Wiring: Commercial and Industrial

26111-05

Front Range Power Plant

Front Range Power Plant in Fountain, Colorado, is a 480-megawatt, natural gas fired, combined-cycle power plant. It utilizes state-of-the-art equipment designed to meet stringent environmental restrictions, including two high-efficiency combustion turbines, two heat-recovery steam generators, and a steam turbine. The project also incorporates an air-cooled condenser that takes the place of a typical cooling tower; it's the length of a football field and stands nearly 100 feet tall. This 2003 project was one of Colorado's largest industrial projects in recent years and the largest power project since the coal-fired plants built in the late 1970s.

26111-05
Wiring: Commercial and Industrial

Topics to be presented in this module include:

Overview

Commercial and industrial electrical installations often use many different types of devices, enclosures, and wiring techniques. It is common to have a number of three-way and four-way switch installations, as well as a variety of ground fault circuit interrupters, disconnects, safety switches, and power distribution equipment at one location. Electricians must be able to identify each device and enclosure, and must be familiar with the wiring methods required to install them.

Three-way and four-way switching circuits are used to control lighting from more than one location. Ground fault circuit interrupting receptacles are often connected to provide GFCI protection to standard receptacles. These types of installations require specific wiring methods in order for all switches and receptacles to operate properly. If the electrician does not know how these switching and receptacle circuits should be wired, the correct number of conductors may not be installed in the raceway systems during the initial conductor installation. This could create additional delay in the overall progress of the job, costing time and money.

Once a thorough understanding of these devices is achieved, it is up to the electrician to demonstrate professional wiring techniques in preparing and splicing the conductors.

Objectives

When you have completed this module, you will be able to do the following:

1. Identify and state the functions and ratings of single-pole, double-pole, three-way, four-way, dimmer, special, and safety switches.
2. Explain NEMA classifications as they relate to switches and enclosures.
3. Explain the *National Electrical Code®* requirements concerning wiring devices.
4. Identify and state the functions and ratings of straight blade, twist lock, and pin and sleeve receptacles.
5. Identify and define receptacle terminals and disconnects.
6. Identify and define ground fault circuit interrupters.
7. Explain the box mounting requirements in the *National Electrical Code®*.
8. Use a wire stripper to strip insulation from a wire.
9. Use a solderless connector to splice wires together.
10. Identify and state the functions of limit switches and relays.
11. Identify and state the function of switchgear.

Trade Terms

Attachment plug (plug cap)
Branch circuit
Disconnecting means
Grounding
Limit switch
Outlet
Pilot device
Polarized
Receptacle
Receptacle outlet
Relay
Switchgear

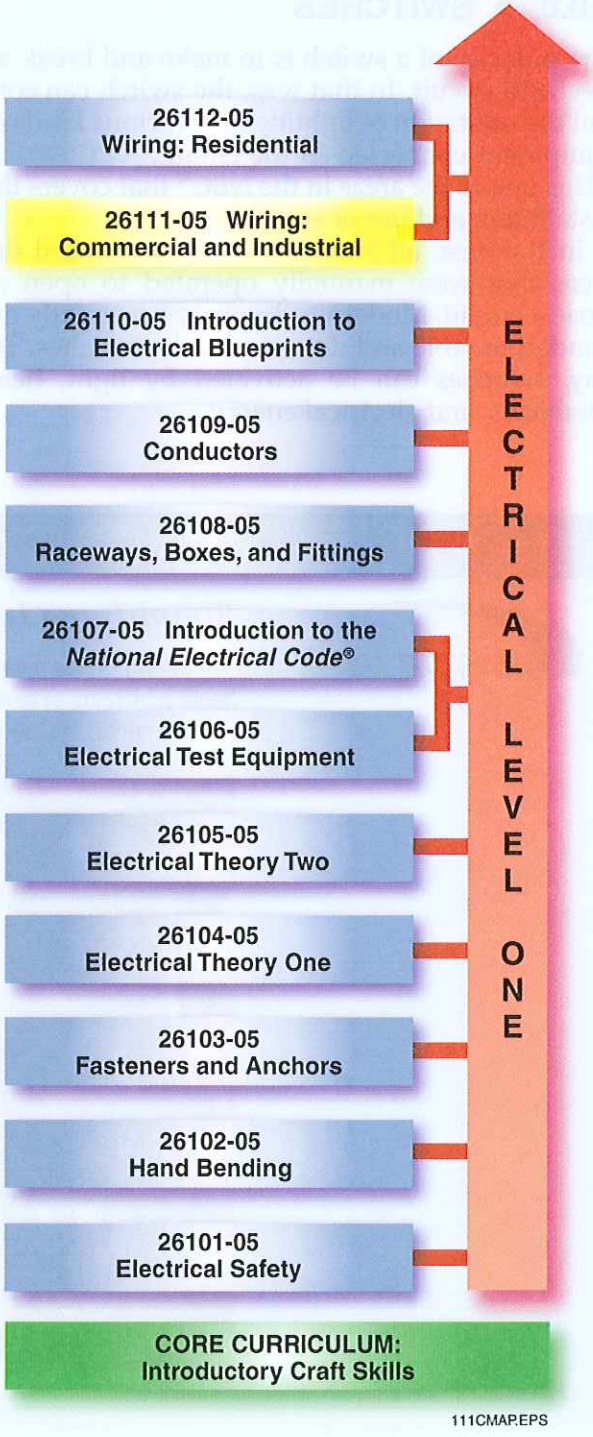
Required Trainee Materials

1. Paper and pencil
2. Copy of the latest edition of the *National Electrical Code®*
3. Appropriate personal protective equipment

Prerequisites

Before you begin this module, it is recommended that you successfully complete *Core Curriculum* and *Electrical Level One*, Modules 26101-05 through 26110-05.

This course map shows all of the modules in *Electrical Level One*. The suggested training order begins at the bottom and proceeds up. Skill levels increase as you advance on the course map. The local Training Program Sponsor may adjust the training order.



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1.0.0 ◆ INTRODUCTION

As an electrician, a large part of your job will be involved with wiring and wiring devices. There are many different types of wiring devices and methods of installing them. This module will help you become familiar with some common devices and the methods for installing them. As with almost all aspects of an electrician's job, the *NEC*® is an important reference for use when installing wiring devices.

2.0.0 ◆ SWITCHES

The purpose of a switch is to make and break an electrical circuit. In that way, the switch can control the operation of lighting and various kinds of equipment connected in the circuit. *NEC Article 404* is one of the areas in the *NEC*® that covers the installation and use of switches.

In the past, all switches were mechanical devices that were manually operated to open or close a circuit. Modern technology has greatly expanded the role and design of early switches. Today, switches can be activated by light, heat, chemicals, and electrical energy.

2.1.0 Common Terms

Two general terms are used to define switches. The term pole refers to the number of conducting paths that the switch will control in the circuit. A single-pole switch breaks the connection on only one conducting path in a circuit. A double-pole switch is used to break the connection on both conducting paths in a two-conductor circuit, usually a 240V, two-wire circuit.

The term throw refers to the number of internal operations that a switch can perform. For example, a single-pole, single-throw (SPST) switch will complete a single circuit only when it is thrown in one direction (the ON position). This circuit will be opened when the switch is thrown in the opposite direction (the OFF position). The common ON/OFF snap switch is an SPST switch.

A double-pole, single-throw (DPST) switch opens or closes two conducting paths at the same time. In this case, both circuits are either open or closed. A DPST switch is common to 240V circuits. In these circuits, both conductors are considered to be energized.

The single-pole, double-throw (SPDT) switch, also known as a three-way switch, is often used to

INSIDE TRACK

Simplifying Industrial Wiring

The wiring of this manufacturing facility might seem complicated, but by applying the basic principles of blueprint reading and a thorough knowledge of the *NEC*® requirements, the job is readily done.

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control a single load, such as a lamp, from two different locations. SPDT switches are discussed in more detail later in this module.

A double-pole, double-throw (DPDT) switch usually directs a 240V, two-wire circuit through one of two different paths. One example of a DPDT switch is an electrical transfer switch used to energize certain circuits from either the main electric service or from an emergency standby generator. The DPDT switch prevents the circuits from being energized from both sources at once.

A four-way switch cannot be classified as an example of a double-pole, double-throw switch. Although a four-way switch does throw the current path in two different directions by moving the switch toggle, only one pole on each side of the switch is allowing current to pass.

Figure 1 summarizes the basic switches and shows their symbols.

2.2.0 Identifying Switches

Switches vary in their grades, capacities, and purposes. For example, a switch that is appropriate for activating a tungsten-filament lamp would not meet the *NEC®* requirements for controlling motor starting. It is very important that switches be used for their designated purpose.

There is a great deal of information given on the switch itself, which can help you determine its function and rating (see *Figure 2*). Most information related to the switch rating will be found on the front of the switch.

- The testing laboratory label is an indication that the device has undergone extensive testing by a nationally recognized testing laboratory and has met the minimum safety requirements. In *Figure 2*, the switch is marked with a "UL," which stands for Underwriters Laboratories, Inc., which was created by the National Board of Fire Underwriters to test electrical devices and materials.
- The Canadian Standards Association (CSA) label is an indication that the material or device has undergone a similar testing procedure by the Canadian Standards Association and is acceptable for use in Canada.

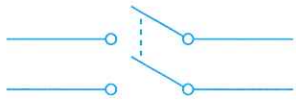
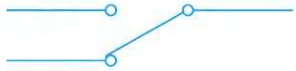
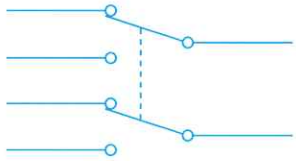
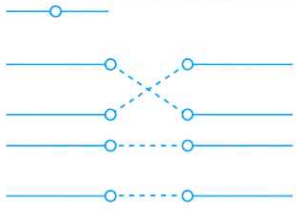
SWITCH TYPE	ABBREVIATION	SYMBOL
SINGLE-POLE SINGLE-THROW	S1	
DOUBLE-POLE SINGLE-THROW	S2	
SINGLE-POLE DOUBLE-THROW (THREE-WAY)	S3	
DOUBLE-POLE DOUBLE-THROW	N/A	
FOUR-WAY	S4	

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Figure 1 ◆ Switch symbols.

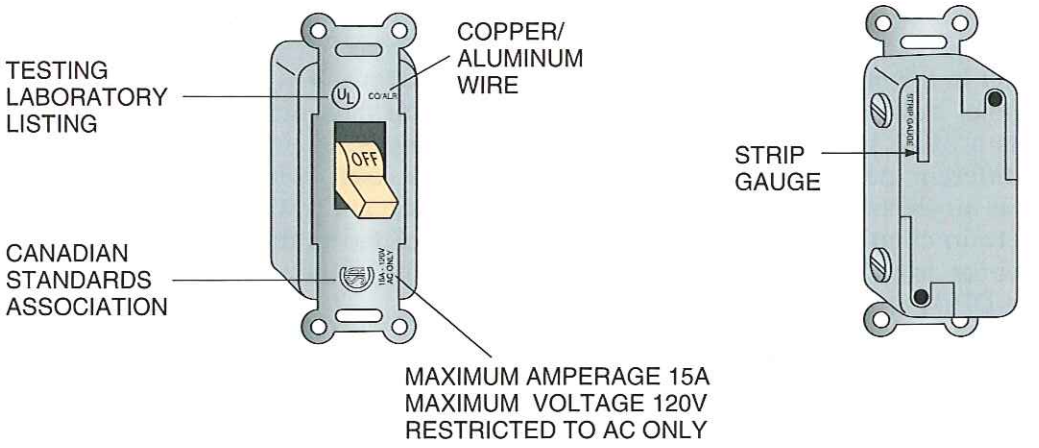


Figure 2 ◆ Typical single-pole switch.

