Conductors
26109-05

Legends Field

Located in Tampa, Florida, Legends Field is the spring training home of the New York Yankees. It is a 31-acre complex that seats 10,000 and was built to the same dimensions as Yankee Stadium. Knowing that the lighting they were creating would play a tremendous role in the presentation of America's favorite pastime, all the electricians working at Legends Field took personal interest in the project.

26109-05
Conductors

Topics to be presented in this module include:

Overview

A conductor is the current-carrying portion of a wire along with its insulation. Electricians spend much of their time installing conductors. Conductors must be selected and installed very carefully. Since conductors carry current, they must be rated for the amount of current they will carry. This is referred to as a conductor's ampacity. If too small a conductor is installed, the conductor can become hot and ignite, which is the major cause of electrical fires. If a conductor's insulation is damaged during installation, the flow of current can take an unintended path back to its source, creating a shorted or ground fault circuit.

When selecting the right conductor for the job, electricians are faced with many options, including conductor material, ampacity, type of insulation, and color-coding. The *National Electrical Code*® regulates the color of conductors that may be used as grounding or grounded conductors. Regional standards may regulate the color of other conductors.

Quality installation of conductors depends on using the right tool for the situation. The installation of large conductors in enclosed raceways sometimes requires power-driven equipment. Smaller conductors can be installed manually using a common tool called a fish tape. Conductor installation can be dangerous, and electricians must take necessary safety precautions. Conductor installations must be planned carefully to complete the job properly and without injury.

Note: *National Electrical Code*® and *NEC*® are registered trademarks of the National Fire Protection Association, Inc., Quincy, MA 02269. All *National Electrical Code*® and *NEC*® references in this module refer to the 2005 edition of the *National Electrical Code*®.

Objectives

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

1. Explain the various sizes and gauges of wire in accordance with American Wire Gauge standards.
2. Identify insulation and jacket types according to conditions and applications.
3. Describe voltage ratings of conductors and cables.
4. Read and identify markings on conductors and cables.
5. Use the tables in the *National Electrical Code*® to determine the ampacity of a conductor.
6. State the purpose of stranded wire.
7. State the purpose of compressed conductors.
8. Describe the different materials from which conductors are made.
9. Describe the different types of conductor insulation.
10. Describe the color coding of insulation.
11. Describe instrumentation control wiring.
12. Describe the equipment required for pulling wire through conduit.
13. Describe the procedure for pulling wire through conduit.
14. Install conductors in conduit.
15. Pull conductors in a conduit system.

Trade Terms

Ampacity	Mouse
Capstan	Wire grip
Fish tape	

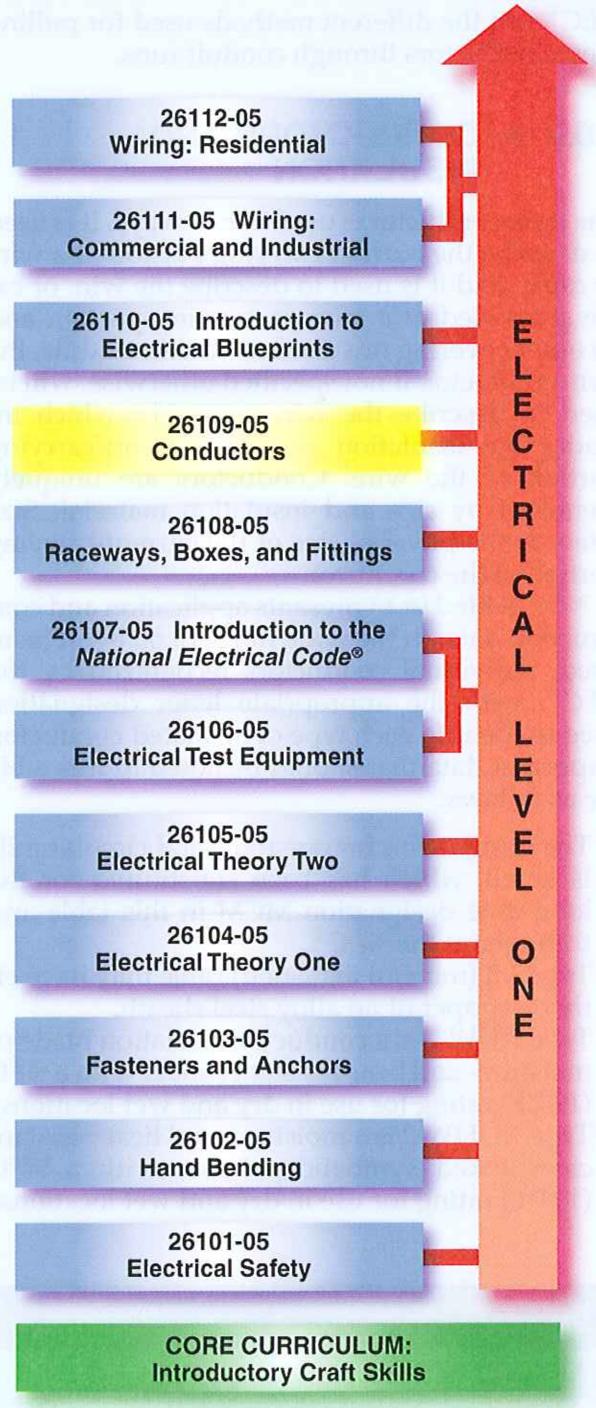
Required Trainee Materials

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 26108-05.

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, you will be required to select the proper wire and/or cable for a job. You will also be required to pull this wire or cable through conduit runs in order to terminate it. This module will examine the different types of conductors and conductor insulation. It will also examine how these conductors are rated and classified by the *NEC®* and the different methods used for pulling these conductors through conduit runs.

2.0.0 ◆ CONDUCTORS AND INSULATION

The term conductor is used in two ways. It is used to describe the current-carrying portion of a wire or cable, and it is used to describe the wire or cable composed of a current-carrying portion and an outer covering (insulation). In this module, the term conductor, if not specified otherwise, will be used to describe the wire assembly, which includes the insulation and the current-carrying portion of the wire. Conductors are uniquely identified by size and insulation material. Size refers to the physical size of the current-carrying portion of the conductor.

NEC Table 310.13 presents application and construction data on the wide range of 600-volt insulated, individual conductors recognized by the *NEC®*, with the appropriate letter designation used to identify each type of insulated conductor. Important data that should be noted in this table are as follows:

- The designation for one thousand circular mils is kcmil, which has been substituted for the long-time designation MCM in this table and throughout the *NEC®*.
- Type MI (mineral insulated) cable may have either a copper or an alloy steel sheath.
- Type RHW-2 is a conductor insulation made of moisture- and heat-resistant rubber with a 90°C (194°F) rating for use in dry and wet locations.
- Type XHHW-2 is a moisture- and heat-resistant cross-linked synthetic polymer with a 90°C (194°F) rating for use in dry and wet locations.
- The suffix LS designates a conductor insulation as low-smoke producing and flame retardant. For example, Type THHN/LS is a THHN conductor with a limited smoke-producing characteristic.
- Type THHW is a moisture- and heat-resistant insulation rated at 75°C (167°F) for wet locations and 90°C (194°F) for dry locations. This is similar to THWN and THHN without the outer nylon covering but with thicker insulation.
- All insulations using asbestos have been deleted from *NEC Table 310.13* because they are no longer made.

2.1.0 Ampacity

Ampacity is the current in amperes a conductor can carry continuously under the conditions of use without exceeding its temperature rating. The ampacity of conductors for given conditions of use are listed in *NEC Tables 310.16 through 310.19.*

2.1.1 NEC® Ampacity Tables

NEC Table 310.16 covers conductors rated up to 2,000 volts where not more than three conductors are installed in a raceway or cable or are directly buried in the earth, based on an ambient temperature of 30°C (86°F).

NEC Table 310.17 covers both copper conductors and aluminum or copper-clad aluminum conductors up to 2,000 volts where conductors are used as single conductors in free air, based on an ambient temperature of 30°C (86°F).

NEC Tables 310.18 and 19 apply to conductors rated at 150°C to 250°C (302°F to 482°F), used either in raceway or cable or as single conductors in free air, based on an ambient temperature of 40°C (104°F).

Example:

Determine the ampacity of a No. 12 Cu (copper) THW conductor.

Solution:

25 amps (from *NEC Table 310.16*).

THINK ABOUT IT

Overheating

What happens when insulation is overheated? What affects the ampacity of an insulated conductor?

2.2.0 Underground

Any conductor used in a wet location (see definition under Location, Wet, in *NEC Article 100*) must be designated as suitable for wet locations. Any conduit run underground is assumed to be subject to water infiltration and is, therefore, in a wet location, requiring the use of only the listed conductor types.

2.2.1 Direct Burial

Direct burial conductors should be trench-laid without crossovers; slightly snaked to allow for possible earth settlement, movement, or heaving due to frost action; and have cushions and covers of sand or screened fill to protect conductors against sharp objects in trenches or backfill.

2.3.0 Wire Size

Wire sizes are expressed in gauge numbers. The standard system of wire sizes in the United States is the American Wire Gauge (AWG) system.

2.3.1 AWG System

The AWG system uses numbers to identify the different sizes of wire and cable (*Figure 1*). The larger the number, the smaller the cross-sectional area of the wire. The larger the cross-sectional area of the current-carrying portion of a conductor, the higher the amount of current the wire can conduct. The AWG numbers range from 50 to 1; then 0, 00, 000, and 0000 (one aught [1/0], two aught [2/0], three aught [3/0], and four aught [4/0]). Any wire larger than 0000 is identified by its area in circular mils. Wire sizes smaller than No. 18 AWG are usually solid, but may be stranded in some cases. Wire sizes of No. 6 AWG or larger are stranded.

For wire sizes larger than No. 16 AWG, the wire size is marked on the insulation (*Figure 2*).

NEC Chapter 9, Table 8 has descriptive information on wire sizes. Again, note that all wires smaller than No. 6 are available as solid or stranded. Wire sizes of No. 6 or larger are shown only as stranded. Solid wire larger than No. 6 is manufactured; however, the *NEC*® only permits the use of solid wire in a raceway for sizes smaller than No. 8 (*NEC Section 310.3*).

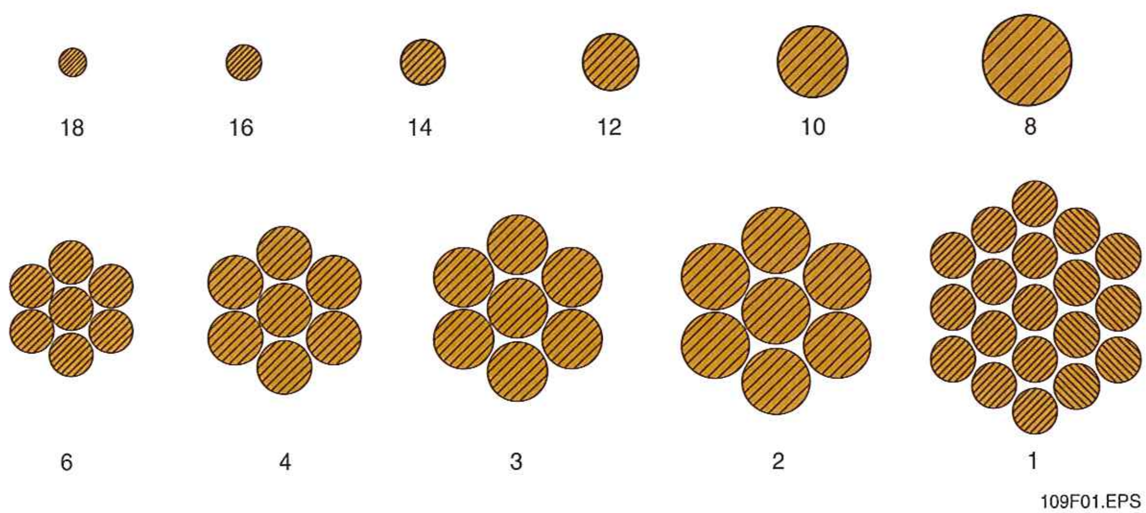

Figure 1 ◆ Comparison of wire sizes (enlarged) from No. 18 to No. 1 AWG.

THINK ABOUT IT

Wire Size

Why is wire size a critical factor in a wiring system? Other than load, what other factors may dictate wire size? What can happen when a wire isn't properly sized for the load?

