Chapter 5
Wiring Methods

Technical Terms

Armored cable (BX)
Auxiliary gutters
Busways
Cable tray
Electrical metallic tubing (EMT)
Electrical nonmetallic tubing (ENT)
Flexible metal conduit (Greenfield)
Intermediate metal conduit (IMC)
Liquidtight flexible conduit
Metal-clad cable
Multiconductor cable
Nonmetallic-sheathed cable (romex)
Rigid metal conduit
Rigid nonmetallic conduit
Service-entrance cable
Surface raceway
Wireways

Objectives

After completing this chapter, you will be able to:

- List the wiring methods available for commercial installation and the rules regarding each method of wiring.
- Size wireways to satisfy *Code* requirements.
- Identify fittings, connectors, supports, and other integral hardware unique to a particular wiring method.
- Select the correct wiring method based on *Code* requirements.
- Calculate wireway size.

This chapter is an introduction to conduits, raceways, busways, wireways, junction boxes, gutters, busbars, pull boxes, device boxes, and a host of other wiring methods and related components. These items compose the system through which electricity is routed.

The *Code* recognizes many wiring methods for use in buildings. These wiring methods fall into several main categories:

- Raceways
- Conductors
- Cable
- Cable trays
- Busways
- Gutters
- Wireways

Some of the wiring methods have very specific applications, while others can be used in a greater variety of conditions. The table in **Figure 5-1** lists wiring methods and their corresponding *Code* articles. This is not a complete list of all wiring methods approved in the *Code*. The reader is encouraged to look into all methods of wiring and techniques covered in the *Code*.

Wiring Methods in the *Code*

Wiring Methods	*Code* Article
Armored Cable	320
Auxiliary Gutters	366
Busways	368
Cable Trays	392
Electrical Metallic Tubing	358
Electrical Nonmetallic Tubing	362
Flexible Metal Conduit	348
Flexible Metallic Tubing	360
Intermediate Metal Conduit	342
Liquidtight Flexible Conduit	350, 356
Metal-Clad Cable	330
Multioutlet Assembly	380
Nonmetallic-Sheathed Cable	334
Rigid Metal Conduit	344
Rigid Nonmetallic Conduit	352
Service-Entrance Cable	338
Surface Raceway	386, 388
Underground Feeder Cable	340
Wireways	376, 378

Figure 5-1. *Code* sections for common wiring methods.

General Rules and Requirements

The *Code*, under *Article 300—Wiring Methods,* addresses the acceptable methods of installing conductors. Choosing the right method for a wiring job depends on the environment where the wiring is to be installed. Certain wiring methods are only permitted in a limited range of conditions. Others are acceptable in a broad variety of situations.

Regardless of the specific wiring method, there are some general rules common to many of the methods. These provisions should be understood before beginning any wiring installation. A brief look at these general provisions follows:

- Whether in cable or as single individual units, conductors should be used within the voltage and temperature range for which they are designed.

WARNING

Conductors placed in service where the voltage or temperature may exceed their specific rating will represent a serious hazard to the electrical system, equipment, structure, and personnel.

- Normally, single conductors may only be installed as part of a wiring method recognized by the *Code.* Thus, routing individual conductors without the protection or support of an approved wiring method is strictly prohibited.
- For a circuit, the current-carrying conductors, neutral conductor (where used), and equipment grounding conductor must all be run within the same conduit, cable, duct, tray, or enclosure. Failure to comply with this requirement could lead to inductance problems.

NEC NOTE 300.3(B)

All conductors of the same circuit and, where used, the grounded conductor and all equipment grounding conductors shall be contained within the same raceway, cable tray, trench, cable, or cord. See exceptions in *Code.*

- Circuits of different voltage may be run in the same raceways or occupy the same spaces (enclosures, equipment) providing that the voltage is less than 600 volts and the conductors each have insulation ratings greater than or equal to that of the circuit with the highest voltage rating. For example, conductors rated for 300 volts can be run in the same raceway as conductors rated for 600 volts as long as the maximum circuit voltage is 300 volts.
- Measures must be taken to protect conductors against physical damage. When running cable through bored holes in framing members, the edge of the hole should be 1 1/4″ away from the nearest edge of the member. If a cable or raceway is placed along notches made in wood framing members, the notches must be protected from nails and screws by using a metal plate (minimum 1/16″ thick) to cover the notches. If cables or nonmetallic raceway is run perpendicular to exposed studs, rafters, or joists and subject to damage, strips of 1 × 1 or 1 × 2 wood stock should be placed along either side to protect the wiring from damage. **Figure 5-2** illustrates methods of protecting conductors from physical damage.

Rules for Buried Conductors

Conduit, cables, and other raceways that are buried must meet specific criteria. The conductors must be protected so that damage does not occur.

Table 300.5 of the *Code* lists the minimum burial depth for conductors 600 volts nominal or less. The table in **Figure 5-3** is a condensed version of *Table 300.5.* Deeper burial is not uncommon due to soil conditions, interferences with other utilities, and structural footings.

Cables under buildings must be installed in raceway and the raceway must extend past the exterior walls of the building. Further, where buried conductors and cables emerge from the ground, protection must be provided by raceways that extend from the minimum cover distance to at least 8′ above grade or to the point of entry into a building. See **Figure 5-4.** At the point where underground conductors emerge from a raceway, the raceway should be fitted with a bushing or sealed.

NEC NOTE 300.5(D)(4)

Where the enclosure or raceway is subject to physical damage, the conductors shall be installed in rigid metal conduit, intermediate metal conduit, or Schedule 80 PVC, or equivalent.

Regardless of the method of wiring used, all underground installations must be grounded and bonded as required by the *Code*. Refer to Chapter 10 of this text and *Article 250—Grounding* of the *Code.*

Splices and taps are permitted in buried conductors and cables. Be sure to use materials that are suitable for underground use. All splicing materials must be suitable for the conditions and environment in which they are installed.

