



The Service Entrance

Objectives

Information in this chapter will enable you to:

- List the components of the service entrance.
- List service drop clearances specified in the *NEC*.
- List eight basic guidelines when locating a residential service entrance.
- Calculate the size of service entrance needed based on the power needs of the dwelling.
- Select proper conductors and components for the service entrance.
- Size and install conductors between the meter socket, main disconnect, and service panel.
- Provide proper grounding for a service entrance.
- Explain the purpose of a step-down transformer and indicate where it is used.

Technical Terms

Drip loop

Insulator

Meter

Meter enclosure

Meter socket

Service drop

Service drop mast

Service entrance

Service head
Service lateral

Temporary wiring
Transformer rule

The *service entrance* includes all the wires, devices, and fittings that carry electricity from the power company's transformer to the consumer. All electrical energy supplied to power-consuming devices in the building must first pass through the service entrance equipment. The service components protect, meter, and distribute the power to the branch circuits.

Service Entrance Components

The service entrance consists of the following electrical equipment and parts:

- Wires from the utility pole or transformer to the dwelling service point
- Service entrance conductors
- Meter socket, pan, or enclosure

service entrance: All of the wires, devices, and fittings that carry electricity from the power company's transformer to the consumer.

- Service entrance panel with breakers or fuses and a main disconnecting means
- Grounding system
- Fittings, fasteners, and other hardware necessary to install the service equipment

Pro Tip

When a piece of equipment is said to be *ahead* of the meter, the equipment is on the transformer side of the meter. Electricians often use this term when describing where to locate disconnects, OCPDs, and service equipment.

Service Location

Conductors brought to the building are run overhead or underground. Those coming in overhead from a utility pole are called the *service drop*. See **Figure 10-1**. Those routed

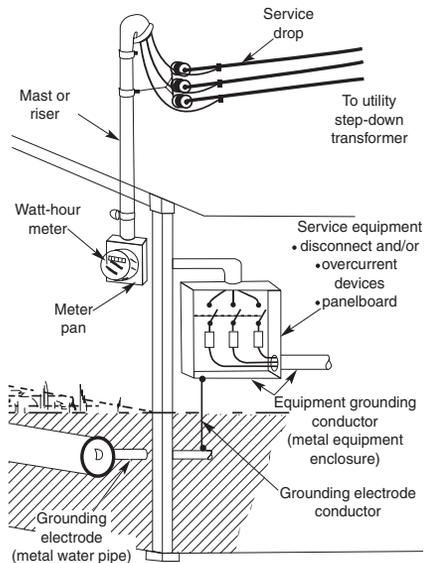


Figure 10-1. This is a typical overhead service drop and service entrance. (OSHA)

underground, from either a pole or transformer pad, are called the *service lateral*. See **Figure 10-2**. In either type, these service wires will be connected to the service entrance wires at the building.

Most often, the power company will locate the point of attachment of the service entrance for the electrician. In many localities this is required. Check the service specifications of the power supplier to be sure of any additional requirements before installing the service entrance. See **Figure 10-3**.

Where to locate service

When selecting the service entrance location, use the following guidelines:

- Underground service entrance conductors, whether enclosed in cable or conduit, should be installed in a straight path to make finding the buried conductors easier.

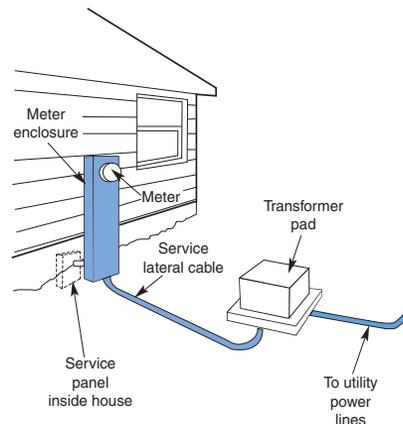


Figure 10-2. This is a typical underground installation for a service entrance.

service drop: Overhead wires brought to the building that are run overhead from the utility pole to the service point.

service lateral: Underground wires brought to the building that are routed underground, from either a pole or transformer pad to the service point.

service point: The point of connection between the facility of the serving utility and the premises wiring.

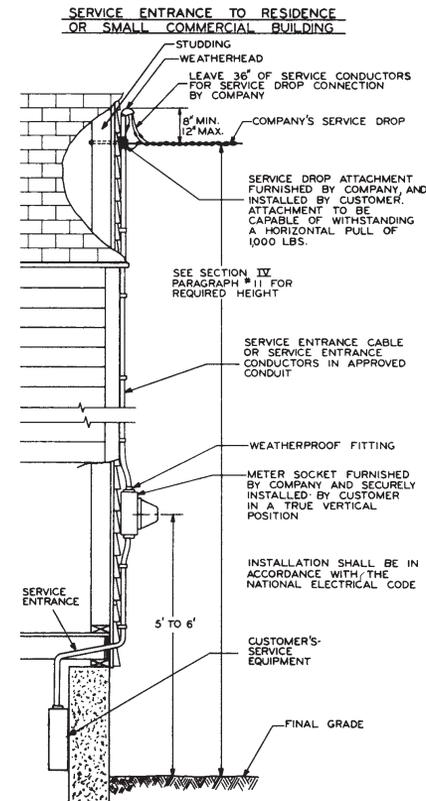


Figure 10-3. Service entrance specifications like these should be secured from the utility company before the service entrance installation. Refer also to the *NEC* and consult the local electrical inspector whenever necessary. (New York State Electric and Gas Corp.)

- Service conductors should be kept as short as practical to minimize voltage drop.
- Service conductors must enter the building as close as possible to the service panel.
- The service disconnect must be at or very near the point of entry.

- The service panel should be located in a central and accessible area, near the major electrical equipment of the building.
- The service equipment must be protected from physical damage, water, and dust.
- Service equipment cannot be placed in bathrooms, storerooms, closets, or damp cellars.

Number of Services

A structure can have only one service. Thus, each building will have one service drop or one service lateral. While this is the basic rule, there are some practical exceptions. The following exceptions are allowed:

- A completely separate service is permitted to supply a fire pump or other emergency electrical apparatus, such as lights or standby power, **Figure 10-4**.
- If a single service cannot supply a large load demand, another may be added.
- If structures are so large that no single service would allow electrical access to all the tenants of the building, additional services may be provided.
- A generator, driven by an engine or wind, may provide additional service.
- Electric power may be supplied by a solar photovoltaic source in addition to the service provided by the utility.

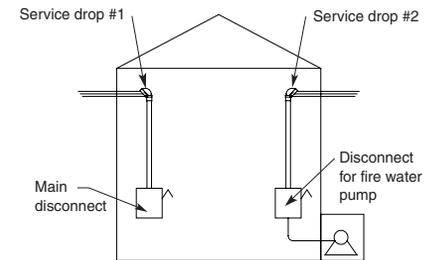


Figure 10-4. A separate service supply is permitted for fire pumps or other emergency electrical equipment.

- If different voltages and phases may be required within the same structure, additional services are allowed.

