conductors are black, blue, and red. In a three-phase,

four-wire delta system with a neutral connected at the midpoint of a winding, the “high leg” phase conductor should be identified with orange markings.

Branch-Circuit Loads

The *Code* places load limitations on branch circuits with **continuous loads** (loads with a duration longer than three hours, such as lighting). The continuous load must not exceed 80% of the circuit rating allotted for it. If the overcurrent protective device is listed for continuous operation at 100% of its rating, the 80% factor is not used.

Branch-circuit loads are classified into five categories:

- Lighting loads.
- Receptacle loads.
- Equipment loads.
- Heating and cooling loads.
- Motor loads.

NOTE

Motor loads are discussed in Chapter 13 of this text.

Lighting Loads

In the broad sense, lighting loads may be categorized as follows:

- General lighting.
- Show-window lighting.
- Track lighting.
- Sign and outline lighting.
- Other lighting.

Each lighting load is computed separately and then combined to determine the total lighting load.

General lighting

General lighting is the overhead lighting within a building. Its intensity should be adequate for any type of work performed in the area. Determining the general lighting load can be based on either the load per area method or the actual full-load current of the fixtures used, whichever is greater. Within a structure, there are normally several different types of areas—storage, office, hallways, and cafeterias—and these must be considered separately.

Most commercial structures have continuous lighting loads and the branch circuits must be adequate for carrying 125% of the calculated load. *Code* requirements for general lighting loads are found in several sections:

- *Section 220.12*—Lighting loads for specified occupancies
- *Section 220.14*—Other loads and all occupancies
- *Section 220.16*—Loads for additions to existing installations
- *Section 220.18*—Maximum loads for branch circuits

Table 220.12 of the *Code* contains minimum general lighting loads (in VA/ft²) for various types of buildings. A condensed version of this table is shown in **Figure 12-3**. The general lighting load is calculated by multiplying the floor area (in ft²) by the unit load (in VA/ft²). If the load is continuous, the calculated load is multiplied by 1.25 (the inverse of 80%) to determine the circuit requirements.

● General Lighting Loads ●	
Type Building	Unit Load (VA/ft ²)
Auditoriums	1
Banks	3 1/2
Barber shops	3
Churches	1
Dwelling units	3
Hospitals	2
Hotels	2
Office buildings	3 1/2
Restaurants	2
Schools	3
Stores	3
Warehouses	1/4

Figure 12-3. Minimum general lighting loads are dependent on the type of area being lit.

Sample Problem 12-1

Problem: A 25,000 ft² office building is being designed. What is the general lighting load and what load does the circuit need to supply?

Solution: From *Table 220.12*, the unit load for an office building is 3 1/2 VA/ft². The general lighting load is determined by multiplying this value by the square footage of the building:

$$3 \frac{1}{2} \text{ VA/ft}^2 \times 25,000 \text{ ft}^2 = 87,500 \text{ VA}$$

The general lighting load is 87,500 volt-amperes. However, the load is continuous and can only be 80% of the load supplied by the circuit. This value must be multiplied by 1.25 to determine the circuit requirements:

$$87,500 \text{ VA} \times 1.25 = 109,375 \text{ VA}$$

The circuit is designed to supply 109.375 kilovolt-amperes.

The general lighting load is not required if the load for each lamp is determined separately. If the individual load is continuous, it must be multiplied by 1.25. When determining the current draw of fluorescent fixtures, use the current rating of the ballast, not the tube wattage.

Sample Problem 12-2

Problem: A 4' long, two-lamp fluorescent fixture ballast draws 0.7 amps at 120 volts. How many of these fixtures can be connected on a 20-amp circuit?

Solution: This is a continuous load, so the current used by the lights can only be 80% of the circuit current rating:

$$\begin{aligned} \text{Allowable current} &= 20 \text{ A} \times 0.80 \\ &= 16 \text{ A} \end{aligned}$$

By dividing the allowable load by the load of each lamp, the total number of lamps is determined:

$$\frac{16 \text{ A}}{0.7 \text{ A}} = 22.8 \text{ fixtures}$$

The maximum number of fixtures on the circuit is 22.

Show-window lighting

The *show-window lighting load* is not considered as part of the general lighting load. *Section 220.43(A)* of the *Code* requires that show-window lighting be computed as 200 volt-amperes per linear foot or as the maximum volt-ampere rating of the equipment and lights, whichever is greater.

NEC NOTE

100

Show Window: Any window used or designed to be used for the display of goods or advertising material, whether it is fully or partly enclosed or entirely open at the rear and whether or not it has a platform raised higher than the street floor level.

The *Code* includes several sections applicable to show-window lighting:

- *Section 220.43(A)*—Show-window lighting.
- *Section 220.14(G)*—Load computation.

The *Code* also requires at least one receptacle outlet for every 12' of show-window space measured horizontally with the load computed at 180 volt-amperes per outlet. This receptacle load is in addition to the show-window lighting load.

NEC NOTE

410.14

Chain-supported fixtures used in a show window shall be permitted to be externally wired. No other externally wired fixtures shall be used.

Sample Problem 12-3

Problem: A department store has two lighted show windows, one 25' long and the other 20' long. What are the branch-circuit requirements for the show-window load?

Solution: Compute the load based on linear feet of show window:

$$\begin{aligned} \text{Total length} &= 25' + 20' \\ &= 45' \end{aligned}$$

$$\begin{aligned} \text{Show-window load} &= 45' \times 200 \text{ VA/ft} \\ &= 9000 \text{ VA} \end{aligned}$$

The lighting is a continuous load, so the show-window load is multiplied by 1.25 to determine the circuit load requirements:

$$\begin{aligned} \text{Circuit requirements} &= 9000 \text{ VA} \times 1.25 \\ &= 11,250 \text{ VA} \end{aligned}$$

The circuits supplying power for the show-window lighting must have a minimum capacity of 11,250 volt-amperes.