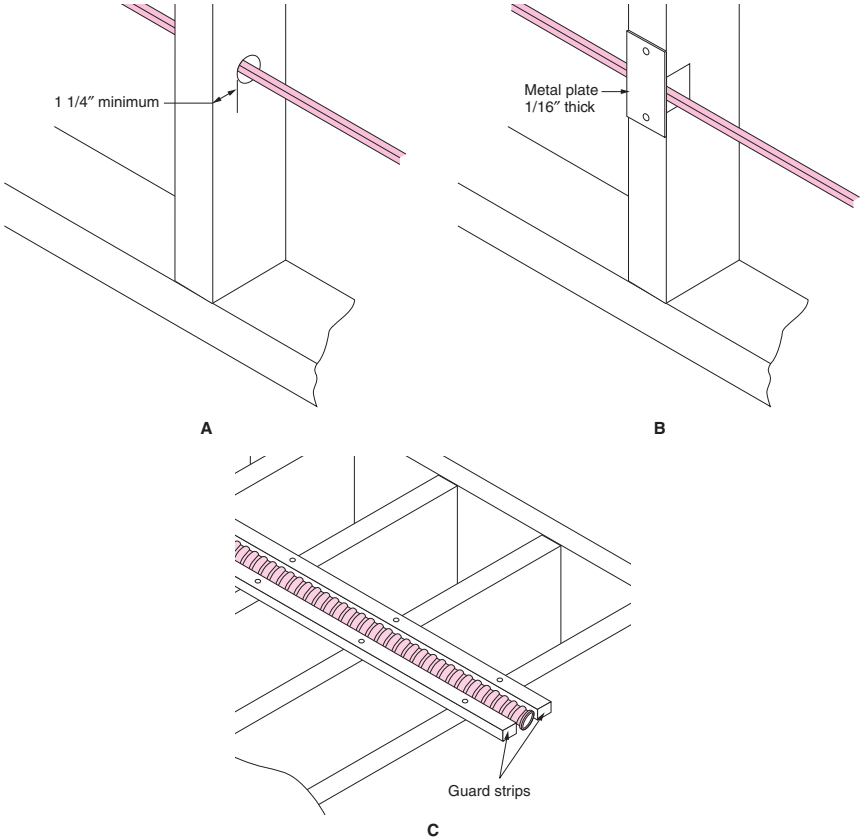

Figure 5-2. Conductors running through framing members must be protected. A—Holes bored through framing members must be at least 1 1/4″ from the edge of the member. B—Notches must be covered by a metal plate to protect conductors from nails and screws. C—Guard strips must be at least as high as the cable they protect.

Minimum Burial Depths (600V or less)

	Cables or Conductors	IMC or Rigid Metal Conduit	Rigid Nonmetallic Conduit
Below streets, alleys, and parking lots	24″	24″	24″
Below building slab or foundation (in raceway)	0″	0″	0″
In trench below 2″ thick concrete or equivalent	18″	6″	12″
Under one- or two-family dwelling driveway	18″	18″	18″

Figure 5-3. Condensed version of *Table 300.5* from the *Code.*

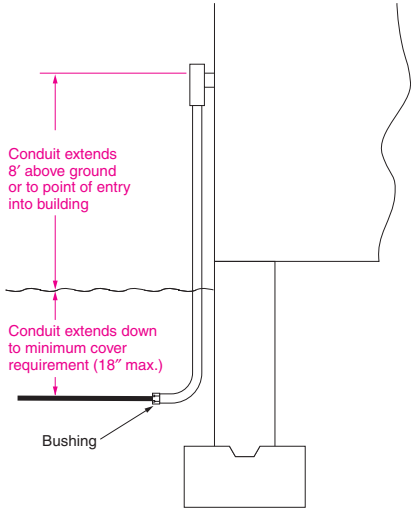

Figure 5-4. Conduit must be installed to protect cables and conductors emerging from underground.

Securing and Supporting Wiring Systems

All wiring must be secured to and supported by structural members. Normally, wiring systems are not used to support other wiring systems or nonelectric equipment. However, *Section 300.11(B)* of the *Code* specifies some conditions under which one raceway can be supported by another raceway.

Mechanical and electrical continuity is required. Metal conduit, cable sheaths, cable armor, and nonmetallic raceway must be continuous between boxes, enclosures, fittings, and cabinets. All connections between the components must be secure prior to pulling conductors. The equipment grounding conductor should be independent of the device connection, so if the device is removed the continuity is not interrupted.

Conductor support in vertical raceway

In buildings where raceways are run vertically, the conductors must be supported at assigned intervals. One cable support at the top of the raceway run and at intervals indicated in the table in **Figure 5-5** are required. This table is a condensed version of *Table 300.19(A)* from the *Code*.

Support of vertical conductors can be accomplished in several ways, including the following:

- Placing insulated wedges between the cable and the inside wall of the raceway or using insulated clamps within an enclosure.
- Installing junction boxes with supports installed and attached to the cable, **Figure 5-6.**
- Installing junction boxes and offsetting the cable at least 90° and using tie wires within the box.

NEC NOTE 300.19(C)(3)

When the cable is supported by bending it at least 90° in a junction box and securing with tie wires, support intervals cannot exceed 20% of the normal maximum support distance. The bend in the conductor must extend horizontally at least twice the diameter of the cable.

Wiring within Air-Handling Spaces

No wiring is permitted within air-handling ducts used for the purpose of transporting dust, flammable vapors, or cooking equipment ventilation. In plenums used for environmental air only, wiring methods employing type MI or MC cable are permitted. Flexible metal conduit and liquidtight flexible metal conduit are also permitted in short lengths (not more than 4′) to connect sensors, louvers, and other devices permitted in these plenums.

For other types of air-handling ducts, refer to *Code Section 300.22(C)* and the local inspection authority, which may have special requirements applicable to the specific conditions.

Vertical Spacing for Conductor Supports

Conductor Size	Maximum Distance between Supports (in feet)	
	Copper Conductors	Aluminum Conductors
18 AWG through 8 AWG	100	100
6 AWG through 1/0 AWG	100	200
2/0 AWG through 4/0 AWG	80	180
Over 4/0 AWG through 350 kcmil	60	135
Over 350 kcmil through 500 kcmil	50	120

Figure 5-5. Condensed version of *Table 300.19(A)* of the *Code*.