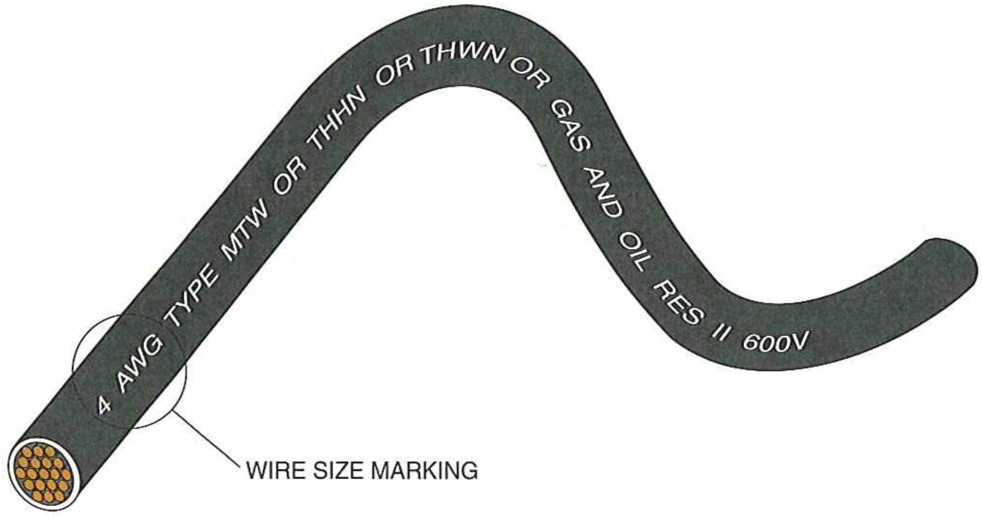

Figure 2 ◆ Wire size marking.

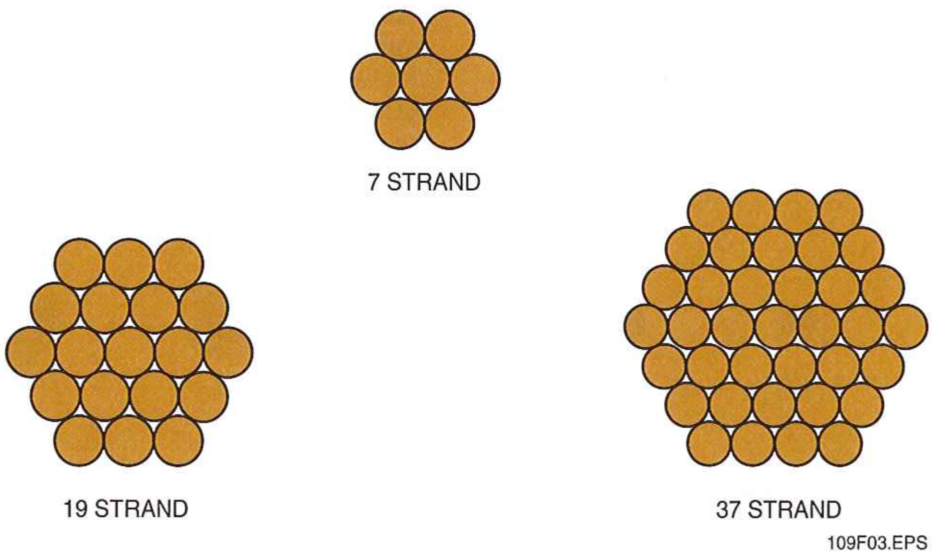

Figure 3 ◆ Strand configurations.

2.3.2 Stranding

According to *NEC Chapter 9, Table 8,* wire sizes No. 18 to No. 2 have seven strands; wire sizes No. 1 to No. 4/0 have 19 strands; and wire sizes between 250 kcmil and 500 kcmil have 37 strands. The purpose of stranding is to increase the flexibility of the wire. Terminating solid wire sizes larger than No. 8 in pull boxes, disconnect switches, and panels would not only be very difficult, but might also result in damage to equipment and wire insulation.

Pulling solid wire in conduit around bends could pose a major problem and cause damage to equipment for wire sizes larger than No. 8. The reason for choosing 7, 19, and 37 strands for stranded conductors is that it is necessary to provide a flexible, almost round conductor. In order for a conductor to be flexible, individual strands must not be too large. *Figure 3* shows how these conductors are configured.

2.3.3 Compact Conductors

A relatively new entry in the scheme of conductors is compact aluminum or copper conductors (*Figure 4*). Compact conductors are those that have been compressed to reduce the air space between the strands.

The purpose of a compact conductor is to reduce the overall diameter of the cable so that it may be installed in a conduit that is smaller than that required for standard conductors of the same wire size. Compact conductors are especially useful when increasing the ampacity of an existing service.

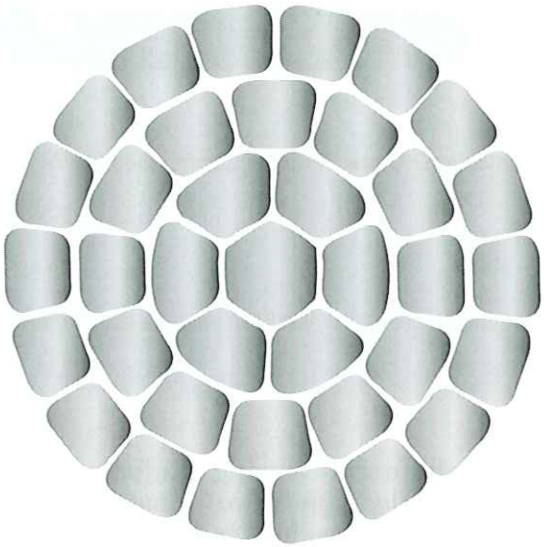

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Figure 4 ◆ Compact conductor.

2.3.4 Circular Mils

A circular mil is a circle that has a diameter of 1 mil. A mil is 0.001 inch. When a wire size is 250 kcmil, the cross-sectional area of the current-carrying portion of the wire is the same as 250,000 circles having a diameter of 0.001 inch. This may seem to be a rather clumsy way of sizing wire at first; however, the alternative would be to size the wire as a function of its cross-sectional area expressed in square inches.

According to *NEC Chapter 9, Table 8,* the cross-sectional area of a 250 kcmil conductor is 0.260 square inch.

If a conductor is to be sized by cross-sectional area, it is much easier to express the wire size in circular mils (or thousands of circular mils) than in square inches.

2.4.0 Conductor Material

The most common conductor material is copper. Copper is used because of its excellent conductivity (low resistance), ease of use, and value. The value of a material as an ingredient for wire is determined by several factors, including conductivity, cost, availability, and workability.

2.4.1 Conductivity

Conductivity is a word that describes the ease (or difficulty) of travel presented to an electric current by a conductor. If a conductor has a low resistance, it has a high conductivity. Silver is one of the best conductors since it has very low resistance and high conductivity. Copper has high conductivity and a lower price than silver. Aluminum, another material with good conductivity, is also a good choice for conductor material. The conductivity of aluminum is approximately two-thirds that of copper.

2.4.2 Cost

Cost is always an issue that contributes to the selection of a material to be used for a given application. Often, a material that has low cost may be selected as a conductor material even though it has physical properties that are inferior to the more expensive material. Such is the case in the selection of copper over platinum. Here, the cost of platinum is very high, and very little thinking is required to determine that copper is a better choice. The choice between copper and aluminum is often more difficult to make.

2.4.3 Availability

The availability of some material is often a concern when selecting components for a job. As applied to wire, the mining industry often controls the availability of raw materials, which could produce shortages of some material. The availability of a substance such as copper or aluminum affects the price of the finished product (copper or aluminum wire).

2.4.4 Workability

It is a good idea to select a material that requires less expense for tools and is easier to work with. Aluminum conductors are lighter than copper conductors of the same size. They are also much more flexible than copper conductors and, in general, are easier to work with. However, terminating aluminum conductors often requires special

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Terminating Aluminum Wire

Care must be taken to use listed connectors when terminating aluminum wire. All aluminum connections also require the use of anti-oxidizing compound. Some connectors are precoated with compound; others require the addition of it. Be sure to check the connectors before beginning the installation.

THINK ABOUT IT

Conductor Insulation

What are the functions of conductor insulation? Under what conditions does the *NEC*® allow uninsulated conductors?

Insulation Types

Use *NEC Table 310.13* to identify two types of insulation that are suitable for use in wet locations.

tools and treatment of termination surfaces with an anti-oxidation material. Splicing and terminating aluminum conductors often requires a higher degree of training on the part of the electrician than do similar efforts with copper wire. This is partly due to the fact that aluminum expands and contracts with heat more than copper.

2.5.0 Conductor Insulation

The first attempt to insulate wire was made in the early 1800s during the development of the telegraph. This insulation was designed to provide physical protection rather than electrical protection. Electrical insulation was not an important issue because the telegraph operated at low-voltage DC. This early form of insulation was a substance composed of tarred hemp or cotton fiber and shellac and was used primarily for weatherproofing long-distance distribution lines to mines, industrial sites, and railroads.

Some early electrical distribution systems utilized the knob-and-tube technique of installing wire. The wire was often bare and was pulled between and wrapped around ceramic knobs that were affixed to the building structure. When it was necessary to pull wire through structural members, it was pulled through ceramic tubes. The structural member (usually wood) was drilled, the tube was pressed into the hole, and the wire was pulled through the hole in the tube. As dangerous as this may appear, older homes still exist that have knob-and-tube wiring that was installed in the early 1900s and is still operational. Knob-and-tube wiring was revised to use insulated conductors and was in use up to 1957 in some areas.

The grounded or neutral conductor in overhead services may be bare. Furthermore, the concentric grounded conductor in Type SE cable may be bare when used as a service-entrance cable. However, all current-carrying conductors (including the grounded conductor) must be insulated when used on the inside of buildings, or after the first overcurrent protection device.

2.5.1 Thermoplastic

Thermoplastic is a popular and effective insulation material used on conductors for the present-day market. The following thermoplastics are widely used as insulation materials:

- *Polyvinyl chloride (PVC)* – The base material used for the manufacture of TW and THW insulation.
- *Polyethylene (PE)* – An excellent weatherproofing material used primarily for insulation of control and communications wiring. It is not used for high-voltage conductors (those exceeding 5,000 volts).
- *Cross-linked polyethylene (XLP)* – An improved PE with superior heat- and moisture-resistant qualities. Used for THHN, THWN, and XHHW wiring as well as most high-voltage cables.
- *Nylon* – Primarily used as jacketing material. THHN building wire has an outer coating of nylon.
- *Teflon*® – A high-temperature insulation. Widely used for telephone wiring in a plenum (where other insulated conductors require conduit routing).

2.5.2 Letter Coding

Conductor insulation as applied to building wire is coded by letters. The letters generally, but not always, indicate the type of insulation or its environmental rating. The types of conductor insulation described in this module will be those indicated at the top of *NEC Table 310.16.* The various insulation designations are:

Letter	Description
B	Braid
E	Ethylene or Entrance
F	Fluorinated or Feeder
H	Heat-Rated or Flame-Retardant
N	Nylon
P	Propylene
R	Rubber
S	Silicon or Synthetic
T	Thermoplastic
U	Underground
W	Weather-Rated
X	Cross-Linked Polyethylene
Z	Modified Ethylene Tetrafluoroethylene
TW	Weather-Rated Thermoplastic (60°C/140°F)
FEP	Fluorinated Ethylene Propylene
FEPB	Fluorinated Ethylene Propylene with Glass Braid
MI	Mineral Insulation
MTW	Moisture, Heat, and Oil-Resistant Thermoplastic
PFA	Perfluoroalkoxy
RH	Heat-Rated Rubber (75°C/167°F)
RHH	Flame-Retardant Heat-Rated Rubber
RHW	Weather-Rated, Heat-Rated Rubber (75°C/167°F)
SA	Silicon
SIS	Synthetic Heat-Resistant
TBS	Thermoplastic Braided Silicon
TFE	Extended Polytetrafluoroethylene
THHN	Heat-Resistant Thermoplastic
THHW	Moisture and Heat-Resistant Thermoplastic
THW	Moisture and Heat-Resistant Thermoset
THWN	Weather-Rated, Heat-Rated Thermoplastic with Nylon Cover
UF	Underground Feeder
USE	Underground Service Entrance
XHH	Thermoset
XHHW	Heat-Rated, Flame-Retardant, Weather-Rated Thermoset
ZW	Weather-Rated Modified Ethylene Tetrafluoroethylene

2.5.3 Color Coding

A color code is used to help identify wires by the color of the insulation. This makes it easier to install and properly connect the wires. A typical color code is as follows:

- *Two-conductor cable* – One white or gray wire, one black wire, and a grounding wire (usually bare)
- *Three-conductor cable* – One white or gray, one black, one red, and a grounding wire
- *Four-conductor cable* – Same as three-conductor cable plus fourth wire (blue)
- *Five-conductor cable* – Same as four-conductor cable plus fifth wire (yellow)

The grounding conductor may be bare, green, or green with a yellow stripe. Color codes are shown in *Figure 5.*

The *NEC®* does not require color coding of ungrounded conductors except where more than one nominal voltage system is present [*NEC Section 210.5(C)*]. The ungrounded conductors may be any color with the exception of white, gray, or green; however, it is a good practice to color code conductors as described here. In fact, many construction specifications require color coding. Furthermore, on a four-wire, delta-connected secondary where the midpoint of one

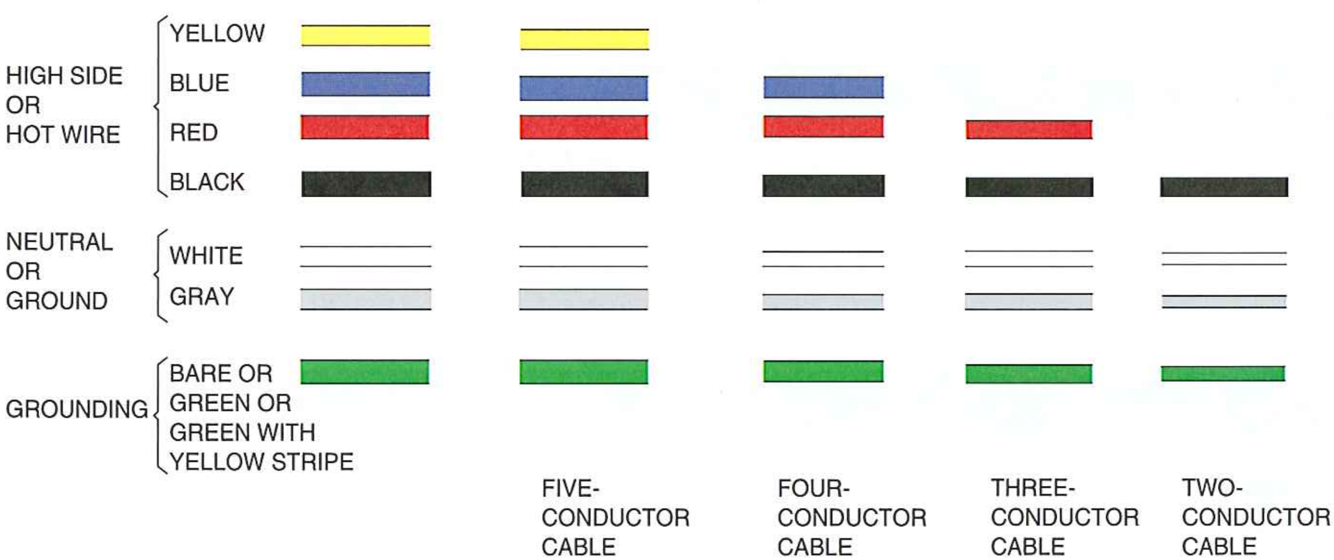

Figure 5 ◆ Typical insulation color codes.

phase is grounded to supply lighting and similar loads, the phase conductor having the higher voltage to ground must be identified by an outer finish that is orange in color, by tagging, or by other effective means. Such identification must be placed at each point where a connection is made if the grounded conductor is also present. In most cases, orange tape is used at all termination points when such a condition exists.

2.5.4 Wire Ratings

Conductor selection is based largely on the temperature rating of the wire. This requirement is extremely important and is the basis of safe operation for insulated conductors. As shown in *NEC Table 310.13,* conductors have various ratings (60°C, 75°C, 90°C, etc.). Since *NEC Tables 310.16 through 310.19* are based on an assumed ambient temperature of 30°C (86°F), conductor ampacities are based on the ambient temperature plus the heat (I^2R) produced by the conductor while carrying current. Therefore, the type of insulation used on the conductor is the first consideration in determining the maximum permitted conductor ampacity.

For example, a No. 3/0 THW copper conductor for use in a raceway has an ampacity of 200 according to *NEC Table 310.16.* In a 30°C ambient temperature, the conductor is subjected to this temperature when it carries no current. Since a THW-insulated conductor is rated at 75°C, this leaves 45°C (75 − 30) for increased temperature due to current flow. If the ambient temperature exceeds 30°C, the conductor maximum load-current rating must be reduced proportionally (see Correction Factors at the bottom of *NEC Table 310.16*) so that the total temperature (ambient plus conductor temperature rise due to current flow) will not exceed the temperature rating of the conductor insulation (60°C, 75°C, etc.). For the same reason, the allowable ampacity must be reduced when more than three conductors are contained in a raceway or cable. See *NEC Section 310.15(B)(2).*

Using the ampacity tables—An important step in circuit design is the selection of the type of conductor to be used (TW, THW, THWN, RHH, THHN, XHHW, etc.). The various types of conductors are covered in *NEC Article 310,* and the ampacities of conductors are given in *NEC Tables 310.16 through 310.19* for the varying conditions of use (e.g., in a raceway, in open air, at normal or higher-than-normal ambient temperatures). Conductors must be used in accordance with the data in these tables and notes.

2.6.0 Fixture Wires

Fixture wire is used for the interior wiring of fixtures and for wiring fixtures to a power source. Guidelines concerning fixture wire are given in *NEC Article 402.* The list of approved types of fixture wire is given in *NEC Table 402.3. Figure 6* shows one example of fixture wire. The wires are composed of insulated conductors with or without an outer jacket. The conductors range in size from No. 18 to No. 10 AWG.

The decision of which fixture wire to use depends primarily upon the operating temperature that is expected within the fixture. Therefore, it is the character of the insulation that will determine the wire selected. For instance, fixture wires insulated with perfluoroalkoxy (PFA) or extruded polytetrafluoroethylene (PTF) would be selected if the operating temperature of the fixture is expected to reach a maximum of 482°F. This is the highest operating temperature allowed for any fixture wire.

THINK ABOUT IT

Color Coding Ungrounded Conductors

Although the *NEC*® does not require the use of color-coded ungrounded current-carrying conductors, why might it be a good idea to use them anyway?

INSIDE TRACK

Color Coding

Color designations are good indicators, but never trust your life to them. Always protect yourself by testing circuits with a voltmeter.

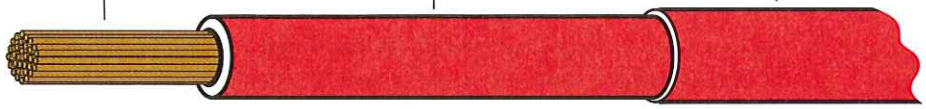

Figure 6 ◆ Fixture wire.

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As indicated by *NEC Section 402.3,* fixture wires are suitable for service at 600 volts unless otherwise specified in *NEC Table 402.3.* The allowed ampacities of fixture wire are given in *NEC Table 402.5.*

Although the primary use for fixture wire is the internal wiring of fixtures, several of the wires listed in *NEC Table 402.3* may be used for wiring remote-control, signaling, or power-limited circuits in accordance with *NEC Section 725.15.* Fixture wires may never be used as substitutes for branch circuit conductors.

2.6.1 Heating Cables

Heating cables are another important group of special wires that are commonly used in the building industry. The purpose of these cables is to produce heat when energized. There are three general categories of heating cables:

- Interior space-heating cables
- De-icing and snow-melting cables
- Pipeline and vessel heating cables

These heating cables consist of a long insulated wire, cabled heating wire, or resistance wire, which produces heat in the wire when it is connected to a power source. The ends of the resistance wire are connected to non-heating lead wires, which extend to a thermostat or junction box.

Guidelines pertaining to heating cable used for interior space heating are given in *NEC Article 424.* The *NEC®* considers the term heating equipment to include any factory-manufactured heating devices such as unit heaters, boilers, and local heating systems, as well as heating cables. Heating cables are specifically covered in *NEC Article 424, Part V.*

Heating cables meant for installation in ceilings are available from the factory in unit lengths from 75 to 1,800 feet, capacities ranging from 200 to 5,000 watts, and voltage ratings of 120, 208, and 240 volts. The cables are usually rated at 2¾ watts per linear foot. The nonheating lead wires are at least seven feet in length and are color coded to indicate the voltage rating. The insulation on the heating wire is designed to be resistant to high temperatures, water absorption, aging, and chemical action.

Heating cables meant for installation in floors have capacities that vary with the cable dimensions and heating wire resistance. They are typically rated at voltages from 120 to 600 volts. There are two popular floor heating cables. In the first type, the resistance wire is covered with a sheath of polyvinyl chloride (PVC). In the second, the resistance wire is encased in a mineral insulation and then covered with a copper sheath. This construction is identical to that of Type MI (mineral-insulated, metal-sheathed cable). In contrast to ceiling heating cables, which are available in specific unit lengths, these heating cables are sold in random lengths, which must be cut and properly terminated at the job site according to the job's heating requirements.

NEC Article 424, Part V specifies guidelines for installing floor and ceiling heating cables; it should be read carefully. Generally, ceiling heating cables are stapled to the ceiling with at least 1½ inches between adjacent runs. According to the *NEC®*, the cables must not come within eight inches of recessed lighting fixtures or within six inches of other metallic materials in the ceiling. Floor heating cables are usually embedded in concrete, with at least a one-inch space between adjacent runs of cable. Spacing must also be maintained between the cable and other metallic objects in the floor, unless a grounded metal-clad cable is used.

Guidelines pertaining to de-icing and snow-melting cables are given in *NEC Article 426.* These cables are similar in construction to interior floor heating cables in that they consist of resistance wires insulated with a sheath of PVC or with mineral insulation and a copper sheath. Most de-icing and snow-melting cables are installed by embedding them in concrete or asphalt. As with floor heating cables, these cables are rated at various voltages and must be cut to the desired length.

Guidelines pertaining to pipeline and vessel heating cables are given in *NEC Article 427.* These cables are generally available in two types of construction. The cable can either be insulated resistance wire with nonheating lead wires attached to each end, or it can be in the form of a flat heating tape. The tape consists of a single piece of heating wire doubled over so that the halves of

INSIDE TRACK

Cable Selection

There are two factors to be considered when determining the type of cable to be used for a specific application: the type of conductor insulation and the cable jacket. Both must be appropriate for the application.

the wire run parallel to each other. The wire is encased in a plastic enclosure, thus producing an assembly that resembles a tape. The nonheating lead wires are attached to the open end of the tape.

The obvious purpose of pipeline and vessel heating cables is to prevent the fluid in the pipeline or vessel from falling below a specified minimum temperature. Flat heating tapes are often used in buildings under construction or not completely enclosed. They can be used on water pipes to keep the water from freezing in cold weather.

2.7.0 Cables

Cables are two or more insulated wires and may contain a grounding wire covered by an outer jacket or sheath. Cable is usually classified by the type of covering it has, either nonmetallic (i.e., plastic) or metallic, also called armored cable.

Cable may also be classified according to where it can be used (see *NEC Table 400.4*). Because water is such a good conductor of electricity, moisture on conductors can cause power loss or short circuits. For this reason, cables are classified for either dry, damp, or wet locations. Cables can also be classified regarding exposure to sunlight and rough use.

2.7.1 Cable Markings

All cables are marked to show important properties and uses. Cable markings show the wire size, number of conductors, cable type, and voltage rating. In addition, a marking may be included to signify approved service or applications. This information is printed on nonmetallic cable (*Figure 7*). On metallic cable, marking information is usually included on a tag.