In addition, receptacles are required for every 12' of show window. A total of five receptacles (two for the 20' window and three for the 25' window) are needed. The receptacle load can then be computed:

$$5 \times 180 \text{ VA} = 900 \text{ VA}$$

$$\begin{aligned} \text{Total load} &= 11,250 \text{ VA} + 900 \text{ VA} \\ &= 12,150 \text{ VA} \end{aligned}$$

Track lighting

Track lighting is often used in commercial buildings for accent lighting. It is discussed in *Part XV* of *Article 410* of the *Code*. The minimum load for track lighting is 150 volt-amperes for every 2' of track. To compute the track lighting load requirements, simply determine the total length of track lighting, divide by two, and multiply by 150 volt-amperes.

NEC NOTE

410.2

Lighting track is a manufactured assembly designed to support and energize luminaires (lighting fixtures) that are capable of being readily repositioned on the track. Its length can be altered by addition or subtraction of sections of track.

Sample Problem 12-4

Problem: Determine the track lighting load for a 22' long section of track.

Solution: Every 2' requires 150 volt-amperes, so the length (in feet) is divided by 2', and then multiplied by 150 volt-amperes:

$$\begin{aligned} \text{Track lighting load} &= \frac{\text{length}}{2'} \times 150 \text{ VA} \\ &= \frac{22'}{2'} \times 150 \text{ VA} \\ &= 1650 \text{ VA} \end{aligned}$$

If this is a continuous load, the circuit requirements would also include a 1.25 factor.

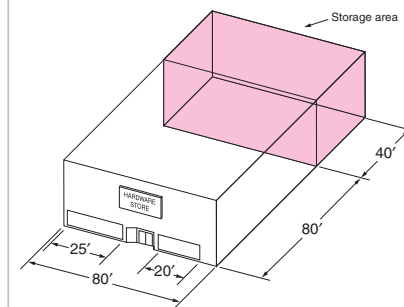
Sign and outline lighting

Sign and outline lighting is discussed in *Article 600* of the *Code*. A structure must have at least one circuit exclusively used to supply sign or outline lighting. The circuit must be designed for a minimum load of 1200 volt-amperes.

Sign and outline lighting loads are considered continuous loads. Therefore, if the rating of the sign and outline fixtures is greater than 960 volt-amperes ($1200 \times 0.8 = 960$), the circuit will be greater than 1200 volt-amperes.

Sample Problem 12-5

Problem: A hardware store measures 80' × 120'. A portion of the building (80' × 40') is used for storage. The remainder of the building is used as a showroom. There is a total of 45' of show windows, and there is one outdoor sign. What is the total lighting load for this building?



(Continued on the following page.)

Sample Problem 12-5 Continued

Solution: Each type of lighting load is computed separately and then combined to determine the total lighting load. First, the general lighting loads for the two areas of the store are calculated:

$$\text{Storage area} = 80' \times 40' \\ = 3200 \text{ ft}^2$$

$$\text{Showroom area} = 80' \times 80' \\ = 6400 \text{ ft}^2$$

Table 220.3(A) lists unit loads for storage and showroom as 1/4 VA/ft² and 3 VA/ft², respectively:

$$\text{General lighting load (storage)} = 3200 \text{ ft}^2 \times 1/4 \text{ VA/ft}^2 \\ = 800 \text{ VA}$$

$$\text{General lighting load (showroom)} = 6400 \text{ ft}^2 \times 3 \text{ VA/ft}^2 \\ = 19,200 \text{ VA}$$

$$\text{General lighting load} = 800 \text{ VA} + 19,200 \text{ VA} \\ = 20,000 \text{ VA}$$

The show-window lighting load is based on 200 VA per linear foot:

$$\text{Show-window lighting load} = 45' \times 200 \text{ VA/ft} \\ = 9000 \text{ VA}$$

The minimum load for the sign lighting is used:

$$\text{Sign lighting} = 1200 \text{ VA}$$

Now the total lighting load can be calculated by adding the parts together:

$$\text{Total lighting load} = 20,000 \text{ VA} + 9000 \text{ VA} + 1200 \text{ VA} \\ = 30,200 \text{ VA}$$

These loads are all continuous, so the total load is multiplied by a factor of 1.25 to determine the circuit requirements.

$$30,200 \text{ VA} \times 1.25 = 37,750 \text{ VA}$$

Additional lighting loads

Additional lighting loads should be computed separately from the general lighting load and then added to the general lighting load. Loads for additional lighting such as security lighting, parking area lighting, sidewalk lighting, roadway lighting, and stadium lighting are calculated using the actual load. These are considered continuous loads where appropriate. The additional lighting load must be treated separately from the general lighting load for computation purposes.

Demand factors for feeder loads

Due to the great diversity of lighting loads on commercial premises, Section 220.42 and Table 220.42 allow the general lighting load to be derated (reduced) for feeder, panel, or service computations. See Figure 12-4. For example, it is highly unlikely that every light in a hospital would be operating at the same time. Of course, there are areas within a hospital where the derating factors should not be applied as these areas (such as operating rooms, emergency rooms, intensive care units, nurses stations, stairways, and cardiac units) are likely to have lighting units on at all times.

NOTE

Derating factors do not apply to branch-circuit conductor or branch-circuit overcurrent protective device calculations.

Demand Factors for Lighting Loads		
Type of Occupancy	Portion of Load (VA)	Demand Factor (%)
Dwelling Unit	0–3000	100
	3001–120,000	35
	Over 120,000	25
Hospital	0–50,000	40
	Over 50,000	20
Hotels and Motels	0–20,000	50
	20,000–100,000	40
	Over 100,000	30
Warehouses	0–12,500	100
	Over 12,500	50
All Others	Total VA	100

Figure 12-4. Lighting loads can be derated for structures where all lights are not in use continuously.

