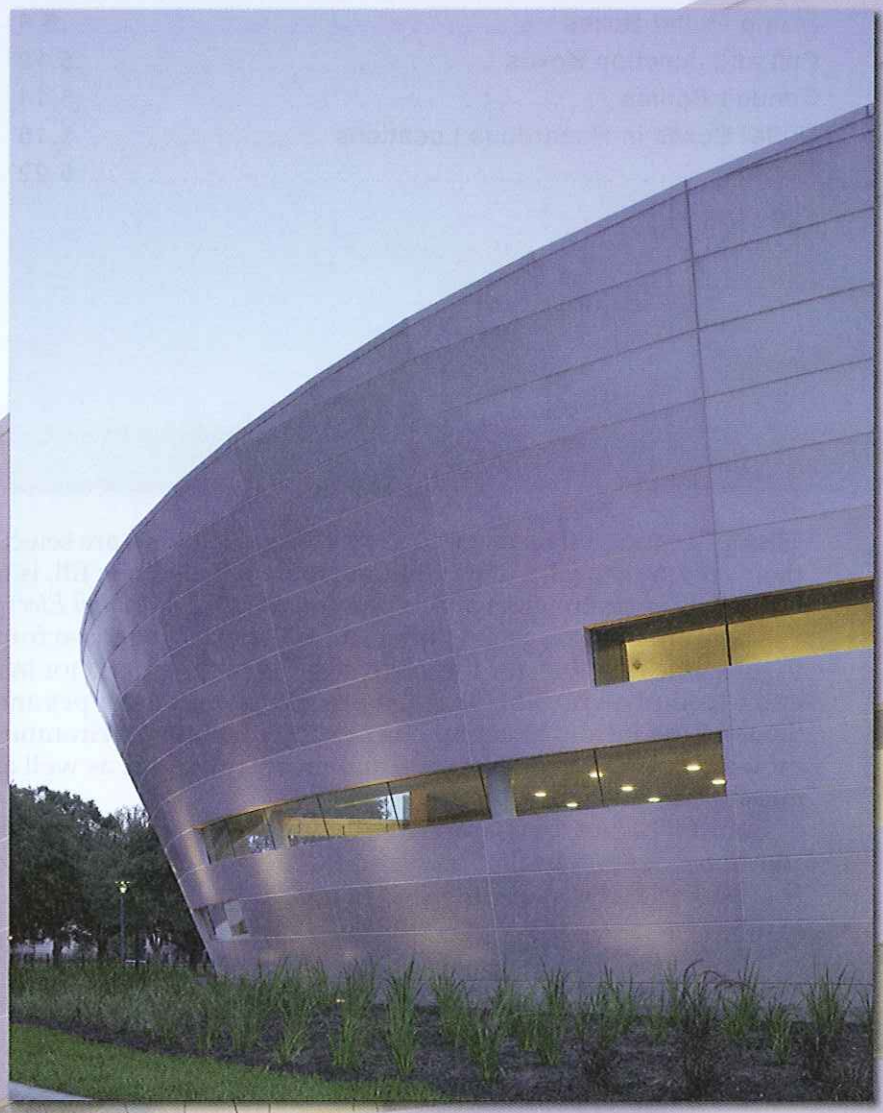
Boxes and Fittings
26205-05

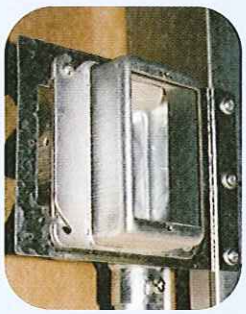


ExxonMobil URC Training Center
Houston, Texas
Commercial $10–25 Million Award Winner
D. E. Harvey Builders

26205-05
Boxes and Fittings

Topics to be presented in this module include:

Overview



The outlet and pull boxes used in an electrical system are selected according to their volume capacity. This volume capacity, called box fill, is measured in cubic inches or centimeters and is regulated by the *National Electrical Code®*.

There are many types of outlet and pull boxes to choose from. It is essential to select the right box for the job in order to make conductor installation easier, and to comply with *NEC®* regulations that govern the types and sizes of boxes. Some of the factors affecting box selection include environmental conditions, mounting surfaces or materials, and raceway design, as well as the size, type, and number of conductors.

Conduit bodies, or condulets as they are often called, also play an important role in conductor installation. The *NEC®* regulates the type of conduit and conduit bodies that may be installed in hazardous locations.

Objectives

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

1. Describe the different types of nonmetallic and metallic boxes.
2. Understand the *NEC®* requirements for box fill.
3. Calculate the required box size for any number and size of conductors.
4. Explain the *NEC®* regulations for volume required per conductor in outlet boxes.
5. Properly locate, install, and support boxes of all types.
6. Describe the *NEC®* regulations governing pull and junction boxes.
7. Explain the radius rule when installing conductors in pull boxes.
8. Understand the *NEC®* requirements for boxes supporting lighting fixtures.
9. Describe the purpose of conduit bodies and Type FS boxes.
10. Install the different types of fittings used in conjunction with boxes.
11. Describe the installation rules for installing boxes and fittings in hazardous areas.
12. Explain how boxes and fittings are selected and installed.
13. Describe the various types of box supports.

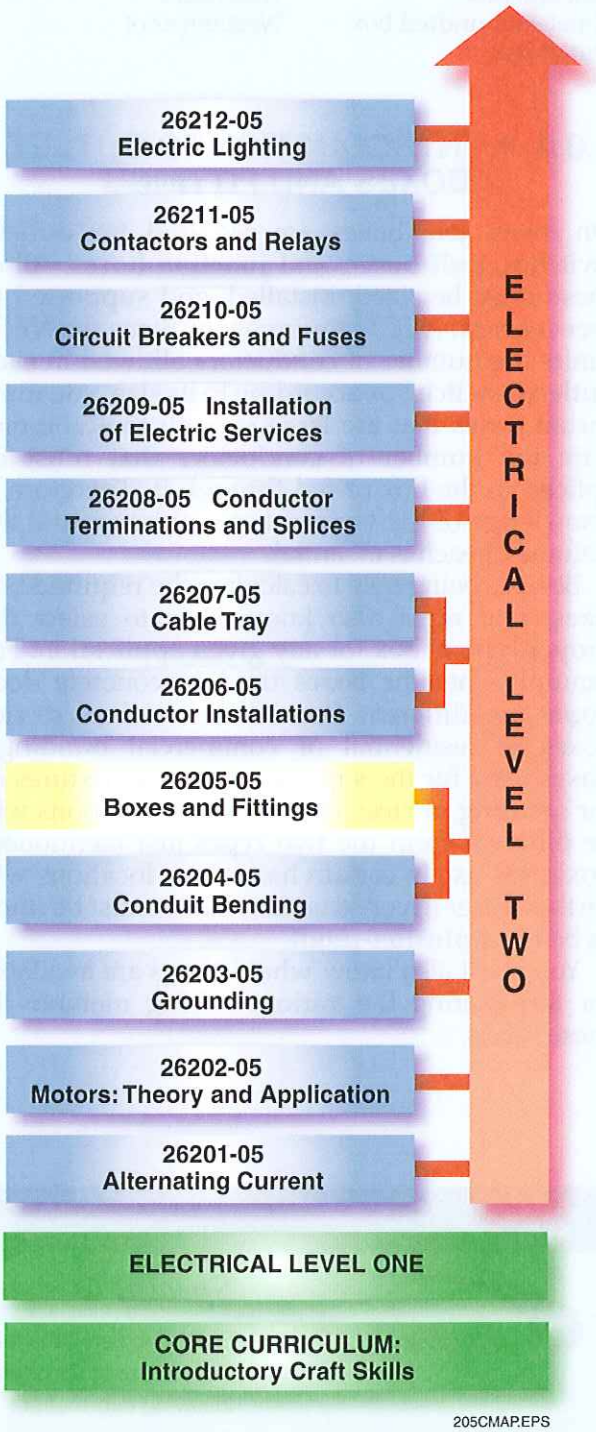
Required Trainee Materials

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

Prerequisites

Before you begin this module, it is recommended that you successfully complete *Core Curriculum; Electrical Level One;* and *Electrical Level Two,* Modules 26201-05 through 26204-05.

This course map shows all of the modules in *Electrical Level Two.* 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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Trade Terms

Conduit body
Connector
Explosion-proof
Handy box
Junction box
Nineteen hundred box
Outlet box
Pull box
Raintight
Sealing compound
Waterproof
Watertight
Weatherproof

1.0.0 ◆ INTRODUCTION TO OUTLET BOXES AND FITTINGS

On every job, boxes are required for outlets, switches, **pull boxes,** and **junction boxes.** All of these must be sized, installed, and supported to meet current *NEC*® requirements. Since the *NEC*® limits the number of conductors allowed in each outlet or switch box according to its size, you must install boxes that are large enough to accommodate the number of conductors that must be spliced in the box or fed through it. Therefore, a knowledge of the various types of boxes and the volume of each is essential.

Besides being able to calculate the required box sizes, you must also know how to select the proper type of box for any given application. For example, metallic boxes used in concrete deck pours are different from those used as device boxes in residential or commercial buildings. Boxes used for the support of lighting fixtures or for securing devices in outdoor installations will be different from the two types just mentioned. Boxes for use in certain hazardous locations will further differ in construction; many must be rated as being **explosion-proof.**

You must also know what fittings are available for terminating the various wiring methods in these boxes.

Electrical drawings rarely indicate the exact types of **outlet boxes** to be used in a given area, with the possible exception of boxes used in hazardous locations. Electricians who lack practical on-the-job experience may not always choose the best box for a given application. The use of improper boxes and other ill-adapted materials will cause excessive time to be taken on the job. For example, outlet boxes for use with Type AC cable should contain built-in clamps; many times boxes will be ordered with knockouts only. This latter case requires the use of additional **connectors,** which may only take a few additional seconds per connection, but when these are added up over the period of a large project, much additional time is wasted. Because the cost of labor is an expensive item, any excess labor required will more than offset any savings gained from the use of inadequate materials.

Excess labor is often consumed due to obstructions that enter conduit installations during the general construction work. Most of these obstructions can be avoided by plugging all conduit terminals with capped bushings or some similar means of protection (*Figure 1*). Care should also be taken to thoroughly tighten all fittings, couplings, and so on. In the case of outlet boxes installed in poured concrete structures, painting the inside of the boxes with grease and using capped bushings will greatly aid in keeping concrete out of the raceway system. If any concrete should enter the box, the grease will prevent it from adhering to the metal box.

This module is designed to cover boxes and fittings in depth, based on the applicable *NEC*® regulations. A knowledge of this material should enable you to approach your work in an efficient manner.

INSIDE TRACK

Special Considerations

Before you can effectively plan and route conductors to their termination points and then select and install the correct types and sizes of boxes, you will need to have the following information:

- Length and number of conductors
- Conductor ampacity
- Allowances for voltage drops
- Type(s) of hazard(s) in the environment

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Figure 1 ◆ Conduit caps.

2.0.0 ◆ TYPES OF BOXES

Outlet boxes normally fall into three categories:

- Pressed steel boxes with knockouts of various sizes for raceway or cable entrances
- Cast iron, aluminum, or brass boxes with threaded hubs of various sizes and locations for raceway entrances
- Nonmetallic boxes

Pressed steel boxes also fall into two categories:

- Boxes with conduit, electric metallic tubing, and cable
- Boxes designed for use with specific types of surface metal moldings

Outlet boxes vary in size and shape depending upon their use, the size of the raceway, the number of conductors entering the box, the type of building construction, the atmospheric conditions of the area, and special requirements.

Outlet box covers are usually required to adapt the box to the particular use it is to serve. For example, a 4" square box is adapted to one-gang or two-gang switches or receptacles by the use of either one-gang or two-gang flush device covers. A one-gang cast hub box can be adapted to provide a vapor-proof switch or a vapor-proof receptacle cover.

Special outlet box hangers are available to facilitate their installation, particularly in frame building construction.

The types of enclosures used as outlet and device boxes for the support of fixtures or for securing devices, such as switches, receptacles, or other equipment, on the same yoke or strap are available in various sizes and shapes. These enclosures may be used in the one-gang, two-gang, three-gang, or four-gang types. Ceiling outlet boxes are available in various shapes. Where a square metal box is used, it may be used for the support of a fixture or device, depending on the type of raised cover used. Device boxes are those that are usually installed to enclose receptacles and switches.

Boxes installed for the support of a lighting fixture are required to be specifically designed for the purpose. Most device boxes are typically not designed or listed for use to support lighting fixtures. The use of a device box to support fixtures is addressed in *NEC Section 314.27(A), Exception*.

A floor box that is listed specifically for installation in a floor is required where receptacles or junction boxes are installed in a floor. Listed floor boxes are provided with covers and gaskets to exclude surface water and cleaning compounds.