Number of Service Entrance Conductor Sets

Since the basic rule is that each building will have only one service drop or service lateral, the usual service installation will have only one set of service entrance conductors. Necessary exceptions include multiple occupancies, such as two-family homes, apartment buildings, and commercial establishments with several offices or stores. These occupancies may have any number of service entrance sets tapped from a single service supply, **Figure 10-5**. The *NEC* permits a maximum of six disconnects from any

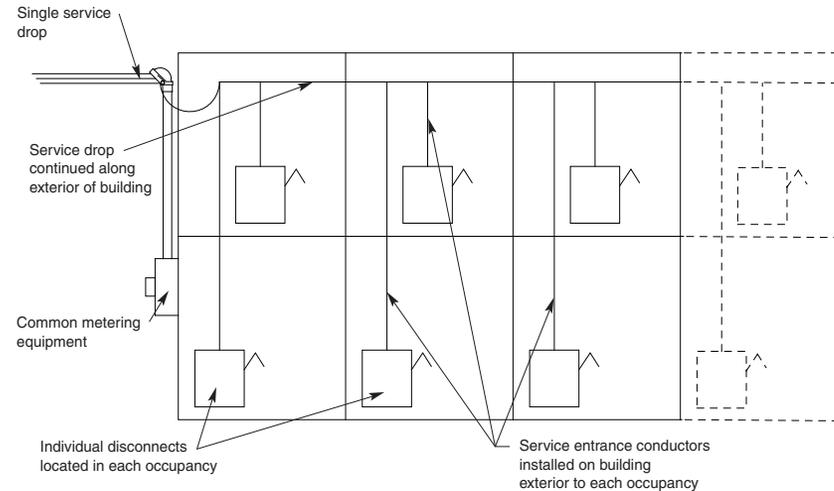


Figure 10-5. Multiple occupancies may have any number of service entrance conductors tapped from a service drop or service lateral.

single service drop or service lateral. **Figure 10-6** illustrates a possible installation of this nature.

Regardless of the number of service drops, laterals, or sets of service entrance conductors, the service should be carefully planned so that the service entrance conductors are not routed through the building interior unless encased in concrete. The service entrance conductors should also terminate at the disconnect outside or close to where they enter the structure. See **Figure 10-7**.

Service Load

For new single-family dwellings, the *NEC* requires at least a 100 A service. For homes with electrical heating systems or where future expansion is likely, 150 A or 200 A service is preferred. However, to be sure that the service

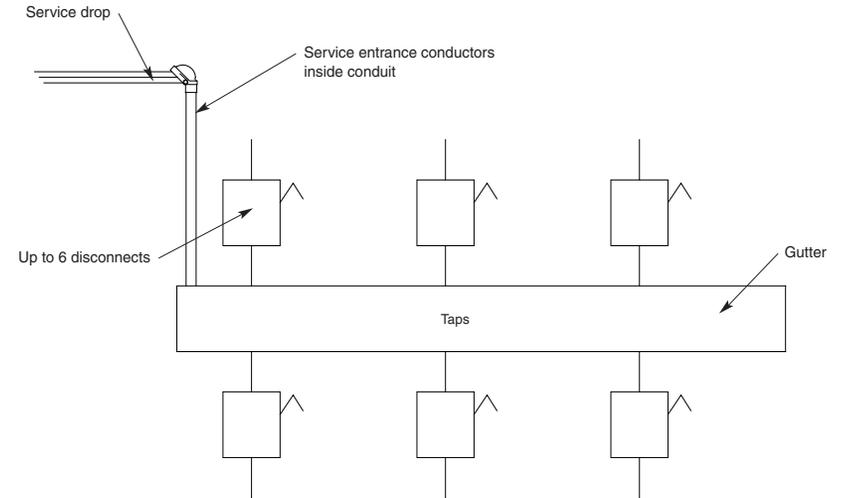


Figure 10-6. A maximum of six disconnects are permitted to be installed at the service entrance. All of these disconnects must be grouped together at a single location.

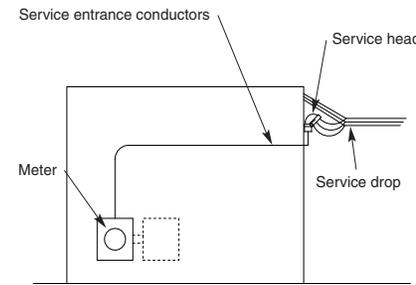


Figure 10-7. Service conductors run along the exterior of a building or are encased in 2" of concrete within the building. These conductors should terminate at the disconnect or service protection equipment close to where they enter the building or leave the concrete enclosure.

is sized correctly for a residence, the total load should be calculated based on the various circuits of the dwelling. A simple series of calculations can help you find this total load. See **Figure 10-8**. Detailed information on these calculations will be presented in Chapter 12, **Branch-Circuit, Feeder, and Service Design**.

Service Entrance Conductors

Service entrance conductors may be type RHH, THW, THWW, XHHW, or RHW. They can be run through conduit or enclosed in a cable assembly called service entrance cable, **Figure 10-9**. Many service drop installations are made with triplex cable, **Figure 10-10**.

Calculation for Total Load of a One-Family Dwelling			
Multiply the total square feet of house by 3 VA.			
Table 230.42 210.11(C)(1) 210.11(C)(2)	1 This is the total general load.	$1800 \text{ ft}^2 \times 3 \text{ VA} = 5400 \text{ VA}$	
	2 Small appliance loads (two kitchen area circuits at 1500 VA each)	3000 VA	
	3 One laundry circuit	1500 VA	
	4 Add lines 1 through 3.	Total = 9900 VA	
5 The first 3000 VA of the total is 100%.			
6 Subtract the first 3000 VA from line 4 to get the remainder.			
Table 230.42	6	Line 4 - 3000 = 6900 VA	
	7	Multiply the remainder by 35%. $6900 \times 0.35 = 2415 \text{ VA}$	
	8	Add line 5 to line 7 to get the net load. Line 5 + line 7 = 5415 VA	
List the nameplate ratings of each fixed appliance.			
230.42 230.54 230.64	9 Range	12,200 VA	
	10 Dryer	4900 VA	
	11 Dishwasher	1200 VA	
	12 Water heater	VA	
	13	VA	
	14	VA	
	15	VA	
	16	VA	
	17	Additional fixed appliances	VA
	17	Add lines 9 through 16. This is the total fixed appliances load.	18300 VA
Add line 8 to line 17.			
18	This is the net calculated load.	Line 8 + line 17 = 23715 VA	
19	Total heating load	5000 VA	
20	Total air conditioning load	3500 VA	
230.52(C)	21	Enter the larger number between line 19 and line 20. 5000 VA	
	22	Multiply line 21 by 40%. $5000 \times 0.40 = 2000 \text{ VA}$	
22 This is the total heating/air conditioning load.			
23	Add line 18 to line 22 for the total house load.	25715 VA	
Total load	24	Enter the voltage provided (120, 240, or other)	
	24	Divide line 23 by line 24. This is the	
	25	total amperage required for the house. Line 23 ÷ line 24 = 107 A	

Review NEC Sections 230.42(B) and 230.79 for service conductors and disconnecting requirements.

Figure 10-8. Use these steps for calculating the total service load.

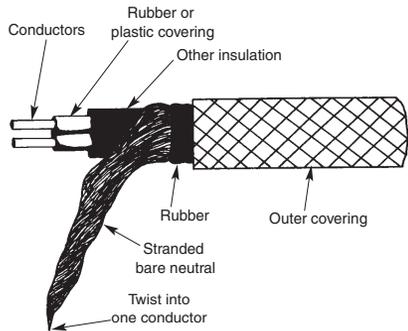


Figure 10-9. Service entrance cable (SEC). Bare, stranded neutral wire must be twisted into a single strand before being connected.

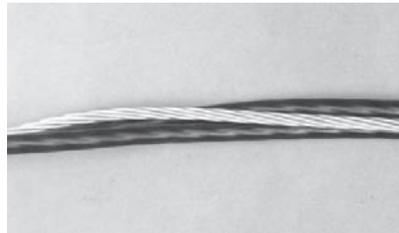


Figure 10-10. Most service drops in new homes are made with triplex cable. It consists of a bare neutral wire around which two insulated cables are loosely wrapped. The neutral wire supports the insulated wires.