Sample Problem 12-6

Problem: A hotel has 250 rooms, each with an area of 400 ft². Determine the general lighting load and then calculate the derated load to be used for feeder calculations.

Solution: First, determine the total area of the hotel rooms:

$$250 \text{ rooms} \times 400 \text{ ft}^2/\text{room} = 100,000 \text{ ft}^2$$

The general lighting load for hotel rooms (from Table 220.12) is 2 VA/ft². Determine the general lighting load:

$$100,000 \text{ ft}^2 \times 2 \text{ VA/ft}^2 = 200,000 \text{ VA}$$

The branch circuits are required to supply the full general load. However, the feeder can be derated using the factors in Table 220.42.

Table 220.42 Lighting Load Demand Factors

Type of Occupancy	Portion of Lighting Load to Which Demand Factor Applies (Volt-Amperes)	Demand Factor (Percent)
Dwelling units	First 3000 or less at	100
	From 3001 to 120,000 at	35
	Remainder over 120,000 at	25
Hospitals*	First 50,000 or less at	40
	Remainder over 50,000 at	20
Hotels and motels, including apartment houses without provision for cooking by tenants*	First 20,000 or less	50
	From 20,001 to 100,000	40
	Remainder over 100,000	30
Warehouses (storage)	First 12,500 or less at	100
	Remainder over 12,500 at	50
All others	Total volt-amperes	100

*The demand factors of this table shall not apply to the computed load of feeders or services supplying areas in hospitals, hotels, and motels where the entire lighting is likely to be used at one time, as in operating rooms, ballrooms, or dining rooms.

The general lighting load must be divided into three parts to correspond to the three different demand factors. The first 20,000 volt-amperes have a demand factor of 50%. The next 80,000 volt-amperes (20,000 to 100,000) have a demand factor of 40%. The final 100,000 volt-amperes (100,000 to 200,000) have a demand factor of 30%. Each section is calculated individually:

$$20,000 \text{ VA} \times 0.50 = 10,000 \text{ VA}$$

$$80,000 \text{ VA} \times 0.40 = 32,000 \text{ VA}$$

$$100,000 \text{ VA} \times 0.30 = 30,000 \text{ VA}$$

To determine the derated feeder load, add the three totals together:

$$10,000 \text{ VA} + 32,000 \text{ VA} + 30,000 \text{ VA} = 72,000 \text{ VA}$$

The derated load used for sizing the feeder is 72,000 volt-amperes.

Receptacle Loads

The majority of receptacles installed in commercial structures do not supply continuous loads. It is difficult to predict what size load will be supplied at a receptacle, unless the receptacle is dedicated (assigned a specific purpose). The Code does not require a minimum number of outlets for commercial buildings. Normally, many receptacles are required.

When a receptacle is the load supplied by an individual branch circuit, the receptacle ampere rating must be equal to or greater than that of the branch circuit. When there are multiple receptacles on a branch circuit, the receptacle rating varies with the current rating. See Figure 12-5, which reflects Table 210.21(B)(3).

Receptacles connected to a 15-amp or 20-amp circuit are grounded. Grounded receptacles should not be used if the circuit is not actually grounded. A GFCI receptacle

● Receptacle Rating ●

Circuit Rating (A)	Receptacle Rating (A)
15	Not over 15
20	15 or 20
30	30
40	40 or 50
50	50

Figure 12-5. Receptacle ratings are determined by the circuit rating.

can be used as a replacement for an ungrounded receptacles outlet.

A load of 180 volt-amperes is assigned to each receptacle, whether it is single, duplex, or triplex. If a receptacle is dedicated for a specific device, then the actual load is used. If the dedicated load is continuous, then the 125% overrate is appropriate.

To calculate the allowable number of receptacles on a branch circuit, multiply the circuit voltage and amperage, then divide by 180 volt-amperes. The receptacle load can be included with the general lighting load by adding a value of 1 VA/ft² to the general lighting unit loads found in Table 220.12. However, this method should only be used when the number of receptacles is unknown.

Sample Problem 12-7

Problem: How many receptacles can be placed on a 120-volt, 20-amp circuit? How many can be placed on a 120-volt, 15-amp circuit?

Solution: Determine the maximum circuit power:

$$P = E \times I \\ = 120 \text{ V} \times 20 \text{ A} \\ = 2400 \text{ VA (for 20-amp circuit)}$$

$$P = 120 \text{ V} \times 15 \text{ A} \\ = 1800 \text{ VA (for 15-amp circuit)}$$

Then divide the power by the load per receptacle (180 volt-amperes):

20-amp circuit:

$$\frac{2400 \text{ VA}}{180 \text{ V}} = 13.3$$

15-amp circuit:

$$\frac{1800 \text{ VA}}{180 \text{ V}} = 10$$

A 120-volt, 20-amp circuit can supply 13 receptacles.
A 120-volt, 15-amp circuit can supply 10 receptacles.

Multioutlet assemblies are frequently installed in repair shops, lighting display areas, electronics departments, and other locations where many outlets are needed. These multioutlet assemblies require 180 volt-amperes for each 5' of length. In stores, repair shops, and laboratories, the Code allows the overall load to be derated in accordance with Table 220.44 (if the load exceeds 10,000 volt-amperes).

The diversity and inconsistent loading of general purpose receptacles allows the total receptacle load to be derated (see Section 220.44). If the load exceeds 10,000 volt-amperes, the first 10 kilowatts are counted at 100%, but additional load is counted at 50%. This may not be used if the Code dictates that the specific appliances cannot be derated. Refer to Sections 220.12 and 220.44 and Table 220.44.