A box used at fan outlets is not permitted to be used as the sole support for ceiling (paddle) fans, unless it is specifically listed for the application as the sole means of support. Where a listed ceiling fan does not exceed 35 pounds in weight, with or without its accessories, it is permitted to be supported by outlet boxes identified for such use. The support of this box must be made so that it is rigidly supported from a structural member of the building. A paddle fan box and its related accessories are shown in *Figure 2*.

INSIDE TRACK

Identifying Boxes

After installing all the boxes in a complex installation, you can save yourself much time and trouble later on if you label each box location according to type. Using a can of spray paint, paint small dots on the floor below each box. Use one dot for a plug receptacle, two dots for a switch box, and three dots for a wall light. After the drywall installers are finished, you'll be able to easily identify any wall box.

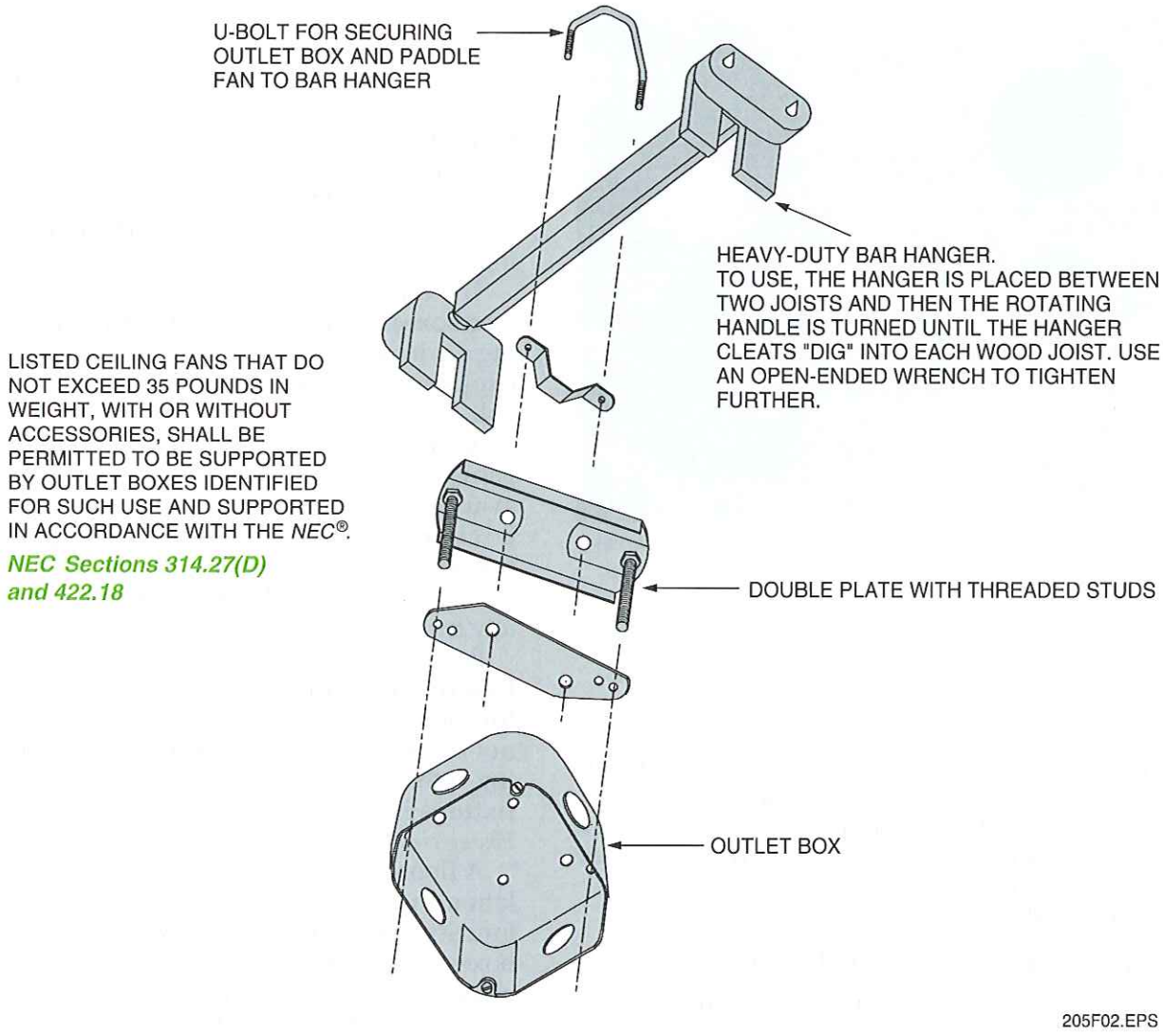

Figure 2 ◆ Typical paddle fan box for installation after the ceiling is installed.

2.1.0 Octagon and Round Boxes

Metallic octagon boxes are available with knockouts for use with either conduit (using locknuts and bushings) or cable box connectors. They are also available with both Type AC and NM cable clamps. The standard width of octagon boxes is four inches, with depths available in 1¼", 1½", or 2⅛". Extension rings are also available for increasing the depth.

Round boxes are available in the same dimensions, but *NEC Section 314.2* prevents using such boxes where conduit or connectors—requiring locknuts and bushings—are connected to the side of the box. The conduit or box connector must terminate in the top of such boxes. Round boxes with cable clamps, however, are permitted for use with Type AC and NM cables that may terminate in either the side or top of the box.

Nonmetallic round boxes are permitted only with open wiring on insulators, concealed knob-and-tube wiring, Type NM cable, and nonmetallic raceways.

Figure 3 shows typical metallic octagon boxes and an octagon extension ring. *Figure 3(A)* shows a box with concentric knockouts for conduit or box connectors, while *Figure 3(B)* shows a box that utilizes cable clamps. *Figure 3(C)* shows the extension ring. *Figure 4* shows a nonmetallic round box with a bar hanger for mounting between studs or joists.

Octagon and round boxes are used mostly for ceiling and wall-mounted incandescent lighting fixtures. However, covers are available for octagon boxes that will support receptacles and switches. Blank covers are also available when the box is used as a junction box.

Locating Boxes on Walls

INSIDE TRACK

The Universal Building Code (UBC) requires boxes on opposite sides of walls between occupancies to be separated by at least 24" in order to maintain the fire rating. (See NEC Section 300.21.)

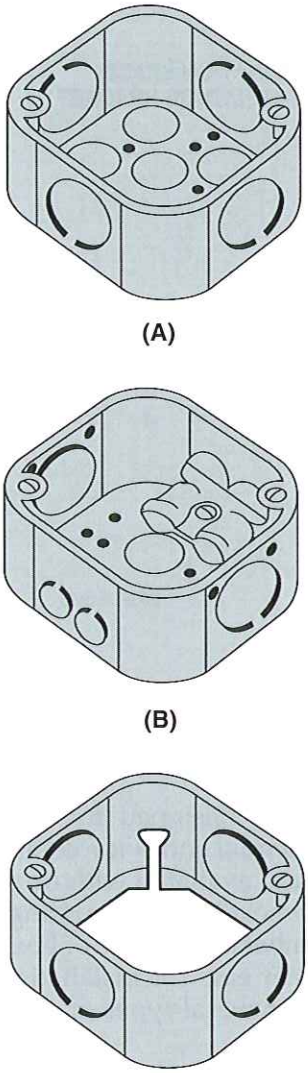

Figure 3 ◆ Typical octagon boxes and octagon extension ring.

Figure 5 shows a cross section of a 3½" round shallow box used for supporting lighting fixtures that have integral wire termination space. *NEC Section 314.24* requires that this and all boxes have a minimum depth of ½". Boxes intended to enclose flush devices must not have a depth of less than 15/16".

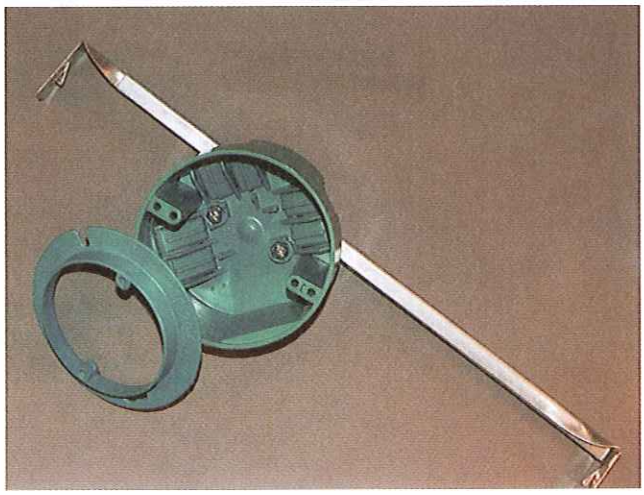

Figure 4 ◆ Nonmetallic round box with mounting bracket.

2.2.0 Square Boxes

Square boxes are available in 4" and 4 11/16" square sizes. Both types are available in depths of 1¼", 1½", and 2⅛". Extension rings are also available to further increase the depth. These boxes are available with or without mounting brackets (for nailing to wooden structural members). Boxes designed for use with cable have either Type AC or NM clamps for securing the cable at the box entrance points. Either type of square box may be used with a single or two-gang device ring (e.g., plaster ring or tile ring) for mounting receptacles or switches. A ring with a round opening is also available for mounting lighting fixtures. Blank covers are available when the boxes are used as junction boxes.

Square boxes have been dubbed **nineteen hundred boxes** by some electricians because one of the early manufacturers gave its square boxes a model number of 1900. *Figure 6* shows a square box with a rectangular extension ring that is used to bring the box to the masonry surface.

Square boxes are used for mounting two wiring devices such as junction boxes, and when the number of wires warrants more capacity than is available in other types of boxes.

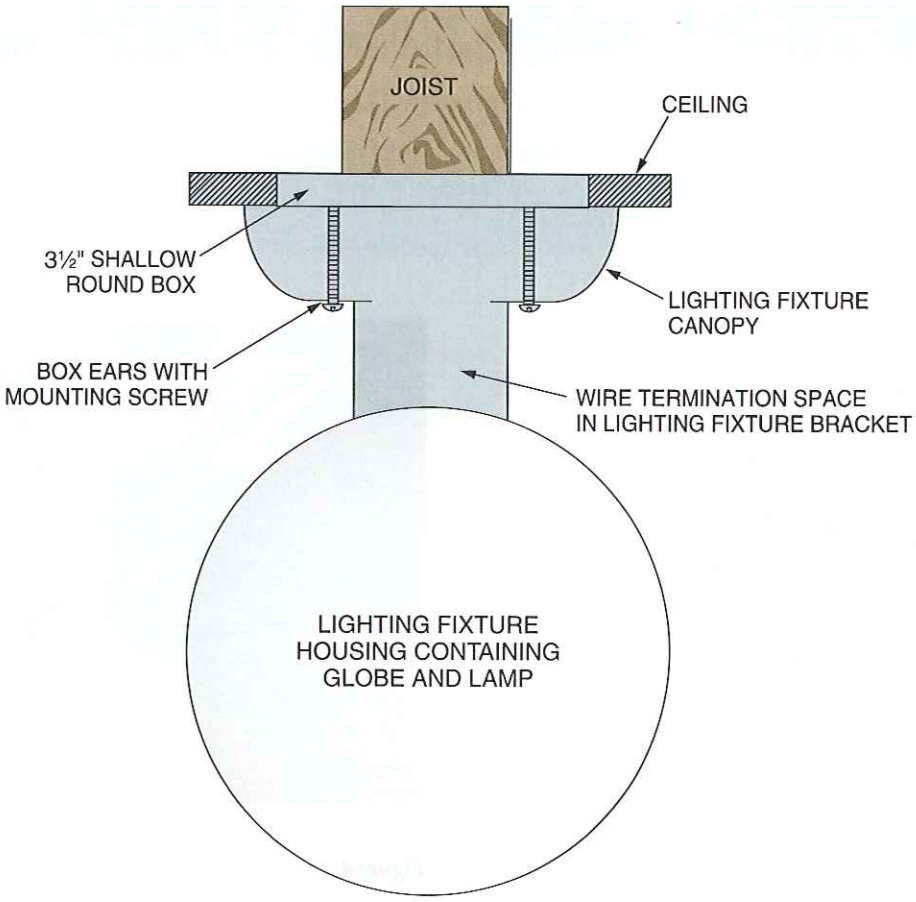

Figure 5 ◆ Shallow round box used for mounting a lighting fixture.