- Current and voltage ratings are listed by maximum amperage and maximum voltage. In *Figure 2*, the maximum current through the device should not exceed 15 amps and the maximum voltage should not exceed 120V. This switch is to be used on alternating current (AC) only. Failure to follow these recommendations could result in damage to the unit or a possible fire hazard.
- The CO/ALR symbol indicates that a switch may be used with copper, aluminum, or copper-clad aluminum wire. The letters ALR stand for aluminum revised. The CO/ALR mark replaces an earlier mark, CU/AL. It was discovered that the earlier CU/AL-rated switches were not suitable for aluminum wire in the 15- to 20-amp range.

NOTE

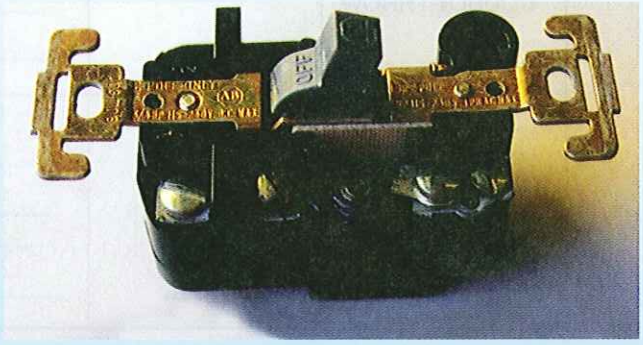
Older switches marked CU/AL should be used for copper only.

- A tungsten (T) rating indicates that the switch can be used with lamps that use tungsten. Tungsten is a metal that is used as the filament in standard incandescent lamps. When it is cold, tungsten has a very low resistance. This low resistance causes the initial current flow to be six to ten times that of the normal current flow. Once the tungsten heats up, which takes about 1/250th of a second, the current flow drops back to normal. This severe overloading can reduce the life expectancy of the switch.

INSIDE TRACK

Identifying Switches

The differences between a light switch and a motor switch will become obvious as you begin to use them. This motor switch has built-in overload protection.



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Another way to identify the function and rating of a switch is by color coding. Switches are typically constructed with a ground screw attached to the metallic strap of the switch. The ground screw is usually a hex-head screw and is indicated by the color green.

On a three-way switch, the color black or bronze (brass) is used to show the common pivot point for the switch. Current will always enter or leave through the pivot point.

NOTE

The color green is used only for ground connections in wiring.

3.0.0 ◆ TYPES OF SWITCHES

There are many types of switches available. This section covers the most common types.

3.1.0 Single-Pole Switches

Single-pole switches are easy to identify because they only have two terminals for conductor connections (*Figure 3*).

NOTE

Figure 3 shows the white wire to the switch as the hot wire. This allows the use of standard black/white pair cable to be used for switch legs, while retaining a black wire for the hot wire to the load.

Many single-pole switches have a third or ground terminal. This type of switch is probably the most widely used switch in residential applications. It is used for the on and off control of lights, fans, and numerous other appliances from a single point.

NOTE

According to ***NEC Section 200.7(C)(2),*** single-pole, three-way, and four-way switch loops can use the white wire (usually reserved for the grounded conductor) for supply to the switch, but the conductor must be permanently re-identified for this use by painting or other effective means.

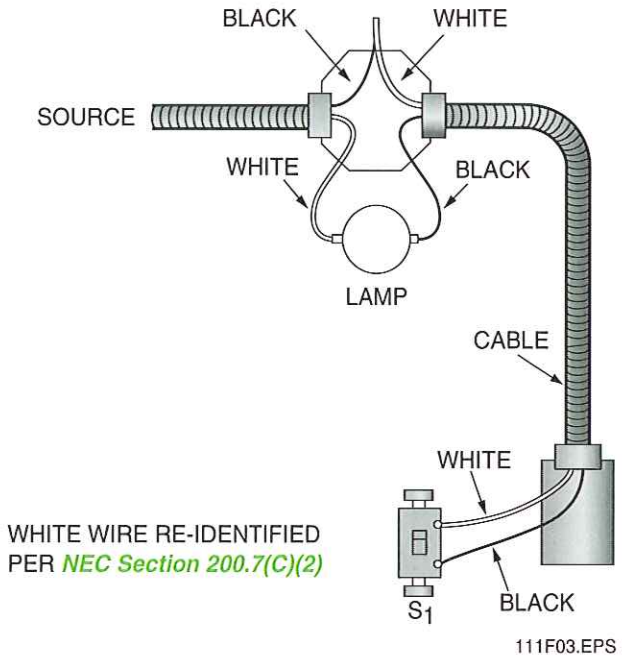

Figure 3 ◆ Single-pole pictorial for cable installation.

Figure 4 shows how a single-pole switch controlling a single light would be represented on a set of blueprints. *Figure 5* shows a schematic representation of a single-pole switch.

3.2.0 Double-Pole Switches

Double-pole switches are really two switches in one. They are used primarily when it is necessary to completely isolate the load. Double-pole switches are connected so that both circuit conductors can be opened or closed at the same time. The double-pole switch has four terminals for conductor connections. These terminals are identified according to polarity. Like the single-pole switch, the double-pole switch has an identified on or off position.

3.3.0 Three-Way Switches

A three-way switch does not perform three separate operations, as its name might suggest. The

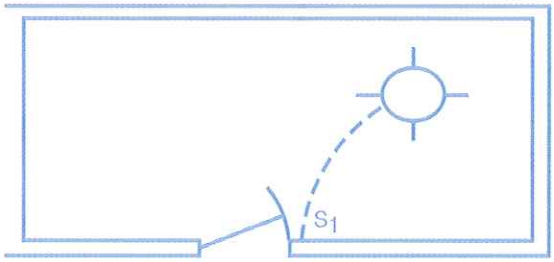

Figure 4 ◆ Single-pole switch as shown on a blueprint.

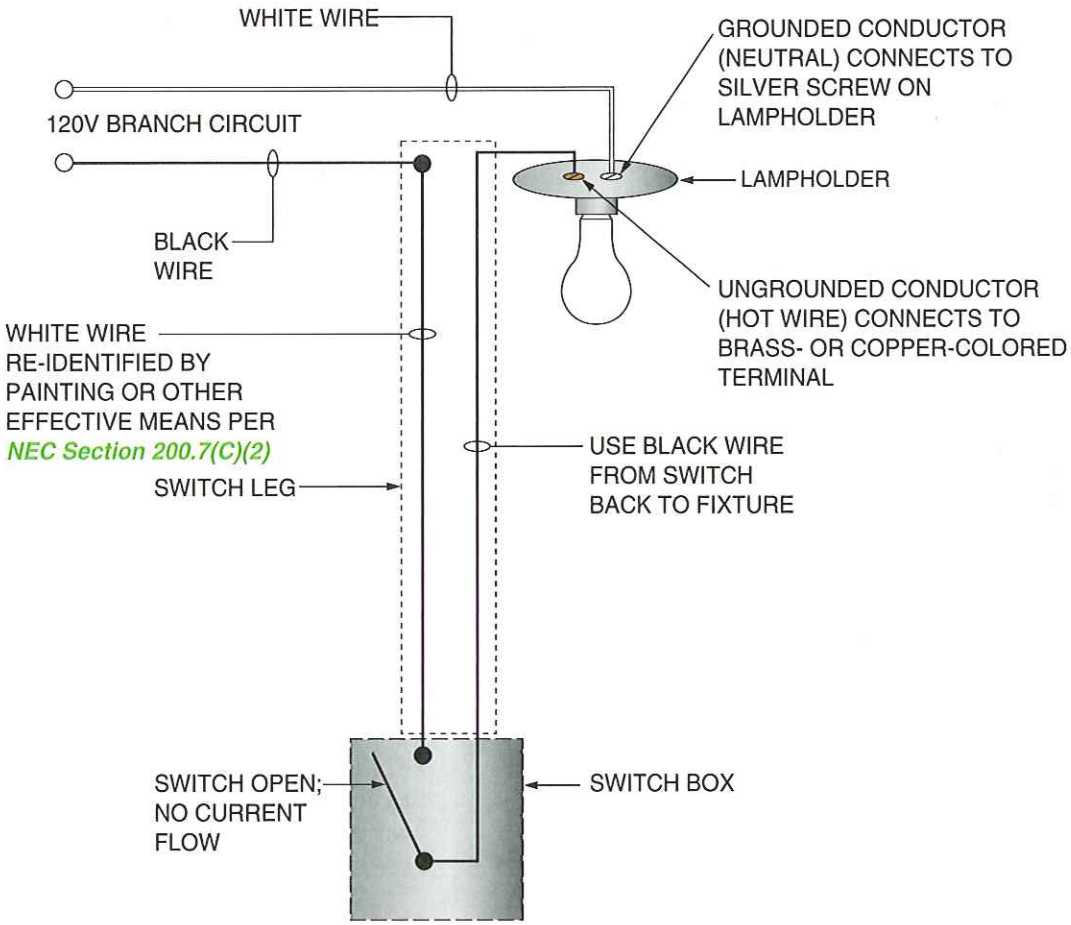

Figure 5 ◆ Single-pole diagram.

three-way switch is a single-pole, double-throw switch without a center off position. A common use for a three-way switch is to control a lamp from two separate locations, such as from the top and bottom of a stairway. In this case, a pair of three-way switches would be used. *Figure 6* shows a pictorial drawing of such a circuit.

NOTE

The switch loop between the two three-way switches requires four conductors when the grounding wire is included.

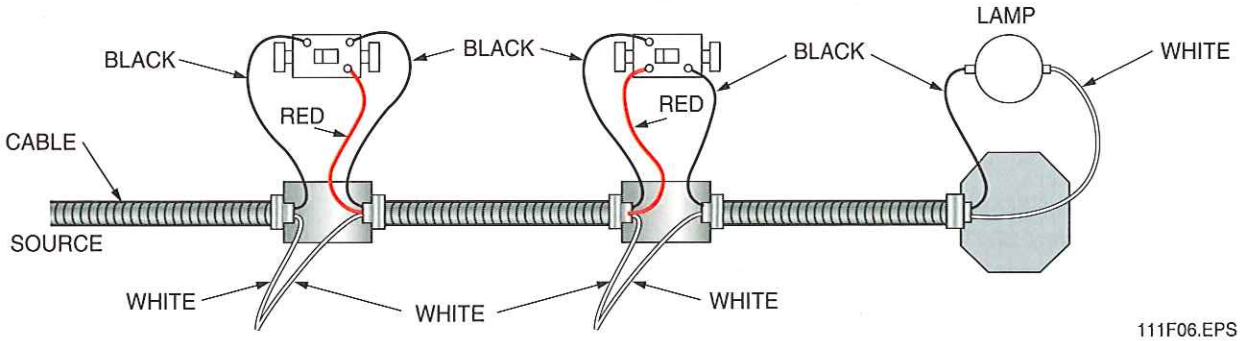

Figure 6 ◆ Three-way pictorial for cable installation.