Sample Problem 12-8

Problem: Determine (a) the receptacle load for an 80' × 120' hardware store and (b) the number of 15-amp circuits needed to supply the load. The number of receptacles is unknown.

Solution: (a) The number of receptacles is unknown, so a receptacle load of 1 VA/ft² can be calculated:

$$\text{Area} = 80' \times 120' \\ = 9600 \text{ ft}^2$$

$$\text{Receptacle load} = 1 \text{ VA/ft}^2 \times 9600 \text{ ft}^2 \\ = 9600 \text{ VA}$$

(b) To determine the number of circuits required, first calculate the allowable load for a single circuit:

$$\text{Max load} = 120 \text{ V} \times 15 \text{ A} \\ = 1800 \text{ VA}$$

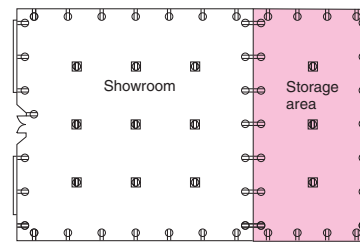
Divide the total receptacle load by the maximum load per circuit to determine the minimum number of circuits:

$$\text{Circuits} = \frac{9600 \text{ VA}}{1800 \text{ V}} \\ = 5.33$$

This is the minimum number, so round up to six circuits.

Sample Problem 12-9

Problem: The hardware store introduced in Sample Problem 12-5 will have one duplex receptacle for every 12' of wall around the storage area and showroom. A total of twelve floor receptacles will be used. Determine the receptacle load, including show-window receptacles for 20' and 25' show windows.



Solution: Receptacles will be placed along six 80'-long walls and two 40'-long walls. Determine the number of receptacles needed for each 80'-long wall:

$$\text{Receptacles per 80' wall} = \frac{80'}{12'} \\ = 6.67$$

Seven receptacles are needed for each 80' wall. Next, determine the number of receptacles needed for each 40' wall:

$$\text{Receptacles per 40' wall} = \frac{40'}{12'} \\ = 3.33$$

Four receptacles are needed for each 40' wall. The total number of wall receptacles can now be calculated:

$$\text{Wall receptacles} = (6 \times 7) + (2 \times 4) \\ = 42 + 8 \\ = 50$$

One receptacle is needed for every 12' of show window length, so the 20' show window requires two receptacles and the 25' show window requires three receptacles. Therefore, the show windows require a total of five receptacles. The total number of receptacles can be found by adding together the wall receptacles, floor receptacles, and show-window receptacles:

$$\text{Total receptacles} = 50 + 12 + 5 \\ = 67 \text{ receptacles}$$

The total receptacle load can then be determined:

$$\text{Receptacle load} = 67 \times 180 \text{ VA} \\ = 12,060 \text{ VA}$$

The total receptacle load is 12,060 VA. For feeder sizing, the first 10,000 VA must be counted at 100%, but only 50% of the additional load needs to be considered. Determine 50% of 2060 VA:

$$2060 \text{ VA} \times 0.50 = 1030 \text{ VA}$$

$$\text{Feeder load} = 10,000 \text{ VA} + 1030 \text{ VA} \\ = 11,030 \text{ VA}$$

The receptacle load on the feeder is 11,030 VA.

Equipment Loads

Within this category of branch-circuit loads is a vast array of equipment, such as appliances, water heaters, washers, dryers, and cooking equipment. Most of these items are used for brief periods and are considered noncontinuous, so the required load supplied by the circuit is identical to the equipment requirement.

Equipment is often hard-wired, but can also be cord-and-plug connected to a receptacle. Branch circuits for appliance loads must have conductors with an ampacity equal to or exceeding the ampacity of the appliance. The ampacity of the appliance is marked on the unit by the manufacturer. If the appliance has a motor, the ampacity of the branch-circuit conductors must be 125% of the current rating of the motor.

Commercial kitchen equipment loads

Loads for commercial cooking equipment are discussed in Section 220.56 of the Code. The total feeder load is simply the sum of the nameplate ratings of the appliances. If there are three or more pieces of cooking equipment, the feeder load can be derated in accordance with Table 220.56. The table in Figure 12-6 lists the demand factors. The branch-circuit loads cannot be derated using these factors.

Ovens, grills, fryers, food warmers, large vat blending machines, booster heaters, conveyors, and tray assemblies are considered kitchen equipment and may be derated in accordance with Table 220.56. Auxiliary equipment such as exhaust fans, space heaters, and air-conditioning units are not counted as kitchen equipment and cannot be derated.

● Feeder Demand Factors for ● Kitchen Equipment	
Units of Equipment	Demand Factors (%)
1–2	100
3	90
4	80
5	70
6+	65

Figure 12-6. The load for multiple pieces of commercial cooking equipment can be derated in accordance with the demand factors listed in *Table 220.56*.

NEC NOTE

220.56

Demand factors for kitchen equipment shall be applied to all equipment that has either thermostatic control or intermittent use as kitchen equipment. They shall not apply to space-heating, ventilating, or air-conditioning equipment.

Heating and Cooling Loads

Regardless of the type of structure—residential, commercial, or industrial—the heating load must be computed at 100% of the nameplate rating of the unit. Depending on the type of heating unit, the branch circuit may require other considerations.

Fixed electric space heating is covered in detail in *Article 424—Fixed Electric Space-Heating Equipment*. This article includes fixed equipment, such as central heating systems, boilers, heating cable, and unit heaters (baseboard, panel, and duct heaters). For information regarding the installation, control, and specifics about each type of heater, refer to *Article 424*.