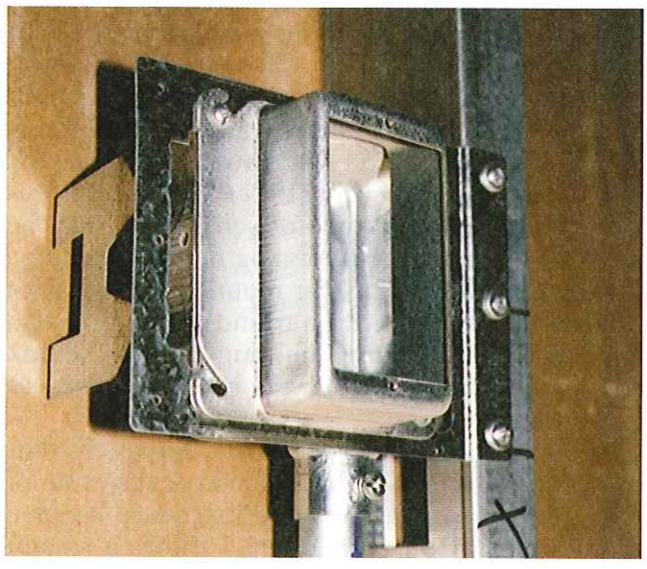

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Figure 6 ◆ Square box with extension ring.

2.3.0 Device Boxes

Device boxes are designed for flush mounting mainly in residential and some commercial applications. They are available with or without cable clamps and brackets for mounting to wooden structural members. This type of box is also available with plaster ears for installation in finished wall partitions. Several types of device boxes are shown in *Figure 7*.

A special single-gang box with rounded edges is also used and is called a **handy box** (also known as a utility box). Such boxes are available in depths of 1½", 1⅞", and 2⅛". Care must be exercised when using these boxes as their limited volume restricts the number of conductors permitted in the box.

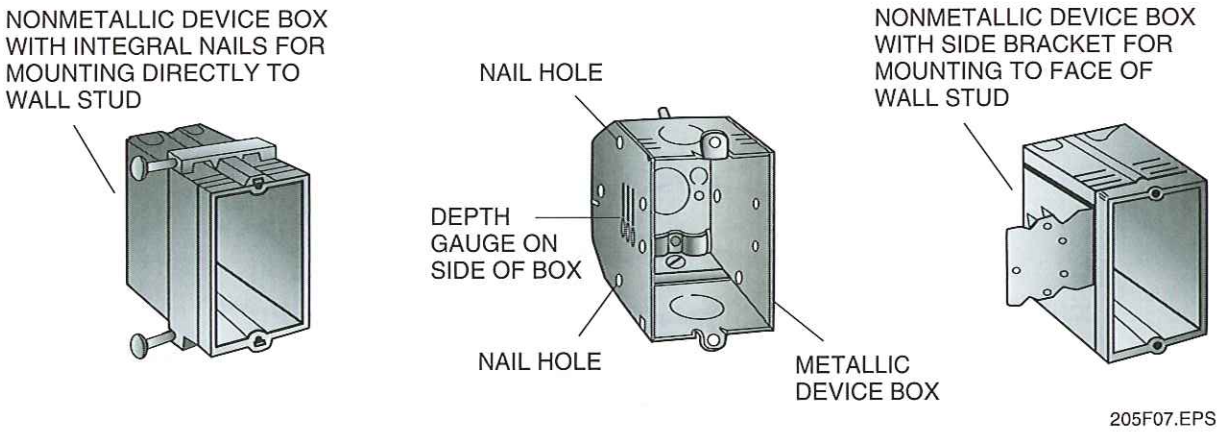


Figure 7 ◆ Typical device boxes.

2.4.0 Concrete Boxes

Special boxes designed for use in concrete pours are used in flat-slab construction jobs. These boxes consist of a sleeve with external ears and a plate which is attached after the sleeve is nailed to the deck.

Concrete boxes are manufactured in different heights and care should be taken to use boxes of sufficient height to allow the knockouts to come well above the reinforcing rods. This eliminates the need for offsets in the conduit where it enters a box. *Figure 8* shows a practical application of a concrete box.

2.5.0 Boxes for Damp and Wet Locations

In damp or wet locations, boxes and fittings must be placed or equipped to prevent moisture or water from entering and accumulating within the box or fitting. It is recommended that approved boxes of nonconductive material be used with nonmetallic sheathed cable or approved nonmetallic conduit when the cable or conduit is used in locations where there is likely to be occasional moisture present. Boxes installed in wet locations must be approved for the purpose per *NEC Section 314.15(A)*.

A wet location is any location subject to saturation with water or other liquids, such as locations exposed to weather or water, washrooms, garages, and interiors that might be hosed down. Underground installations or those in concrete slabs or masonry in direct contact with the earth must be considered to be wet locations. **Raintight, waterproof,** or **watertight** equipment (including fittings) may satisfy the requirements for **weatherproof** equipment. Boxes with threaded conduit hubs and gasketed covers will normally prevent water from entering the box except for condensation within the box.

A damp location is a location subject to some degree of moisture. Such locations include partially protected outdoor locations—such as under canopies, marquees, and roofed open porches. It also includes interior locations subject to moderate degrees of moisture—such as some basements, some barns, and cold storage warehouses.

Weatherproof covers for outdoor receptacles must be chosen with care. If the receptacle feeds a permanently connected load (such as a lighting fixture), the entire enclosure must be weatherproof with the plug inserted. If the receptacle is

INSIDE TRACK

Use of Round Boxes Is Limited

Round boxes are not to be used in cases where conduit must enter from the side of the box because it is difficult to make a good connection with a locknut or bushing on a rounded surface.

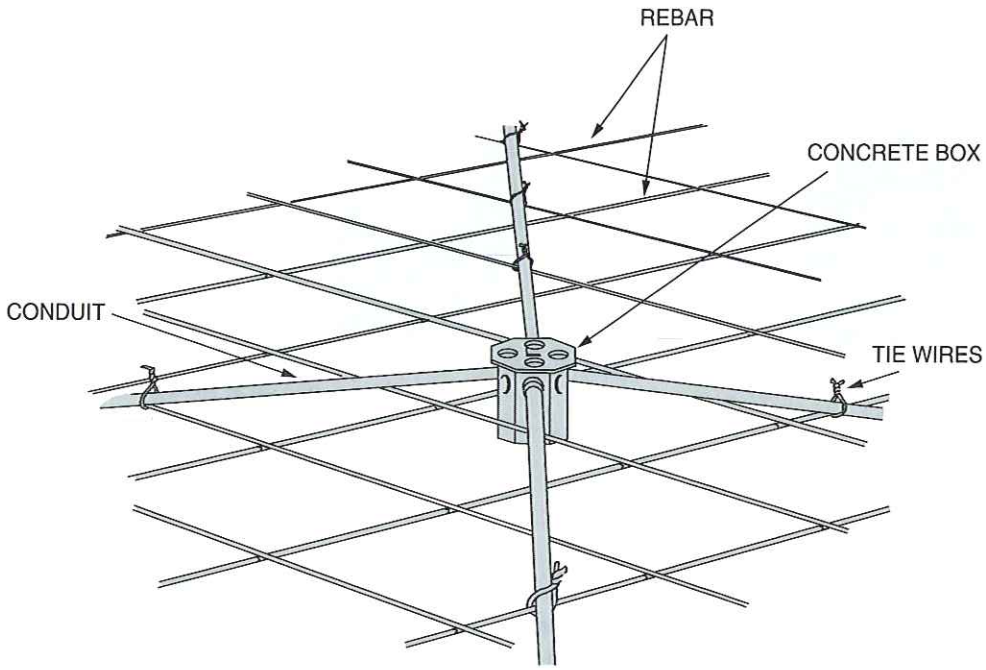


Figure 8 ◆ Practical application of concrete boxes.

INSIDE TRACK

Knockouts

When completing building renovations, it may be difficult to remove a knockout from a previously installed box without dislodging the box. One way to do it is to drill into the knockout and partially insert a self-tapping screw. Then use diagonal or side-cut pliers to pull the knockout from the box.

used only with portable tools or other portable equipment, the enclosure must be weatherproof with the cover closed and the cover must be self-closing. *NEC Section 406.8* covers installation of receptacles in damp or wet locations.

3.0.0 ◆ SIZING OUTLET BOXES

In general, the maximum number of conductors permitted in standard outlet boxes is listed in *NEC Table 314.16(A).* These figures apply where no fittings or devices such as fixture studs, cable clamps, switches, or receptacles are contained in the box and where no grounding conductors are part of the wiring within the box. Obviously, in all modern residential wiring systems there will be one or more of these items contained in the outlet box. Therefore, where one or more of the above-mentioned items are present, the number of conductors is reduced by one less than that shown in the table for each type of fitting and by two for each device strap. For example, a deduction of two conductors must be made for each strap containing a device such as a switch or duplex receptacle; a further deduction of one conductor shall be made for one or more grounding conductors entering the box. For example, a 3" × 2" × 3½" box is listed in the table as containing a maximum number of eight No. 12 wires. If the box contains cable clamps and a duplex receptacle, three wires will have to be deducted from the total of eight—providing for only five No. 12 wires. If a ground wire is used, only four No. 12 wires may be used, which might be the case when a three-wire cable with ground is used to feed a three-way wall switch.

A pictorial definition of stipulated conditions as they apply to *NEC Section 314.16* is shown in the following illustrations. *Figure 9* illustrates an assortment of raised covers and outlet box extensions. These components, when combined with the appropriate outlet boxes, serve to increase the

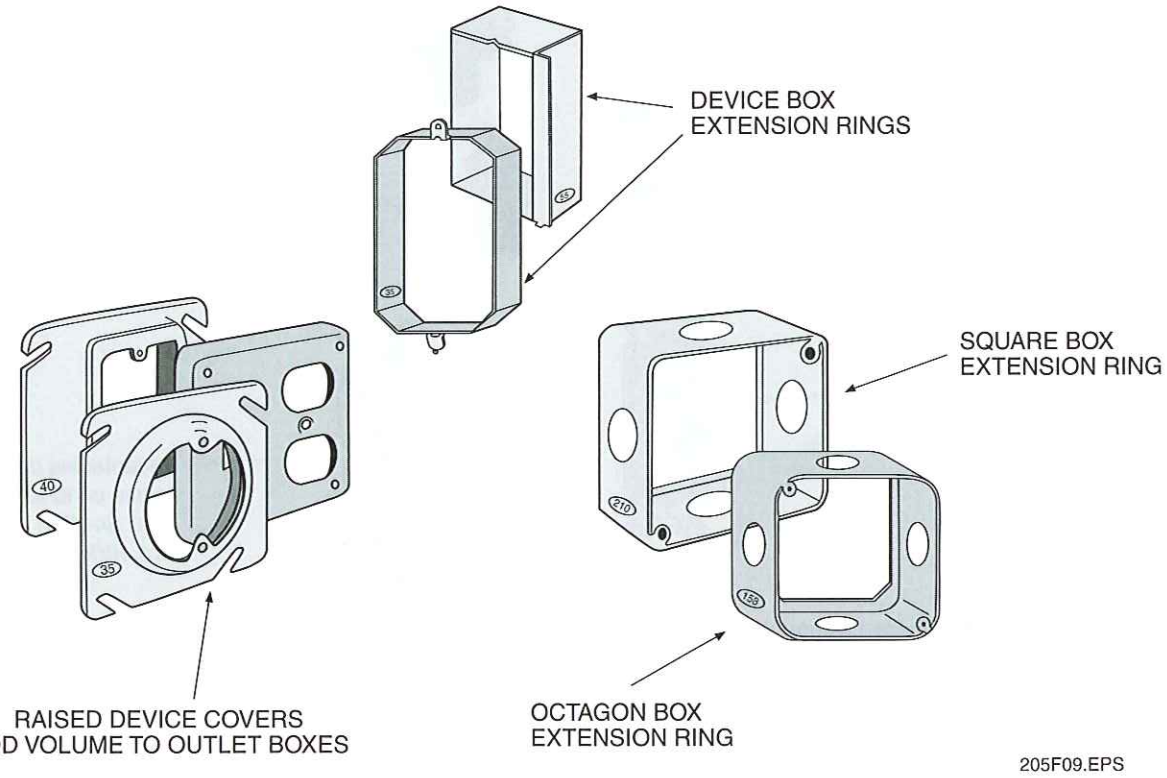


Figure 9 ◆ Devices or components that add to outlet box capacity.

usable work space. Each type is marked with its cubic inch capacity, which may be added to the figures in *NEC Table 314.16(A)* to calculate the increased number of conductors allowed.

Figure 10 shows typical wiring configurations, which must be counted as conductors when calculating the total capacity of outlet boxes. A wire passing through the box without a splice or tap is counted as one conductor. Therefore, a cable containing two wires that passes in and out of an outlet box with a splice or tap is counted as two conductors. However, wires that enter a box and are either spliced or connected to a terminal, and then exit again, are counted as two conductors. In the case of two cables that each have two wires, the total conductors charged will be four. Wires that enter and terminate in the same box are charged as individual conductors and in this case, the total charge would be two conductors. Remember, when one or more grounding wires enter the box and are joined, a deduction on only one is required, regardless of their number.