2.7.2 Nonmetallic-Sheathed Cable

Nonmetallic-sheathed cable (Type NM and Type NMC) is widely used for branch circuits and feeders in residential and commercial systems. See *Figure 8*. Both types are commonly called Romex®, even though the cable manufacturer only calls Type NM cable Romex®. Guidelines for

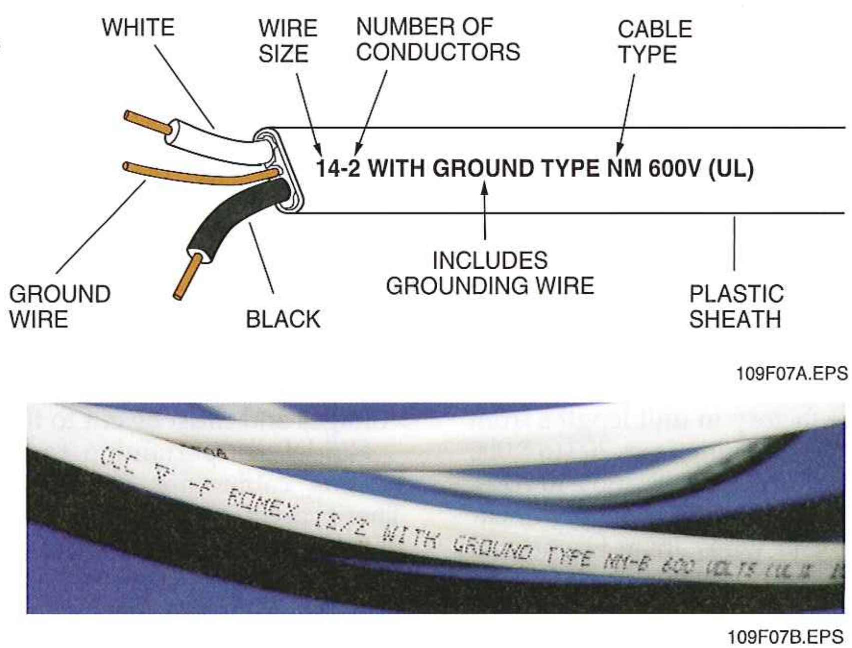


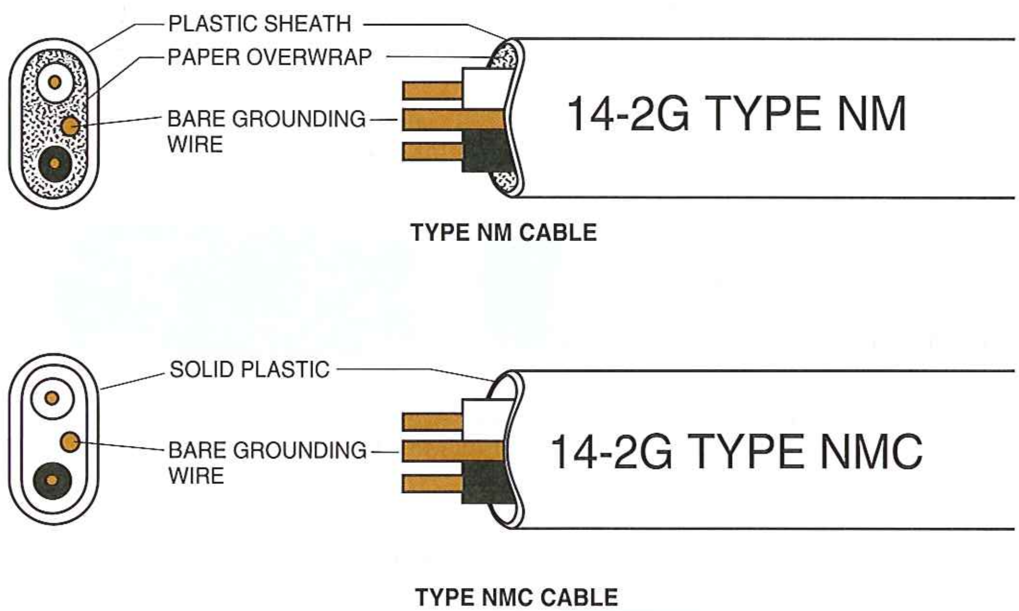
Figure 7 ◆ Nonmetallic cable markings.

the use of nonmetallic-sheathed cable are given in *NEC Article 334.* This cable consists of two or three insulated conductors and one bare conductor enclosed in a nonmetallic sheath. The conductors may be wrapped individually with paper, and the spaces between the conductors may be filled with jute, paper, or other material to protect the conductors and help the cable keep its shape. The sheath covering both Type NM cable and Type NMC cable is flame-retardant and moisture-resistant. The sheath covering Type NMC cable has the additional characteristics of being fungus- and corrosion-resistant.

NEC Article 334 lists the allowed and prohibited uses for Type NM cable and Type NMC cable. Both are allowed to be installed in either exposed or concealed work. The primary difference in their applied uses is that Type NM cable is suitable for dry locations only, whereas Type NMC is permitted for dry, moist, damp, or corrosive locations. Since you will probably work with these two cables often, read *NEC Article 334* carefully.

Guidelines for the use of Type SE (service-entrance) cable are given in *NEC Article 338.* The *NEC*® contains no specifications for the construction of this cable; it is left to UL to determine what types of cable should be approved for this purpose. Currently, service-entrance cable is labeled in sizes No. 12 AWG and larger for copper, and No. 10 AWG and larger for aluminum or copper-clad aluminum, with Types RH, RHW, RHH, or XHHW conductors. If the type designation for the conductor is marked on the outside surface of the cable, the temperature rating of the cable corresponds to the rating of the individual conductor. When this marking does not appear, the temperature rating of the cable is 75°C (167°F). Type SE cable is for above-ground installation.

When used as a service-entrance cable, Type SE must be installed as specified in *NEC Article 230.*



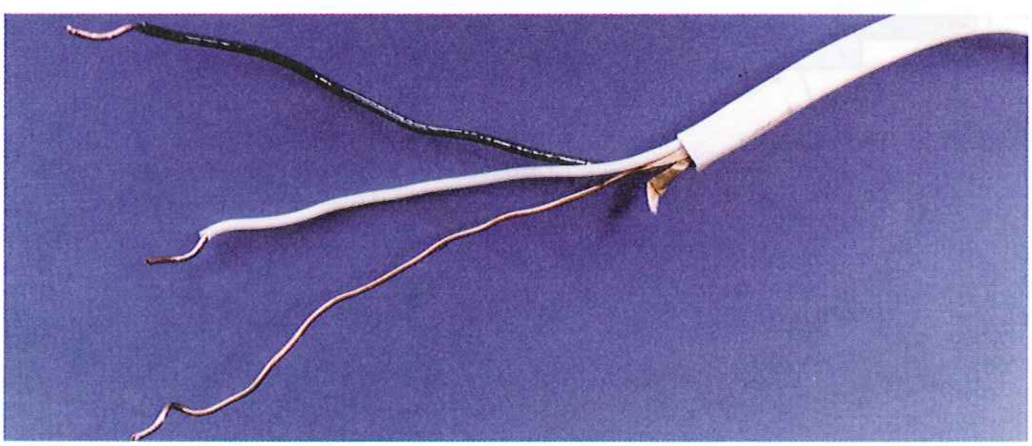


Figure 8 ◆ Nonmetallic-sheathed cable.

Service-entrance cable may also be used as feeder and branch circuit cable. Guidelines for the use of service-entrance cable are given in *NEC Section 338.10.*

2.7.3 Type UF Cable

Guidelines for the use of Type UF (underground feeder and branch circuit) cable are given in *NEC Article 340.* Type UF cable is very similar in appearance, construction, and use to Type NMC cable. The main difference between these two cables is that Type UF cable is suitable for direct burial, whereas Type NMC cable is not.

2.7.4 Type NMS Cable

Refer to *NEC Sections 334.10 and 334.12* for the applications of Type NMS cable. Type NMS cable is a form of nonmetallic-sheathed cable that contains a factory assembly of power, communications, and signaling conductors enclosed within a moisture-resistant, flame-retardant sheath.

2.7.5 Type MV Cable

Type MV (medium-voltage) cable is covered in *NEC Article 328.* It consists of one or more insulated conductors encased in an outer jacket. This cable is suitable for use with voltages ranging from 2,001 to 35,000 volts. It may be installed in wet and dry locations and may be buried directly in the earth.

2.7.6 High-Voltage Shielded Cable

Shielding of high-voltage cables protects the conductor assembly against surface discharge or burning due to corona discharge in ionized air, which can be destructive to the insulation and jacketing.

Electrostatic shielding of cables makes use of both nonmetallic and metallic materials (*Figures 9* and *10*).

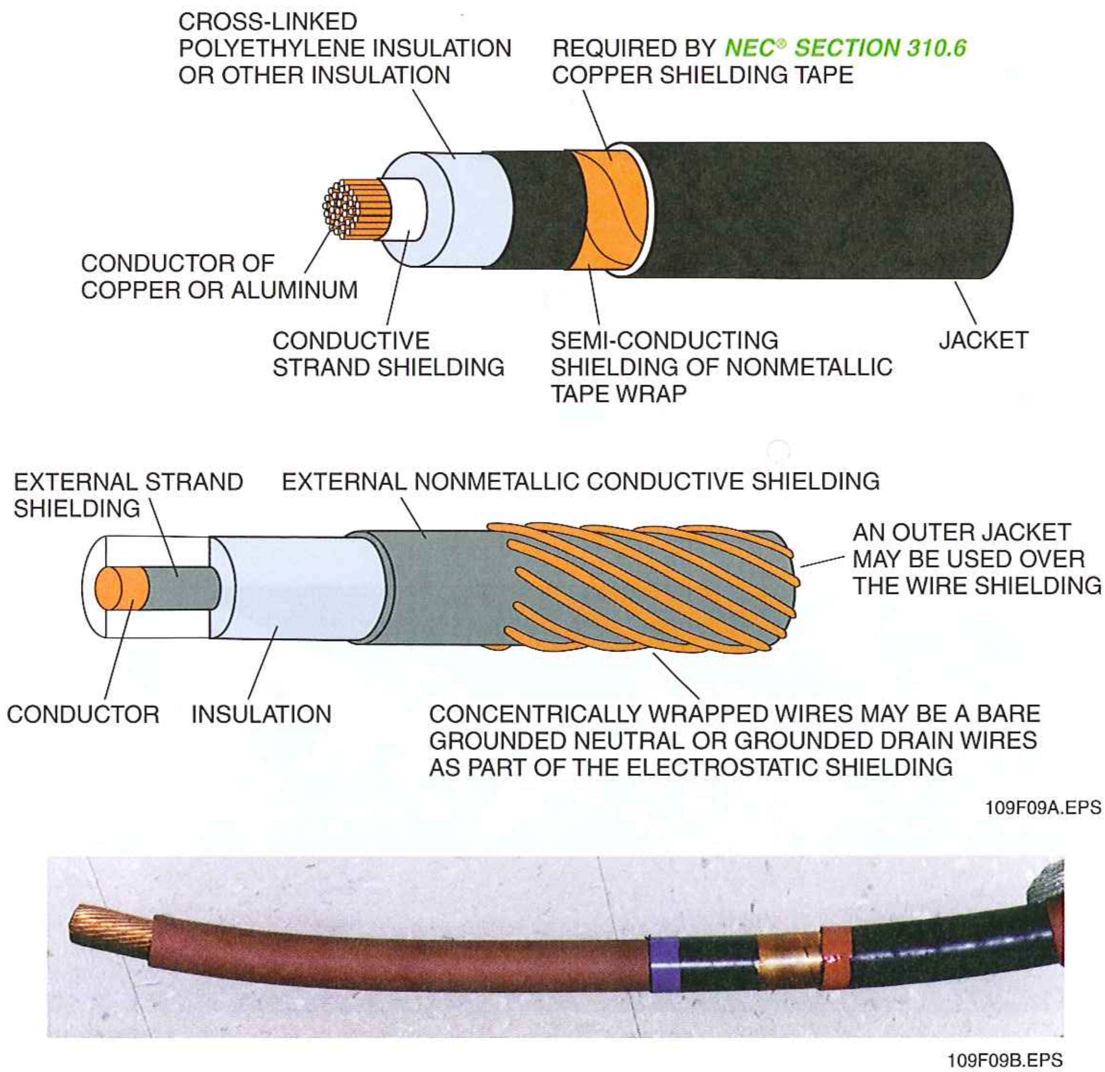


Figure 9 ◆ Metallic shielding.

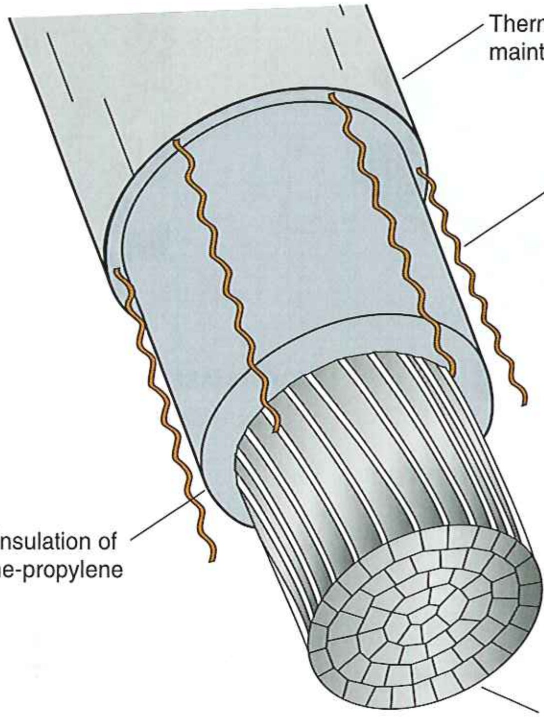


Figure 10 ◆ Nonmetallic shielding.