The *Code* also requires a disconnect for the heater and motor controller, as well as supplementary overcurrent protection for any fixed electric space-heating units. The disconnect is for safety during maintenance. The disconnecting means must be within sight of the unit and must disconnect all components of the heating unit, including any overcurrent protective devices, contactors, elements, and motor controllers.

The rules for sizing the branch-circuit wiring and overcurrent protection are very specific. The rating on the equipment nameplate is used to determine the load. If the equipment operates continuously for at least three hours, its rating must be increased by a factor of 1.25.

Fixed electric space heating shall be considered continuous load. Several general rules must be followed when sizing the overcurrent protective devices for branch

circuits supplying heating equipment (see *Section 424.22*):

- Heating equipment is protected by the branch-circuit overcurrent protective device. This can be a set of fuses or circuit breakers.
- Motors used in conjunction with the heating equipment must also have overcurrent protection.
- Heating units having resistance elements exceeding 48 amps must have their load subdivided. Each of the loads must have overcurrent protection provided by the manufacturer. Conductors from the overcurrent devices to the heating unit must be sized at 125% if the load is 50 kilowatts or less.
- If the unit load for the heating equipment is greater than 50 kilowatts, the conductors can be sized at 100% provided the heating unit has a controller (thermostat). If this is not the case, then the conductors must be sized at 125% of the load.
- For conditions other than those described above, size the conductors at 125% of the load.

Sample Problem 12-10

Problem: A 30-kilowatt, 240-volt heating unit with a 6-amp fan motor is being installed for a shoe store. Determine the size of the THW conductors and overcurrent protective device for the circuit supplying the equipment.

Solution: First, determine the current required for the heating unit:

$$I = \frac{P}{E}$$

$$= \frac{30,000 \text{ VA}}{240 \text{ V}}$$

$$= 125 \text{ A}$$

Combining the current for the heating unit and the motor:

$$\text{Required current} = 125 \text{ A} + 6 \text{ A}$$

$$= 131 \text{ A}$$

The conductors must be designed for 125% of this current (*Section 424.3(B)*):

$$\text{Required conductor capacity} = 131 \text{ A} \times 1.25$$

$$= 164 \text{ A}$$

The overcurrent protective device must be the next highest standard size (*Section 240.6*), which is 175 amps. Using *Table 310.15(B)(16)*, 2/0 AWG copper conductors are needed. The equipment grounding conductor can be a 6 AWG copper conductor (*Section 250.122*).

Feeders

The conductors between the service equipment and the branch-circuit overcurrent devices are called *feeders*. *Article 215—Feeders* provides information regarding the safe and adequate sizing and installation of these conductors. This article also applies to subfeeders, which provide power to branch-circuit panels but originate at power distribution centers rather than the service equipment.

Feeder loading is dependent on the total power requirement of the system. If it is possible for all connected loads to operate simultaneously, then the feeder must be of sufficient ampacity to meet that demand. If only 75% of the connected loads will ever be operating at the same time, then the feeder would be sized larger than the service conductors.

Prior to installation, certain factors must be considered to ensure the feeder size, type, and overcurrent protection is correct for the application:

- **Material**—The feeder can be copper or aluminum.
- **Location**—The environment around the feeder (damp, hot, corrosive) must be considered.
- **Wiring method**—The feeder can be run in conduit, cable trays, or other systems.
- **Cable**—Single or multiconductor cable can be used.
- **Type**—Feeders can be paralleled or individual.
- **Length**—Voltage drop becomes a consideration in long feeders.
- **Derating factor**—Conductor sizing includes several factors: conduit fill, ambient temperature, and connected load demand.
- **Neutral**—A neutral wire may not be necessary with the feeder.
- **Demand factor**—Continuous loads will affect feeder size.
- **Protection**—Various overcurrent protective devices can be used with feeders.

Summary of Commercial Service Load Computation Procedure

1. Determine the general lighting load based on the total square footage multiplied by the volt-ampere load indicated in *Table 220.12*.
2. If the lighting is a continuous load, as is true of most commercial lighting, increase the load by 125%. That is, multiply by 1.25. (*Section 210.20(A)*)
3. For feeder and service loads, use *Table 220.42* and apply the lighting demand factor required for the type of building.
4. After computing both air-conditioning and heating loads, omit the smaller of the two. (*Section 220.60*)

An air-conditioning branch-circuit load is determined from the data provided on the nameplate affixed to the unit. The nameplate will list the phase, voltage, frequency, full-load current, and other pertinent information of the hermetic motor compressor. The full-load current rating shown on the nameplate serves as the basis for determining the branch-circuit conductor size, overcurrent protection requirement, controller rating, and disconnect size.

Sometimes the branch-circuit current rating is also included on the nameplate. In such instances, use the larger of the branch-circuit current rating or full-load current rating for sizing the circuit. If a unit has two or more motors, then the circuit ampacity must be computed at 125% of the largest motor plus the sum of the other motors. For a single-motor unit disconnect, use 115% of the full-load current.

NOTE

A disconnecting means must be within sight of the unit and it must be correctly sized at 115% of the total current rating.

The overcurrent protective device cannot exceed 175% of the motor full-load current or branch-circuit rating, whichever is larger. This can be increased to 225% if the motor will not start or come up to full speed without tripping an overcurrent protective device rated for 175%.

The label may include the rating of the motor in horsepower. This rating must be converted prior to determining the branch-circuit load rating. Use *Tables 430.247* through *430.250* for converting horsepower to amperes. These tables are contained in the Reference Section at the end of the text.

Sample Problem 12-11

Problem: For an air-conditioning unit with a three-phase, 230-volt, 20-hp motor, what is the required size of the branch-circuit overcurrent protective device?