Further components that require deduction adjustments from those specified in *NEC Table 314.16(A)* include fixture studs, hickeys, and fixture stud extensions *[NEC Section 314.16(B)(3)]*. One conductor must be deducted from the total for each type of fitting used. Two conductors must be deducted for each strap-mounted device, such as duplex receptacles and wall switches; a deduction of one conductor is made when one or more internally mounted cable clamps are used *[NEC Section 314.16(B)(2) and (4)]*.

INSIDE TRACK

Outdoor Boxes

Outdoor wiring must be able to resist the entry of water. Outdoor boxes are either drip tight, which means sealed against falling water from above, or watertight, which means sealed against water from any direction. Drip-tight boxes simply have lids that deflect rain; they are not waterproof. Watertight boxes are sealed with gaskets to prevent the entry of water from any angle.

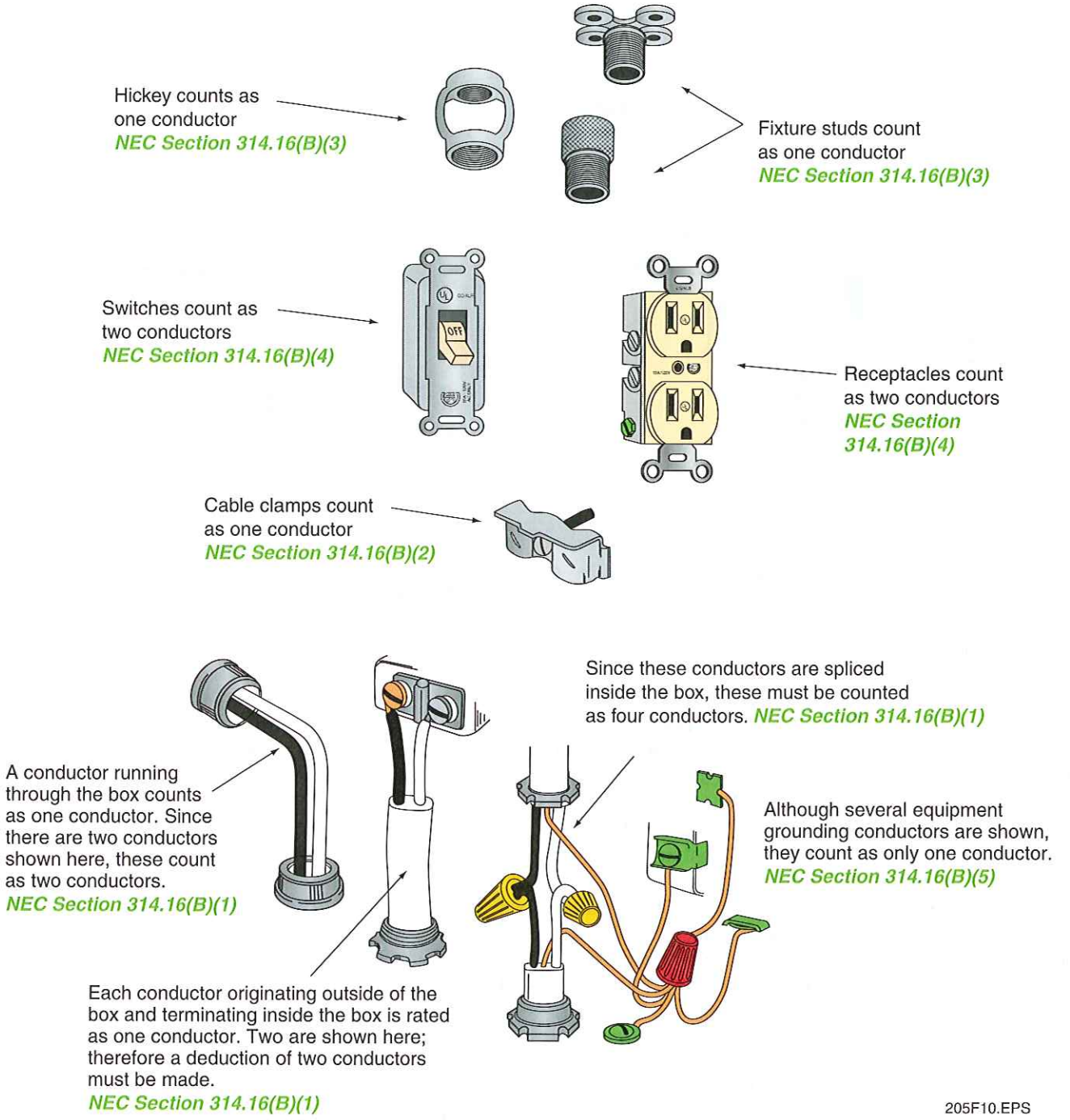


Figure 10 ◆ Devices and components that require deductions in outlet box capacity.

Figure 11 shows components that may be used in outlet boxes without affecting the total number of conductors. Such items include grounding clips and screws, wire nuts, and cable connectors when the latter are inserted through knockout holes in the outlet box and secured with locknuts. Prewired fixture wires are not counted against the total number of allowable conductors in an outlet box; neither are conductors originating and ending in the box.

To better understand how outlet boxes are sized, we will take two No. 12 AWG conductors installed in ½" EMT and terminating into a metallic outlet box containing one duplex receptacle. What size outlet box will meet *NEC*® requirements?

The first step is to count the total number of conductors and equivalents that will be used in the box *(NEC Section 314.16)*.

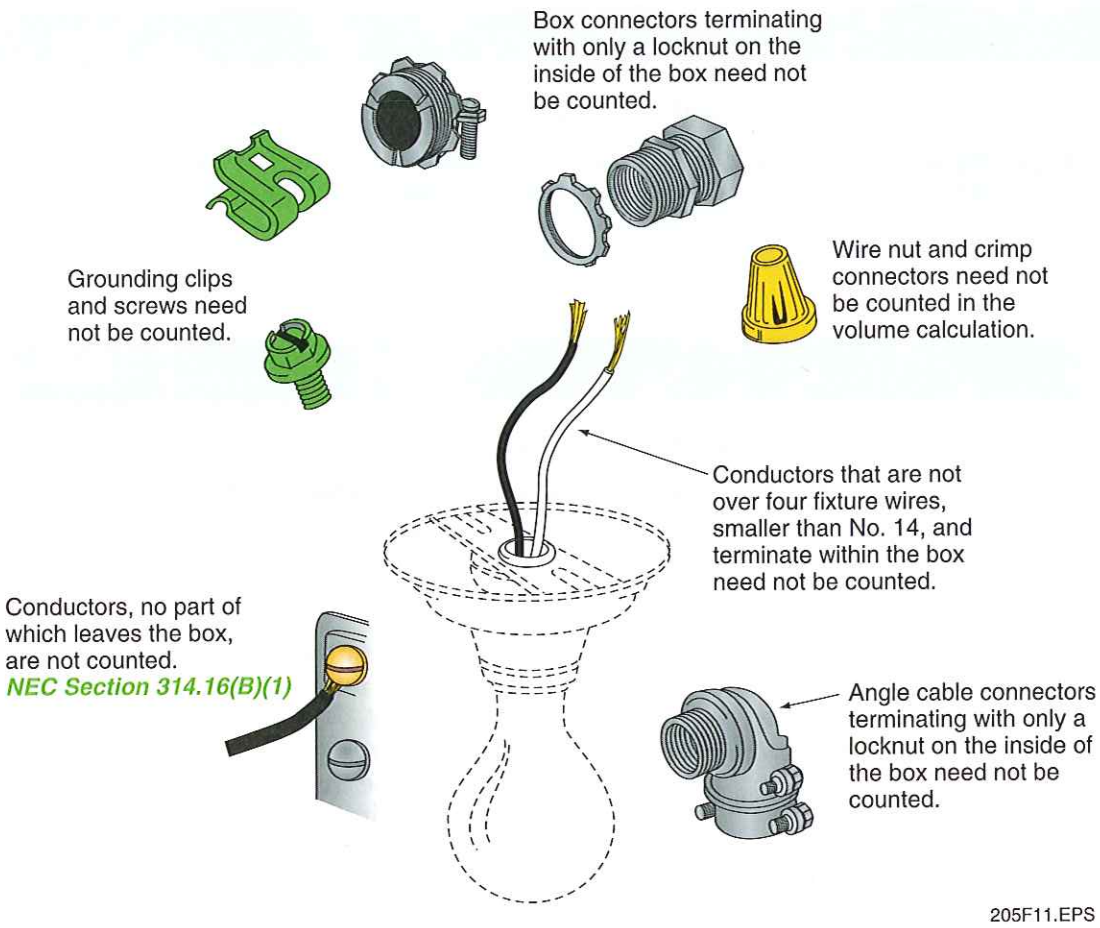


Figure 11 ◆ Items that may be disregarded when calculating outlet box capacity.

INSIDE TRACK

Allocating Space in a Box

Here is a summary of the *NEC*® rules for determining the capacity of a box. Add the number of conductor equivalents indicated for each device:

Each conductor	1
Each strap containing a device	2
Each fixture, stud, or hickey	1
One or more grounding conductors	1
One or more cable clamps	1

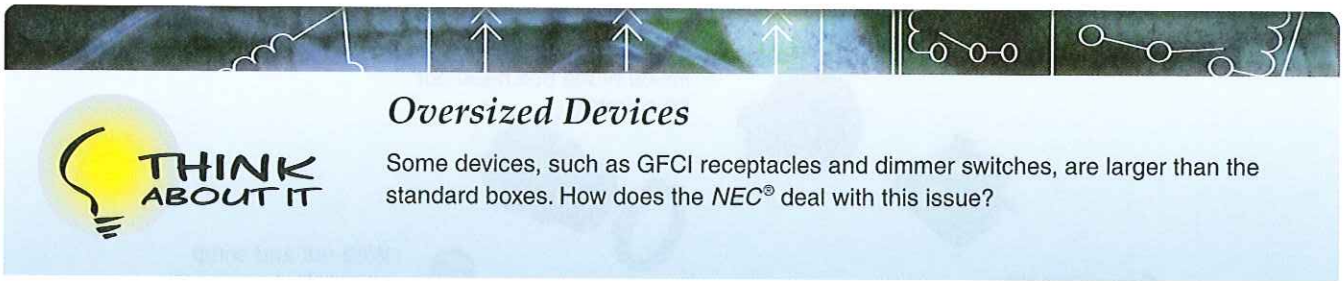
Also add one extra allowance for an additional grounding conductor when it is an isolating ground conductor.

Step 1 Calculate the total number of conductors and their equivalents:

One receptacle = 2
Two #12 conductors = 2
Total #12 conductors = 4

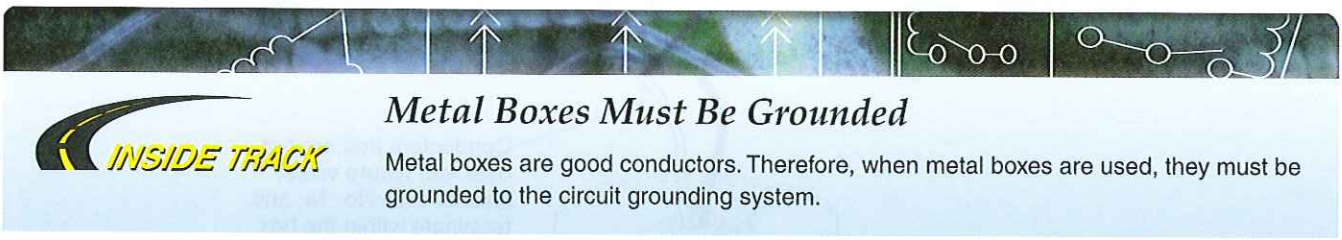
Step 2 Determine the amount of space required for each conductor. *NEC Table 314.16(B)* gives the box volume required for each conductor:

No. 12 AWG = 2.25 cubic inches



Oversized Devices

Some devices, such as GFCI receptacles and dimmer switches, are larger than the standard boxes. How does the *NEC*® deal with this issue?



Metal Boxes Must Be Grounded

Metal boxes are good conductors. Therefore, when metal boxes are used, they must be grounded to the circuit grounding system.

Step 3 Calculate the outlet box space required by multiplying the number of cubic inches required for each conductor by the number of conductors found in Step 1 above.

$$4 \times 2.25 = 9.00 \text{ cubic inches}$$

Step 4 Once you have determined the required box capacity, again refer to *NEC Table 314.16(A)* and note that a 3" × 2" × 2" box comes closest to our requirements. This box size is rated for 10.0 cubic inches.