2.7.7 Channel Wire Assemblies

Channel wire assemblies (Type FC) comprise an entire wiring system, which includes the cable, cable supports, splicers, circuit taps, fixture hangers, and fittings (*Figure 11*). Guidelines for the use of this system are given in *NEC Article 322.* Type FC cable is a flat cable assembly with three or four parallel No. 10 special stranded copper conductors. The assembly is installed in an approved U-channel surface metal raceway with one side open. Tap devices can be inserted anywhere along the run. Connections from the tap devices to the flat cable assembly are made by pin-type contacts when the tap devices are fastened in place. The pin-type contacts penetrate the insulation of the cable assembly and contact the multi-stranded conductors in a matched phase sequence. These taps can then be wired to lighting fixtures or power outlets (*Figure 12*).

As indicated in *NEC Section 322.10,* this wiring system is suitable for branch circuits that only supply small appliances and lights. This system is suitable for exposed wiring only and may not be concealed within the building structure. It is ideal for quick branch circuit wiring at field installations.

2.7.8 Flat Conductor Cable

Type FCC (flat conductor) cable comprises an entire branch wiring system similar in many respects to Type FC flat conductor assemblies. Guidelines for the use of this system are given in *NEC Article 324.* Type FCC cable consists of three to five flat conductors placed edge-to-edge, separated, and enclosed in a moisture-resistant and flame-retardant insulating assembly. Accessories include cable connectors, terminators, power source adapters, and receptacles.

This wiring system has been designed to supply floor outlets in office areas and other commercial and institutional interiors. It is meant to be run under carpets so that no floor drilling is required. This system is also suitable for wall mounting. As indicated in *NEC Article 324,* telephone and other communications circuits may share the same enclosure as Type FCC flat cable. The main advantage of the system is its ease of installation. It is the ideal wiring system for use when remodeling or expanding existing office facilities.

2.7.9 Type TC Cable

Guidelines for the use of Type TC (power and control tray) cable are given in *NEC Article 336.* Type TC cable consists of two or more insulated conductors twisted together, with or without associated bare or fully insulated grounding conductors, and covered with a nonmetallic jacket. The cables are rated at 600 volts. The cable is listed in conductor sizes No. 18 AWG to 2,000 kcmil copper or No. 12 AWG to 2,000 kcmil aluminum or copper-clad aluminum (*Figure 13*).

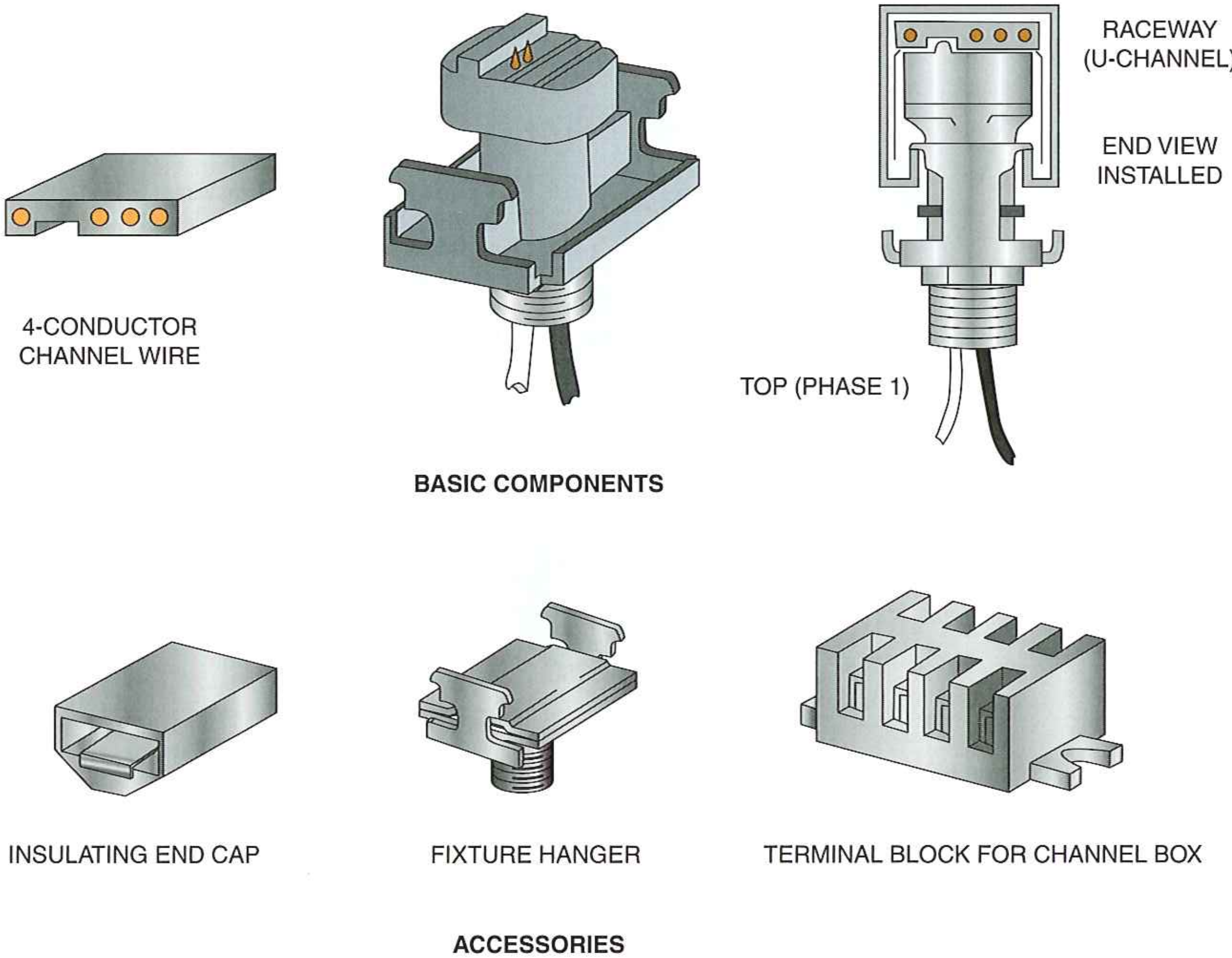


Figure 11 ◆ Channel wire components and accessories.

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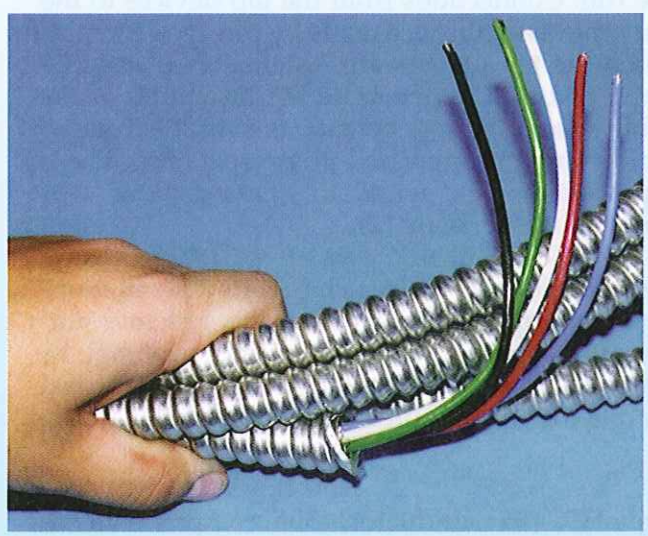
INSIDE TRACK

Type MC Cable

Metal clad cable (Type MC) is a type of cable that is widely used in both commercial and industrial environments. It is available in many configurations, with or without an outer jacket. Some of the special applications of MC cable include homerun cables, super neutrals, direct burial, fire alarm cable, and wiring in healthcare facilities.



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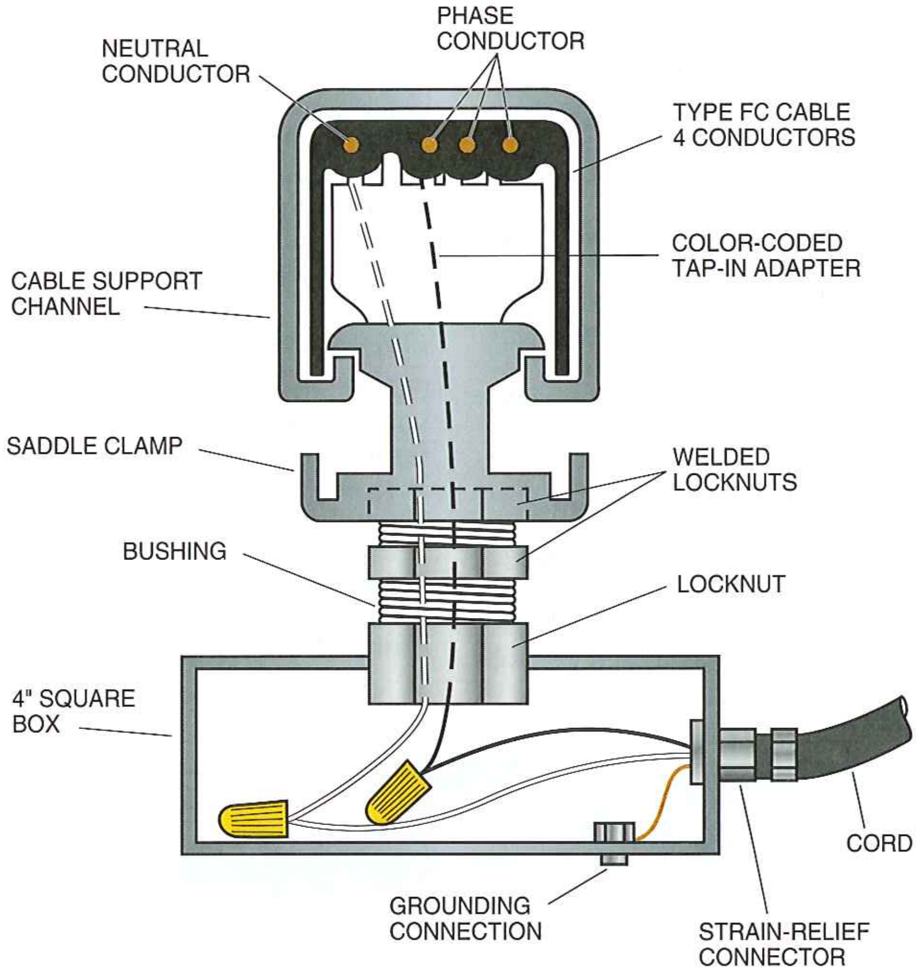

Figure 12 ◆ Type FC connection.

As the T in the letter designator indicates, this cable is tray cable. It can be used in cable trays and raceways. It may also be buried directly if the sheathing material is suitable for this use. Type TC cable is also good for use in sunlight when indicated by the cable markings.

2.7.10 Type USE Cable

Type USE cable is for underground installation including burial directly in the earth. Type USE cable in sizes No. 4/0 AWG and smaller with all conductors insulated is suitable for all of the underground uses for which Type UF cable is permitted by the *NEC®*.

Type USE cable may consist of either single conductors or a multi-conductor assembly provided with a moisture-resistant covering, but it is not required to have a flame-retardant covering. This type of cable may have a bare copper conductor

Figure 13 ◆ Type TC cable.

cabled with the assembly. Furthermore, Type USE single, parallel, or cabled conductor assemblies recognized for underground use may have a bare copper concentric conductor applied. These constructions do not require an outer overall covering. Guidelines for the use of Type USE cable are specified in *NEC Article 338.* See *Figure 14.*

When used as a service-entrance cable, Type USE cable must be installed as specified in *NEC Article 230.* Take the time to read *NEC Article 230* to ensure proper installation. Type USE service-entrance cable may also be used as feeder and branch circuit cable. Guidelines for this use of service-entrance cable are given in *NEC Section 338.10.*

2.8.0 Instrumentation Control Wiring

Instrumentation control wiring links the field-sensing, controlling, printout, and operating devices that form an electronic instrumentation control system. The style and size of instrumentation control wiring must be matched to a specific job.