Solution: Use *Table 430.250* to convert horsepower to amperes. 20 horsepower with a 230-volt supply is equal to 54 amps. This load must be increased by 125% for the conductor ampacity:

$$\text{Conductor ampacity} = 54 \text{ A} \times 1.25$$

$$= 67.5 \text{ A}$$

The next highest standard overcurrent protective device rating is 70 amps.

5. Compute receptacle outlets as follows:
 - Receptacles as 180VA each. (Section 220.14(I))
 - Multioutlet assemblies at 180 VA per each 5' portion. (Section 220.14(H)(1))
 - Show windows at either of the following (Section 220.14(G)):
 - (1) The unit load per outlet as required in other provisions of Section 220.14
 - (2) At 200 VA per 300 mm (1 foot) of show window
 - Heavy-duty lamp holders at 600 VA each. (Section 220.14(E))
 - Others as outlined in Section 220.14
6. Apply any of the demand factors as shown in Table 220.44 for receptacle loads and Table 220.56 for kitchen equipment loads.
7. Add the sign lighting load (1200 VA minimum). (Section 220.14(F))
8. Compute the motor loads using the appropriate tables in Article 430.
9. Increase largest motor load based on full-load current by 25%. (Section 430.24)
10. Size the service and service conductors. Compute by dividing the total load by the line voltage. Conductor size is selected from Table 310.15(B)(16).
11. Using the guideline given in Section 250.24(C), size the grounded service conductor. Be sure the grounded service conductor is not smaller than the grounding electrode conductor as given in Table 250.66.
12. Provided there is no discharge lighting, the neutral load—if over 200 amperes—can be derated by 70%. Refer to Section 220.61.

Sample Problems

The following examples represent a small sampling of situations requiring computations to determine correct sizing of equipment, conductors, overcurrent protection, and other load demands encountered in commercial wiring. The main purpose is to introduce the concept and give the reader a general feel for the overall procedure. Numerous other factors such as wiring methods, routing, distances, and voltage drop (to name a few) have been purposefully ignored here for the sake of simplicity. Still, by reviewing and understanding these examples and the step-by-step methodology, the commercial electrician, designer, engineer, and student will be better equipped to move on to the "real" calculations required in practical design situations.

The following problems illustrate load calculation and feeder sizing for commercial structures:

- **Small retail store**—Sample Problem 12-12.
- **Office building**—Sample Problem 12-13.
- **Restaurant**—Sample Problem 12-14.
- **Hotel**—Sample Problem 12-15.

Sample Problem 12-12

Problem: A small retail store is being constructed. Its power supply is single-phase, 120/240-volt. The store is 80' × 60' and has several loads:

- 50-kVA heating equipment
- 25-kVA air-conditioning unit
- 1/2-hp, 240-volt ventilating unit
- 60 duplex receptacles
- 40 linear feet of show-window lighting
- 1.2-kVA outdoor sign lighting

Copper THW conductors are used as feeders. What size should the current-carrying feeders be?

Solution: First, all the loads must be computed. The heating unit and air-conditioning unit will not be used at the same time, so only the larger load is needed. The 1/2-hp, 240-volt motor draws a current of 4.9 amps, as shown in Table 430.248.

$$\text{General lighting load} = 80' \times 60' \times 3 \text{ VA/ft}^2 = 14,400 \text{ VA}$$

$$\text{Show-window lighting load} = 40' \times 200 \text{ VA} = 8000 \text{ VA}$$

$$\text{Sign lighting load} = 1200 \text{ VA}$$

$$\text{Receptacle load} = 60 \times 180 \text{ VA} = 10,800 \text{ VA}$$

$$\text{Heating/air-conditioning load} = 50,000 \text{ VA}$$

$$\text{Motor load} = 4.9 \text{ A} \times 240 \text{ V} = 1176 \text{ VA}$$

The total lighting load is the combination of the three separate lighting loads.

$$\text{Total lighting load} = 14,400 \text{ VA} + 8000 \text{ VA} + 1200 \text{ VA} = 23,600 \text{ VA}$$

The motor load and lighting loads are continuous, so the conductors must supply 125% of the full-load current:

$$\text{Total lighting load} = 23,600 \text{ VA} \times 1.25 = 29,500 \text{ VA}$$

$$\text{Motor load} = 1176 \text{ VA} \times 1.25 = 1470 \text{ VA}$$

(Continued on the following page.)

Sample Problem 12-12 Continued

All loads are added to determine the total load:

$$\text{Total load} = 29,500 \text{ VA} + 10,800 \text{ VA} + 50,000 \text{ VA} + 1470 \text{ VA} = 91,770 \text{ VA}$$

The total current can be calculated:

$$I = \frac{P}{E} = \frac{91,770 \text{ VA}}{240 \text{ V}} = 382 \text{ A}$$

Using Table 310.16, 500 kcmil conductors will be sufficient.

The neutral feeder conductor is sized for the 120-volt loads (lighting and receptacles) only.

$$\begin{aligned} \text{Neutral feeder load} &= \text{Lighting load} + \text{Receptacle load} \\ &= 29,500 \text{ VA} + 10,800 \text{ VA} \\ &= 40,300 \text{ VA} \end{aligned}$$

The current can be calculated:

$$I = \frac{P}{E} = \frac{40,300 \text{ VA}}{240 \text{ V}} = 168 \text{ A}$$

A 2/0 AWG copper conductor should be used for the neutral feeder conductor.

Sample Problem 12-13

Problem: A two-story office building (80' × 80') is supplied with 120/208-volt service. Several loads are supplied:

- 75-kVA air-conditioning unit
- 85-kVA heating unit
- 200 duplex receptacles
- 50 linear feet of show window
- 30 exterior light fixtures (175 VA each)
- 3 blower motors (3/4-hp, 208-volt)

Copper THW conductors are used as feeders. What size should the current-carrying conductors be?