Double-Pole Switches

THINK ABOUT IT

How would a double-pole switch isolate an electrical load? Why might you want to isolate a device or branch circuit?

The three-way switch has three terminal connections (four if a ground or green terminal is present). The single terminal located at one end of the switch is called the common. This terminal is darker in color (either black or brass-colored) than the other two terminals. The hot leg is always connected to this darker terminal. The remaining two terminals are lighter in color and are referred to as the traveler terminals. *Figure 7* shows how the actual connection of the three-way switching circuit is made.

With the hot leg connected to the common of the first switch, the current is given a choice of paths to follow depending upon the relative position of the switch. The current then proceeds along one of the travelers (or alternating switch loops) to the second switch. At the second switch, the circuit will either be completed or opened, depending upon the position of this second switch. There are four possible combinations of the switch contact positions, as shown in *Figure 8*.

Of the four possible combinations of switch contact positions, only two will result in a complete circuit. Changing the position of either switch will always change the state of the lamp.

Figure 9 illustrates how a three-way switch is shown on a blueprint.

WARNING!

Wiring a three-way switching situation in any other fashion will result in a polarity change at the light fixture. This is prohibited by ***NEC Section 200.11.*** If the polarity is changed on the light fixture, the shell of the light socket will then be hot in relation to ground. This is a personal safety hazard that could result in someone receiving a shock.

3.4.0 Four-Way Switches

Four-way switches can be used if it is necessary to control a light or group of lights from more than two locations. The four-way switch (or switches) must always be connected in the traveler conductors between the three-way switches. *Figure 10* shows how a four-way switch could be added to the circuit previously shown in *Figure 6*. The path for the current to follow is relative to the positions of the switch handle.

Note that the only difference between this circuit and the three-way switch circuit is the inclusion of the four-way switch in the traveler conductors between the two three-way switches. If it is necessary to control a lamp (or lamps) from more than three positions, more four-way switches can be installed in the travelers or carrier conductors.

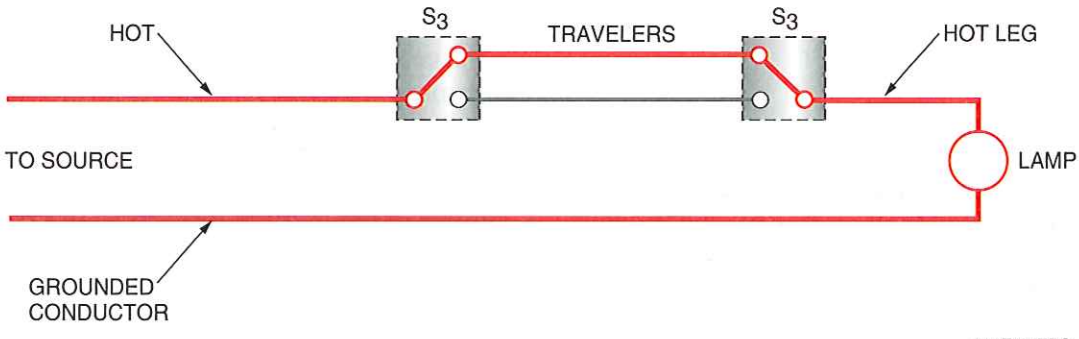

Figure 7 ◆ Three-way schematic.

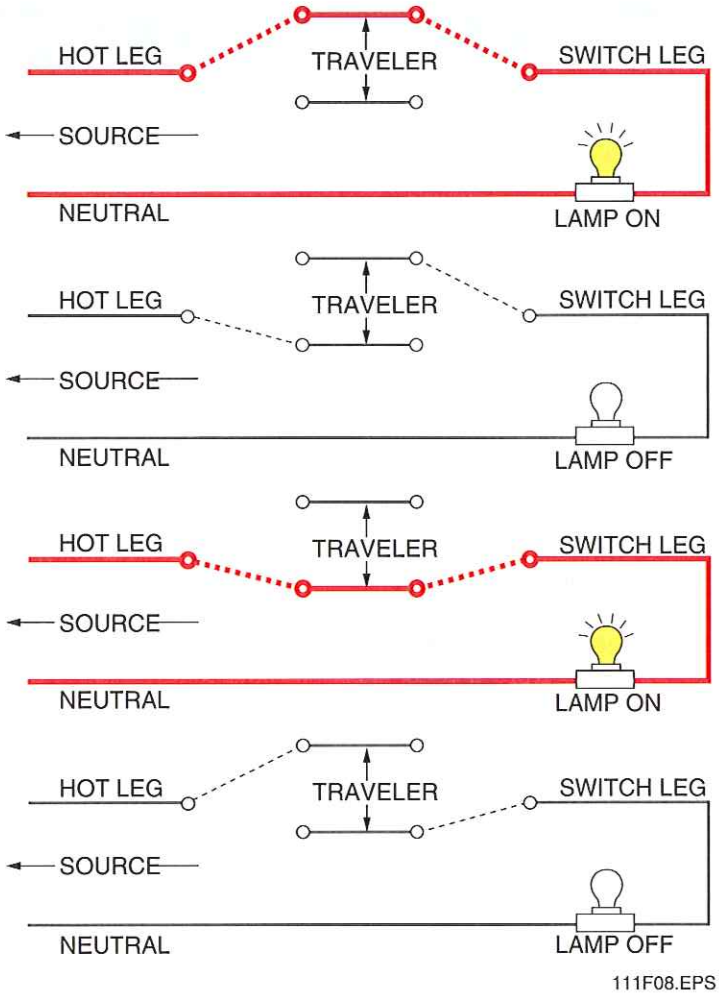

Figure 8 ◆ Possible combinations of a three-way switch.

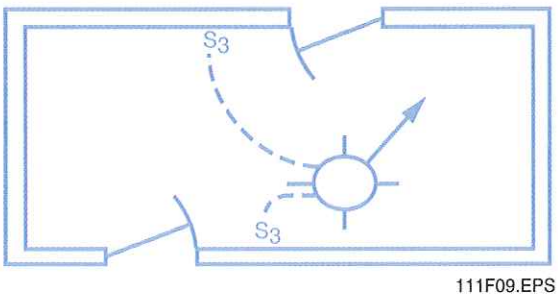

Figure 9 ◆ Three-way switch as shown on a blueprint.

3.5.0 Special Switches

Another common switch is the dimmer switch (*Figure 11*). This switch not only turns the light on and off, but also provides a means of controlling the light's brilliance. Dimmer switches are used where full brightness is not always desired. The standard models are available in single-pole and three-way types. They mount in a standard switch box. Single-pole dimmers can replace single-pole switches. However, three-way dimmers must be used with a three-way toggle switch at the other switch location. In other words, two three-way dimmers cannot be used to control the same load.

Incandescent dimmers are normally rated at 600, 1,000, 1,500, or 2,000 watts, 120 volts AC. Because incandescent dimmers are rated by wattage, it is easy to select lamp loads that will not exceed the dimmer rating. Specialized dimmer systems are also available. Incandescent dimmers shall not be used to control receptacles, appliances, fluorescent lamps, or fluorescent ballasts.

The wiring procedure for dimmer switches is similar to the method used for standard switches. However, it is important to give special attention to the connections and the **grounding.** Some dimmer switches are solid-state devices, and their electronic circuitry can be damaged if connected improperly.

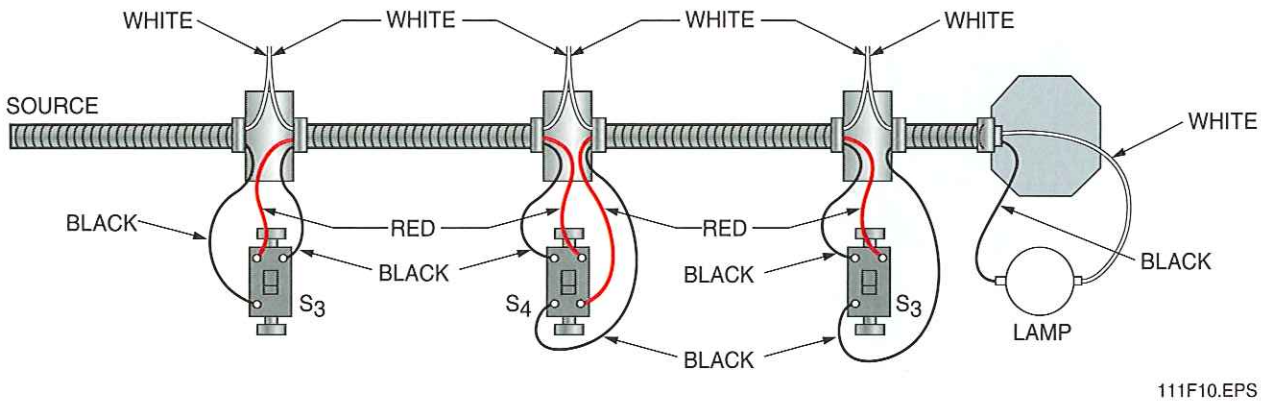

Figure 10 ◆ Four-way pictorial.

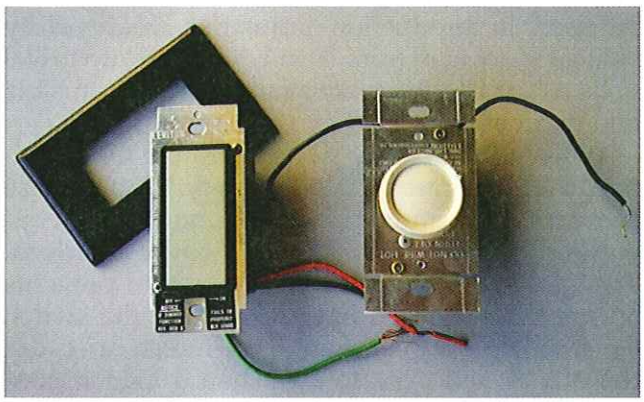

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Figure 11 ◆ Dimmer switches.

CAUTION

Effectively identified disconnect devices are critically important to safety when a switch or circuit breaker has to be opened to quickly de-energize a circuit.

3.6.0 Disconnects

NEC Article 100 defines a disconnecting means as a device, group of devices, or other means by which the conductors of a circuit can be disconnected from their source of supply. All disconnect devices (switches or circuit breakers) for load devices and circuits must be clearly and permanently marked to show the purpose of the disconnect. This is a must according to the *NEC®*. Under OSHA, this rule applies to all existing electrical systems, no matter how old, and also to new, modernized, expanded, or altered electrical systems. *NEC Section 110.22* covers the identification of **disconnecting means.**

3.6.1 Safety Switches

In the early 1900s, an open knife switch was commonly used for manual switching and disconnecting. It consisted of a stationary jaw and a movable blade pivoting in a hinge post. These early devices carried current adequately, but were insufficient from a safety standpoint. The load-make and load-break manual switching relied on an operator to open or close the blade quickly, and there were also exposed live parts.

Because of the danger of exposed live parts, the switches were eventually mounted in service boxes to increase operator safety. In the early 1920s, an externally operated handle was added to make the switch safe. A quick-make, quick-break mechanism was connected to the handle and installed inside the enclosure in the 1930s. This made opening and closing the breaker contacts independent of the operator's hand speed. These devices became known as safety switches.