Instrumentation control wiring usually has two or more insulated conductor wires. These wires may also have a shield and a ground wire. An outer layer called the jacket protects the wiring (*Figure 15*). Instrumentation conductor wires come in pairs. The number of pairs in a multi-conductor cable depends on the size of the wire used. A multi-pair cable may have as many as 60 pairs of conductor wires.

2.8.1 Shields

Shields are provided on instrumentation control wiring to protect the electrical signals traveling through the conductors from electrical interference or noise. Shields are usually constructed of aluminum foil bonded to a plastic film (*Figure 16*). If the wiring is not properly shielded, electrical noise may cause erratic or erroneous control signals, false indications, and improper operation of control devices.

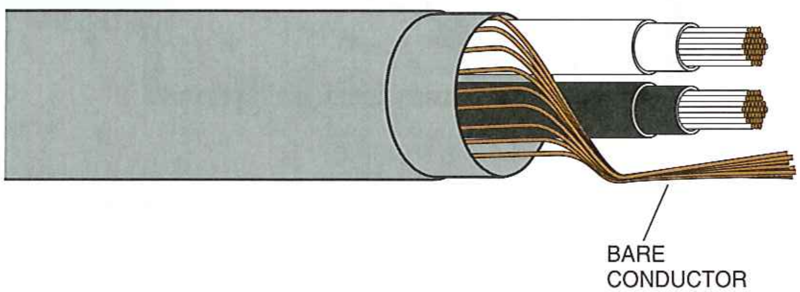

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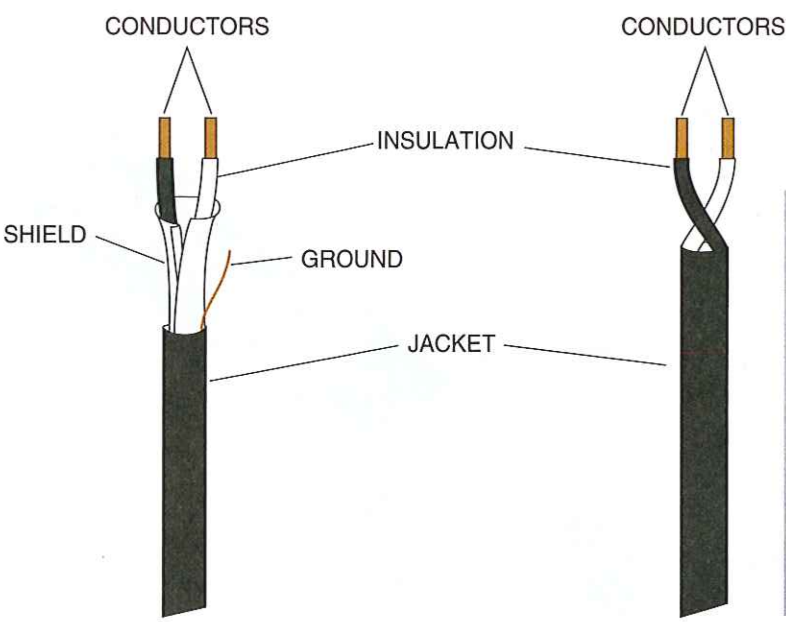
Figure 14 ◆ Type USE cable.



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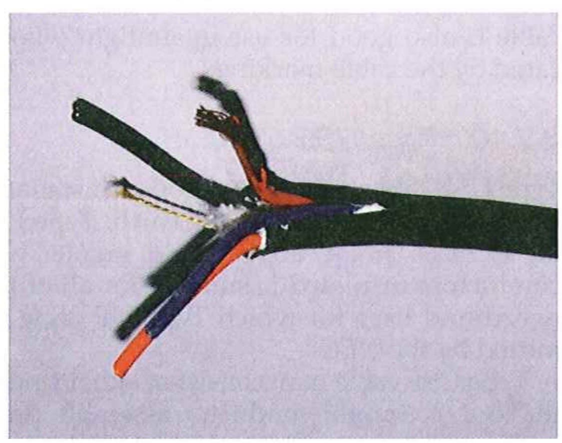

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Figure 15 ◆ Instrumentation control wiring.

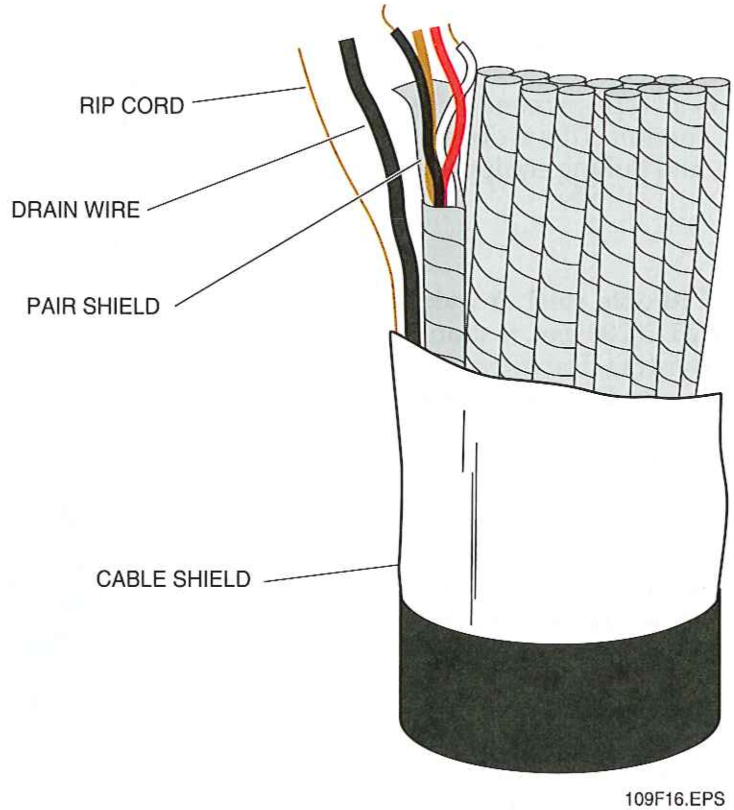

Figure 16 ◆ Multi-conductor instrumentation control wiring with shields.

2.8.2 Shield Grounding

A shield ground wire is a bare copper wire used to provide continuous contact with a specified grounding terminal. A shield ground wire allows connection of all the instruments within a loop to a common grounding system. In some electronic systems, the grounding wire is called a drain wire. Always refer to the loop diagram to determine whether or not the ground wire is to be terminated.

Usually, instrumentation is not grounded at both ends of the wire. This is to prevent unwanted ground loops in the system. If the ground is not to be connected at the end of the wire you are installing, do not remove the ground wire. Fold it back and tape it to the cable. This is called floating the ground. This is done in case the ground at the other end ever develops a problem. In that case, that ground can be removed and the wire taped to the cable can be untaped and installed.

2.8.3 Jackets

A plastic jacket covers and protects the components within the wire. Polyethylene (PE) and polyvinyl chloride (PVC) jackets are the most commonly used (*Figure 17*). Some jackets have a nylon rip cord that allows the jacket to be peeled back without the use of a knife or cable cutter. This eliminates nicking of the conductor insulation when preparing for termination.

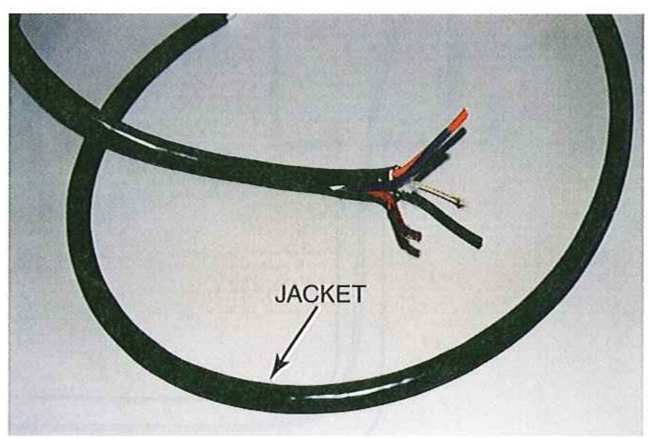

Figure 17 ◆ Wire jacket.

3.0.0 ◆ INSTALLING CONDUCTORS IN CONDUIT SYSTEMS

Conductors are installed in all types of conduit by pulling them through the conduit. This is done by using **fish tape,** pull lines, and pulling equipment.

3.1.0 Fish Tape

Fish tape can be made of flexible steel or nylon and is available in coils of 25 to 200 feet. It should be kept on a reel to avoid twisting. Fish tape has a hook or loop on one end to attach to the conductors to be pulled (*Figure 18*). Broken or damaged fish tape should not be used. To prevent electrical shock, fish tape should not be used near or in live circuits.

Fish tape is fed through the conduit from its reel. The tape usually enters at one outlet or junction box and is fed through to another outlet or junction box (*Figure 19*).

3.1.1 Power Conduit Fishing Systems

String lines can be installed by using different types of power systems. The power system is similar to an industrial vacuum cleaner and pulls a string or rope attached to a piston-like plug (sometimes called a **mouse**) through the conduit. Once the string emerges at the opposite end, either the conductor or a pull rope is then attached and pulled through the conduit, either manually or with power tools. See *Figure 20*.

The hose connection on these vacuum systems can also be reversed to push the mouse through the conduit as shown in *Figure 21*. In other words, the system can either suck or blow the mouse through the conduit, depending on which method is best in a given situation. In either case, a fish tape is then attached to the string for retrieving through the conduit.

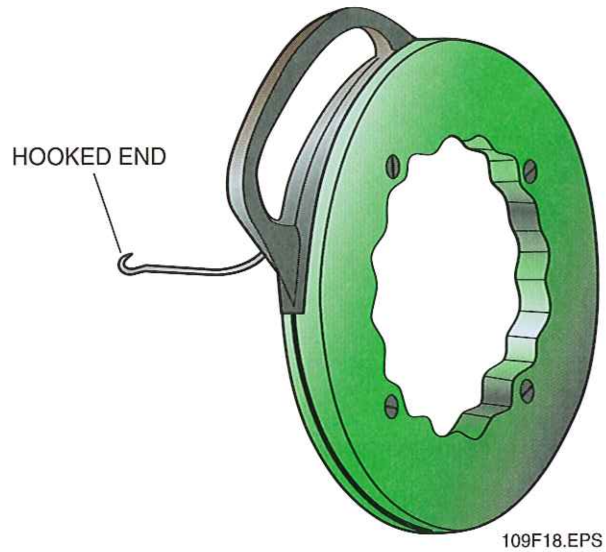

Figure 18 ◆ Fish tape.

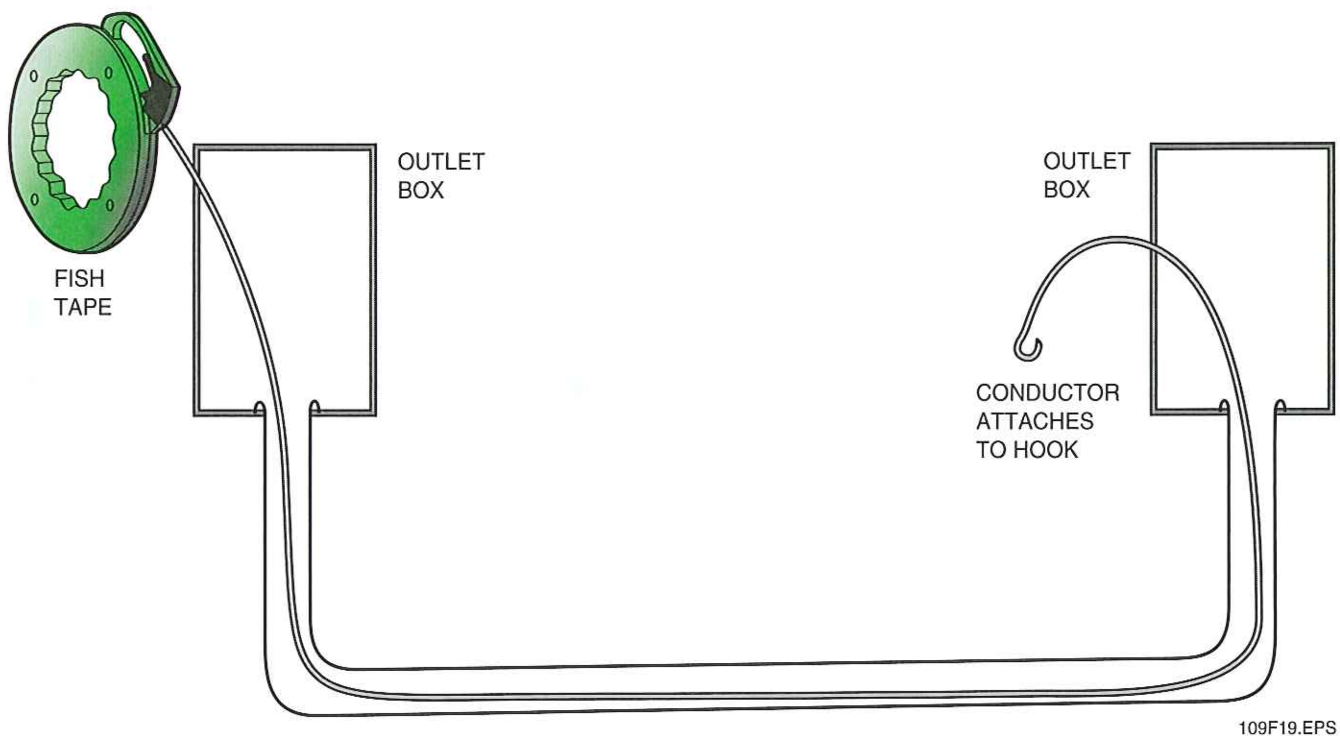

Figure 19 ◆ Fish tape installation.