When in conduit, all the conductors are insulated. The neutral is white, yellow, or gray. The hot wires are black or red. Service entrance cable is similar, but the neutral is bare.

Whether conduit or cable is used will depend upon customer preference, local codes, building structure, environment, utility specifications, and the electrician's experience. In either case, the conduit or cable must be securely fastened to the building with the proper clamps or supports as shown later in this chapter.

Sizing service entrance conductors

In addition to proper types of service conductors, the right conductor size is essential. As mentioned earlier, Table 310.15(B)(16) of the NEC establishes the allowable ampacities of insulated conductors. Section 310.15(B)(7) instructs us on proper types and sizes of conductors for three-wire, single-phase dwelling entrance services. See Figure 10-11.

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

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

Figure 10-11. Service entrance cable sizes are specified by the NEC.

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Service Drop Mast and Insulator

Very rarely are the service drop mast (or riser) and insulators supplied and installed by the power company. In most situations, the electrician makes the installation. The service drop mast is usually a length of rigid metal conduit or, if allowed, rigid nonmetallic conduit. This conduit contains the service entrance cable and is mounted between the service head and the meter.

An insulator is a nonconductive device that supports the service drop wires near the service head. It can be clamped to the conduit or attached to the exterior of the building. Insulators are placed approximately 12" below the service head. See Figure 10-12.

Service Head

A service head is a fitting installed at the top of the conduit or service entrance cable to prevent water from entering the meter socket and shorting out the conductors. Service heads are designed to be used with either conduit or cable. See Figure 10-13. The service conductors should extend through the head for approximately 3' to

provide a suitable drip loop. A drip loop is merely a formed curvature of the service conductor to prevent water from entering the service head around the cable or conduit. See Figure 10-14.

Metering Equipment

The amount of electrical power used within a residence must be measured, so the utility knows how much to charge the customer. The meter is the device that measures and records the amount of electricity used. The meter socket is the receptacle that the meter plugs into. This

service drop mast: A length of rigid conduit that contains the service entrance cable and is mounted between the service head and the meter.

insulator: A nonconductive device that supports the service drop wires near the service head.

service head: A fitting installed at the top of the service entrance cable to prevent water from entering the meter socket.

drip loop: A formed curvature of the service conductor to prevent water from entering the service head.

meter: The device that measures and records the amount of electricity used.

meter socket: The receptacle that a meter plugs into.

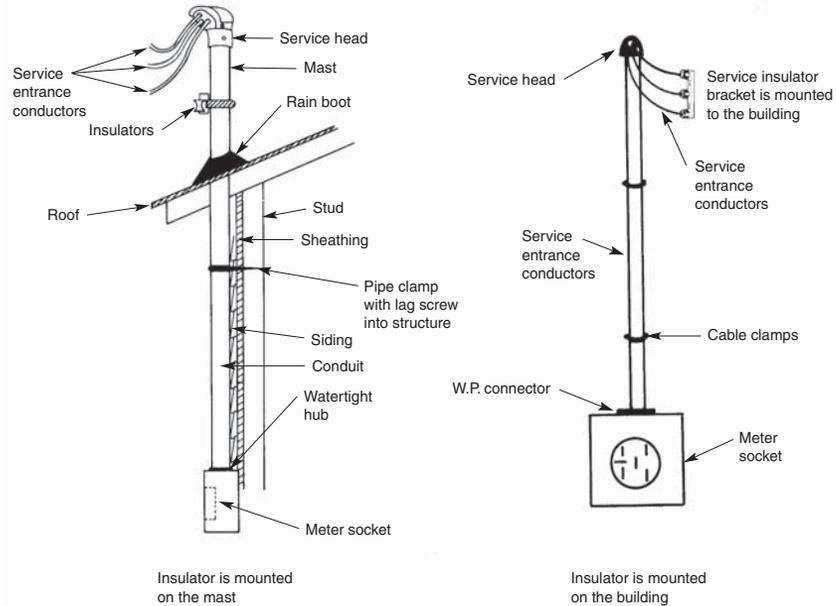


Figure 10-12. The insulator may be mounted on the mast or the building.

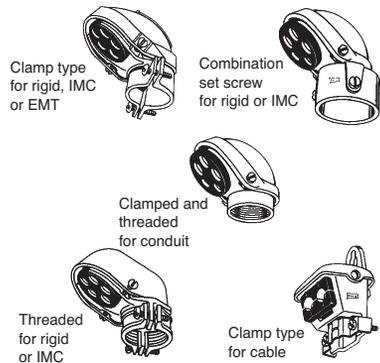


Figure 10-13. Service heads are fittings designed to keep water from entering the service entrance cable or the conduit leading to the meter enclosure. These service heads are designed for specific connections. (Hubbell, Inc.)

allows the utility to remove the meter without having to detach any cables. The meter socket is contained inside the *meter enclosure*, which is the box that attaches to the service conduit. The meter socket and enclosure are usually sold together and referred to as a meter socket. See Figure 10-15.

Service conductors enter the enclosure and are secured to the line-side lugs of the socket. Note that the neutral conductor is always connected to the center contact and continues essentially uninterrupted through the meter socket on its journey to the service main disconnect or panel. The meter itself will be installed by the utility when the service drop or lateral is completed.

meter enclosure: A box that attaches to the service conduit.

Weatherproof Connectors

Fittings called weatherproof connectors are used to connect service entrance cable to the meter enclosure when conduit is not used. One is shown in Figure 10-16. The purpose of this fitting is to prevent moisture from entering the meter enclosure.

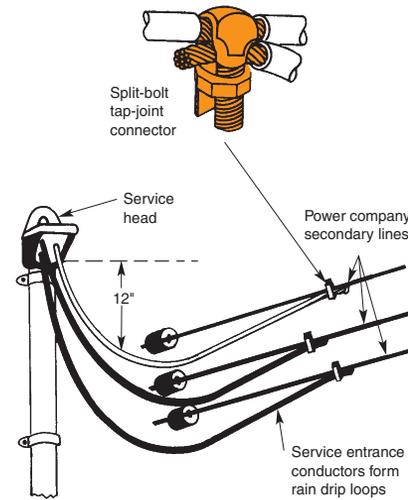


Figure 10-14. A drip loop prevents water from following the cable into the service head.

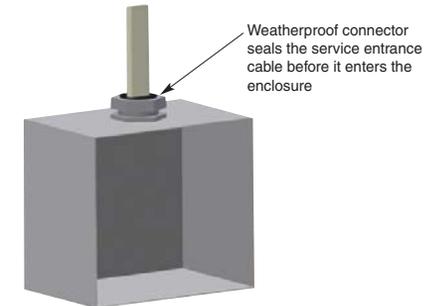
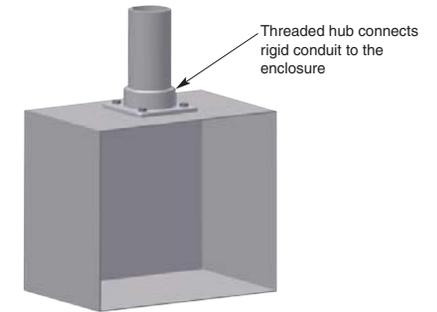


Figure 10-16. Select the proper fittings to prevent water from entering the meter socket enclosure.