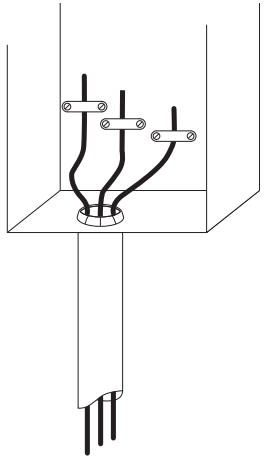

Figure 5-6. Cable must be supported vertically within the maximum support distance. Clamping the conductors to the junction box is one method of vertical support.

Temporary Installations

The provisions of *Article 590* of the *Code* are specifically tailored to apply to temporary electrical wiring methods, which may be less exacting than a permanent wiring system. Temporary wiring installations are allowed for the purpose of providing power and lighting to facilities during construction. Temporary wiring can also be used for testing, experimental, and developmental purposes. Upon completion of the activity, the temporary lighting must be removed.

Bear in mind that *Article 590* simply modifies *Code* requirements, and that except for those specifically modified under that article, all other requirements of the *Code* apply. Some of the modifications and specific requirements for temporary wiring are as follows:

- All lamps for general lighting will be protected from breakage by a guard over or around the lampholder.
- Splices in conductors do not require junction or splice boxes if the conductors are part of a multiconductor cable or open conductors.
- Ground-fault circuit-interrupters are required for all 125-volt, single-phase, 15- and 20-amp receptacles that are not fed from permanent wiring circuits.
- Regularly scheduled maintenance checks will be performed on equipment grounding conductors. The checks will be performed at not more than three month intervals and will verify continuity, any damaged condition, and proper polarity relative to the grounding electrode conductor.

NEC NOTE 590.3(B)

Temporary electrical power and lighting for holiday decoration and similar purposes is allowed for a period not to exceed 90 days.

Wiring Methods

There are three broad classes of wiring methods: cable, raceways, and cable trays. All of the methods are used to connect the power supply, devices, and switches in an electrical circuit.

Cable consists of several conductors wrapped by a flexible outer covering. Raceways are enclosures installed between equipment or devices that are to be connected by conductors. The conductors or cables are placed inside the raceway, which protects and supports the wiring. Unlike raceways, cable trays are not enclosed; they are simply trays on which cables are laid.

Multiconductor Cable

Multiconductor cables are flexible assemblies of conductors having an overall protective covering. There are essentially four major types of multiconductor cable assemblies:

- Service-entrance cable
- Armored cable
- Nonmetallic-sheathed cable
- Metal-clad cable

Service-entrance cable (SE, USE, and ASE)

Service-entrance cable has conductors that can be used not only for service-entrance wiring, but also for indoor applications. Type SE, as shown in **Figure 5-7,** is unarmored, moisture resistant, and flame retardant. It can be composed of two or three insulated conductors and an additional bare conductor. It is readily available in AWG sizes 12 AWG through 4/0 AWG.

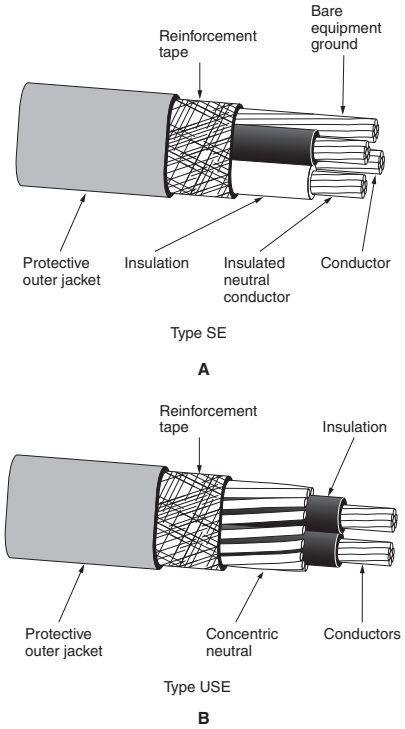

Figure 5-7. Service-entrance cable can be used for general indoor wiring as well as at the service entrance. A—Type SE cable. B—Type USE cable is used for underground applications.

Type USE is basically the same as type SE except the outer jacketing is better suited for direct burial. It is highly moisture and corrosion resistant. Type ASE has an armored jacket, which provides additional protection.

As already noted, service-entrance cable can be used for interior wiring or for service-entrance cable between the utility supply and main service disconnect. When it is used for interior wiring, the grounded neutral conductor must be insulated, with the following exceptions:

- When used as a feeder between two buildings.
- When used as the circuit conductor or branch wiring to clothes dryers, counter-mounted cooktops, ranges, and ovens.

Service-entrance cable may not be used for interior wiring of buildings of any type exceeding three stories high.

Armored cable (AC and ACL)

Type AC or ACL (often called "BX" cable) is used in both dry and wet locations, but is not permitted to be buried, see **Figure 5-8.** This type of cable, once commonly used in many applications, has some limitations for commercial use. It may not be used in places of assembly, studios, movie theaters, hazardous locations, commercial garages, areas with vapors and corrosive agents, lifts, cranes, hoists, elevators, or battery rooms.

Armored cable can be used in the following situations:

- As flexible connections to motors or vibrating equipment (up to 24″ length).
- As fixture whips (up to 6′ length).
- In dry locations.
- Concealed behind walls (may be fished behind walls in old work).
- Exposed along wall surfaces.
- Where exposed to weather or moisture (type ACL only).

Armored cable must be properly supported at intervals of 4′ - 6″ and within 12″ of terminal boxes or fittings. When routing BX cable through wall, floor, or ceiling members, the member must be drilled through the center or notched and covered with a metal plate to protect the cable from nails. The cable can be run along the sides of studs, joists, or rafters without further protection. Guard strips made of 1 × 1 or 1 × 2 stock are used to protect BX or AC cable when it is run along attic floor joists.

CAUTION

Antishort insulating bushing must be placed between conductors and the outer armor wherever the cable is cut. The bushings protect the conductor insulation from any sharp edges on the cut armor.