For another example, if four No. 12 conductors enter the box, two additional No. 12 conductors must be added to our previous count for a total of six conductors.

$$6 \times 2.25 = 13.5 \text{ cubic inches}$$

Again, refer to *NEC Table 314.16(A)* and note that a 3" × 2" × 2¾" device box with a rated capacity of 14.0 cubic inches is the closest device box that meets *NEC*® requirements. Of course, any box with a larger capacity is permitted.

4.0.0 ◆ PULL AND JUNCTION BOXES

Pull and junction boxes are provided in an electrical installation to facilitate the installation of conductors, or to provide a junction point for the connection of conductors, or both. In some instances, the location and size of pull boxes are designated on the drawings. In most cases, however, the electricians on the job will have to determine the proper number, location, and sizes of pull or junction boxes to facilitate conductor installation.

Pull boxes should be as large as possible. Workers need space within the box for both hands and in the case of the larger wire sizes, workers will need room for their arms to feed the wire. *NEC Section 314.28* specifies that pull and junction boxes must provide adequate space and dimensions for the installation of conductors. For raceways containing conductors of No. 4 or larger, and for cables containing conductors of No. 4 or larger, the minimum dimensions of pull or junction boxes installed in a raceway or cable run shall comply with the following:

- In straight pulls, the length of the box shall not be less than eight times the trade diameter of the largest raceway.
- Where angle or U pulls are made, the distance between each raceway entry inside the box and the opposite wall of the box shall not be less than six times the trade diameter of the largest raceway in a row. This distance shall be increased for additional entries by the amount of the sum of the diameter of all other raceway entries in the same row on the same wall of the box. Each row shall be calculated individually, and the single row that provides the maximum distance shall be used.
- The distance between raceway entries enclosing the same conductor shall not be less than six times the trade diameter of the larger raceway.
- When transposing cable size into raceway size, the minimum trade size raceway required for the number and size of conductors in the cable shall be used.

Long runs of conductors should not be made in one pull. Pull boxes, installed at convenient intervals, will relieve much of the strain on the conductors. The length of the pull, in many cases, is

left to the judgment of the workers or their supervisor, and the condition under which the work is installed.

The installation of pull boxes may seem to cause a great deal of extra work and trouble, but they save a considerable amount of time and hard work when pulling conductors. Properly placed, they eliminate many bends and elbows and do away with the necessity of fishing from both ends of a conduit run.

If possible, pull boxes should be installed in a location that allows electricians to work easily and conveniently. For example, in an installation where the conduit comes up a corner of a wall and changes direction at the ceiling, a pull box that is installed too high will force the electrician to stand on a ladder when feeding conductors, and will allow no room for supporting the weight of the wire loop or for the cable-pulling tools.

Unless the contract drawings or project engineer state otherwise, it is just as easy for the pull boxes to be placed at a convenient height that allows workers to stand on the floor with sufficient room for both wire loop and tools.

In some electrical installations, a number of junction boxes must be installed to route the conduit in the shortest, most economical way. The *NEC®* requires all junction boxes to be readily accessible. This means that a person must be able to get to the conductors inside the box without removing plaster, wall covering, or any other part of the building.

Junction boxes detract from the decorative scheme of a building. Therefore, where such boxes will be used in areas open to the public or in other areas where the boxes will be unattractive, they should be installed above suspended ceilings, in closets, or at least in corners of the room or area.

Junction boxes or pull boxes must be securely fastened in place on walls or ceilings or adequately suspended.

While certain sizes of factory-constructed boxes are available with concentric knockouts, in many instances it will be necessary to have them custom built to meet the job requirements. When it is not possible to accurately anticipate the raceway entrance requirements, it will be necessary to cut the required knockouts on the job using hydraulic knockout cutters to keep labor to a minimum.

In the case of large pull boxes and troughs, shop drawings should be prepared prior to the construction of these items with all required knockouts accurately indicated in relation to the conduit run requirements.

4.1.0 Sizing Pull and Junction Boxes

Figure 12 shows a junction box with several runs of conduit. Since this is a straight pull, and 4" conduit is the largest size in the group, the minimum length required for the box can be determined by the following calculation:

Trade size of conduit × 8 [per ***NEC Section 314.28(A)(1)***] = minimum length of box

or:

$$4" \times 8 = 32"$$

Therefore, this particular pull box must be at least 32" in length. The width of the box, however, need only be of sufficient size to enable locknuts and bushings to be installed on all the conduits or connectors entering the enclosure.

Junction or pull boxes in which the conductors are pulled at an angle (*Figure 13*) must have a distance of not less than six times the trade diameter of the largest conduit *[NEC Section 314.28(A)(2)]*. The distance must be increased for additional conduit entries by the amount of the sum of the diameter of all other conduits entering the box on the same side. The distance between raceway entries enclosing the same conductors must not be less than six times the trade diameter of the largest conduit.

Since the 4" conduit is the largest size in this case:

$$L_1 = 6 \times 4" + (3 + 2) = 29"$$

Since the same conduit runs are located on the adjacent wall of the box, L_2 is calculated in the same way; therefore, $L_2 = 29"$.

INSIDE TRACK

Using Pull Boxes

Pull boxes make it easier to install conductors. They can also be installed to avoid having more than 360° worth of bends in a single run. (Remember, if a pull box is used, it is considered the end of the run for the purposes of the *NEC®* 360° rule.)

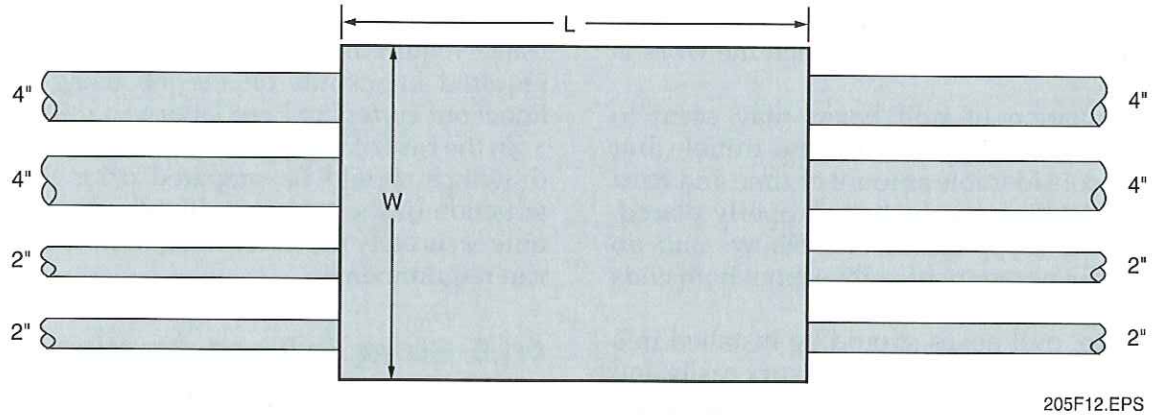


Figure 12 ◆ Pull box with two 4" and two 2" conduit runs.

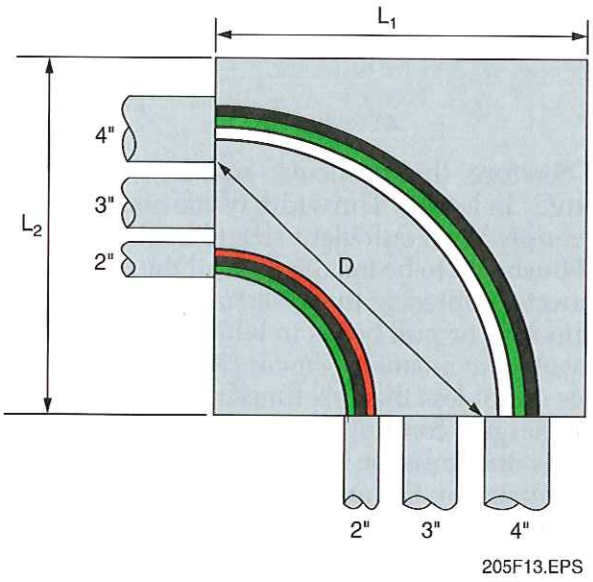


Figure 13 ◆ Pull box with conduit runs entering at right angles.

The distance (D) = 6 × 4" or 24". This is the minimum distance permitted between conduit entries enclosing the same conductor.

The depth of the box need only be of sufficient size to permit locknuts and bushings to be properly installed. In this case, a 6" deep box would suffice.

5.0.0 ◆ CONDUIT BODIES

Conduit bodies, also called condulets, are defined in *NEC Article 100* as a separate portion of a conduit or tubing system that provides access through a removable cover to the interior of the system at a junction of two or more sections of the system or at a terminal point of the system. Conduit bodies are usually used with RMC and IMC. The cost of conduit bodies, because they are cast, is significantly higher than the stamped steel boxes. Splicing in conduit bodies is typically not recommended; however, it is permitted under certain conditions as specified in *NEC Section 314.16(C)(2)*.

As an electrical trainee, you will hear such terms as LL, LR, as well as other letters to distinguish between the various types of conduit bodies. To identify certain conduit bodies, an old trick of the trade is to hold the conduit body like a pistol (*Figure 14*). When doing so, if the oval-shaped opening of the conduit body is to your left, it is called an LL—the first L stands for elbow and the second L stands for left. If the opening is on your right, it is called an LR—the R stands for right. If the opening is facing upward, this type of conduit body is called an LB—the B stands for back. If there is an opening on both sides, it is called an LRL—for both left and right. The other popular

INSIDE TRACK

Label Junction Boxes

It's a good idea to label every junction box plate with the circuit number, the panel it came from, and its destination. The next person to service the installation will be grateful for this extra help.

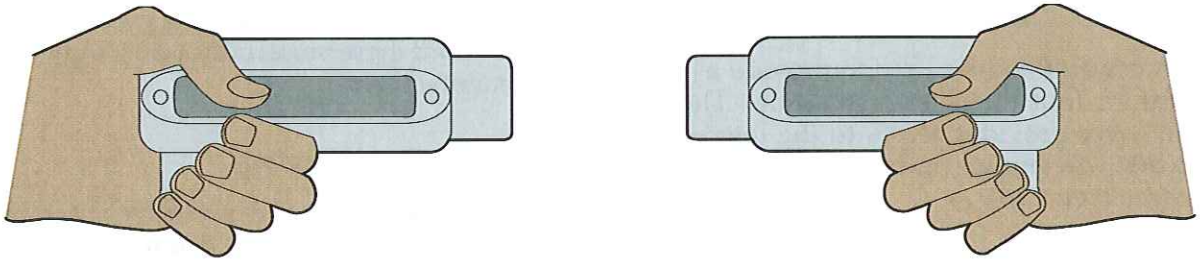


Figure 14 ◆ Identifying conduit bodies.

shapes are named for their letter look-alikes, that is, T and X. The only exception is the C conduit body. Let us take a closer look at each of these.

5.1.0 Type C Conduit Body

A Type C conduit body (*Figure 15*) may be used to provide a pull point in a long conduit run or a conduit run that has bends totaling more than 360° (see *NEC Sections 342.26, 344.26, and 358.26*). In this application, the Type C conduit body is used as a pull point.

5.2.0 Type L Conduit Bodies

A Type L conduit body (*Figure 16*) is used as a pulling point for conduit that requires a 90° change in direction. (Again, the letter L is short for elbow.) To use a Type L conduit body, the cover is removed, the wire is pulled out and coiled on the ground (or floor), and then it is reinserted into the other opening and pulled. Type L conduit bodies are available with the cover on the back (Type LB), on the sides (Type LL and Type LR), or on both sides (Type LRL). The cover and gasket for conduit body fittings must be ordered separately; do not assume that these parts come with the conduit body when it is ordered.


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Figure 16 ◆ Type L conduit bodies.

5.3.0 Type T Conduit Body

A Type T conduit body, also known as a tee, is used to provide a junction point for three intersecting conduits (*Figure 17*). Tees are used extensively in rigid conduit systems. The cost of a tee conduit body is more than twice that of a standard 4" square box with a cover. Therefore, the use of Type T conduit bodies with EMT is limited. According to *NEC Section 314.16(C)(2),* conductor splicing is permitted in a Type T conduit body if the necessary conditions are satisfied.

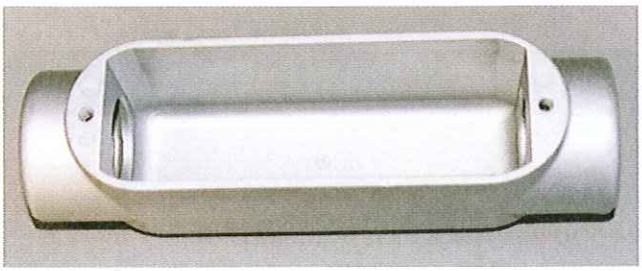
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Figure 15 ◆ Type C conduit body.