Further safety features have been added over the years:

- Arc shields for electrical protection and maximum horsepower ratings
- Interiors that could be removed easily for wire pulling
- Coilproof dual-defeatable interlocks that increase safety and ease of inspection by authorized personnel
- Bold on/off and handle markings that clearly indicate the contact position from a distance
- Faceplates that cover the front of the switch and protect exposed wires

Figure 12 shows a safety switch that is typically used in commercial and industrial applications.

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Figure 12 ◆ Safety switch.

Safety switches are individually enclosed, manually operated disconnects that must be installed and operated in accordance with the *NEC®*. Safety switches are voltage-rated and must be used with the appropriate voltage level. Unless otherwise noted, all safety switches are listed under UL 98 (Enclosed Switches). Safety switches must provide several features that are required by the *NEC®*, including the following:

- Protection from live parts by a metallic enclosure that completely surrounds the disconnecting means
- Highly visible indication of the contact position
- Provisions for padlocking the external, manually operated handle in the OFF position

4.0.0 ◆ NEMA CLASSIFICATIONS

The National Electrical Manufacturers Association (NEMA) is a nonprofit organization supported by the manufacturers of electrical equipment and supplies. NEMA develops standards that are used when purchasing equipment. The classifications help to match the product to the application.

4.1.0 Switch Classifications

There are two NEMA classifications for enclosed switches: general-duty switches and heavy-duty, motor-rated switches.

4.1.1 General-Duty Switches

A general-duty switch is designed for use in residential and commercial applications. It is used where the service factor is not high (e.g., in lighting, air conditioning, and appliance loads). There are several kinds of general-duty, single-throw switches. They range from a simple two-wire switch to a solid neutral switch with one blade and one fuse, which is rated for 120 volts AC. The other end of the range includes four-wire switches with solid neutral, three-blade, three-fuse construction, which are rated for 240 volts AC. General-duty two- and three-pole switches are designed for industrial use where the service demands are not high. They are rated from 30 to 1,200 amps, up to 600 volts AC or DC, and are available in fusible and nonfusible types. The safety switch shown in *Figure 12* is a general-duty switch.

4.1.2 Heavy-Duty, Motor-Rated Switches

Heavy-duty, motor-rated switches are designed to be used in production industries. Heavy-duty switches are rated from 30 to 1,200 amps, up to 600 volts AC or DC. They are available in both fusible and nonfusible types.

When a heavy-duty switch is in the OFF position, the blades are visible for safety. Most of these switches also feature quick-make, quick-break operating mechanisms and a full-cover interlock. The quick-make, quick-break operation prevents an operator from closing or opening the switch too slowly. Slow operation of the switch can cause the blades and clips to arc when a load is connected. Arcing is more pronounced on larger switches. In time, the blades and clips burn away. *Figure 13* shows a heavy-duty switch.

When the switch is closed, the door is locked. The door can be opened only when the switch handle is in the open position. In addition, the switch cannot be closed with the door open.

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Figure 13 ◆ Heavy-duty switch.

INSIDE TRACK

Check the Specifications before Wiring

Always refer to the project plans and/or specifications before selecting a wiring method. Often, the specifications will disallow certain techniques. Also, be sure to check that the equipment is suitable for the application. For example, equipment installed in a classified area must meet or exceed the rating for that area.

However, for maintenance purposes, the interlock device can be tripped so that the switch can be closed with the door open. The switch handle can be locked with a padlock to prevent unauthorized operation. When you need to work on the circuit or the switch controls, pull the handle to open the circuit. Next, open the switch door and remove the fuses. Padlock the handle in the open position; that way, the switch cannot be closed by anyone while you are working. Tie a safety tag with your name onto the padlock. When you are finished working on the circuit, replace the fuses and remove your lock and tag. After verifying that it is safe to close the switch, do so.

WARNING!
Make sure to always follow your site-specific lockout/tagout procedure.

The manufacturer's list shows the switch's current rating, voltage rating, and the types of enclosures available. If the switch is intended for interrupting a motor circuit, the switch must also be horsepower-rated.

4.2.0 Enclosure Classifications

NEMA also classifies the enclosures designed for specific conditions. When choosing devices for use in hazardous locations, the proper NEMA-type enclosure must be specified. The NEMA numbers are not marked on the enclosures, but are included in the manufacturers' catalogs. *NEC Table 430.91* provides a list of enclosures.

4.2.1 General Purpose Indoor (Type 1)

The Type 1 general purpose indoor enclosure is made of sheet metal. This enclosure is primarily intended to protect people against accidental contact with equipment. It is not dust-tight. This enclosure often has pre-punched knockouts that are easily removed for connection to a raceway. *Figure 13* shows a NEMA Type 1 enclosure.

4.2.2 Drip-Proof Indoor (Type 2)

The Type 2 general purpose indoor enclosure is similar to Type 1, but it also has drip shields or their equivalent.

4.2.3 Dust-Tight, Rain-Tight, and Sleet-Resistant (Type 3)

The Type 3 enclosure is intended for outdoor use to protect against windblown dust and water.

4.2.4 Rainproof and Sleet-Resistant (Type 3R)

The Type 3R enclosure (*Figure 14*) is intended for outdoor use. This enclosure meets the requirements of UL 508. This enclosure often contains knockouts below the level of the lowest live component.

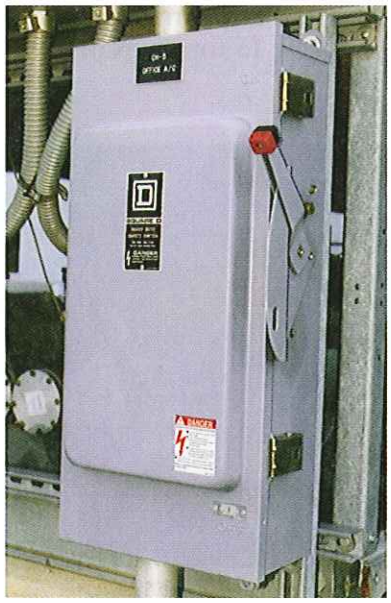

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Figure 14 ◆ NEMA Type 3R enclosure.

4.2.5 Dust-Tight, Rain-Tight, and Sleet-Proof (Type 3S)

Similar to Type 3, the Type 3S enclosure is intended for use outdoors to protect equipment from windblown dust and water. However, the enclosure can operate even when covered by external snow and sleet.

NOTE

Types 3, 3R, and 3S are not considered watertight but are intended to keep water at a safe distance from live internal parts. These enclosures may have weep holes built in to allow any water that may enter to drain quickly.

4.2.6 Watertight and Dust-Tight (Type 4)

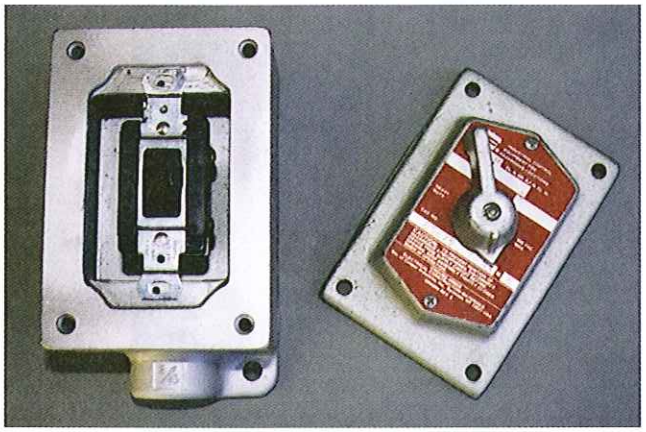
The Type 4 enclosure is made of rigid cast metal or sheet metal. It is designed to withstand a standard hose-stream test.

4.2.7 Submersible, Watertight, and Dust-Tight (Type 6)

The Type 6 enclosure can be submerged in water. It is also resistant to dust and sleet (ice), and can be installed either indoors or outdoors.

4.2.8 Hazardous Locations, Class I (Type 7)

The Type 7 enclosure is used for air-break devices. It meets the *NEC*® requirements for Class I, Groups A, B, C, or D hazardous locations. These locations may have flammable gases or vapors present. See *Figure 15* for an example of a Type 7 enclosure.



111F15.EPS

Figure 15 ◆ Snap switch in explosion-proof (Type 7) enclosure.

4.2.9 Hazardous Locations, Class I (Type 8)

A Type 8 enclosure is similar to the Type 7 enclosure. However, the Type 8 enclosure is designed for oil-immersed equipment.

4.2.10 Hazardous Locations, Class II (Type 9)

The Type 9 enclosure meets the *NEC*® requirements for Class II, Groups E, F, and G hazardous locations. These locations have combustible dust in the air.

4.2.11 Bureau of Mines (Type 10)

The Type 10 enclosure meets the requirements of the U.S. Bureau of Mines.

4.2.12 Corrosion-Resistant, Drip-Proof Indoor (Type 11)

The Type 11 enclosure is designed for oil-immersed equipment and is suitable for use in locations subject to corrosive acid or fumes.

4.2.13 Dust-Tight and Drip-Tight Industrial Use (Type 12)

The Type 12 enclosure keeps out dust, lint, fibers, and other airborne particles. A gasket fits between the case and the cover. There are no holes in the enclosure and no conduit knockouts or conduit openings.

4.2.14 Oil-Tight and Dust-Tight (Type 13)

The Type 13 enclosure is used indoors mainly to house **pilot devices,** including limit switches, foot switches, and pushbuttons. This enclosure protects the devices from lint, dust, and seepage.

NOTE

Hazardous locations are described in ***NEC Article 500.***

4.2.15 Ingress Protection (IP) Classifications

The Ingress Protection (IP) Classification System uses a two-digit number to classify the degree of protection provided by an enclosure (*Table 1*). The first digit (0 through 6) represents the degree of protection against solid objects, while the second digit (0 through 8) represents the degree of protection against water.

Switch Enclosures

THINK ABOUT IT

What type of enclosure would you use for a pool lighting fixture that is 3' from the pool's edge? What type would you use in the paint room of an auto body shop?

Table 1 IP Classification System

First Number Degree of protection against solid objects	Second Number Degree of protection against water
0. Not protected. 1. Protected against a solid object greater than 50 mm, such as a hand. 2. Protected against a solid object greater than 12 mm, such as a finger. 3. Protected against a solid object greater than 2.5 mm, such as a wire or tool. 4. Protected against a solid object greater than 1.0 mm, such as wire or thin strips of metal. 5. Dust-protected. Prevents ingress of dust sufficient to cause harm. 6. Dust-tight. No dust ingress.	0. Not protected. 1. Protected against water dripping vertically, such as condensation. 2. Protected against dripping water when tilted up to 15°. 3. Protected against water when spraying at an angle of up to 60°. 4. Protected against water splashing from any direction. 5. Protected against jets of water from any direction. 6. Protected against heavy seas or powerful jets of water. Prevents ingress sufficient to cause harm. 7. Protected against harmful ingress of water when immersed between a depth of 150 mm to 1 m. 8. Protected against submersion. Suitable for continuous immersion in water.

NOTE

The IP Classification System does not indicate corrosion resistance.