Solution: First, all loads must be computed. The heating unit and air-conditioning unit will not be used at the same time, so only the larger load is

(Continued)

Sample Problem 12-13 Continued

needed. The 3/4-hp, 208-volt motors draw 3.5 amps, as shown in Table 430.250. The actual motor voltage is 208 V × 1.732 (or 360 volts) because the service is three-phase.

$$\begin{aligned} \text{General lighting load} &= 2 \times 80' \times 80' \times 3 \text{ 1/2 VA/ft}^2 \\ &= 44,800 \text{ VA} \end{aligned}$$

$$\begin{aligned} \text{Show-window lighting load} &= 50' \times 200 \text{ VA} \\ &= 10,000 \text{ VA} \end{aligned}$$

$$\begin{aligned} \text{Exterior lighting load} &= 30 \times 175 \text{ VA} \\ &= 5250 \text{ VA} \end{aligned}$$

$$\begin{aligned} \text{Receptacle load} &= 200 \times 180 \text{ VA} \\ &= 36,000 \text{ VA} \end{aligned}$$

$$\text{Heating/air-conditioning load} = 85,000 \text{ VA}$$

$$\begin{aligned} \text{Motor load} &= 3 \times 3.5 \text{ A} \times 360 \text{ V} \\ &= 3780 \text{ VA} \end{aligned}$$

The total lighting load is the combination of the three separate lighting loads.

$$\begin{aligned} \text{Total lighting load} &= 44,800 \text{ VA} + 10,000 \text{ VA} + 5250 \text{ VA} \\ &= 60,050 \text{ VA} \end{aligned}$$

The motor load and lighting loads are continuous, so the conductors must supply 125% of the full-load current:

$$\begin{aligned} \text{Total lighting load} &= 60,050 \text{ VA} \times 1.25 \\ &= 75,063 \text{ VA} \end{aligned}$$

$$\begin{aligned} \text{Motor load} &= 3780 \text{ VA} \times 1.25 \\ &= 4725 \text{ VA} \end{aligned}$$

All loads are added to determine the total load:

$$\begin{aligned} \text{Total load} &= 75,063 \text{ VA} + 36,000 \text{ VA} + 85,000 \text{ VA} + 4725 \text{ VA} \\ &= 200,788 \text{ VA} \end{aligned}$$

The total current can be calculated:

$$I = \frac{P}{E} = \frac{200,788 \text{ VA}}{360 \text{ V}} = 557 \text{ A}$$

Using Table 310.16, 1250 kcmil conductors will be sufficient.

Sample Problem 12-14

Problem: A restaurant is supplied with three-wire, 120/240-volt service. The restaurant is 50' × 80' and has several loads:

- (1) 12-kW electric range (120-volt)
- (1) 10-kW water heater (240-volt)
- (2) 8-kW fryers (240-volt)
- (2) 1.5-kW coffeemakers (120-volt)
- (1) 2.5-kW steam table (120-volt)
- (2) 3.0-kW toasters (120-volt)
- (1) 2.5-kW disposal unit (120-volt)
- (1) 1.5-kW outdoor sign (120-volt)
- (1) 40-kW heating unit duplex receptacles

Copper THW conductors are used as feeders. What size should the current-carrying feeders be?

Solution: First, the loads must be computed.

$$\begin{aligned} \text{General lighting load} &= 50' \times 80' \times 2 \text{ VA/ft}^2 \\ &= 8000 \text{ VA} \end{aligned}$$

$$\text{Sign lighting load} = 1500 \text{ VA}$$

$$\begin{aligned} \text{Receptacle load} &= 26 \times 180 \text{ VA} \\ &= 4680 \text{ VA} \end{aligned}$$

$$\text{Heating load} = 40,000 \text{ VA}$$

The cooking equipment will be combined as the cooking equipment load:

$$\begin{aligned} \text{Electric range:} & 12,000 \text{ VA} \\ \text{Water heater:} & 10,000 \text{ VA} \\ \text{Fryers:} & 16,000 \text{ VA} \\ \text{Coffeemakers:} & 3000 \text{ VA} \\ \text{Steam table:} & 2500 \text{ VA} \\ \text{Toasters:} & 6000 \text{ VA} \\ \text{Disposal unit:} & 2500 \text{ VA} \end{aligned}$$

$$\text{Cooking equipment load} = 52,000 \text{ VA}$$

Table 220.56 contains load-reduction factors for commercial kitchen equipment. For six or more pieces of equipment, the feeder conductors can be designed for 65% of the load.

$$\begin{aligned} \text{Reduced cooking equipment load} &= 52,000 \text{ VA} \times 0.65 \\ &= 33,800 \text{ VA} \end{aligned}$$

The total lighting load is the combination of the two separate lighting loads.

$$\begin{aligned} \text{Total lighting load} &= 8000 \text{ VA} + 1500 \text{ VA} \\ &= 9500 \text{ VA} \end{aligned}$$

The lighting loads are continuous, so the conductors must supply 125% of the full-load current:

$$\begin{aligned} \text{Total lighting load} &= 9500 \text{ VA} \times 1.25 \\ &= 11,875 \text{ VA} \end{aligned}$$

All loads are added to determine the total load:

$$\begin{aligned} \text{Load} &= 11,875 \text{ VA} + 4680 \text{ VA} + 40,000 \text{ VA} + 33,800 \text{ VA} \\ &= 90,355 \text{ VA} \end{aligned}$$

The total current can be calculated:

$$\begin{aligned} I &= \frac{P}{E} \\ &= \frac{90,355 \text{ VA}}{240 \text{ V}} \\ &= 377 \text{ A} \end{aligned}$$

Using Table 310.15(B)(16), 500 kcmil conductors will be sufficient.