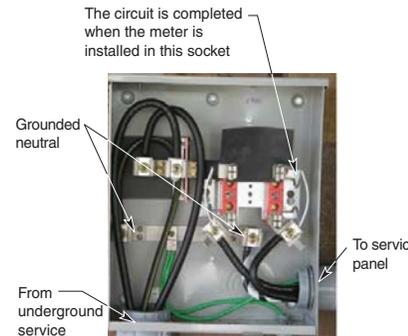


Figure 10-15. This meter socket is connected to the service cables from the transformer and the cables that connect to the service panel. The grounded neutral is connected, even when the meter is removed.

Temporary Wiring

Temporary wiring is done to provide electrical power only during construction, remodeling, demolition, repair, or large-scale maintenance of a building. This wiring must be removed when the work is completed. *Article 590* of the *NEC* covers this subject.

Although temporary wiring safety requirements may be less exacting than permanent wiring, most of the same rules apply. However, there are several important differences. Temporary wiring can be used on a construction site during the entire term of construction, regardless of the type of construction, **Figure 10-17**. In addition, temporary power can be brought in for emergency situations, testing, and experimentation.

The key factors for installation of all temporary wiring are:

- All temporary wiring, devices, and equipment should be located in a safe place and should be as neat as possible. Temporary wiring should be kept overhead as much as possible.

- All 15-, 20-, and 30-amp receptacles require GFCI protection.
- Protect temporary wiring from physical damage.
- Use portable ground-fault circuit interrupter boxes. See **Figure 10-18**.
- Grounding must be in compliance with *Article 250* of the *NEC*.
- All lamps should have protective covers or caging. They should be mounted at heights of 7' or higher.
- All circuits must originate from approved panels or power outlets and must have overcurrent protection.
- Receptacle circuits and lighting circuits must be separated.
- Weatherproof devices and housings should be used wherever there is dampness or exposure to weather.
- Locking type plugs and connectors should be used on power ends.
- Temporary wiring should be inspected frequently for damage.

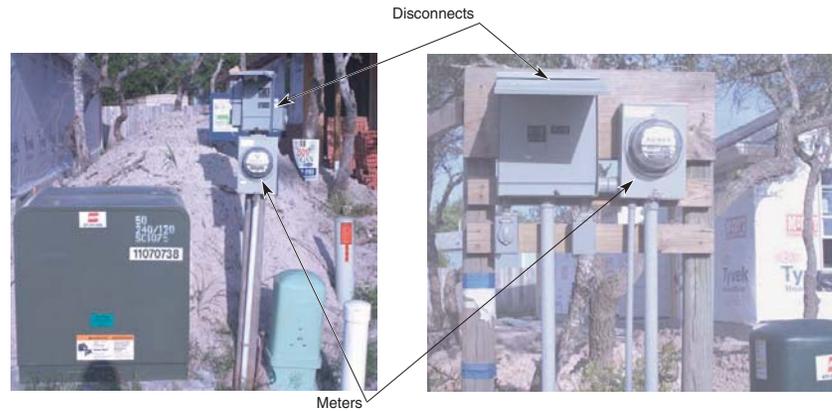


Figure 10-17. These are typical temporary service installations installed at construction sites.

temporary wiring: A method of providing electrical power only during construction, remodeling, demolition, repair, or large-scale maintenance of a building.



GFCI power distribution box



GFCI adapter

Figure 10-18. Use GFCI equipment to protect yourself and other workers. (Coleman Cable, Inc.)

Service Disconnects

Section 230.71(A) of the *NEC* requires that disconnect means or service entrance conductors cannot exceed six switches either in a single enclosure or a group of separate enclosures. Several permissible arrangements are shown in **Figure 10-19**.

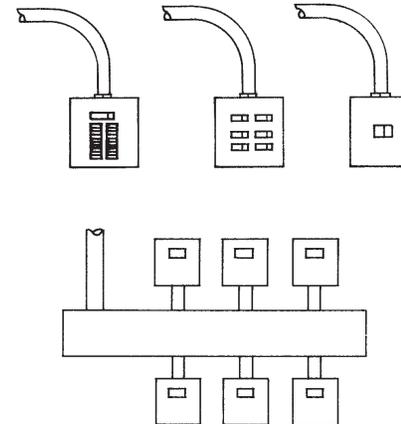


Figure 10-19. Permissible service disconnects.

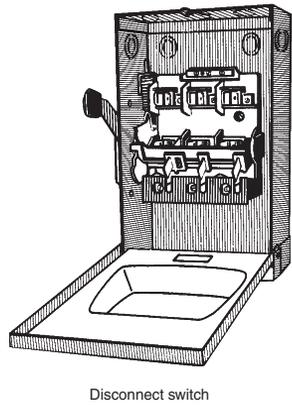
Main Disconnect and Service Panel

There must be equipment that will disconnect all wiring from the power source. This can be arranged by using a single main disconnect switch or a main circuit breaker that is part of the service panel. See **Figure 10-20**. Regardless of the method used, the disconnect must be located in an accessible place. Further, it must be located as close as possible to the point where the service conductors enter the structure.

Service Grounding

Grounding the service entrance is vital to the safety of the entire electrical system. Careful attention should be given to this section to ensure a thorough understanding of the procedures involved. In addition, you should study all sections of *Article 250* of the *NEC* before undertaking any electrical installation.

Grounding the service entrance involves connecting the neutral or white service conductor with the earth. This is done by means of the grounding conductor. This conductor connects the neutral lug of the meter housing or the neutral bus bar of the service switch (service panel) to the metallic water supply pipe. See **Figure 10-21**.



Disconnect switch



Main circuit breaker is the disconnect switch

Figure 10-20. Within every structure, there must be a means of disconnecting all conductors from the service conductors. These disconnects must be clearly marked and easily accessible. (Wadsworth Electric Mfg. Co., Inc. and Square D Co.)

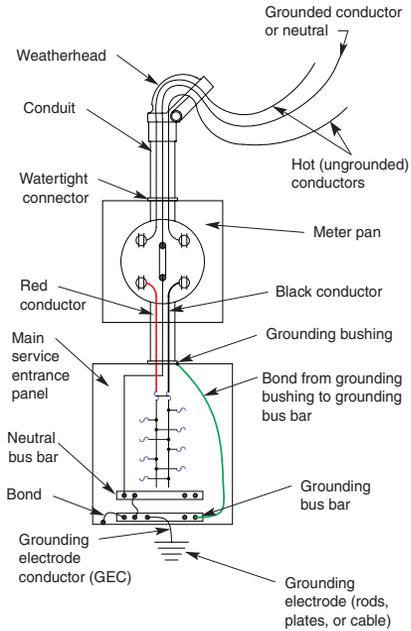


Figure 10-21. The service entrance layout must have continuity of the grounded neutral and grounding electrode through grounding electrode conductor. Metal conduit must also be bonded to grounding means.

In addition to or in place of the water supply pipe, other grounding electrode systems shall be used:

- Metal frames of buildings
- Metal electrodes encased in 2" of concrete within or near the bottom of a concrete foundation
- 20' of 2 AWG bare copper wire buried not less than 2 1/2' below the surface
- Underground metal tanks or other such underground systems or structures

- Rod or pipe electrodes that are at least 8' long, fully driven into the ground or buried not less than 4' below the surface
- Metal plate of no less than 2 ft² surface area

Where two or more grounding electrodes are used, they should be separated by a distance of 6' and bonded (linked with a copper conductor). The resistance between the grounding electrode and the earth must not exceed 25 ohms

resistance. For that reason, the conductor is typically copper, aluminum, or copper-clad aluminum. The grounding electrode conductor must also be firmly attached to grounding electrode using approved fittings, **Figure 10-22**. As with all conductors involved in grounding, the grounding electrode conductor must never be interrupted.