5.0.0 ◆ RECEPTACLES

A **receptacle** is a contact device that is installed at an **outlet** so that a single **attachment plug** can be connected. According to *NEC Article 100,* a **receptacle outlet** is an outlet where one or more receptacles are installed. Receptacles are rated according to their voltage and amperage capacity. This rating determines the number and configuration of the contacts. *Figure 16* shows a portion of the NEMA configurations for general purpose nonlocking plugs and receptacles, as well as other common receptacles. In most cases, a distinction is made between the system grounded conductor (W) and the grounding conductor (G). You will note that plugs are often **polarized** (one blade is wider than the other). This prevents the user from plugging the device in the wrong way.

Grounded conductors, which are labeled W, may carry current in normal operation. *NEC Article 100* defines a grounded conductor as a system or circuit conductor that is intentionally grounded. Grounded conductors are commonly referred to as neutrals.

Grounding conductors (equipment grounds) are labeled G. They carry current only when part of the equipment, which was never intended to be energized, becomes energized through a fault. These are commonly referred to as grounding conductors. *NEC Article 100* defines a grounding conductor as a conductor used to connect equipment or the grounded circuit of a wiring system to a grounding electrode or electrodes.

NEC Article 406 covers the rating, type, and installation of receptacles, cord connectors, and attachment plugs (cord caps). *NEC Section 406.3(A)* states that receptacles installed on 15A and 20A **branch circuits** must be of the grounding type. *Figure 17* shows a grounding-type duplex receptacle. On all new installations, a grounding-type device must be installed.

The receptacle current rating must be at least equal to that of the conductors feeding it. If there is more than one receptacle on the circuit, the total load plugged into these receptacles cannot exceed the rating of the conductors. *NEC Tables 210.21(B)(2) and (3)* list these requirements.

		15 AMPERE		20 AMPERE		30 AMPERE		50 AMPERE	
		RECEPTACLE	PLUG	RECEPTACLE	PLUG	RECEPTACLE	PLUG	RECEPTACLE	PLUG
2-POLE 3-WIRE GROUNDING	5 125V	5-15R	5-15P	5-20R	5-20P	5-30R	5-30P	5-50R	5-50P
	6 250V	6-15R	6-15P	6-20R	6-20P	6-30R	6-30P	6-50R	6-50P
	7 277V	7-15R	7-15P	7-20R	7-20P	7-30R	7-30P	7-50R	7-50P

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Figure 16 ◆ Typical NEMA plug configurations.

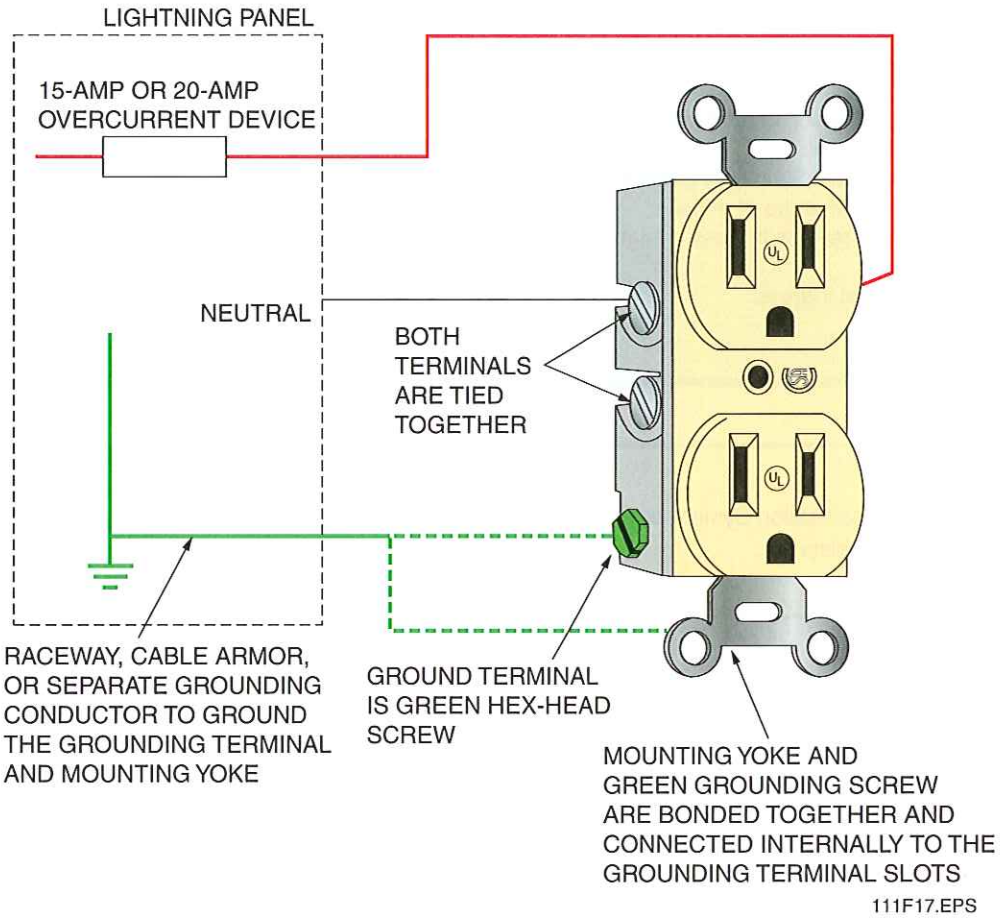

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Figure 17 ◆ Grounding-type duplex receptacle.

NOTE

NEC Section 210.21 allows the installation of 15A receptacles on a 20A circuit if the circuit feeds more than one receptacle.

5.1.0 Identifying Receptacles

Receptacles, like switches, have various symbols and information printed on them that help to determine their proper use and ratings (*Figure 18*). In addition, the shapes and positions of the openings also determine the use of the receptacle.

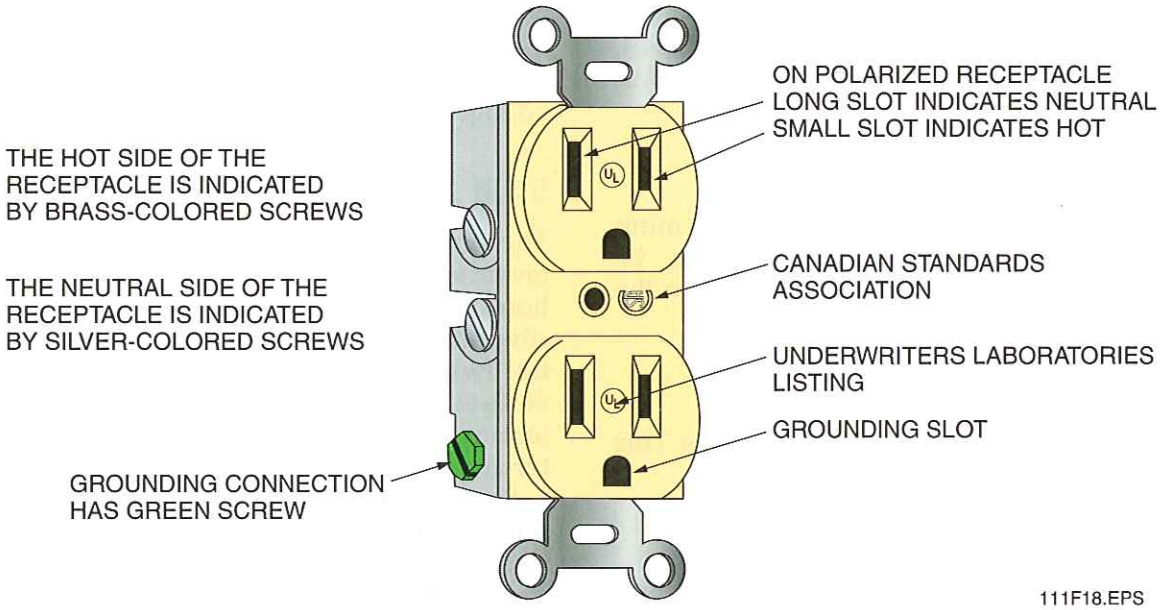
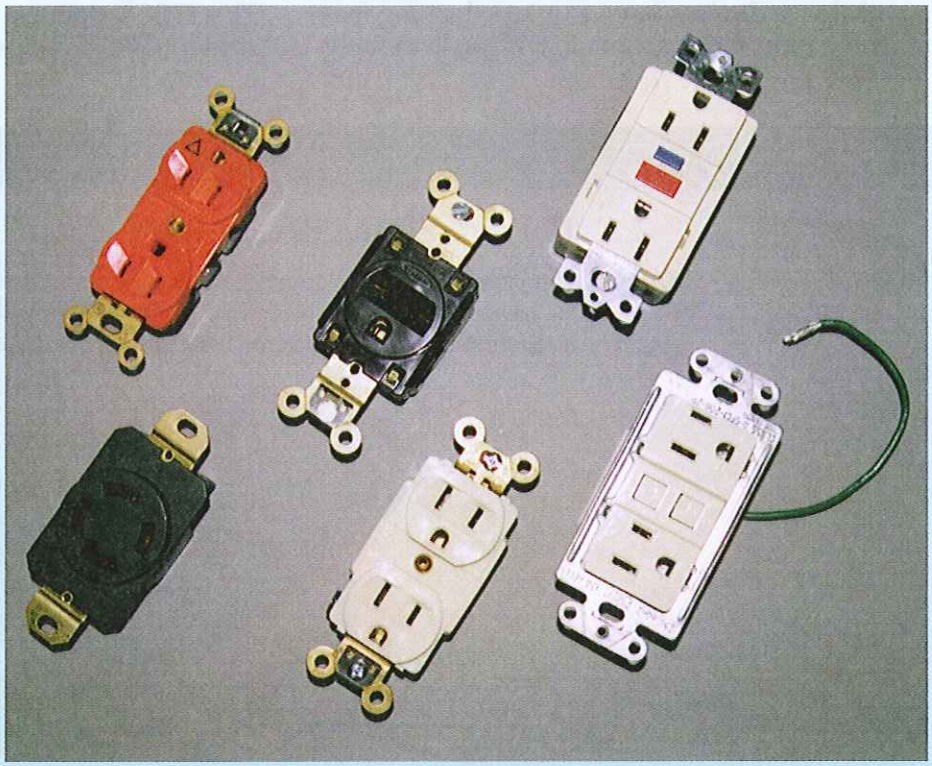


Figure 18 ◆ Standard duplex receptacle.

INSIDE TRACK

Identifying Receptacles

The picture shown here will get you started on identifying various receptacles. From left to right, the receptacles pictured are: TOP: Insulated ground receptacle; 220V receptacle; ground fault circuit interrupter (GFCI) with ground screw. BOTTOM: Twist lock receptacle; standard 120V receptacle; GFCI with ground tail.



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The printed information on the receptacle is similar to the information printed on switches. The information on receptacles includes the following:

- The UL label
- The CSA label
- Current and voltage ratings listed by maximum amperage and maximum voltage (may be shown on the front or back, depending on the switch)

5.2.0 Types of Receptacles

There are many different types of receptacles. This section covers the most common types.

5.2.1 Straight Blade Receptacles

Straight blade receptacles, as their name implies, will accept a straight blade connector or plug. These receptacles are the most common type.

5.2.2 Twist Lock Receptacles

Twist lock receptacles accept a curved blade connector or plug. The plug/connector and the receptacle lock together with a slight twist. The locking action prevents accidental unplugging of the equipment.