Nonmetallic-sheathed cable (NM, NMC, and UF)

Often referred to as ***Romex,*** nonmetallic-sheathed cable is frequently used as the preferred wiring method in small commercial establishments, as well as in residential structures. This cable is made up of two to four insulated conductors plus a green insulated or bare grounding conductor with an overall nonmetallic sheath. See **Figure 5-9.**

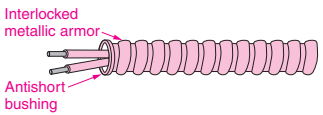

Figure 5-8. Types AC and ACL cable are also commonly referred to as BX cable.

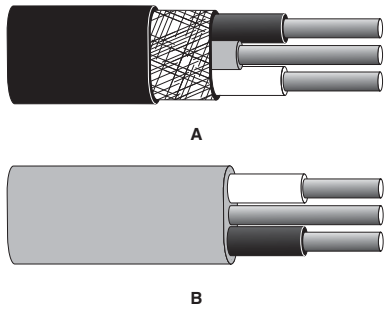

Figure 5-9. Nonmetallic-sheathed cable. A—Type NM is often called Romex. B—Type UF cable is used both indoors and outdoors.

Type NM is used strictly indoors while types NMC and UF are suitable for either indoor or outdoor applications. Further, type UF can be directly buried in the ground.

Nonmetallic cable must be supported every 4′ - 6″ and within 12″ of a terminal box, junction box, outlet, or fitting. It may be installed alongside or through studs, joists, rafters, and other building members with the same protection requirements and restrictions as with armored cable. This type of cable may also be installed in unfinished basements, attics, and crawl spaces, and may be terminated in metal or nonmetallic boxes.

Metal-clad cable (MC)

This type of cable is a heavy-duty commercial and industrial assembly consisting of one or more conductors individually insulated and enclosed in an interlocked metallic armor that consists of corrugated tubing or interlocking tape. This type of cable looks similar to armored cable (BX). MC cable is available in sizes 14 AWG up to 1000 kcmil. Its use is permitted in a wide range of applications:

- Indoors or outdoors.
- Exposed or concealed.
- For direct burial.
- As open run cable, or in a raceway or a conduit tray.
- As aerial cable on a messenger wire.
- In hazardous locations.
- In wet and dry locations.
- For feeders, branch circuits, and service conductors.
- For power, control, lighting, and other circuit applications.

Type MC cable cannot be used in destructive corrosive environments, such as buried in concrete or earth that exposes the cable to harmful chemicals and contaminants.

Raceways

A wiring method using raceways is more secure and safe than a method using only cables. This is a result of the added protection provided by the raceway. Unfortunately, a method using raceways is also more expensive.

There are many different types of raceway. The selection of a particular type depends on the specific application.

NEC NOTE 100

Raceway: An enclosed channel of metal or nonmetallic materials designed expressly for holding wires, cables, or busbars, with additional functions as permitted in this *Code.*

Rigid metal conduit (RMC)

This extremely strong and versatile wiring method may be installed inside, outside, in damp, wet, dry locations and in almost any kind of building. It can be installed exposed or concealed in nearly all locations. When connected and joined properly, the metal-to-metal continuity is excellent and provides good grounding for equipment fed by the conduit system.

Rigid metal conduit is manufactured in 10′ lengths, but other sizes can be ordered. It can be field cut and threaded. Threading must have a taper equivalent to 3/4″ to every foot. Bushings should be used at ends where wires enter or exit the conduit to prevent damage to the insulation.

There are numerous connectors and fittings used with rigid metal conduit. See **Figure 5-10.** Most of these fittings are also used with intermediate metal conduit.

Generally, the conduit should be supported every 10′ and within 3′ of a junction, outlet, or fitting. The total number of bends in a run of rigid metal conduit must not exceed 360°, **Figure 5-11.**

NEC NOTE 344.30(B)(3)

For vertical rigid metal conduit risers from machinery with threaded coupling, the distance between supports can be increased to 20′, provided that both ends of the riser are securely fastened and no means of intermediate support is readily available.

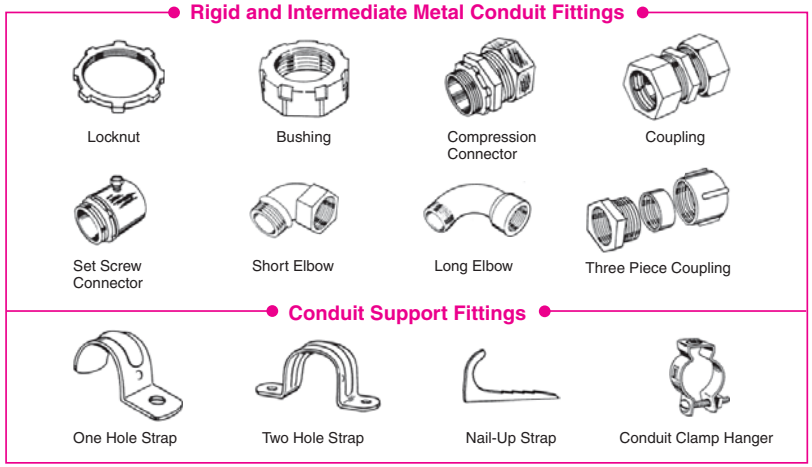

Figure 5-10. Many types of fittings are used with rigid metal conduit and IMC. The conduit support fittings are also used to support cables. (RACO, Inc.)