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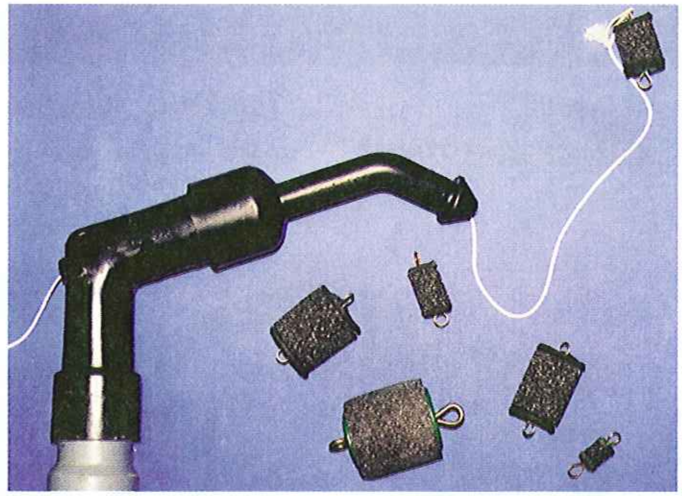

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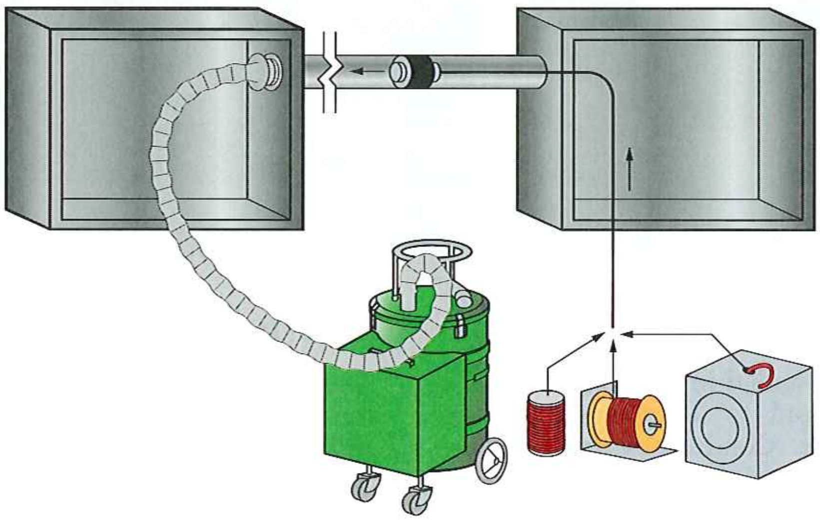

FISHING SYSTEM IN VACUUM MODE 109F20C.EPS

Figure 20 ◆ Power fishing system.

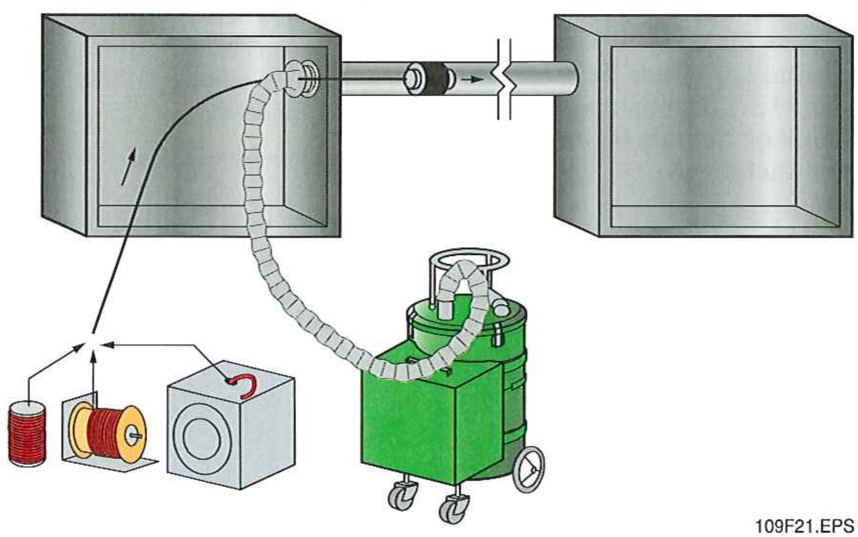

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Figure 21 ◆ Power fishing system in blower mode.

INSIDE TRACK

Fish Tape Selection

Metal fish tape (A) generally comes in longer lengths and is the type used most often. Nylon fish tape (B) generally comes in shorter lengths and is used when fishing in areas where it is impossible to remove the power.

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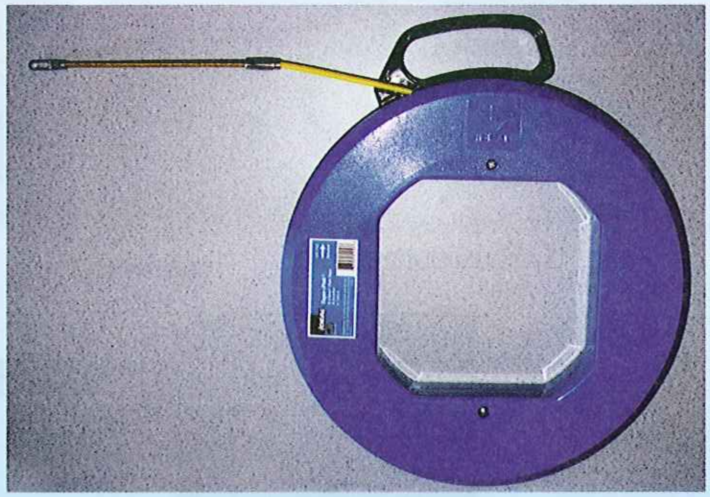

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3.1.2 Connecting Wire to a String Line

Once the string is installed in the conduit run, a fish tape is connected to it and pulled back through the conduit. Conductors are then attached to the hooked end of the fish tape or else connected to a basket grip. In most cases, all required conductors are pulled at one time.

3.2.0 Wire Grips

Wire grips are used to attach the cable to the pull tape. One type of wire grip used is a basket grip (sometimes called Chinese Fingers). A basket grip is a steel mesh basket that slips over the end of a large wire or cable (*Figure* 22). The fish tape hooks onto the end and the pull on the fish tape tightens the basket over the conductor.

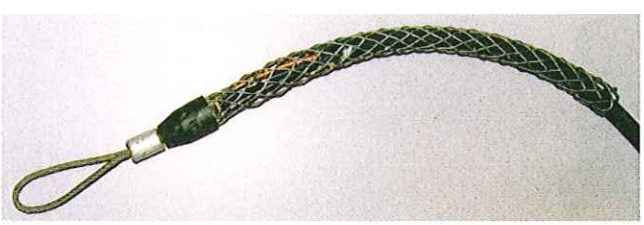

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Figure 22 ◆ Basket grip.

3.3.0 Pull Lines

After the tape has been inserted into the conduit run, you must determine if the pull on the wire will be easy or difficult. If the pull is going to be difficult because of bends in the conduit or the size of the conductors, or if several conductors are to be pulled together, a pull line should be used.

WARNING!

When using pull lines, exercise extreme caution and never stand in a direct line with the pulling rope. If the rope breaks, the line will whip back with great force. This can result in serious injury or death.

A pull line is usually made of nylon or some other synthetic fiber. It is made with a factory-spliced eye for easy connection to fish tape or conductors.

3.4.0 Safety Precautions

The following are several important safety precautions that will help to reduce the chance of being injured while pulling cable.

- To avoid electrical shock, never use fish tape near or in live circuits. If wires must be pulled into boxes that contain live circuits, use rubber blankets over the exposed live circuitry.
- Read and understand both the operating and safety instructions for the pull system before pulling cable.
- When moving reels of cable, avoid back strain by using your legs to lift (rather than your back) and asking for help with heavy loads. Also, when manually pulling wire, spread your legs to maintain your balance and do not stretch.
- Select a rope that has a pulling load rating greater than the estimated forces required for the pull.
- Use only low-stretch rope such as multiplex and double-braided polyester for cable pulling. High-stretch ropes store energy much like a stretched rubber band. If there is a failure of the rope, pulling grip, conductors, or any other component in the pulling system, this potential energy will suddenly be unleashed. The whipping action of a rope can cause considerable damage, serious injury, or death.
- Inspect the rope thoroughly before use. Make sure there are no cuts or frays in the rope. Remember, the rope is only as strong as its weakest point.
- When designing the pull, keep the rope confined in conduit wherever possible. Should the rope break or any other part of the pulling system fail, releasing the stored energy in the rope, the confinement in the conduit will work against the whipping action of the rope by playing out much of this energy within the conduit.
- Do not stand in a direct line with the pulling rope.
- Wrap up the pulling rope after use to prevent others from tripping over it.

3.5.0 Pulling Equipment

Many types of pulling equipment are available to help pull conductors through conduit. Pulling equipment can be operated both manually and electrically. A manually operated puller is used mainly for smaller pulling jobs where hand pulling is not possible or practical *(Figure 23)*. It is also used in many locations where hand pulling would put an unnecessary strain on the conductors because of the angle of the pull involved.


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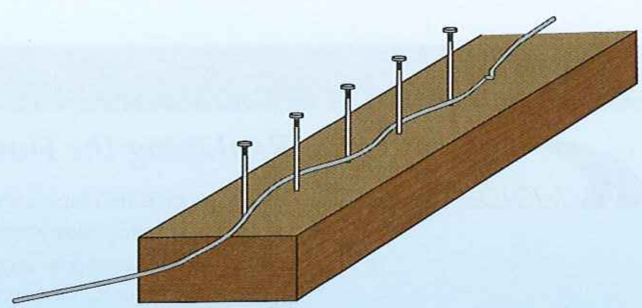
Figure 23 ◆ Manual wire puller.

INSIDE TRACK

Straightening a Bent Fish Tape

To straighten a bent fish tape, drive five 16-penny (16d) nails into a 2 × 4 about 1" apart in a straight line. Then wind the fish tape through the nails in a slalom fashion. This will straighten the tape.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Electrically driven power pullers are used where long runs, several bends, or large conductors are involved (*Figure 24*).

The main parts of a power puller are the electric motor, the chain or sprocket drive, the **capstan,** the sheave, and the pull line.

The pull line is routed over the sheave to ensure a straight pull. The pull line is wrapped around the capstan two or three times to provide a good grip on the capstan. The capstan is driven by the electric motor and does the actual pulling. The pull line is unwound by hand at the same speed at which the capstan is pulling. This eliminates the need for a large spool on the puller to wind the pull line.

Attachments to power pullers, such as special application sheaves and extensions, are available for most pulling jobs (*Figure 25*). Follow the manufacturer's instructions for setup and operation of the puller.