Sample Problem 12-15

Problem: A 200-unit hotel is supplied with three-phase, 120/208-volt service. Each unit is 300 ft², has a 30-amp air conditioner (208-volt) and has a heating load of 8 kilowatts. The hotel also has a 30-kilowatt continuous load for general equipment. What is the total current that must be supplied to the hotel?

Solution: First, all loads must be computed. The heating unit and air-conditioning unit will not be used at the same time, so only the larger load is needed. Section 220.14 explains that the receptacle loads do not need to be included.

$$\begin{aligned} \text{General lighting load} &= 200 \times 300 \text{ ft}^2 \times 2 \text{ VA/ft}^2 \\ &= 120,000 \text{ VA} \end{aligned}$$

This load can be reduced in accordance with Table 220.42:

$$\begin{aligned} 50\% \text{ of } 0\text{--}20 \text{ kW} &= 10,000 \text{ VA} \\ 40\% \text{ of } 20\text{--}100 \text{ kW} &= 32,000 \text{ VA} \\ 30\% \text{ of } 100\text{--}120 \text{ kW} &= 8000 \text{ VA} \end{aligned}$$

(Continued on the following page.)

Sample Problem 12-15 Continued

The total reduced lighting load is determined:

$$\begin{aligned} \text{Lighting load} &= 10,000 \text{ VA} + 32,000 \text{ VA} + 8000 \text{ VA} \\ &= 50,000 \text{ VA} \end{aligned}$$

The air-conditioning load must be calculated. The voltage is 208 V × 1.732 (360 volts) due to the three-phase supply:

$$\begin{aligned} \text{Air-conditioning load} &= 360 \text{ V} \times 30 \text{ A} \\ &= 10,800 \text{ VA} \end{aligned}$$

This is larger than the heating load, so the air-conditioning load is used in the total load. The load per room is 10,800 VA, so it must be multiplied by 200 to determine the total load:

$$\begin{aligned} \text{Total air-conditioning load} &= 10,800 \text{ VA} \times 200 \\ &= 2,160,000 \text{ VA} \end{aligned}$$

$$\begin{aligned} \text{General equipment load} &= 30,000 \text{ VA} \times 1.25 \\ &= 37,500 \text{ VA} \end{aligned}$$

All loads are added to determine the total load:

$$\begin{aligned} \text{Total load} &= 50,000 \text{ VA} + 2,160,000 \text{ VA} + 37,500 \text{ VA} \\ &= 2,247,500 \text{ VA} \end{aligned}$$

The total current can be calculated:

$$\begin{aligned} I &= \frac{P}{E} \\ &= \frac{2,247,500 \text{ VA}}{360 \text{ V}} \\ &= 6243 \text{ A} \end{aligned}$$

The total current is 6243 A.

Review Questions

Answer the following questions. Do not write in this book.

- What type of conductors extend beyond the final overcurrent device?
- What type of conductors originate at the main disconnect device and terminate at panelboards and load centers?
- How is the rating of a branch circuit determined?
- What is the smallest conductor permitted for use in a branch circuit?
- What color insulation is used on equipment grounding conductors?
- Define *continuous* load.
- What are the five general types of branch-circuit loads?
- If the exact number of receptacles is unknown, how can the receptacle load be calculated?
- How is the show-window lighting load determined?
- How many receptacles must be installed for the nondwelling receptacle loads derating to reduce the total receptacle load?
- A large hotel has 2500 ft² of hallway space. Assuming continuous load, how many volt-amperes should be allowed for this load for service computation?
- Calculate the general lighting load for a commercial warehouse having an area of 90,000 ft². Assume continuous duty.
- What is the demand factor used for four kitchen equipment loads in a commercial cafeteria?
- Compute the receptacle load for a department store having 165 duplex receptacles.
- A furniture store has 60 linear feet of show window. Calculate this continuous load.
- What is the minimum outside sign lighting load required by the Code?
- What is the general lighting load for a 50-room motel where each room is 12' × 20'?
- A 24-hour service restaurant has 75 duplex receptacles. Calculate the total load for feeder calculations.
- What is the service demand for a small bank measuring 2500 ft² and supplied with 208/120-volt, three-phase service? Assume lighting as continuous. The bank has the following loads:
15 kW heating (208-volt)
7.5 hp air conditioning
50 linear feet of show window
25 duplex receptacles
- A new high school is to be erected, supplied with 208/120-volt, single-phase power. The school has the following dimensions and loads. Calculate the total feeder conductor and feeder neutral loads. Assume all lighting loads are continuous.
30,000 ft² classroom space
6000 ft² auditorium
5000 ft² cafeteria (use restaurant load)
10 kW outside lighting (120-volt)
225 duplex receptacles (120-volt)

Kitchen equipment:

- (2) 15 kW ovens (208-volt)
- (2) 10 kW ranges (208-volt)
- (4) 4 kW fryers (208-volt)
- (1) 10 kW water heater (208-volt)
- (1) 3 kW dishwasher (208-volt)
- (2) 2.5 kW toasters (208-volt)
- (1) 1/2 hp vent fan (120-volt)
- (1) 3/4 hp blower motor (120-volt)

Heating:

- 40 kW electric heat (208-volt)

USING THE NEC

Refer to the National Electrical Code to answer the following questions. Do not write in this book.

1. In addition to Article 210, which other section contains information on branch circuits supplying pipe organs?
2. What is the minimum branch-circuit current rating for cooking ranges with ratings of 8 3/4 kW or higher?
3. How near to the appliance does a dedicated appliance receptacle need to be installed?
4. How is the size for a feeder overcurrent protective device determined?
5. Article 220 addresses branch-circuit, feeder, and service calculations. How are fractions of amperes handled in calculations?
6. Show-window loads can be computed in two ways. Name the ways.