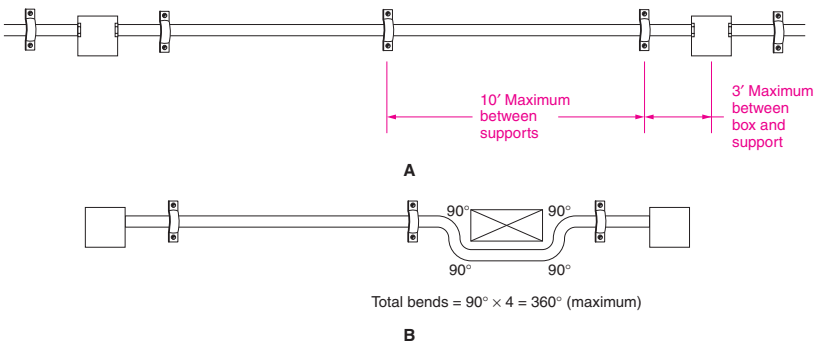

Figure 5-11. Conduit support and bending limitations for rigid metal conduit, IMC, EMT, and rigid nonmetallic conduit. A—Conduit must be supported within 3′ of a box. The maximum distance between supports is 10′. B—The total number of bends in a conduit must not exceed 360°. Here, the maximum number of bends have been made.

Intermediate metal conduit (IMC)

IMC has a thinner wall than rigid metal conduit, but is nearly as strong. It is approximately 25% lighter than rigid conduit and is less costly. IMC can be threaded and reamed in the field.

This conduit has the same permitted uses as rigid metal conduit. It is manufactured in sizes of 1/2″ to 4″. IMC also serves as an excellent equipment ground.

Just like rigid metal conduit, IMC must be supported every 10′ and within 3′ of every outlet and fitting. The total number of bends in each run must be less than 360°.

Electrical metallic tubing (EMT)

EMT, or thinwall conduit, is about half as heavy as rigid metal conduit. This is due to the fact that EMT has a much thinner wall (about 60% less) than rigid metal

Conduit Properties

Trade Size	Rigid Steel Conduit				EMT			
	OD	ID	Wall Thickness	Weight (lb/1000′)	OD	ID	Wall Thickness	Weight (lb/1000′)
1/2	0.840	0.622	0.109	820	0.706	0.622	0.042	295
3/4	1.050	0.824	0.113	1120	0.922	0.824	0.049	445
1	1.315	1.049	0.133	1600	1.163	1.049	0.057	650
2	2.375	2.067	0.154	3500	2.197	2.067	0.065	1410
3	3.500	3.068	0.216	7120	3.500	3.356	0.072	2700
4	4.500	4.026	0.237	10,300	4.500	4.334	0.083	4000

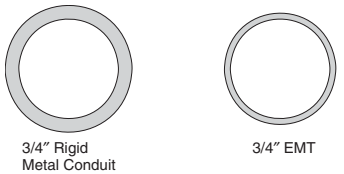

Figure 5-12. This table compares several sizes of rigid metal conduit and EMT. Cross sections of nominal 3/4″ raceway are shown. The EMT is lighter and more affordable, while the rigid metal conduit is more sturdy and durable.

conduit, although their outer diameters are about the same. See **Figure 5-12.** IMC is also thicker than EMT.

This advantage of lighter weight is offset by the loss in ability to withstand physical damage. EMT does not enjoy as wide a variety of permitted usage as does rigid metal or intermediate metal conduit. Still, EMT may be used in most locations.

EMT is not threaded. Its couplings and connectors can be set screw, compression, or indenter types. See **Figure 5-13.** It is supported at intervals of no more than

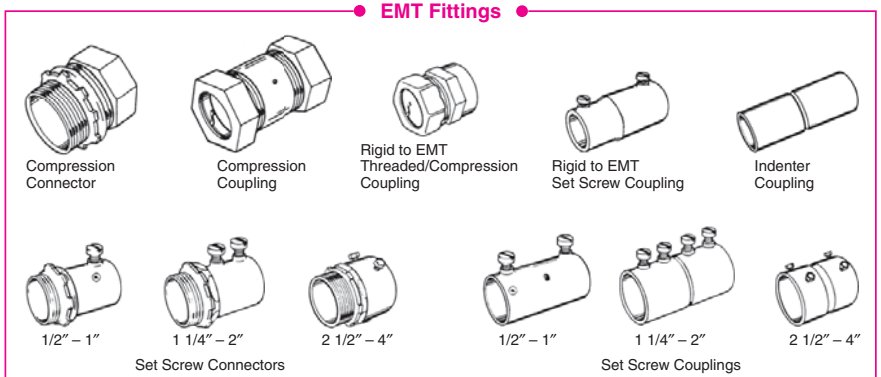

Figure 5-13. EMT couplings and connectors. (RACO, Inc.)

10′ and within 3′ of outlets and fittings. The number of conductors permitted in EMT is determined from the tables in *Chapter 9* of the *Code*. As with rigid metal conduit and IMC, the total bends between raceway ends must not exceed 360°.

Flexible metal conduit (FMC)

Flexible metal conduit is very similar in appearance to armored cable. The primary differences are that FMC does not come with conductors and the armor is more closely interlocked.

This type of conduit may be installed in dry or wet locations (providing the conductors are "W" rated and the flex is liquidtight), hoistways, hazardous areas (Class I, Division 2), and oil and gasoline areas if the conductor insulation is suitable for the purpose.

FMC is manufactured in sizes 3/8″ to 4″ diameter, the 3/8″ size being permitted for use in connections not over 6′ in length for fixture whips, motor connections, under plaster extensions, and manufactured wiring systems. In such lengths or less, the FMC may serve as the equipment grounding conductor. Flexible metal conduit fittings are shown in **Figure 5-14.**

FMC must be supported at intervals less than 4′ - 6″ and within 12″ of each end. It should also be firmly supported at every bend. Lengths of FMC less than 3′ do not need to be supported, **Figure 5-15.** As with other forms of conduit, the total bends between termination points must not exceed 360°.

The maximum number of conductors permitted in 1/2″ to 4″ FMC is determined by using the tables in *Chapter 9* of the *Code.* For 3/8″ FMC, the number of conductors is indicated in *Table 348.22* of the *Code.*

NOTE

Conduit sizing is discussed in Chapter 6 of this text.

Liquidtight flexible metal conduit (LFMC)

Liquidtight flexible metal conduit is identical to flexible metal conduit except it has an outer plastic jacket that makes it impervious to liquids. It is manufactured in sizes from 3/8″ to 4″ in diameter. The connectors are watertight as well.