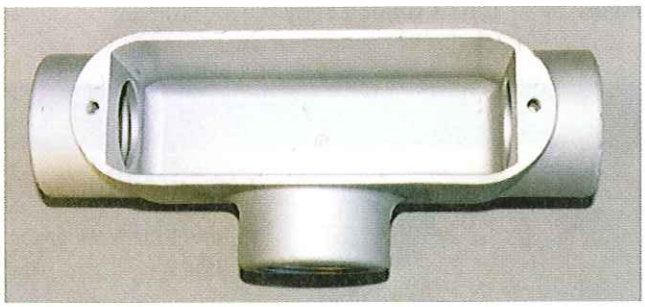
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Figure 17 ◆ Type T conduit body.

5.4.0 Type X Conduit Body

A Type X conduit body is used to provide a junction point for four intersecting conduits. The removable cover provides access to the interior of the X so that wire pulling and splicing may be performed (see *Figure 18*).

5.5.0 FS and FD Boxes

FS boxes are cast boxes available in single-gang, two-gang, and three-gang configurations. They are sized to permit the installation of switches and receptacles. Covers for switches and receptacles are available for FS boxes that have formed openings much like switch and receptacle plates. FD boxes are similar to FS boxes. The letter D in the FD box indicates it is a deeper box (2½" deep versus 1⅝" deep for an FS box). Neither FS nor FD boxes are considered by the *NEC*® to be conduit bodies. FS and FD boxes may be used in environments defined by NEMA 1 (dry, clean environments); NEMA 3R (outdoor, wet environments); and NEMA 12 (dusty, oily environments). NEMA stands for the National Electrical Manufacturers Association.

Engineers specify and electricians install FS and FD boxes for a reason. Never alter these boxes by drilling mounting holes in them. Most are provided with cast-in mounting eyes for this purpose. Mount these boxes only as recommended by the manufacturer.

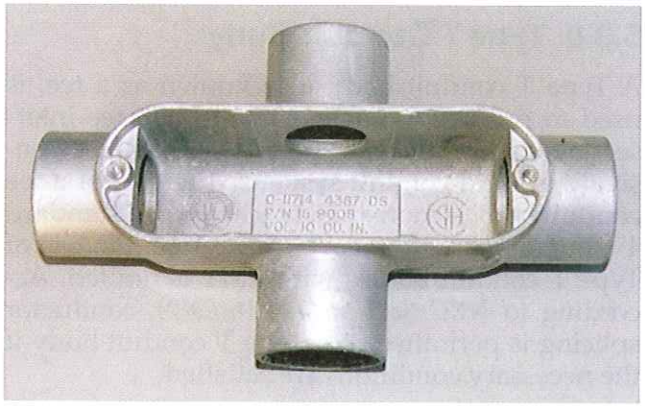

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Figure 18 ◆ Type X conduit body.

5.6.0 Pulling Elbows

Pulling elbows are used exclusively for pulling wire at a corner point of a conduit run. The volume of a pulling elbow is too low to permit splicing wire. See *Figure 19(A)*.

5.7.0 Entrance Ell (SLB)

An entrance ell, or SLB, is built with an offset so that it may be attached directly to the surface that is to have a conduit penetration. A cover on the back of the SLB permits wire to be pulled out and reinserted into the conduit that penetrates the support surface. See *Figure 19(B)*.

6.0.0 ◆ OUTLET BOXES IN HAZARDOUS LOCATIONS

Any area in which the atmosphere or a material in the area is such that the arcing of operating electrical contacts, components, and equipment may cause an explosion or fire is considered a hazardous location. In all such cases, explosion-proof equipment, raceways, and fittings are used to provide an explosion-proof wiring system, including the outlet boxes.

Hazardous locations have been classified in the *NEC*® into certain class locations. Various atmospheric groups have been established (on the basis of the explosive character of the atmosphere) for the testing and approval of equipment for use in the various groups.

6.1.0 Class I Locations

Those locations in which flammable gases or vapors may be present in the air in quantities sufficient to produce explosive or ignitable mixtures are classified as Class I locations. Examples of such locations are interiors of spray paint booths

INSIDE TRACK

FS and FD Boxes

FS and FD boxes are precision-molded boxes with a cover and gasket designed to provide a tight seal. Because they cost significantly more than standard boxes, they are typically used only in industrial environments where the boxes are subjected to moisture, dirt, dust, and corrosion.

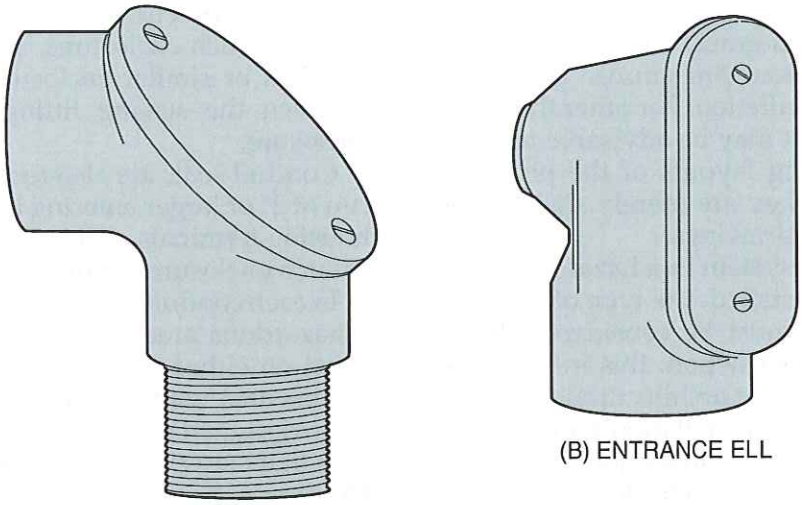
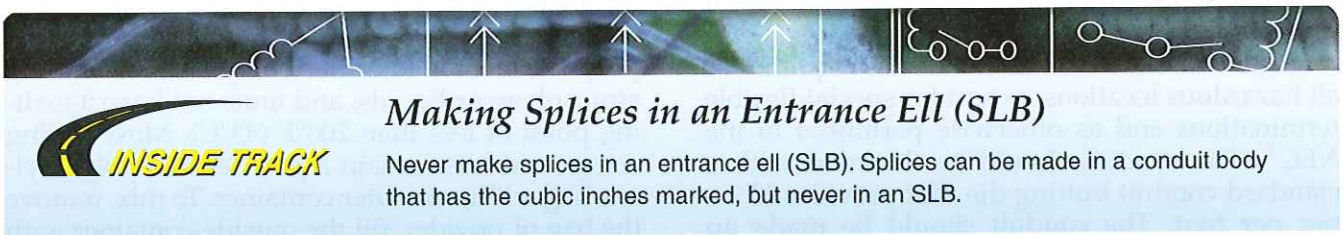


Figure 19 ◆ Elbows.



where volatile, flammable solvents are used, inadequately ventilated pump rooms where flammable gas is pumped, and drying rooms for the evaporation of flammable solvents.

6.2.0 Class II Locations

Class II locations are those that are hazardous because of the presence of combustible dust. Class II, Division 1 locations are areas where combustible dust under normal operating conditions may be present in the air in quantities sufficient to produce explosive or ignitable mixtures; examples are working areas of grain handling and storage plants and rooms containing grinders or pulverizers. Class II, Division 2 locations are areas where dangerous concentrations of suspended dust are not likely, but where dust accumulations might form.

6.3.0 Class III Locations

These locations are those areas that are hazardous because of the presence of easily ignitable fibers or flyings, but such fibers and flyings are not likely to be suspended in the air in these locations in quantities sufficient to produce ignitable mixtures. Such locations usually include some parts of rayon, cotton, and textile mills; clothing manufacturing plants; and woodworking plants.

The wide assortment of explosion-proof equipment now available makes it possible to provide adequate electrical installations under any of these hazardous conditions; however, you must be thoroughly familiar with all *NEC®* requirements. You must also know what fittings are available, how to install them properly, and where and when to use them.

The usual construction documents (drawings and specifications) for a hazardous area are drawn the same as the layout of an electrical system for a non-hazardous area—the only distinction is a note on the drawings stating that the wiring in this particular area must conform to the *NEC®* requirements for hazardous locations. The drafter or designer will sometimes add the letters EXP or XP next to all the symbols of the outlets that are to be explosion-proof. A few large-scale detail drawings may also be present. However, few engineers or drafters detail their drawings for hazardous areas sufficiently for the electricians to proceed with the installation

without additional study and layout work on the job site. Therefore, you must be familiar with the layout and installation procedures before attempting such an installation. For other than very simple installations, it may be advisable to make rough, detailed wiring layouts of the proposed installation, even if they are merely sketches on the original working drawings.

When an electrical system in a hazardous location is designed or installed, the type of building structure and finish must be considered. If the building is under construction, this information may be obtained from the architectural drawings and specifications. If the installation is made in an existing building, a preliminary job site investigation is often necessary. The location of the explosion-proof outlets, whether concealed or exposed, and the class of hazardous locations should appear in the electrical drawings and specifications. If such information is not provided, the contractor or electrician will have to determine this information from the architect, owner, or local inspection authority.

In general, rigid metallic conduit is required for all hazardous locations, except for special flexible terminations and as otherwise permitted in the *NEC®*. The conduit should be threaded with a standard conduit butting die that provides ¾" taper per foot. The conduit should be made up wrench-tight in order to minimize sparking in the event that fault current flows through the conduit system [*NEC Section 500.8(D)*]. Where it is impractical to make a threaded joint tight, a bonding jumper should be used. All boxes, fittings, and joints must be threaded for connection to the conduit system and must be of an approved, explosion-proof type. Threaded joints must be made up with at least five threads fully engaged. Where it becomes necessary to employ flexible connectors at motor or fixture terminals, flexible fittings approved for the particular class location must be used.

6.4.0 Seal-Off Fittings

Seal-off fittings are required in conduit systems to minimize the passage of gases and vapors and prevent the passage of flames from one portion of the electrical installation to another through the conduit. For Class I, Division 1 locations, *NEC Section 501.15(A)(1)* states that in each conduit run entering an explosion-proof enclosure containing switches, circuit breakers, fuses, relays, resistors, or other apparatus that may produce arcs, sparks, or high temperatures, seals shall be placed as close as practicable and in no case more than 18" from such enclosures. There shall be no junction box or similar enclosure in the conduit run between the sealing fitting and the apparatus enclosure.

Conduit seals are also required in each conduit run of 2" or larger entering the enclosure or fitting housing terminals, splices, or taps, and within 18" of such enclosures or fittings.

In each conduit run leaving the Class I, Division 1 hazardous area, the sealing fitting may be located on either side of the boundary of the hazardous area within 10' of the boundary, but shall be so designed and installed that any gases or vapors that may enter the conduit system, within the Division 1 hazardous area, will not enter or be communicated to the conduit beyond the seal. There shall be no union, coupling, box, or fitting, except approved explosion-proof reducers at the sealing fitting, in the conduit between the sealing fitting and the point at which the conduit leaves the area.

Sealing compound must be approved for the purpose, must not be affected by the surrounding atmosphere or liquids, and must not have a melting point of less than 200°F (93°C). Most sealing compound kits contain a powder in a polyethylene bag within an outer container. To mix, remove the bag of powder, fill the outside container with water up to the marked line on the container, pour in the powder, and mix.

To pack the seal-off, remove the threaded plug or plugs from the fitting and insert the fiber supplied with the packing kit. Tamp the fiber between the wires and the hub before pouring the sealing compound into the fitting. Then, pour in the sealing cement and reset the threaded plug tightly. The fiber packing prevents the sealing compound (in the liquid state) from entering the conduit lines.

The seal-off (sealing) fittings shown in *Figure 20* are typical of those used. *Figure 20(A)* is for vertical mounting and is provided with a threaded, plugged opening into which the sealing cement is poured. The seal-off in *Figure 20(B)* is for either horizontal or vertical runs, and has an additional plugged opening in the lower hub to facilitate packing fiber around the conductors in order to form a dam for the sealing cement.

Choosing the correct type of seal-off compound is very important. Always use a type that is compatible with the type of conductor insulation and is recommended by the manufacturer of the seal-off itself. There are certain types on the market that are designed for certain applications; make sure you use the right one.