5.2.3 Pin and Sleeve Receptacles

Pin and sleeve devices have a unique locking feature. These receptacles are made with an extremely heavy-duty plastic housing that makes them virtually indestructible. They come with long brass pins for long life and are color coded according to voltage for easy identification.

5.3.0 Receptacle Terminals

The terminals on a receptacle are color coded. The green terminal is the equipment ground connection and is associated with the U-shaped slot. The silver-colored terminal is associated with the neutral (white) conductor and the larger of the two vertical slots on the receptacle. The brass-colored terminal is associated with the hot (black) conductor and the smaller vertical slot on the receptacle.

Similar to switches, receptacles have either screw terminals for attaching wires or quick-wire terminals located on the back. Although UL-approved, the push-in quick-wire terminals on receptacles and switches do not provide as good a connection as a wire that is properly terminated on the screw terminal. Use quick-wire terminals only for lightly loaded circuits. Receptacle terminals must be listed for the type of wire that is used in the system. If copper or copper-clad wire is used, all types of terminals are acceptable. If aluminum wire is used, the terminal must be rated for aluminum.

5.4.0 Ground Fault Circuit Interrupters

The *NEC*® defines a ground fault circuit interrupter (GFCI) as a protective device that functions

INSIDE TRACK

Pin and Sleeve Receptacles

This picture shows the locking feature of a pin and sleeve receptacle. When you unplug the device, the cover snaps down automatically, protecting the receptacle from dirt and moisture. These receptacles are used in industrial applications.

111P1104.EPS

to de-energize a circuit or portion thereof within an established period of time when a current to ground exceeds some predetermined value that is less than that required to operate the overcurrent protective device of the supply circuit. *NEC Section 210.8* defines locations for GFCI-protected receptacles.

Electricity normally flows into a tool or appliance through an energized wire and returns through a neutral wire. A GFCI compares the amount of current going out of the hot wire to the amount of current returning on the neutral wire. Any current that goes out of the hot wire but does not return on the neutral wire must be taking an unintended path or ground fault. Ground faults may be caused by worn or damp insulation or faulty wiring. If someone is in that current path, that person can complete the circuit necessary for the flow of current. Shock, injury, or electrocution can result, depending on the age and health of the person involved, how well grounded the person is, and the path the current takes through the person's body.

When a ground fault leak of some predetermined value (usually 5mA) is detected, the sensitive electronic circuitry within the GFCI will automatically trip a switch. This interrupts the circuit and cuts off the power. The interruption takes place within 1/40th of a second or less and prevents possible injury. *Figure 19* shows a typical GFCI. GFCIs are available as circuit breakers, receptacles, or on extension cords and adapters that plug into standard receptacles.

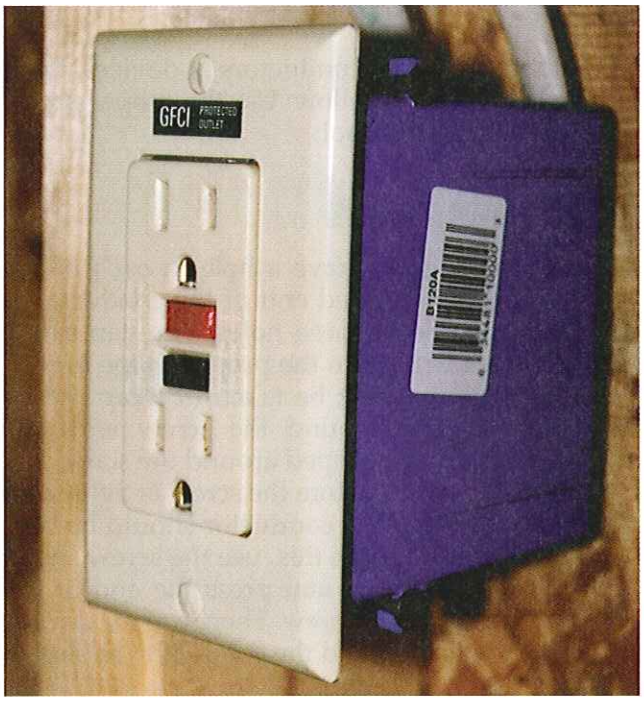

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Figure 19 ◆ Typical GFCI.

NEC Section 590.6 covers the rules that concern GFCI protection for all 15A, 20A, and 30A receptacle outlets on construction sites. The *NEC*® states that ground fault circuit interrupters (either GFCI circuit breakers or GFCI receptacles) must be used to provide personnel protection for all receptacles of the designated rating that are in use by employees.

NOTE

When installed properly, one GFCI receptacle can protect up to six receptacles on the same circuit, as shown in *Figure 20*.

NOTE

All GFCIs should be functionally tested before each use.

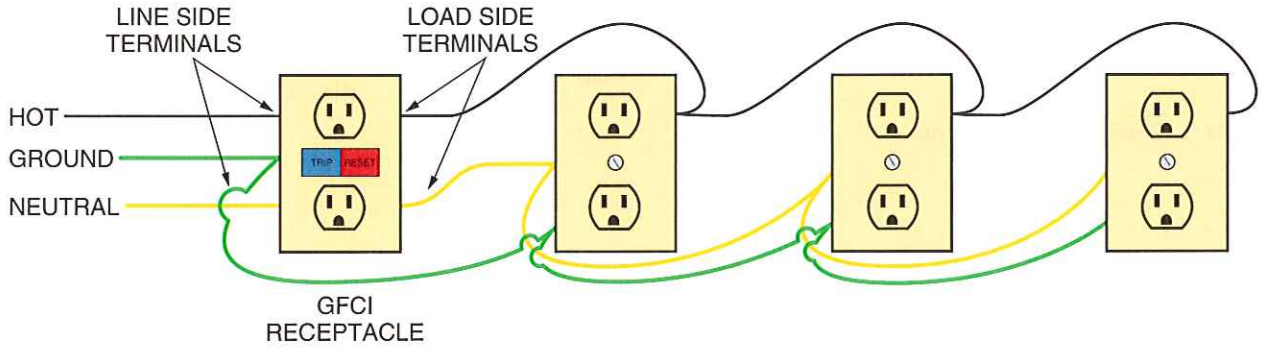

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Figure 20 ◆ GFCI protecting several standard receptacles.

6.0.0 ◆ WIRING TECHNIQUES

When you terminate conductors at devices, there is one simple rule to follow: Use the proper procedure and the correct tool.

6.1.0 Bending Wire

Many wire strippers have a hole in each of the jaws. When the stripped end of the conductor is inserted into one of these holes, you can safely bend the conductor into the proper shape for terminating it. Care must be taken to wrap the U-shaped conductor around the screw with the short end of the U wrapped around the screw in a clockwise direction. Before the screw is tightened, the stripped end of the conductor should be bent against the screw. To do this, use the screw shank with the wire stripper and press the end of the conductor against the screw. Then, use the jaws of the wire stripper to bend the conductor, as shown in *Figure 21*.

After the conductor is bent, the screw can be tightened to make a good electrical connection. The wire is actually twisted around the screw as it is tightened. For this reason, the wire must be wrapped around the screw in a clockwise direction.

6.2.0 Branch Circuit Wiring

According to *NEC Article 100,* a branch circuit is the circuit conductors between the final overcurrent device protecting the circuit and the outlet(s). That means that all outlets are supplied by branch circuits.

CAUTION

The torque applied to the terminal screw must be just right. Too much torque can strip the terminal. Too little torque can cause the termination to come apart.

NOTE

Certain receptacles are specially rated and designed for stranded wire.

6.2.1 *Planning*

The first step in branch circuit wiring is to check the drawings to determine the exact location of all outlet boxes for general purpose receptacles, switches, lighting fixtures, and special purpose receptacles. The *NEC®* requirements for the number of circuits, protective measures, and special circuits are determined at this time.

NOTE

The drawings may not show the actual conductor runs or homeruns for the wiring installation. Prior to planning the branch circuit wiring for an electrical installation, you should review the applicable articles of the *NEC®*.

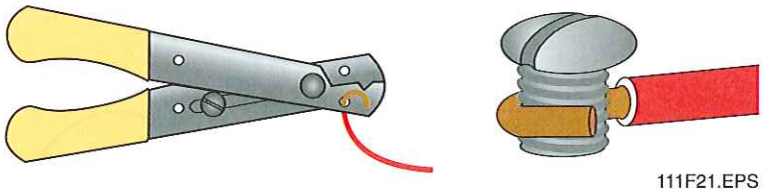

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Figure 21 ◆ Bending the conductor.

INSIDE TRACK

Selecting Wire Strippers

Wire strippers come in various sizes. Always select the correct tool for the wire to be stripped and work slowly and carefully to avoid damaging the conductor.

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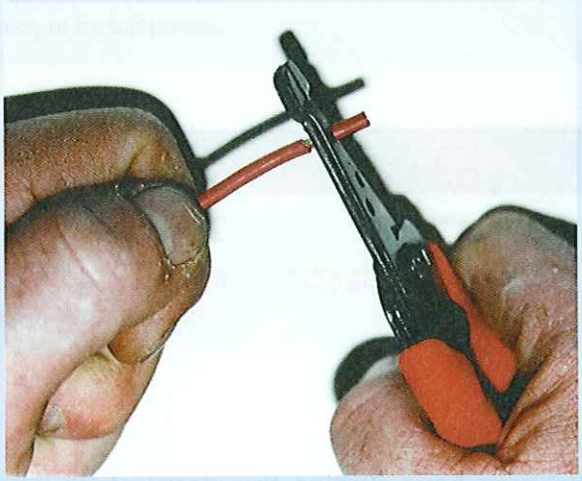
CHOOSE THE CORRECT TOOL



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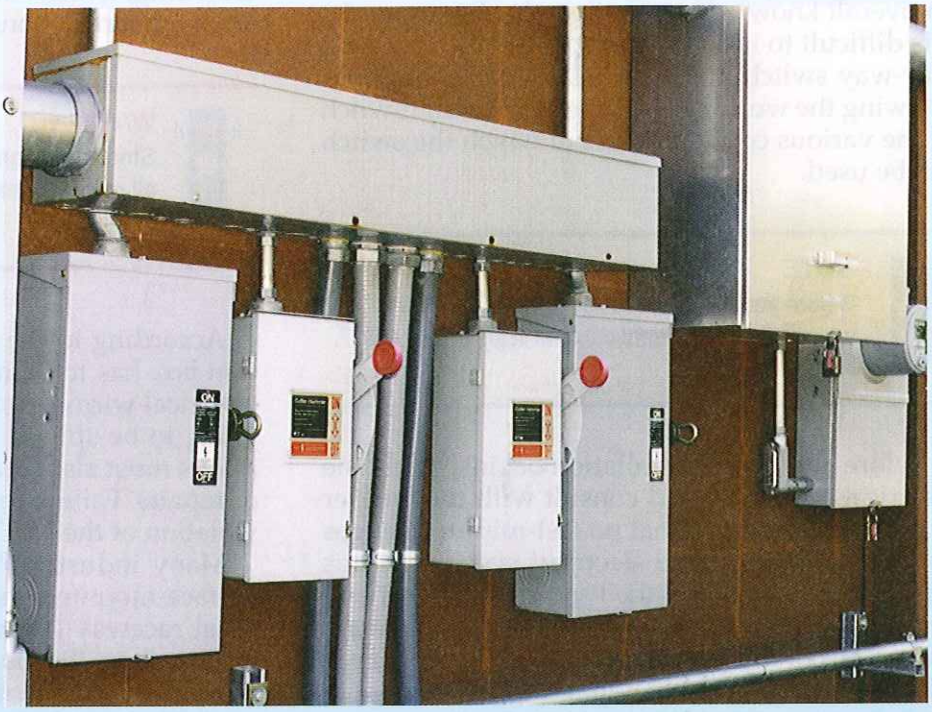
WORK SLOWLY AND CAREFULLY

INSIDE TRACK

Roughing in Commercial Wiring

Roughing in commercial wiring begins at the service entrance.