Requirements for number of conductors, bends permitted, and supporting liquidtight metal flex are the same

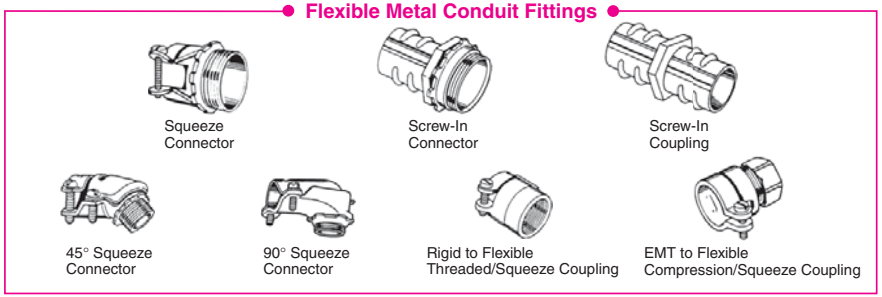

Figure 5-14. FMC connectors are tightened around the conduit to maintain a solid fit. (RACO, Inc.)

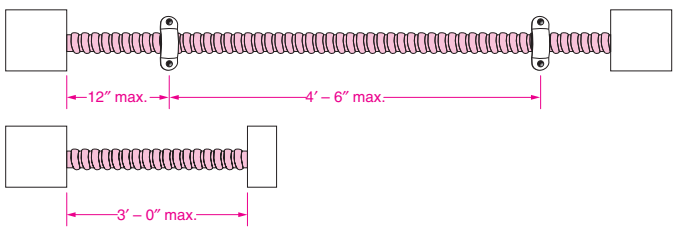

Figure 5-15. Support requirements for flexible metal conduit. No support is needed for lengths less than 3′. For longer lengths, conduit is supported within 12″ of boxes, with a maximum space of 4′ – 6″ between supports.

as for standard flexible metal conduit. As with standard metal flex, lengths of 3′ and less need not be supported.

Uses of liquidtight flexible metal conduit include direct burial, concrete embedment, exposed surfaces, and through walls (concealed). Sizes of 3/8″ to 1 1/4″ liquidtight flexible metal conduit are suitable for equipment grounding in lengths not exceeding 6′; longer lengths and sizes 2″ or larger require a separate equipment grounding conductor to be run inside the conduit.

Liquidtight flexible nonmetallic conduit (LFNC) shares all the same rules as its metallic counterpart except for the following:

- The maximum permitted size is 2″.
- Lengths of more than 6′ are prohibited.
- The grounding electrode conductor, where required, is run inside or outside the flex.

Rigid polyvinyl chloride conduit (PVC)

There are several types of rigid nonmetallic conduit on the market today, but rigid polyvinyl chloride conduit (PVC) is the most popular. The combination of low cost, ease of installation, strength, and availability makes PVC a good choice when a metallic conduit is not required.

Article 352 of the Code addresses the rules regarding the installation of PVC. You will find in this article that PVC is permitted to be used in wet locations. This feature makes PVC an excellent choice for underground, farm, and outdoor installations. Make sure to use the stronger schedule 80 PVC for exposed areas of physical damage. Some of the other considerations when deciding to use PVC are the following:

- PVC conduit can be used in concealed areas such as walls, floors, and ceilings.
- Do not use PVC conduit to support any fixtures or luminaires.
- Do not use PVC conduit in areas with an ambient temperature in excess of 122° F.
- Use expansion fittings when the length of the conduit may expand or contract by 1/4″ or more. This can be determined by using *Table 352.44* of the NEC.
- Use bushings when connecting PVC conduit to a box unless the box, fitting, or enclosure design provides similar protection.

Electrical nonmetallic tubing (ENT)

ENT is a very versatile wiring method. The tubing is composed of a corrugated nonmetallic material (typically plastic). The tubing can be bent by hand, making it very easy to install, **Figure 5-16.** ENT is available in 1/2″ to 2″ sizes.

Support for ENT must be provided within 3′ of each box and every 3′ along the length of tubing. Compared to other wiring methods, ENT requires more support due to its flexibility.

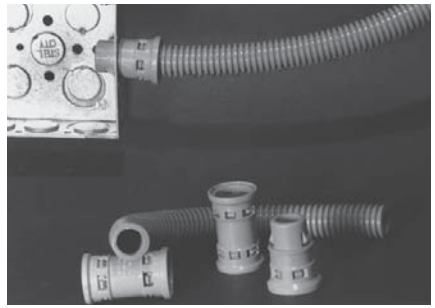

Figure 5-16. ENT is easy to install and can be used in a wide variety of applications.

Article 362—Electrical Nonmetallic Tubing specifies the uses for ENT. The following is a partial list of these uses:

- For exposed work in areas not subject to physical damage in buildings three stories and less.
- Concealed in walls, floors, and ceilings.
- Above suspended ceilings with a 15-minute finish rating.
- Embedded in concrete.

CAUTION

Some types of ENT may become brittle in cold temperatures. If the tubing becomes brittle, it could be easily damaged.

Surface raceway

In many situations there arises a need to add new circuits in an area where the existing wiring is not accessible. The wiring could be embedded in concrete or in conduit behind walls.

In such conditions, the needed changes can be made using surface raceway, **Figure 5-17.** Surface raceway consists of one- or two-piece channels and are easily installed. These raceways are used not only for power outlets and lighting, but are also permitted, when provided with internal barriers, to route communication wiring and fire protection cable.

The number of conductors permitted in surface raceway is not defined by the *Code* but is provided by the manufacturer. As with wireway and auxiliary gutters, splices and taps are permitted (in those raceways having removable covers) so long as they do not occupy more than 75% of the cross-sectional area. The one-piece unit must be installed and secured prior to pulling conductors. There are numerous types of fittings, switches, receptacles, elbows, and adapters available for surface raceway.

Figure 5-17. Surface raceway can be used to supply power outlets, lighting, and communication outlets. (Wiremold)

Wireways

Wireways are rectangular sheet metal enclosures with removable covers. Fittings, such as elbows, clips, and end pieces, enable the sections to be joined to form an overall wiring system. Concentric knockouts are provided in each side and at the ends.