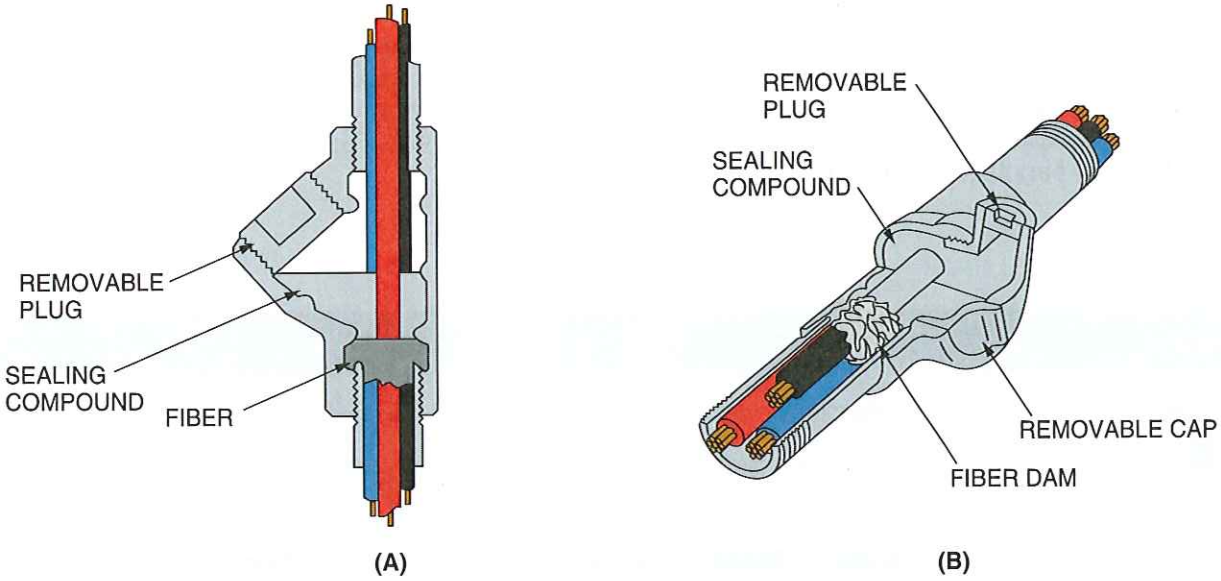


Figure 20 ◆ Typical seal-off fittings.

Most other explosion-proof fittings are provided with threaded hubs for securing the conduit. Typical fittings include switch and junction boxes, conduit bodies, union end connectors, flexible couplings, explosion-proof lighting fixtures, receptacles, and panelboard and motor starter enclosures. A practical representation of these and other fittings appears in *Figure 21*.

In certain hazardous locations, flexible couplings are used to connect vibrating machines, such as motors. Such a connection is shown in *Figure 22*.

INSIDE TRACK

Hazardous Locations Summarized

This table provides an overview of how hazards are organized by class and division. Refer to ***NEC Article 500*** for more detail.

Class	Division	Hazard	Example
I	1	Flammable gas or vapors exist under normal conditions	Spray paint facilities where flammable solvents are used; rooms where flammable gas is pumped
II	2	Flammable gas or vapors exist but are normally contained	Areas adjacent to Division 1 facilities; areas where flammable gases or vapors are handled in a closed system; similar areas where proper ventilation is provided
III	1	High concentrations of airborne combustible dust	Grain handling or storage plants
	2	Combustible dust accumulation on surfaces	Same as Division 1
	1	Easily ignitable fibers or airborne particles released through a manufacturing process	Textile mills; woodworking plants
	2	Ignitable fiber storage	Same as Division 1

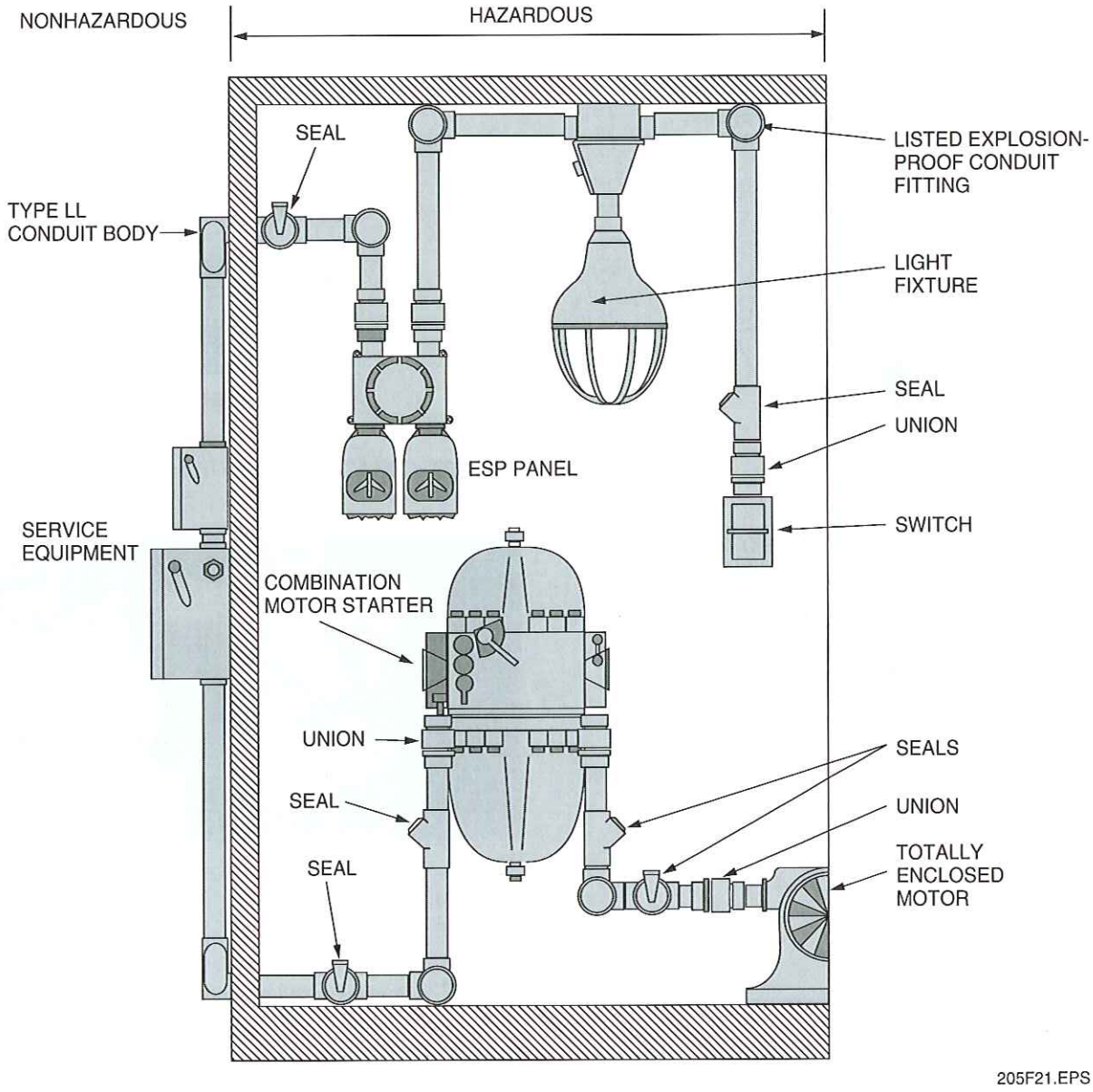


Figure 21 ◆ Practical representation of explosion-proof fittings in Class I, Division 1.

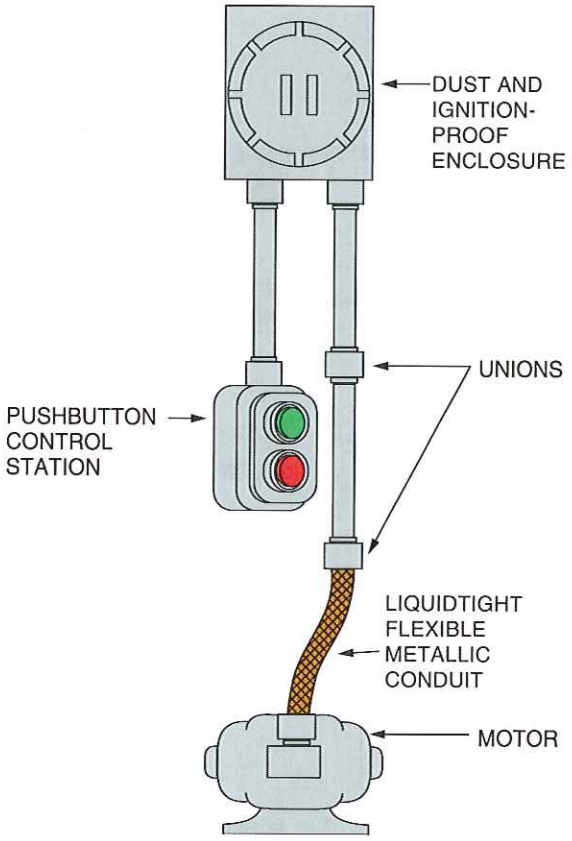


Figure 22 ◆ Power diagram for Class II, Division 2 installation with flexible conduit to motor.

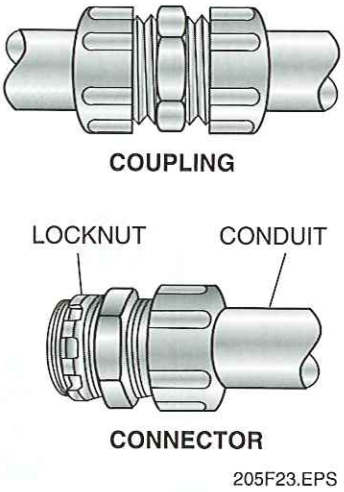


Figure 23 ◆ EMT compression fittings.

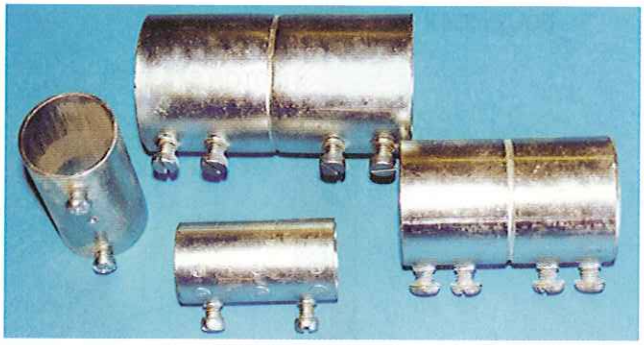


Figure 24 ◆ Setscrew fittings.

7.0.0 ◆ FITTINGS

Certain fittings are required in every raceway system for joining runs of conduit and also when the raceway terminates in an outlet box or other enclosure. Most metallic raceways qualify as an equipment grounding conductor provided they are tightly connected at each joint and termination point to provide a continuous grounding path.

7.1.0 EMT Fittings

Because EMT or thinwall is too thin for threads, special fittings must be used. For wet or damp locations, compression fittings such as those shown in *Figure 23* are used. This type of fitting contains compression rings made of plastic or other soft material that forms a watertight seal.

EMT fittings for dry locations can be either the setscrew type or the compression type. To use the setscrew type, the reamed ends of the EMT are inserted into the sleeve and the setscrews are tightened with a screwdriver to secure them and the conduit in place. Various types of setscrew couplings are shown in *Figure 24*.

EMT also requires connectors at each termination point, and EMT connectors are available to match the couplings described previously, that is, compression and setscrew types. They are similar to the couplings except that one end of the connector is threaded to accept a locknut and bushing.

7.2.0 Rigid, Aluminum, and IMC Fittings

Rigid metal conduit, aluminum conduit, and intermediate metal conduit all have sufficient wall thicknesses to permit threading. Consequently, all three types may be joined with threaded couplings (*Figure 25*) and when any of these types terminate into an outlet box or other enclosure, double locknuts are used to secure the conduit to the box opening. Running threads are not permitted for connection at couplings.

Sometimes rigid conduit or tubing must be connected to flexible metal conduit for connection to electric motors and other machinery that may

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Figure 25 ◆ Rigid metal conduit with coupling.

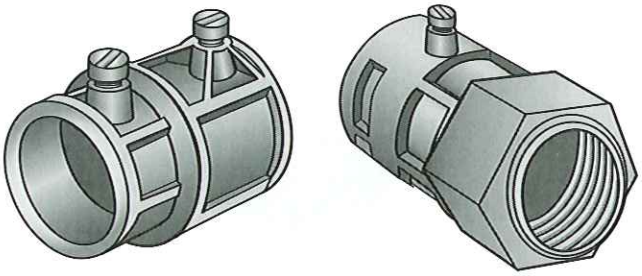

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Figure 26 ◆ Combination couplings.

vibrate during operation. Combination couplings (*Figure 26*) are used to make the transition. When using combination couplings, be sure the flexible conduit is pushed as far as possible into the coupling. This covers the sharp edges of the conduit to protect the conductors from damage.

Threadless couplings and connectors may also be used under certain conditions with rigid, IMC, and aluminum conduit. When used, they must be made up wrench-tight and where buried in masonry or concrete, they must be concrete-tight. Where installed in wet locations, they must be rainproof. This type of coupling is not permitted in most hazardous locations.