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INSIDE TRACK

Making Connections

Always get in the habit of making your connections in the following order: first the grounding conductors, then the grounded conductors, and finally, the ungrounded conductors. If you approach each job in a systematic manner, it will soon become second nature to you and you'll be less likely to make mistakes.

INSIDE TRACK

Terminations

For each branch circuit, terminate the devices starting from the furthest location in the circuit and working back toward the panel. Terminate the branch circuit breakers last.

6.2.2 Installation

After you have studied the electrical drawings and determined the general layout of the electrical system, the general rough-in stage begins. The rough-in stage involves the following:

- Installing outlet boxes and the service-entrance panel
- Establishing the conductor pathway
- Pulling or installing the cable or raceway

Roughing-in and the following step (installing switches, receptacles, etc.) require that you have an overall knowledge of both tasks. For example, it is difficult to install the proper conductors for a four-way switch in a particular location without knowing the working characteristics of the switch or the various configurations in which the switch can be used.

NOTE

Before you begin the roughing-in stage of the wiring, review the applicable articles of the *NEC®*.

Before any actual installation begins, study the electrical floor plan and consult with the builder or architect to ensure that no last-minute changes have been made in the electrical system. At this time, you should select the type of boxes that will be used at particular locations. The sizes of the required boxes must be determined in accordance with *NEC Article 314.* Pay particular attention to *NEC Sections 314.16(A) and (B)* for box sizing, *NEC Section 300.15* for locations where boxes are required, and *NEC Section 314.29,* which requires boxes to be accessible.

The size of the box is rated according to its cubic-inch capacity (volume). Although the *NEC®* states what practices must be followed, the *NEC®* does not explain why such a practice is required except that all provisions are designed to promote safety and prevent damage. Minimum volume capacities are required for different reasons. For example, too many wires too close together can cause overheating. In addition, adequate volume allows for greater air circulation and reduces crowding, which could cause damage to the insulation or connections of the wires.

WARNING!

Strict observance of the *NEC®* is mandatory and all required calculations must be taken very seriously.

According to the *NEC®*, an outlet box or junction box has to be installed at every point in the electrical wiring system where the wiring cable is going to be spliced or terminated. Each of these points must also be accessible for future revisions or repairs. Failure to make all boxes accessible is a violation of the *NEC®*.

Many industrial/commercial outlet boxes are surface-mounted and connect directly to the electrical raceway (*Figure 22*). These boxes are often mounted to the building steel or to a support channel or strut that is welded or clamped to the steel. The installation of outlet boxes or raceways should be coordinated so as not to interfere with

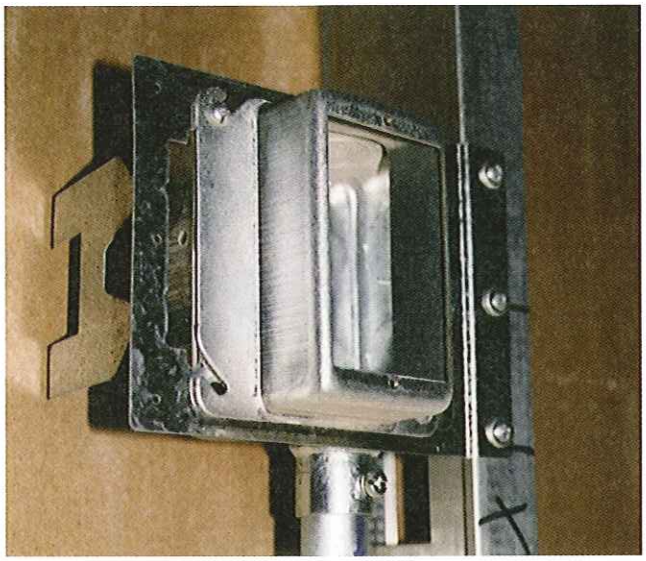

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Figure 22 ◆ Outlet box.

piping, ductwork, fireproofing, and other items that may or may not already be in place.

Commercial wiring may involve flush wiring similar to residential work. *NEC Section 314.20* requires that recessed switch, receptacle, and fixture boxes be mounted flush with the finished face of the wall surface when combustible material, such as plywood or paneling, is being used. If noncombustible material is used as the finish surface, the box may be recessed by as much as ¼ inch. The distance that the box is extended past the wall stud or building member is referred to as the mounting depth or setout. Many boxes have several setout measurements inscribed on the box (*Figure 23*).

NEC Section 314.21 addresses the repair of wall surfaces so that there will be no gaps or open spaces greater than ⅛ inch at the edge of the box or fitting.

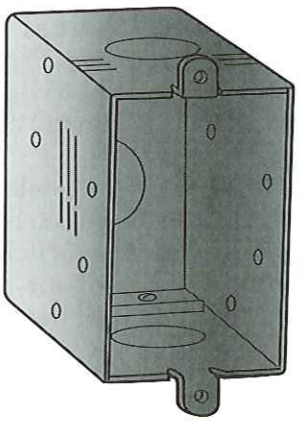

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Figure 23 ◆ Box with setout measurements inscribed.

These marks provide a quick and easy method of measuring the setout required for a particular wall finish. This saves time and effort when installing the box.

NOTE

Front-mounting bracket boxes will have the setout determined by the bracket assembly.

Install all boxes in accordance with the electrical drawings. The spacing should be as even as possible. The box center is the midpoint on the vertical dimension of the box. Make sure that you check the door swing direction so that the switches are not installed behind a door. Measure the height of the switch boxes from the floor so that they will be at the proper height when installed.

6.2.3 Splicing

Wires are spliced when they are joined or connected. Splices are required when installing switches, lighting, and other electrical equipment. There are three major steps for making a splice: removing the insulation, making the splice, and insulating the splice.

Wire strippers should be used to remove the insulation. Knives should not be used because of the possibility of nicking the wire. Use the following procedure to strip wire using a wire stripper:

Step 1 Insert the wire into the proper slot on the side of the stripper marked for solid wire.

Step 2 Twist the stripper back and forth a few times to cut through the insulation.

Step 3 Pull the stripper back to pull the insulation off.

Most industrial and commercial lighting and receptacle circuits are spliced using solderless connectors. Solderless connectors, commonly referred to as Wirenuts®, are plastic caps that contain a tapered and threaded metal insert, as shown in *Figure 24*.

When using a solderless connector, screw the wire nut over the twisted ends to hold the conductors together. (Some manufacturers recommend first twisting the conductors together to ensure good electrical contact.) Solderless connectors are rated for size, temperature, and number of conductors. Make sure you use a properly rated connector, and always follow the manufacturer's instructions when using any connector.

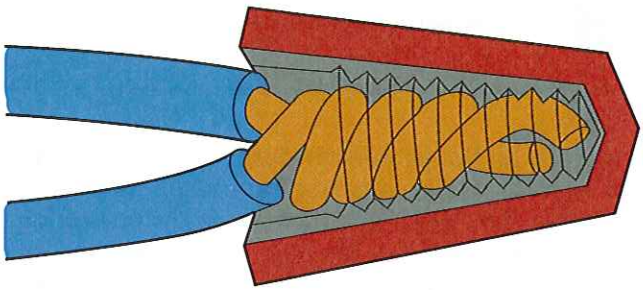

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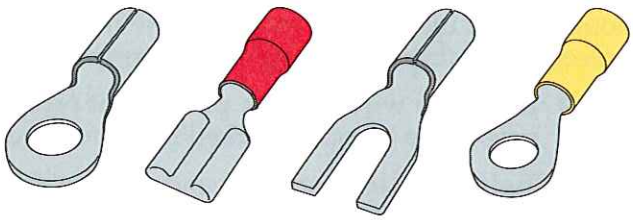
Figure 24 ◆ Solderless connectors.

111F24B.EPS

Most industrial and commercial control circuits and signal wires (for devices such as transmitters, motor stop/start circuits, etc.) are spliced on fixed terminal blocks with crimp-on lugs. Examples of lugs are shown in *Figure 25*. Lugs help to keep the conductors organized and greatly aid in troubleshooting. When installing lugs, make sure your crimping tool is designed for the particular lugs you are using.



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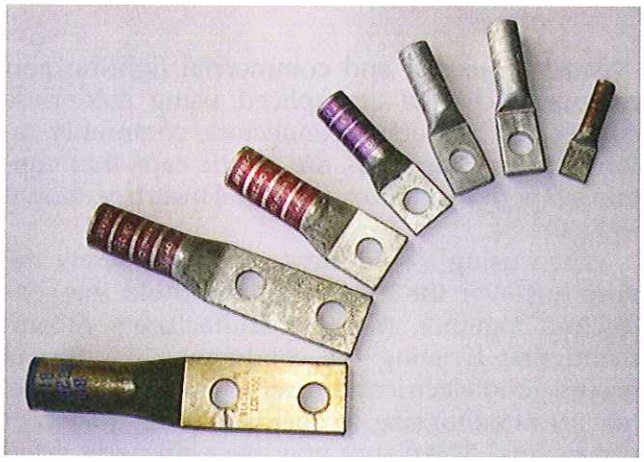

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Figure 25 ◆ Crimp-on wire lugs.

7.0.0 ◆ CONTROL DEVICES

One of the major differences between industrial/commercial wiring and residential wiring is the complexity of controls for electrical machinery. Whereas most loads in a home are turned on manually using a wall switch, industrial machinery is controlled by a variety of devices, including relays and limit switches.

7.1.0 Relays

A **relay** acts as a remote-controlled switch that opens and closes to supply power to a load such as a motor, heater, or light. The electromagnetic coil of a relay acts as a load for the control circuit. This allows switches and other controlling devices to control a large load while only carrying a very small current. For this reason, these controlling devices are often referred to as pilot devices. The pilot devices work together in a control circuit to ultimately close a relay that has contacts that are rated for the full load current. These relay contacts are what connect the load to its source voltage. *Figure 26* shows a typical relay along with its internal electrical arrangement.