When installed vertically, wireways are supported every 15′. Each wireway system must be complete prior to installing the conductors. Entry into a wireway can be made using other wiring methods, such as mineral-insulated metal-sheathed cable (MI), metal-clad cable (MC), rigid conduit, intermediate conduit, electrical metallic tubing, electrical nonmetallic tubing, and rigid nonmetallic conduit.

The total cross-sectional area of all conductors in a wireway must be less than 20% of the cross-sectional area of the wireway. Splices and taps are permitted in the wireway, but must take up less than 75% of the cross-sectional area. See **Figure 5-18.**

Sample Problem 5-1

Problem: What is the minimum cross-sectional area for a wireway that will accommodate four 2/0 AWG THW, ten 6 AWG THWN, and ten 10 AWG THWN insulated copper conductors?

Solution: First, determine the cross-sectional areas of all of the conductors. Cross-sectional areas of conductors are found in *Chapter 9, Table 5* in the *Code*.

2/0 AWG THW: $4 \times 0.2624\ in^2 = 1.05\ in^2$
6 AWG THWN: $10 \times 0.0507\ in^2 = 0.51\ in^2$
10 AWG THWN: $10 \times 0.0211\ in^2 = 0.21\ in^2$
Total area = $1.77\ in^2$

The wireway size must be large enough that $1.77\ in^2$ is less than 20% of the total area. If $1.77\ in^2$ is 20%, dividing $1.77\ in^2$ by 0.20 will equal the area equivalent to 100%. This is the minimum wireway cross section:

$$1.77\ in^2 \div 0.20 = 8.85\ in^2$$

Therefore, the wireway must have a cross section of $8.85\ in^2$ or larger.

Type	Size (AWG or kcmil)	Approximate Diameter mm	Approximate Diameter in.	Approximate Area mm²	Approximate Area in.²
Type: RHH*, RHW*, RHW-2*, THHN, THHW, THW, THW-2, TFN, TFFN, THWN, THWN-2, XF, XFF					
RHH,* RHW,* RHW-2,* XF, XFF	10	5.232	0.206	21.48	0.0333
RHH*, RHW*, RHW-2*	8	6.756	0.266	35.87	0.0556
TW, THW, THHW, THW-2, RHH*, RHW*, RHW-2*	6	7.722	0.304	46.84	0.0726
	4	8.941	0.352	62.77	0.0973
	3	9.652	0.380	73.16	0.1134
	2	10.46	0.412	86.00	0.1333
	1	12.50	0.492	122.6	0.1901
	1/0	13.51	0.532	143.4	0.2223
	2/0	14.68	0.578	169.3	0.2624
	3/0	16.00	0.630	201.1	0.3117
	4/0	17.48	0.688	239.9	0.3718
TFN, TFFN	18	2.134	0.084	3.548	0.0055
	16	2.438	0.096	4.645	0.0072
THHN, THWN, THWN-2	14	2.819	0.111	6.258	0.0097
	12	3.302	0.130	8.581	0.0133
	10	4.166	0.164	13.61	0.0211
	8	5.486	0.216	23.61	0.0366
	6	6.452	0.254	32.71	0.0507
	4	8.230	0.324	53.16	0.0824
	3	8.941	0.352	62.77	0.0973
	2	9.754	0.384	74.71	0.1158
	1	11.33	0.446	100.8	0.1562
	1/0	12.34	0.486	119.7	0.1855
	2/0	13.51	0.532	143.4	0.2223
	3/0	14.83	0.584	172.8	0.2679
	4/0	16.31	0.642	208.8	0.3237
	250	18.06	0.711	256.1	0.3970
	300	19.46	0.766	297.3	0.4608

Additional information and requirements concerning the design and use of wireways can be found under *Article 376* and *Article 378* of the *Code*. Some key points within this article include the following:

- Wireways are not to be installed where subject to damage.
- Wireways are not to be placed in corrosive environments.
- Wireways are not to be concealed.
- Wireways are normally restricted to no more than thirty current-carrying conductors. More than thirty current-carrying conductors can be contained in a wireway if their ampacity rating is derated per *Section 310.15(B)(3)(a)* of the *Code*.

NEC NOTE 376.22(B), 378.22

Conductors for signaling circuits or controller conductors between a motor and its starter and used only for starting duty shall not be considered as current-carrying conductors.

Auxiliary gutters

Essentially identical in construction and appearance to wireways, ***auxiliary gutters*** are primarily used to extend or supplement wiring spaces at load centers, transformers, and metering cabinets. Auxiliary gutters cannot extend beyond 30′ from the equipment they supplement. The same rules regarding fill (20%) and splices or taps (75%) apply as with wireways.

Busways

Busways are sheet metal enclosures into which conductors are installed at the factory. These conductors, which are actually copper or aluminum busbars, are supported by insulating material. Busways commonly come in up to 10′ sections that are bolted together. When installed horizontally, busways require supports every 5′ unless otherwise designated. Busway systems are often used in commercial buildings as the primary wiring method.

There are three types of busways available:

- Feeder busways
- Plug-in busways
- Trolley busways

A plug-in busway is illustrated in **Figure 5-19.** Although the initial cost of busway material is higher than other wiring methods, the installation labor costs are much lower. This often makes it a more cost-effective system.

There are numerous wiring methods that are permitted for use with busways as taps or branch circuits:

- Rigid nonmetallic conduit (PVC)
- Electrical nonmetallic tubing (ENT)
- Intermediate metal conduit (IMC)
- Electrical metallic tubing (EMT)
- Flexible metal conduit
- Rigid metal conduit
- Armored cable (AC)
- Surface metal raceway

Wireway Cross-Sectional Area

Wireway Size (in.)	Cross-Sectional Area (in²) 100%	75%	20%
2 1/2 × 2 1/2	6.25	4.68	1.25
4 × 4	16	12	3.20
6 × 6	36	27	7.20
8 × 8	64	48	12.80

Figure 5-18. This table lists allowable fill for common wireway sizes.