Sizing the grounding electrode conductor

Table 250.66 of the NEC indicates the proper sizes for the grounding electrode conductor. This is based on the service entrance conductor size. See **Figure 10-23**.

For example, the installation of a 200 A service entrance using 3/0 AWG copper service wires would require a 4 AWG copper grounding electrode conductor.

Grounding Electrode Conductor

The grounding electrode conductor connects the grounding bus bar to the grounding electrode. This conductor should provide little

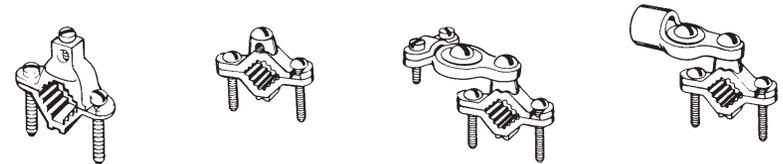


Figure 10-22. Always firmly attach the grounding electrode conductor to the grounding electrode using approved fittings.

Grounding Electrode Conductor Sizing			
Size of Largest Service-Entrance Conductor (AWG/kcmil)		Size of Grounding Electrode Conductor (AWG/kcmil)	
Copper	Aluminum or Copper-Clad Aluminum	Copper	Aluminum or Copper-Clad Aluminum
2 or smaller	1/0 or smaller	8	6
1 or 1/0	2/0 or 3/0	6	4
2/0 or 3/0	4/0 or 250	4	2
Over 3/0 – 350	Over 250 – 500	2	1/0
Over 350 – 600	Over 500 – 900	1/0	3/0
Over 600 – 1100	Over 900 – 1750	2/0	4/0
Over 1100	Over 1750	3/0	250

Figure 10-23. Refer to NEC Table 250.66 when determining the size of the grounding electrode conductor.

Service Clearances

Where overhead services are installed, certain regulations concerning clearances must be strictly observed. The *NEC* indicates that clearances for overhead service drop conductors shall be as follows:

- Above roofs, **Figure 10-24**
 - A. 8' as measured vertically from all points
 - B. 3' if the slope is not less than 4" in 12"
 - C. 18" over an overhanging portion of a roof

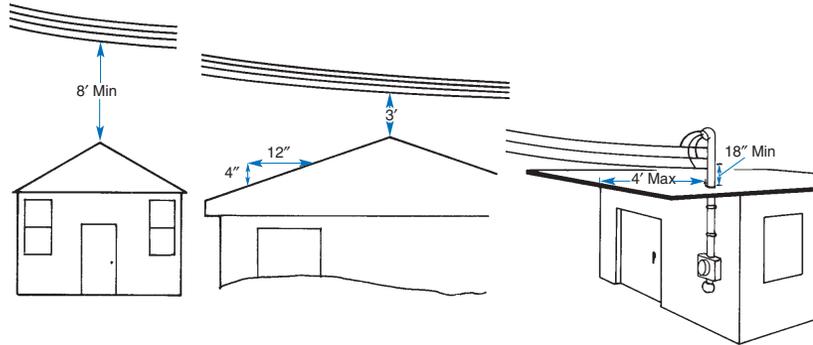


Figure 10-24. Above-roof clearance for overhead conductors. (OSHA)

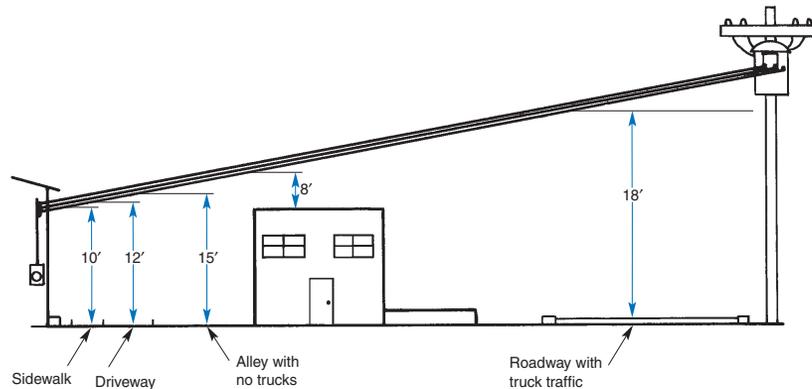


Figure 10-25. Above-grade minimum clearances.

- Above final grade, **Figure 10-25**
 - A. 10' above sidewalks
 - B. 12' above residential driveways
 - C. 18' above public alleys or thoroughfares subject to truck traffic
- At building openings, **Figure 10-26**
 - A. Not less than 10' above a finished surface platform, or other accessible surface
 - B. Not less than 3' from a window in any direction (except above the window)

Additional information regarding clearances is found in *Section 230.24* of the *NEC*.

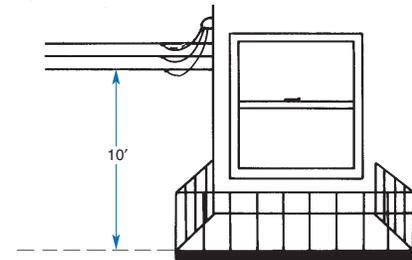
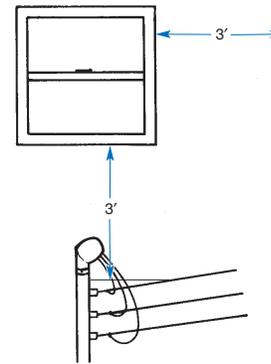


Figure 10-26. Clearances around building platforms and openings.

Service Completion

When the service entrance installation or rough-in is completed, it will be inspected by the electrical inspector. After this, the power company will install the service drop or lateral by connecting the wires from their transformer to the service entrance conductors.

Figure 10-27 shows a typical completed service entrance. Note the drip loops discussed earlier, as well as the positioning of other components in the finished service system.

Transformers

While the residential electrician will not be working on transformers, it is helpful to understand how transformers are made and how they work. Due to the voltages involved, you should be careful when working around this equipment. Transformers are installed and serviced by trained lineworkers employed by the power company.

Transformer Operation

A transformer has a relatively simple structure, **Figure 10-28**. Basically, it contains two coils of wire or *windings* and a common

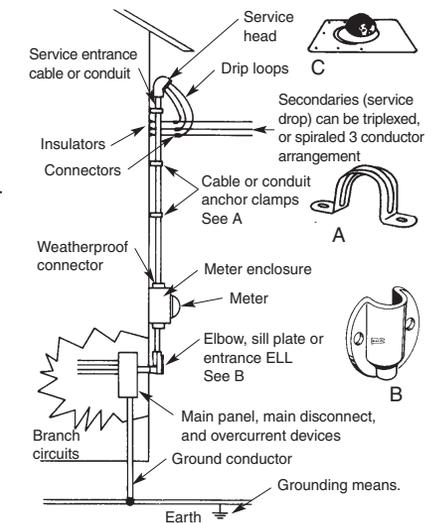


Figure 10-27. Completed service entrance and various fittings. Note relative position of components and special fittings. A—Cable, conduit, or anchor clamps fasten cable and conduit to structure. B—Elbow, sill plate, or entrance ell protect conductors at point where they enter structure. (Hubbell, Inc. and Electroline Mfg. Co.) C—Rain boot (not shown in drawing) is used to protect from leaks when service mast goes through roof.

metal core. When an alternating current is sent through the first coil, the *primary*, it magnetizes the metal core, **Figure 10-29**, causing surges of magnetic flux. These surges are constantly reversing directions. This magnetic flux also moves through the other coil, which is called the

secondary. A current is created there, too. Since the same magnetic flux exists throughout the core, the same voltage per wire turn is created. Therefore, any voltage difference is the direct result of differences in the number of turns in the primary and secondary windings.