The pilot devices that control a relay may be activated by a variety of methods, such as air or hydraulic pressure for pressure switches, heat for temperature switches, or light for photoelectric switches, to name a few. One of the most popular industrial pilot devices is the mechanical **limit switch.**

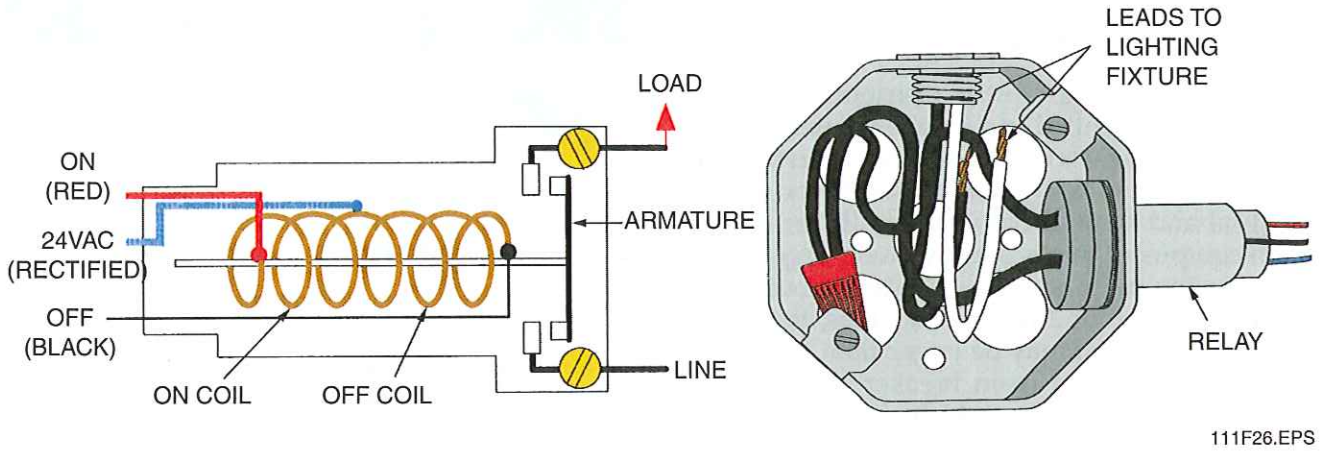

Figure 26 ◆ Typical low-voltage relay.

7.2.0 Limit Switches

Limit switches use mechanical movement to open or close electrical contacts. Limit switches are frequently used on manufacturing equipment, conveyor belts, automatic doors, and many other devices that have repeated motion or travel limits. A typical limit switch is shown in *Figure 27*. Limit switches can be fitted with numerous types of mechanical arms to suit specific equipment configurations.

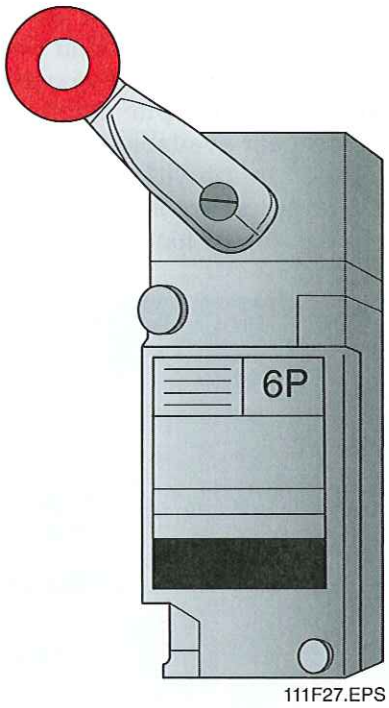

Figure 27 ◆ Limit switch.

THINK ABOUT IT

Relays

Relays are very common switching controls that we take for granted. You often use relays (either directly or indirectly) in your everyday life. What examples can you think of?

8.0.0 ◆ POWER DISTRIBUTION EQUIPMENT

In residential wiring, power distribution equipment is usually limited to a breaker panel or fuse panel. Modern panels contain the main and branch circuit breakers in one relatively small enclosure. Industrial and commercial wiring calls for distribution equipment that is usually much larger.

Due to the high amount of load current and higher voltages found in large facilities, the main circuit breaker itself may be larger than the average refrigerator. This main breaker may feed a step-down transformer, which in turn feeds feeder circuit breakers. Power is distributed from the feeder breakers to the required loads. This configuration (main breaker, transformer, and feeder breakers) may be repeated at more than one location, depending on the size of the facility.

Distribution equipment, commonly referred to as **switchgear,** may be comprised of individually enclosed and mounted devices that are wired together, or it may all be included in one enclosure, as shown in *Figure 28*. Despite the many configurations of switchgear available, the purpose is always the same: to provide a safe system of controlling a large power source and supplying this power to the remote loads where it is needed.

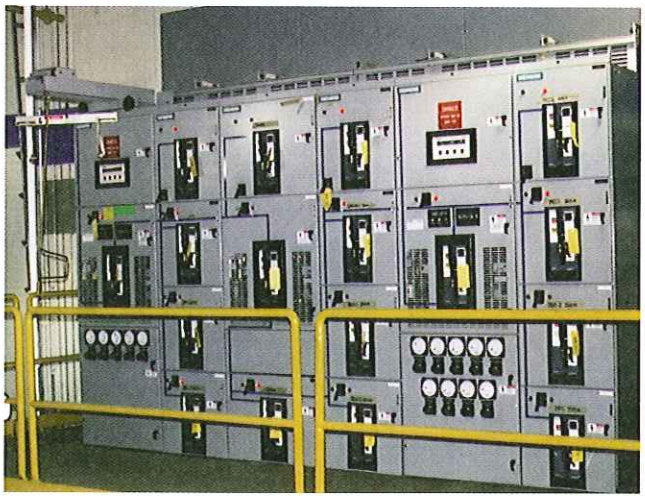

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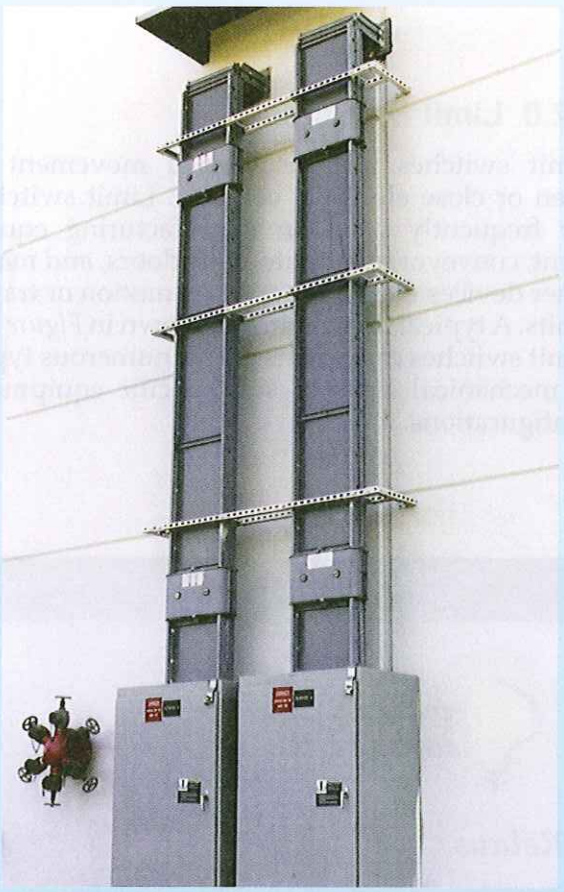
Figure 28 ◆ Switchgear.

INSIDE TRACK

Minimizing Conduit for Large Service Entrances

The large industrial plant shown here uses busduct at the service entrance rather than conduit. It provides a nicer appearance as well as minimizes the time required for installation and the space needed for the service entrance conductors. If this industrial service used standard conduit, it would take up several times the space of the copper busduct used here.



111P1108.EPS

THINK ABOUT IT

Putting It All Together

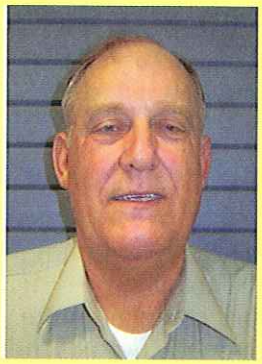
Think about the use of various devices in two vastly different applications, such as a hospital and a small office building. How do you imagine the installations will be similar?

Summary

Wiring and installing wiring devices will make up a large portion of your job as an electrician. Knowing how to relate the rules and regulations in the *NEC*® to your job will improve your skills and ensure that the devices are installed properly.

Notes

Profile in Success



John Autrey

Trident Technical College

What positions have you held in the industry?

I made a career of the U.S. Navy and retired after 28 years of service. While in the Navy, I maintained complex electromechanical and electronic systems, taught electrical/electronics courses in Navy vocational schools, got progressively more responsibilities, and was ultimately commissioned a Chief Warrant Officer. In this capacity, I managed the repair and troubleshooting efforts of 125 technicians in thirteen separate shops at an ashore repair facility and was the electrical/electronics repair officer on surface ships. After retiring from the U.S. Navy in 1992, I obtained a master electrician and an electrical contractor's license in South Carolina and did various contracting work. In 1996, I was hired by Trident Technical College as the Program Coordinator for the Industrial Electricity and Electronics Program. Additionally, I'm a certified NCCER Master Trainer, Electrical craft instructor, and serve as an SME on NCCER's Electrical Committee.

What would you say is the primary factor in achieving success?

Truly enjoying your work and having confidence in your abilities and competence in your actions.

What does your current job involve?

I'm responsible for all aspects of the program curriculum, scheduling, and sequencing of classes, student advisement, and liaison with industry for both generalized and specialized electrical/electronic training for their maintenance technicians.

Do you have any advice for someone just entering the trade?

Do the very best job you're capable of instead of the bare minimum. Don't be afraid to ask questions and take every opportunity to enhance or advance your knowledge. In short, be professional in your work and your outlook.

Trade Terms Introduced in This Module

Attachment plug (plug cap): A device which, by insertion in a receptacle, establishes a connection between the conductors of the attached flexible cord and the conductors connected permanently to the receptacle.

Branch circuit: The circuit conductors between the final overcurrent device protecting the circuit and the outlet(s).

Disconnecting means: A device, group of devices, or other means by which the conductors of a circuit can be disconnected from their source of supply.

Grounding: The process of connecting noncurrent-carrying metal parts of equipment to earth to provide an intentional path for fault current.

Limit switch: A type of pilot device that uses a mechanical movement to open or close electrical contacts.

Outlet: A point on a wiring system at which current is taken to supply utilization equipment.

Pilot device: Any of several types of electrical switches that are actuated by air pressure, temperature, level, or other mechanical or electrical means. These devices are wired to energize relays, which in turn connect power to larger loads.

Polarized: A physical difference between the grounded and positive and negative poles of a plug or receptacle. The difference is accomplished by making the grounded (neutral) blade of a plug larger than the ungrounded blade. The purpose of polarizing is to ensure that the grounded lead of a plug-and-cord assembly cannot be connected to the ungrounded terminal of a receptacle.

Receptacle: A contact device installed at the outlet for the connection of a single attachment plug.

Receptacle outlet: An outlet in which one or more receptacles are installed.

Relay: An electromagnetic switch for controlling one or more separate circuits remotely by applying voltage to the coil. Contacts attached to a moving plunger are connected to, or disconnected from, stationary contacts as the plunger is pulled by the magnetic field of the energized coil.

Switchgear: A term used for a wide variety of enclosed circuit breakers, disconnects, busways, and associated items that distribute power from a common point.

Additional Resources

This module is intended to present thorough resources for task training. The following reference work is suggested for further study. This is optional material for continued education rather than for task training.

National Electrical Code® Handbook, Latest Edition. Quincy, MA: National Fire Protection Association.

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Instructors – If you found that additional materials were necessary in order to teach this module effectively, please let us know so that we may include them in the Equipment/Materials list in the Annotated Instructor's Guide.

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