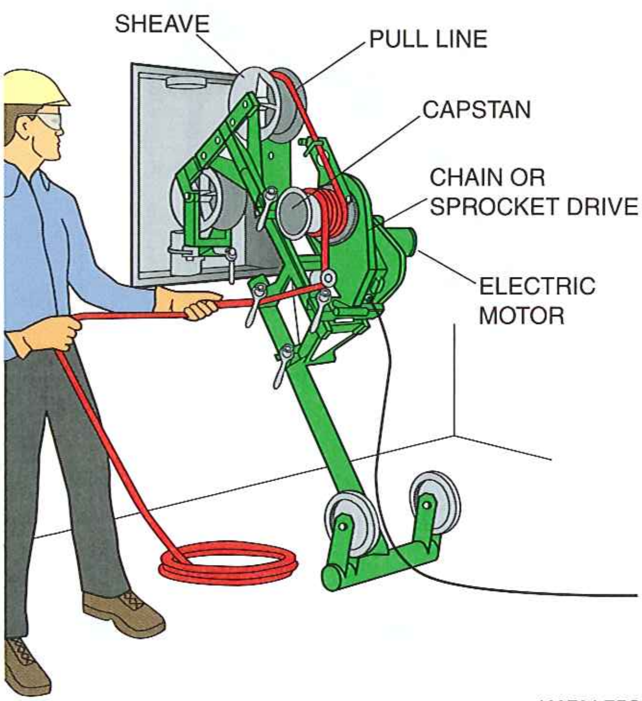

Figure 24 ◆ Power puller.

CAUTION

Before using power pullers, a qualified person must verify the amount of pull or tension that can be withstood by the conductors being pulled.

3.6.0 Feeding Conductors into Conduit

After the fish tape or pull line is attached to the conductors, they must be pulled back through the conduit. As the fish tape is pulled, the attached conductors must be properly fed into the conduit.

Usually, more than one conductor is fed into the conduit during a wire pull. It is important to keep the conductors straight and parallel, and free from kinks, bends, and crossovers. Conductors that are allowed to cross each other will form a bulge and make pulling difficult. This could also damage the conductors.

Spools and rolls of conductors must be set up so that they unwind easily, without kinks and bends.

When several conductors must be fed into the conduit at the same time, a reel cart is used (*Figure 26*). The reel cart will allow the spools to turn freely and help prevent the wires from tangling.

3.7.0 Conductor Lubrication

When conductors are fed into long runs of conduit or conduit with several bends, the wires are lubricated with a compound designed for wire lubrication.

Several types of formulated compounds designed for wire lubrication are available in either dry powder, paste, or gel form. These compounds must be noncorrosive to the insulation material of the conductor and to the conduit itself. The compounds are applied by hand to the conductors as they are fed into the conduit. Avoid excess lubrication.

INSIDE TRACK

Replacing the Hook on a Metal Fish Tape

The hook on a fish tape can be replaced using a propane torch. IMPORTANT: Always work in an appropriate environment and wear the necessary protective equipment. Hold the fish tape securely in a pair of pliers, heat the end with a propane torch until it softens, then use a second set of pliers to form a hook in the fish tape. Allow it to air cool.

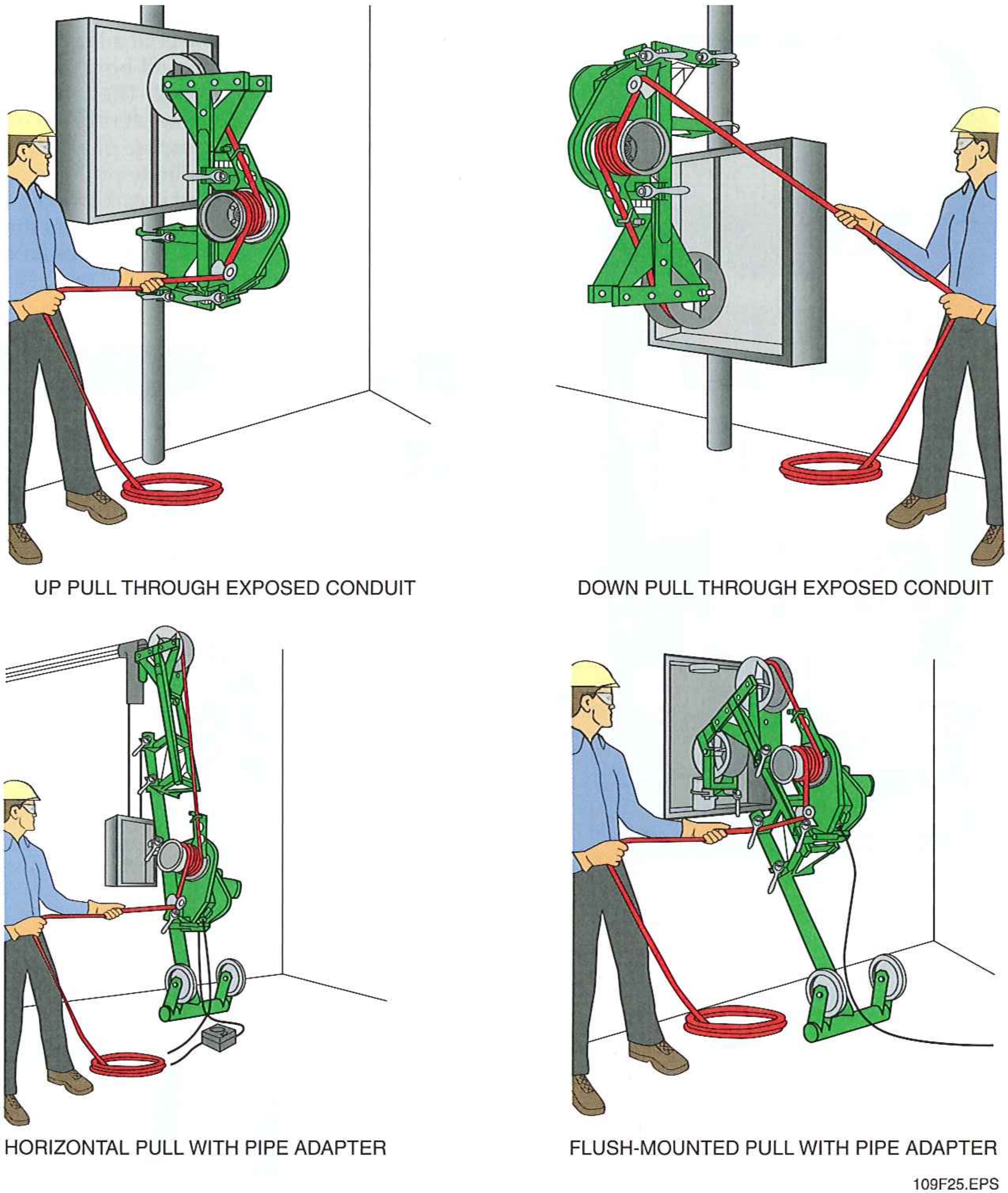

Figure 25 ◆ Power puller uses.

INSIDE TRACK

Cleanup

A professional always takes the time to clean up the work area, removing excess lubricant from the boxes, bushings, and conductors. Completing a job in a professional manner is not only good business, it is also an *NEC*® requirement ***(NEC Section 110.12).***

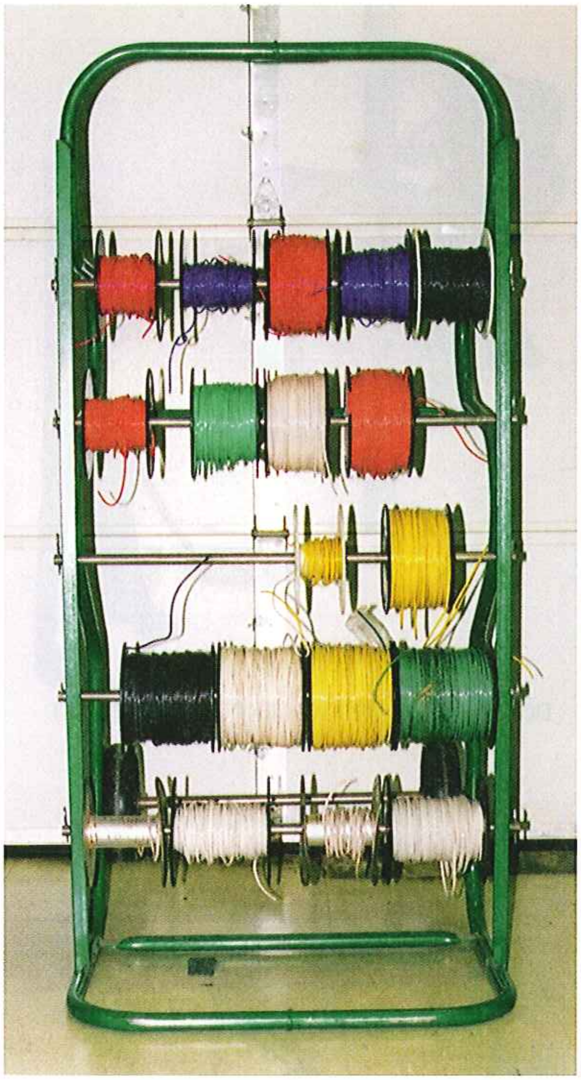

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Figure 26 ◆ Reel cart.

3.8.0 Conductor Termination

The amount of free conductor at each junction or outlet box must meet certain *NEC®* specifications. For example, there must be sufficient free conductor so that bends or terminations inside the box, cabinet, or enclosure may be made to a radius as specified in the *NEC®*. The *NEC®* specifies a minimum of six inches for connections made to wiring devices or for splices. Where conductors pass through junction or pull boxes, enough slack should be provided for splices at a later date.

When a box is used as a pull box, the conductors are not necessarily spliced. They may merely enter the pull box via one conduit run and exit via another conduit run. The purpose of a pull box, as the name suggests, is to facilitate pulling conductors on long runs. A junction box, however, is not only used to facilitate pulling conductors through the raceway system, but it also provides an enclosure for splices in the conductors.

INSIDE TRACK

Cutting Cable

Large cable is best cut using cable cutters.

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THINK ABOUT IT

Putting It All Together

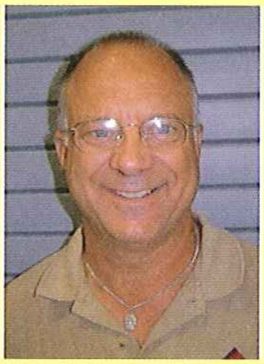
Think about the design of conductor installations. How does the location of pull points affect the ease of the pull?

Summary

Knowing the different types of conductors, how they are rated, and what they are used for will help you when selecting conductors for a specific job. Pulling wires and cables through conduit systems is an important part of your job as an electrician. The more you learn about the concepts involved in pulling cable, the safer and more efficient you will be.

Notes

Profile in Success



L.J. LeBlanc

Pumba Electric, LLC.

What made you decide to become an electrician?
My dad was an electrician. He had me wiring houses at 9 years old. He was very knowledgeable in the field, having been educated at the Coyne American Institute in Chicago, Illinois. The challenge of the electrical field has always interested me.

How did you learn the trade?
My education came from vo-tech training in Louisiana. It was a self-taught program that was supplemented by on-the-job training. Having the benefit of working side by side with some great craftsmen from all over the U.S. and Canada gave me a broad base of electrical experience. Working maintenance really improved my troubleshooting skills.

What kinds of jobs did you hold on your way to your current position?
I began as a helper and then started trade school in an apprenticeship program in 1965. Work was so plentiful that I was stepped up to a foreman within a year. I took a 2-week job that turned out to last 14 years. I began as a journeyman and ended up as a shop superintendent.

Today I work for my son's company. I do just about all phases of electrical work from estimating, bidding, and installation to troubleshooting.

What factors have contributed most to your success?
I believe in giving eight hours work for eight hours pay. I thirst for knowledge, and I love a challenge. If a man made it, I can fix it. I am never late for work. If I can't be there on time, I show up early.

What advice would you give to someone entering the electrical trade?
Get a good education and complement that education with on-the-job training. Listen to the advice of your peers. What's most important is what you learn after you think you know it all.

Trade Terms Introduced in This Module

Ampacity: The current in amperes a conductor can carry continuously under the conditions of use without exceeding its temperature rating.

Capstan: The turning drum of the cable puller on which the rope is wrapped and pulled.

Fish tape: A hand device used to pull a wire through a conduit run.

Mouse: A cylinder of foam rubber that fits inside the conduit and is then propelled by compressed air or vacuumed through the conduit run, pulling a line or tape.

Wire grip: A device used to link pulling rope to cable during a pull.

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.

The NCCER makes every effort to keep these textbooks up-to-date and free of technical errors. We appreciate your help in this process. If you have an idea for improving this textbook, or if you find an error, a typographical mistake, or an inaccuracy in NCCER's *Contren®* textbooks, please write us, using this form or a photocopy. Be sure to include the exact module number, page number, a detailed description, and the correction, if applicable. Your input will be brought to the attention of the Technical Review Committee. Thank you for your assistance.

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.

Write: Product Development
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