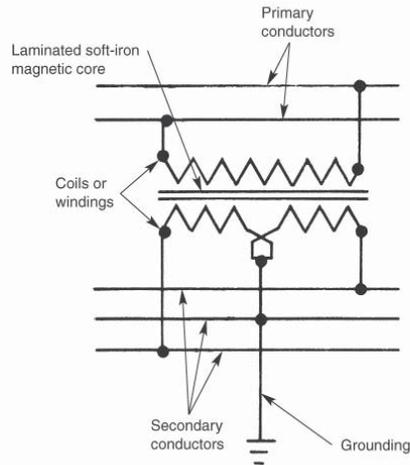
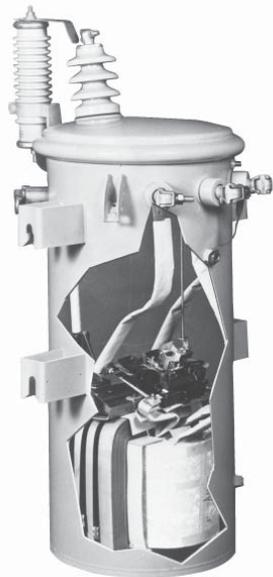
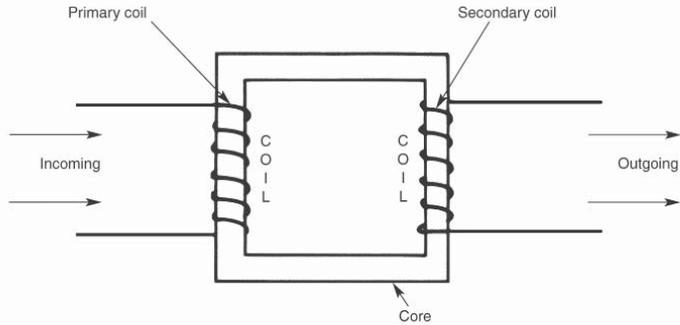


Figure 10-28. Transformers have a simple makeup. They consist of a metal core with windings or turns of wire around opposite sides. Note schematic at right.

Using the equation just given:

$$\frac{12 \text{ V}}{x} = \frac{120 \text{ V}}{20 \text{ A}}$$

by cross-multiplying

$$\frac{12 \text{ V}}{x} = \frac{120 \text{ V}}{20 \text{ A}}$$

$$120x = 240$$

$$x = 240/120$$

$$x = 2 \text{ Amperes}$$

Since a transformer changes voltage, it can either increase or decrease the primary voltage. One that increases the primary voltage is called a *step-up transformer*. One that decreases the primary voltage is called a *step-down transformer*, **Figure 10-30**. Directions for selecting the proper transformer to match the electrical load are found at the end of this chapter.

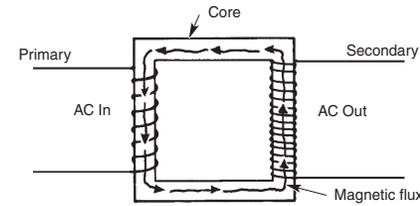


Figure 10-29. Application of alternating current causes a magnetic flux within the transformer core. This magnetic flux creates a current in the secondary side (outgoing) of the transformer.

Transformer Rule

Mathematically stated, the total voltage in the primary coil is to the total voltage in the secondary coil as the number of turns in the primary is to the number of turns in the secondary. This is the *transformer rule* and it can be expressed as:

$$\frac{\text{Voltage of Primary}}{\text{Voltage of Secondary}} = \frac{\text{Turns of Primary}}{\text{Turns of Secondary}}$$

Power into and out of a transformer is (ideally) the same. Since voltage changes within the transformer, so must amperage. Remember, power equals volts \times amperes. For this reason, the amperage must change proportionately but inversely, as does the voltage. This can be stated mathematically as:

$$\frac{\text{Primary Voltage}}{\text{Secondary Amperage}} = \frac{\text{Secondary Voltage}}{\text{Primary Amperage}}$$

For example, suppose the primary voltage entering a transformer is 12 volts and the primary amperage is 20 amperes. What will the secondary amperage be if the secondary voltage is 120 volts?

Service Designation

The power delivered by the power company is routed through a chain of transformers, **Figure 10-31**. The last transformer is near the

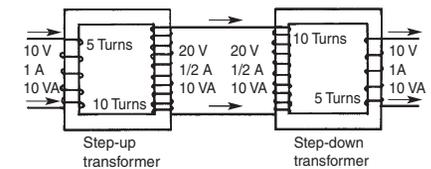


Figure 10-30. Step-up transformers increase the voltage and step-down transformers decrease the voltage.

transformer rule: The total voltage in the primary coil is to the total voltage in the secondary coil as the number of turns in the primary is to the number of turns in the secondary.

building that is supplied. See **Figure 10-32**. These transformers are designed to supply the following service ratings:

No. of Wires	Phase	Voltage	Comments
2	Single	120	These installations are no longer made
3	Single	120/240	Most common residential service
4	Three	120/208	
4	Three	120/240	

Phases

Phase refers to the angle between various generated ac currents. The term three-phase indicates three separately derived ac currents that are “out-of-step” from each other by 120 electrical degrees.

Two-phase current occurs when two alternating currents are generated 90° apart. The typical single-phase current exists when one current is produced at regular intervals. **Figure 10-33** illustrates this important variance in electrical power generation.

Single-phase, two-phase, and three-phase are abbreviated as 1φ, 2φ, and 3φ. Single-phase and three-phase current are used commonly in electrical generation. Two-phase has little practical application today.

Three-Wire, Single-Phase System

The most common residential service is a three-wire, single-phase system. This consists of two ungrounded conductors and one grounded conductor. See **Figure 10-34**. One ungrounded conductor is usually black and the other red. The grounded conductor is usually yellow. This system will provide 120 V and 240 V, depending

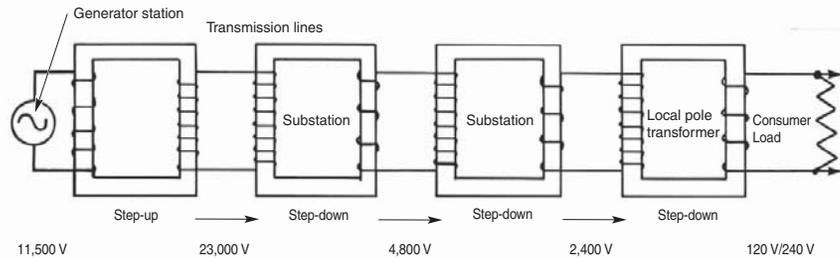


Figure 10-31. Power companies rely on transformers to efficiently transmit electricity over long distances. A chain of transformers links the generating plant with the consumer.

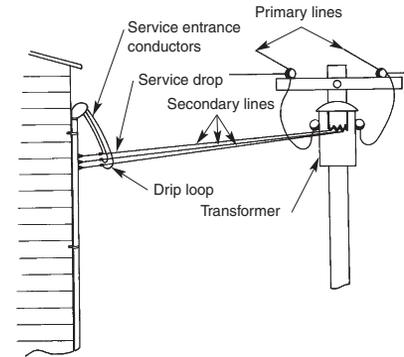


Figure 10-32. The final step-down occurs at the local pole transformer near the structure it serves. Overhead conductors provide the last link to the customer's service wires at the service point.

on how the branch circuit is connected within the distribution panel.