Figure 5-19. Plug-in busways provide many locations for an electrical hookup. (Star Products Division, US Trolley Corp.)

Overcurrent protection of busways is required at the supply end. If a smaller busway is tapped from a larger busway, overcurrent protection at the tap point should protect the smaller busway. An exception allows a short tap (50′ or less) with an ampere rating of at least 1/3 that of the overcurrent device protecting the larger busway to be exempt from the required overcurrent protection at the tap point.

Further information and requirements concerning busways can be found within *Article 368* of the *Code.*

CAUTION

Busways must not be used where subject to mechanical or physical damage, where there are corrosive surroundings (such as in battery rooms), where it is damp or wet, where there are explosive gases or vapors, where there is ignitable dust or fibers, where embedded in concrete, underground, in any outdoor or hazardous area—except where expressly approved for the purpose.

Figure 5-20. Cable trays are used to support cables in industrial settings. (PW Industries, Inc.)

Cable Trays

Cable trays are open cable-supporting assemblies used in a variety of commercial and industrial buildings. Cable trays are not enclosed, so they do not fit the description of raceways, but they have the same function. Tray systems are fully recognized as an approved method for wiring.

Cable trays resemble troughs, open at the top (although covers are often used), with ventilated bottom sections, **Figure 5-20.** There are two main types of cable trays: trough and ladder.

There are many specific rules regarding the types of wire and cable that can be used in a tray system, and how those wires and cables must be arranged within the tray. *Article 392* of the *Code* permits trays to be used as a support system for wiring methods that can be used without a tray. Uses permitted and not permitted are as follows:

- Where single conductor building wire is used in a tray, only size 1/0 AWG or larger is permitted and must be marked as suitable for tray installation. Further, this only applies to industrial installations; only multiconductor cable is permitted in a tray within commercial premises.
- A metallic cable tray is acceptable as the equipment grounding conductor for the circuits within the tray.
- Nonmetallic cable trays are permitted in areas where there are corrosive conditions.
- Multiconductor cables rated 600 volts or less may be placed in the same cable tray. Tray cable rated over 600 volts can be placed in the same tray with cables rated under 600 volts if a noncombustable barrier is installed to separate the high and low voltage cables.
- Cables within a cable tray can be spliced.
- Single-conductor cable can be used only if multiconductor cable is not available.

Multioutlet Assemblies

The *Code* addresses multioutlet assemblies in *Article 380.* Essentially, these are two-piece assemblies. The top piece (cover) is prepunched to accept receptacles at close (6″ and up) intervals. The receptacles can be factory installed.

This method of wiring is particularly useful and commonly found in laboratories, workshops, stores, schools, and offices. It is installed exposed on the surface like other surface raceway. It may pass through walls provided there is no receptacle within the partition and the covers on either side can be easily removed.

Review Questions

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

1. What is the maximum ambient temperature for PVC conduit?
2. What is the maximum interval for vertical support of a 4 AWG copper conductor?

3. Regarding cable trays, what is allowed in industrial applications that is not allowed in commercial applications?
4. Describe surface raceway.
5. Which *Code* article contains the requirements for underground feeder cable?
6. What is normally the maximum number of conductors that can be placed in a single wireway?
7. Can the conductors for a single circuit be located in different conduit runs?
8. Which conduit has thicker walls: IMC or EMT?
9. Compare the support requirements of ENT with other wiring methods. What is the reason for the difference?
10. Under what conditions can conductors with different voltage ratings be located within the same conduit?
11. What are the four main types of cable?
12. What are the requirements for protecting conduit running through wall studs?
13. What percentage of wireway area can be filled by conductor splices?
14. What type of cable is called *Romex*?
15. What is the minimum burial depth of rigid metal conduit below a residential driveway?
16. In what situations is service-entrance cable used?
17. Is direct burial of type USE cable allowed?
18. When underground wiring is used, how far above ground level must the raceway extend at the point where the conductors exit the ground?
19. What methods can be used to support vertical conductors?
20. Which type of cable does FMC resemble?
21. What is the maximum total cross-sectional area of conductors that can be placed in a 4″ × 4″ rectangular wireway?
22. A cable splice that will occupy 8.8 in^2 is proposed to be located in a 3″ × 4″ wireway. Will this splice satisfy wireway space limitation requirements?

USING THE NEC

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

1. *Section 392.10* defines two areas in which nonmetallic cable trays can be used. What are these two areas?
2. *Table 300.5* lists minimum burial depths. In general, which needs to be buried *deeper*, IMC or PVC conduit?
3. *Section 300.4* defines requirements for protecting wiring methods. What must be installed to protect electrical nonmetallic tubing running through metal framing members?
4. An inspector cited a violation for supporting one conduit with a hanger attached to another conduit. Which *Code* section does this practice violate?
5. Can an IMC wiring system be installed in an air duct containing flammable vapors?
6. Is a 2″ × 4″ rectangular wireway large enough to safely contain six 3/0 AWG XHHW, six 12 AWG XHHW, and four 14 AWG XHHW conductors?
7. Metal-clad cable is permitted for use in wet locations if any one of three conditions are met. What are these conditions?
8. A wireway containing six 2/0 AWG THHN and two 14 AWG THHN conductors is needed for a project. The wireway must be 2″ wide. What depth of wireway should be ordered (assuming the depth must be ordered in 1″ increments)?
9. What is the maximum allowable interval between supports for strut-type channel raceway?
10. The length of rigid nonmetallic conduit changes due to thermal contraction and expansion. Expansion fittings are used to compensate for these changes. What is the maximum allowable length change in a straight run of conduit without expansion fittings?
11. When lighting busways and trolley busways are not provided with covers, what is the minimum height above the floor at which they can be installed?
12. Of metal wireways and nonmetallic wireways, which can be used where subject to corrosive vapors?

Although residential and commercial installations are similar in theory, commercial electrical work involves larger equipment, conduit, and conductors. This fixture, located in the Von Braun Civic Center in Huntsville, Alabama, is much larger than any fixtures encountered in residential work. (Armstrong World Industries, Inc.)