Other types of fittings used with raceway systems are shown in *Figure 27*.

Components Used in Hazardous Locations

THINK ABOUT IT

Photo (A) shows a special motor starter designed for use in a hazardous location. Photo (B) shows the same starter with the cover removed. Photo (C) shows an explosion-proof seal. Examine these components. How do they differ from standard components?

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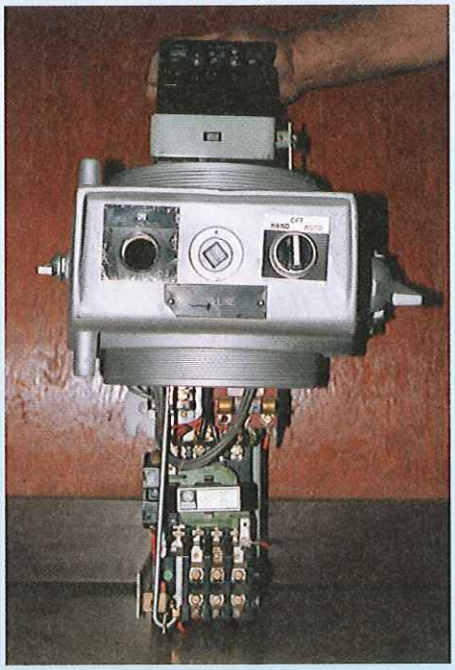
(A)



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(B)

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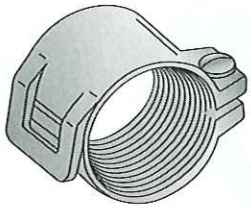
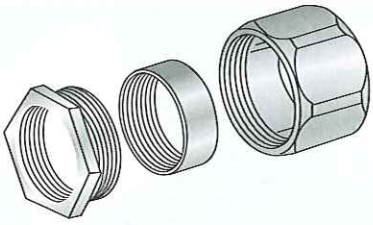
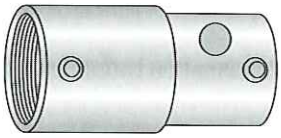
(C)



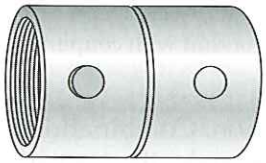
HINGED COUPLING



THREE-PIECE COUPLING



EMT TO RIGID



CONCRETE-TIGHT SETSCREW

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Figure 27 ◆ Metal conduit couplings.

7.3.0 Locknuts and Bushings

In general, locknuts are used on the inside and outside walls of outlet boxes or other enclosures to which threaded conduit is connected. When conduit connectors are used, such as EMT connectors, only one locknut is required on the threads that protrude inside the box. A grounding locknut may be needed if bonding jumpers are used inside the box or enclosure. Special sealing locknuts are also available for use in wet locations. Locknuts are shown in *Figure 28*.

Bushings protect the wires from the sharp edges of the conduit or connector. Bushings are usually made of plastic, fiber, or metal. Some metal bushings have a grounding screw to permit an equipment or bonding jumper wire to be installed. Several types of bushings are shown in *Figure 29*.

INSIDE TRACK

Explosion-proof Flex

This photo shows a special type of metal conduit for use in hazardous locations. Note that all conduit of this type comes with factory-made fittings for optimum protection under extreme conditions.

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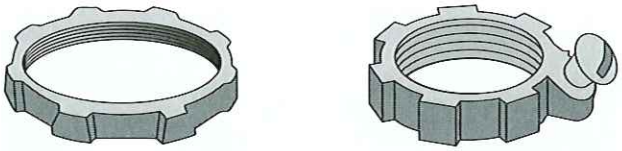


Figure 28 ◆ Common types of locknuts.

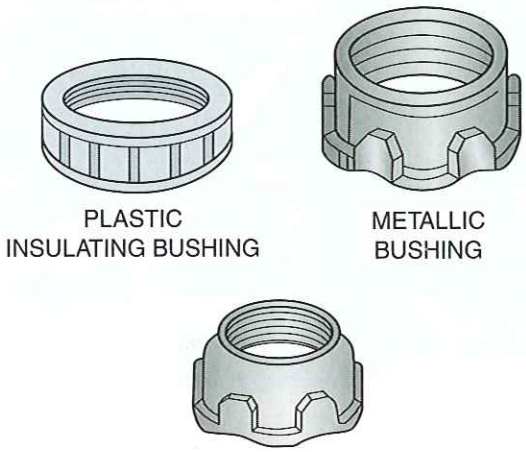


Figure 29 ◆ Typical bushings used at termination points.

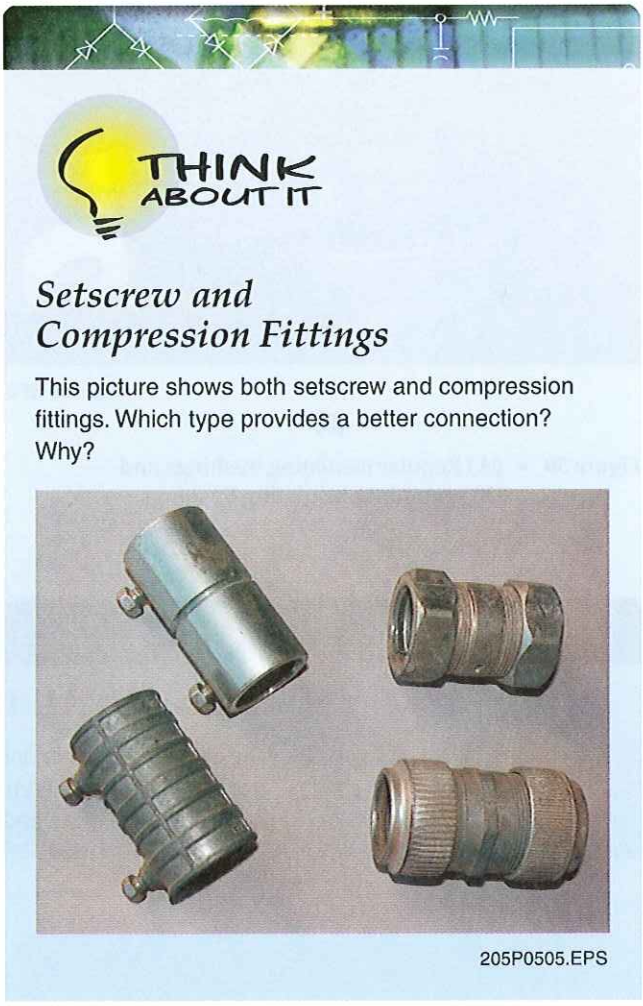
An insulating bushing is installed on the threaded end of conduit that enters a sheet metal enclosure. The purpose of the bushing is to protect the conductors from being damaged by the sharp edges of the threaded conduit end. Any ungrounded conductor, No. 4 AWG or larger, that enters a raceway, box, or enclosure must be protected with an insulating bushing, as required in *NEC Sections 300.4(F), 312.6(C), and 314.17(D).*

A grounding insulated bushing has provisions for protecting conductors and also has provisions for the connection of a ground wire. The ground wire, once connected to the grounding bushing, may be connected to the box to which the conduit is connected. See *Figure 30.*

An opening must be provided in the outlet box or enclosure for the entrance of conduit and connectors when raceway systems terminate. Most boxes and enclosures are provided with an adequate number of concentric knockouts. However, some may not have precut knockouts or the ones that are available may not be in the required location. In these cases, a knockout punch must be used to make a hole for the conduit connection. A hand-operated knockout punch is shown in *Figure 31.*

To use the knockout punch, the center of the hole is located in the box or enclosure and marked with a center punch. A pilot hole is then drilled to accept the threaded drive bolt of the knockout punch. The punch is separated from the drive screw, the screw is then placed through the pilot hole with the die on one side of the box wall, and the punch is screwed onto the drive screw on the opposite side of the wall. The punch is then aligned and screwed onto the drive screw hand-tight, in which case the punch should lightly bite into the wall of the enclosure. A wrench is then used to tighten the drive nut until the punch is drawn through the enclosure wall, making a neat circular opening.

Where many such openings must be made, or when knockouts for the larger sizes of conduit must be cut, contractors normally furnish workers with power knockout tools to facilitate the operation.



205F30A.EPS

(A)

205F30B.EPS

(B)

Figure 30 ◆ (A) Regular insulating bushings and (B) grounding insulating bushings.

205F31.EPS

Figure 31 ◆ Knockout punch kit.

THINK ABOUT IT

Putting It All Together

Turn off the power in one area of your home and then remove some of the switch and receptacle plates. Examine the wiring inside each box. Is the box adequately sized for the number of wires and devices?

Review Questions

1. The maximum weight allowed by the *NEC*® when ceiling fans are mounted directly to an approved outlet box is _____ pounds.
   a. 25
   b. 35
   c. 45
   d. 55

2. Square outlet boxes are available in 4" and _____ sizes.
   a. 4 11/16"
   b. 5"
   c. 5¼"
   d. 6"

3. Concrete boxes are normally used _____.
   a. in residential wiring to house wiring devices
   b. to feed lay-in troffer lighting fixtures
   c. in flat-slab construction projects
   d. in airport runway lighting

4. Deduct _____ conductor(s) for each strap-mounted device in a device box.
   a. one
   b. two
   c. three
   d. four

5. Using _____ adds to the capacity of an outlet box.
   a. fixture studs
   b. wire nuts
   c. strap-mounted devices
   d. raised device covers

6. When calculating the pull box size for straight pulls, the length of the box must not be less than _____ times the trade diameter of the largest raceway.
   a. two
   b. four
   c. six
   d. eight

7. If the largest trade diameter of a raceway entering a pull box is 3", and it is a straight pull, the minimum size box allowed is _____.
   a. 20"
   b. 24"
   c. 30"
   d. 36"

8. A _____ conduit body has openings on four different sides plus an access opening.
   a. Type X
   b. Type C
   c. Type T
   d. Type LL

9. Which of the following best describes how Type FS boxes should be installed?
   a. Holes should be drilled in back of the box for mounting screws.
   b. Holes should be drilled on the sides of the box only for mounting screws.
   c. No holes should be drilled in the box for mounting.
   d. Holes may be drilled only in existing installations.

10. The purpose of using seals or seal-off fittings in hazardous areas is to prevent _____.
    a. other conductors from being pulled into the raceway
    b. the passage of gases or vapors
    c. water from entering the raceway system
    d. the conductors from being removed from the raceway system

Summary

Electricians work with boxes and fittings almost every day on every project. Consequently, you must have a thorough knowledge of the types available and their applications. Portions of *NEC Chapters 3 and 4* cover the installation of boxes and fittings, so refer to appropriate sections in these chapters whenever a question arises.

One of the best ways to learn about boxes and fittings is to study manufacturers' catalogs. You will find a wealth of information in each of these, including detailed instructions (in many of them) on installation techniques. Some of these catalogs also provide simplified *NEC*® explanations of the use of the manufacturer's products.

Notes

Trade Terms Introduced in This Module

Conduit body: A separate portion of a conduit or tubing system that provides access through a removable cover (or covers) to the interior of the system at a junction of two or more sections of the system or at a terminal point of the system. Boxes such as FS and FD or larger cast or sheet metal boxes are not classified as conduit bodies.

Connector: Device used to physically connect conduit or cable to an outlet box, cabinet, or other enclosure.

Explosion-proof: Designed and constructed to withstand an internal explosion without creating an external explosion or fire.

Handy box: Single-gang outlet box used for surface mounting to enclose receptacles or wall switches on concrete or concrete block construction of industrial and commercial buildings; nongangable; also made for recessed mounting; also known as a utility box.

Junction box: An enclosure where one or more raceways or cables enter, and in which electrical conductors can be, or are, spliced.

Nineteen hundred box: A term commonly used to refer to any two-gang, four-inch-square outlet box.

Outlet box: A metallic or nonmetallic box installed in an electrical wiring system from which current is taken to supply some apparatus or device.

Pull box: A sheet metal box-like enclosure used in conduit runs to facilitate the pulling of cables from point to point in long runs, or to provide for the installation of conduit support bushings needed to support the weight of long riser cables, or to provide for turns in multiple-conduit runs.

Raintight: Constructed or protected so that exposure to a beating rain will not result in the entrance of water under specified test conditions.

Sealing compound: The material poured into an electrical fitting (seal-off) to seal and minimize the passage of vapors.

Waterproof: Constructed so that moisture will not interfere with successful operation.

Watertight: Constructed so that water will not enter the enclosure under specified test conditions.

Weatherproof: Constructed or protected so that exposure to the weather will not interfere with successful operation.

Additional Resources

This module is intended to present thorough resources for task training. The following reference works are suggested for further study. These are optional materials for continued education rather than for task training.

American Electrician's Handbook, Latest Edition. New York: Croft and Summers, McGraw-Hill.

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