Multiphase Systems

There may be situations where a homeowner requests a system with more than one phase. This is a multiphase system that is usually installed to power heavy-duty or special equipment such as a milling machine or a lathe. Be sure to review local codes for any restrictions regarding installing a multiphase system.

Wye, four-wire, three-phase system

Figure 10-35 illustrates a wye-connected, four-wire, three-phase, 120/208-volt arrangement. Such a system can supply both single-phase 120-volt circuits and three-phase 208-volt circuits.

Study the main-panel wiring diagram shown in **Figure 10-36**. Note particularly the different circuit arrangements that are possible. In this type of panel, there are three hot bus bars. Each has 120 volts to ground when connected to the neutral. For 120-volt circuits, the circuit

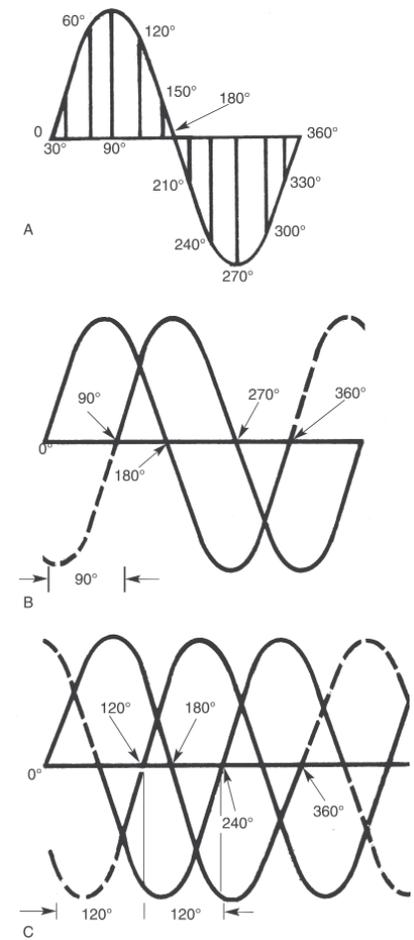


Figure 10-33. The meaning of phase. Electrical energy may be expressed graphically by using sine-wave forms. A—Single-phase electrical energy generation. B—Two-phase current is accomplished by simultaneously generating two single-phase currents 90° apart. C—By generating three, single-phase currents 120° apart, three-phase current is created.

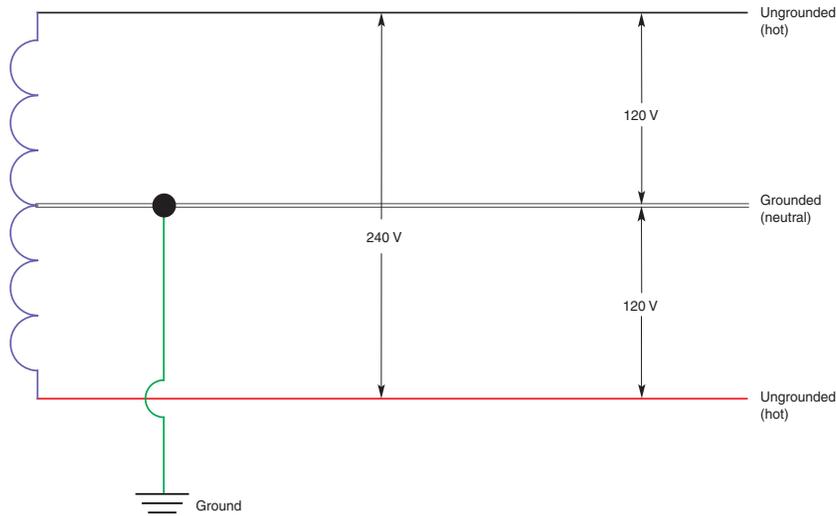


Figure 10-34. Single-phase, three-wire system. By connecting an ungrounded wire and a grounded wire to a load, 120 V service is obtained. Connecting both ungrounded wires to a load will deliver 240 V.

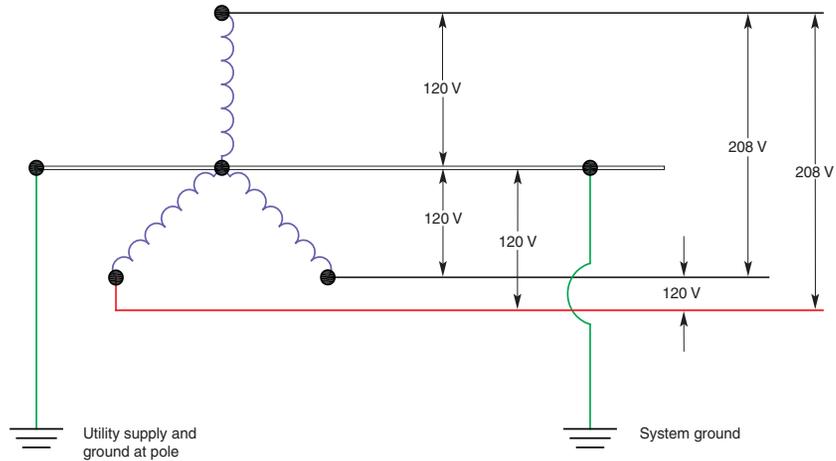


Figure 10-35. A more versatile alternative to single-phase wiring is three-phase wiring. The wye-connected, three-phase, four-wire arrangement provides 120 V/208 V circuits.

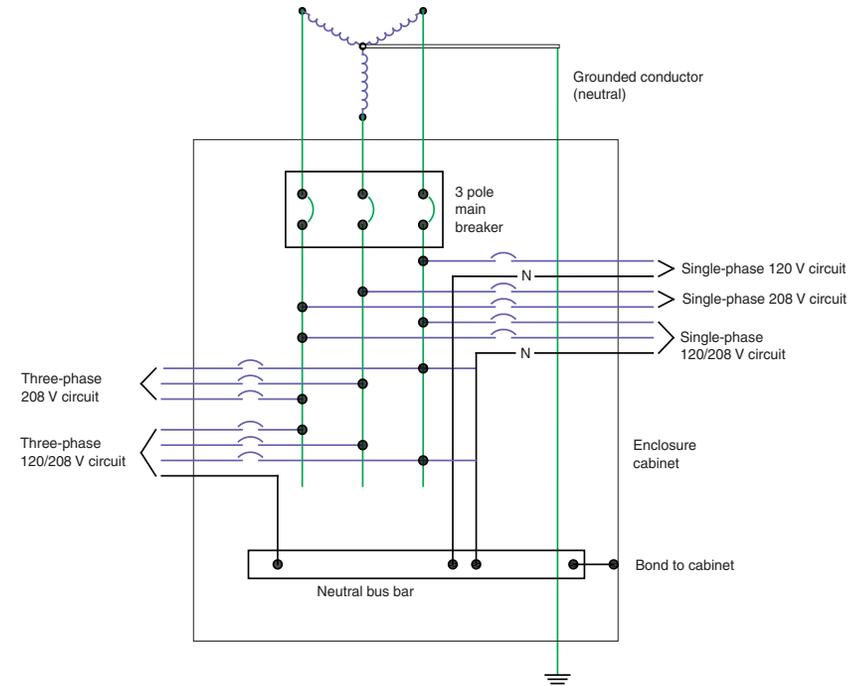


Figure 10-36. Main breaker and panel circuit connections for a wye-connected three-phase, four-wire service. Hot bus bars are marked A, B, and C.

breaker connections are the same as in three-wire, single-phase services.

The black (hot) circuit wire goes to the circuit breaker terminal and the white neutral circuit wire is connected to the neutral bus bar. As with single-phase systems, the 120-volt circuits should be balanced or equally arranged among the three hot buses.

Two-pole circuit breakers are also installed in the same manner as with three-wire, single-phase service panels. That is, the double-pole breaker is attached to any two of the three hot bus bars. Again, carefully balance these between all the buses. These comprise the two-wire, single-phase, 208-volt circuits.

Code Alert

Section 408.3(E)

Phase Arrangement. The phase arrangement on three-phase buses shall be A, B, C from front to back, top to bottom, or left to right, as viewed from the front of the switchboard or panelboard. The B phase shall be that phase having the higher voltage to ground on three-phase, four-wire, delta-connected systems. (See the *NEC* for the complete section)

Delta, four-wire, three-phase system

Another service alternative is the delta-connected, four-wire, three-phase, 120/240-volt system. A schematic for this type is illustrated in **Figure 10-37**. It can provide 120-volt single-phase 240-volt single-phase, and 240-volt three-phase power.

The panel connections, as shown in **Figure 10-38**, are made as follows:

1. For 120-volt single-phase circuits, connect one circuit wire (white) to the neutral and the other (black) to an ordinary single-pole breaker attached to phase A or C only. Note: the breaker must not be attached to phase B for this type of circuit since this would provide 208 volts. Equipment designed for 120-volt operation would be ruined.

The phase B wire of this system is often called the “high leg” or “wild leg” and must be identified as such at all accessible points with an orange-colored indicator. See *NEC, Section 110.15*. At the panel, wire B is connected to the center bus bar.

2. To derive power at 240-volt single-phase, you simply connect both circuit wires to

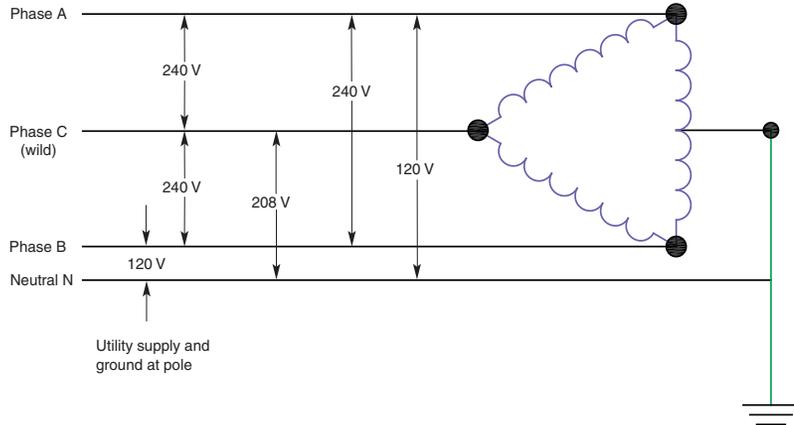


Figure 10-37. Popular delta-connected, three-phase, four-wire service supplies 120 V single-phase, 240 V single-phase, and 240 V three-phase circuits. The “wild” phase C must always be identified at all terminations and accessible points. Usually it is indicated by the color orange.

a double-pole circuit breaker attached to any two phases. Do not include a neutral grounded wire in this circuit.

3. For 240-volt three-phase circuits, run three circuit wires to a three-pole breaker attached to all three phases. Again, ignore the neutral for this type of circuit.

Other variations of multiphase service systems are possible and, in fact, available in many locations:

- Four-wire, wye-connected, three-phase, 277/480-volt systems are very similar to the 120/208-volt system already discussed. The major difference is that the transformer secondary supplying such a system has a higher voltage. Since most major appliances, lighting fixtures, and heating units do not operate at more than 240 volts, this system has limited use.
- Three-wire, delta-connected, three-phase, 240-volt systems have severe limitations. It may supply 240-volt three-phase or 240-volt single-phase circuits only.

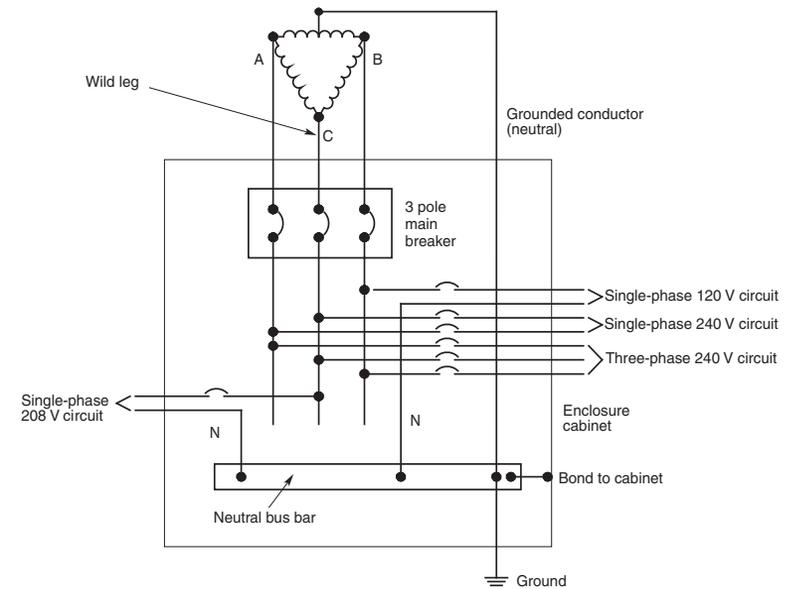


Figure 10-38. Main breaker and panel circuit connections for a wye-connected three-phase, four-wire service. Hot bus bars are marked A, B, and C.

Making a Single-Phase Connection on a Three-Phase System

A more versatile three-wire, 120/208 volt, single-phase circuit can be formed by connecting two circuit wires to a double-pole breaker as previously described and adding a grounded conductor to the circuit. A circuit such as this can be used for 120-volt receptacles and lighting outlets. It can also supply 120/240 volts for electric ranges, counter cooktops, and other devices designed for that purpose.

Three-phase, three-wire 208-volt circuits are derived by connecting the circuit wires to a three-pole circuit breaker. These circuits are specifically designed to operate special

three-phase devices such as heaters and various heavy-duty motor-driven equipment.

Last, but not least, a four-wire, three-phase, 120/208-volt circuit is connected in the same manner as the three-wire, 208-volt circuit with the addition of a grounded wire connected to the neutral bus. This type of circuit is extremely useful when extending an electrical system to other circuit panels.

Review Questions

Write your answers on a separate sheet of paper.

Do not write in this book.

1. List five major components of a service entrance.
2. The minimum service entrance rating for new buildings is _____ amperes.

3The proper size service for 200 ampere service is ____ AWG copper wire.

4. Explain what is meant by:

- A. Service drop.
- B. Service lateral.

5. The neutral bus bar at the service entrance panel provides an interconnection means for the ____ conductor(s) and ____ conductor.

6The minimum clearance of service wires above a sidewalk is ____ feet.

The minimum size grounding electrode conductor is ____ AWG.

8. Describe, in your own words, the purpose and location of the following service entrance components:

- A. Meter enclosure.
- B. Service head.
- C. Main disconnect.

Know the Code

A copy of the NEC 2011 is required to answer these questions.

1. Which temporary installations have a 90-day limit?

2Which part of the grounding system is covered in Section 250.52?



Installing underground service cable requires a trench of sufficient depth. The depth is mandated by local codes, but is usually 18" to 24". A trencher is able to dig 2' to 5' without destroying the nearby grass. (Bobcat Company)