

CHAPTER III

ELECTRICAL WIRING COMPONENTS

3.1 –BASIC WIRING TOOLS

When wiring or testing the electrical system in buildings, a wide variety of tools is used. The most common employed tools are the following.

Screwdrivers.

Intended for tighten or loose screws. They are available in a variety of sizes and shapes. Figure 3.1 shows in a) different flat-blade screwdrivers, and in b) Phillips screwdrivers are shown.

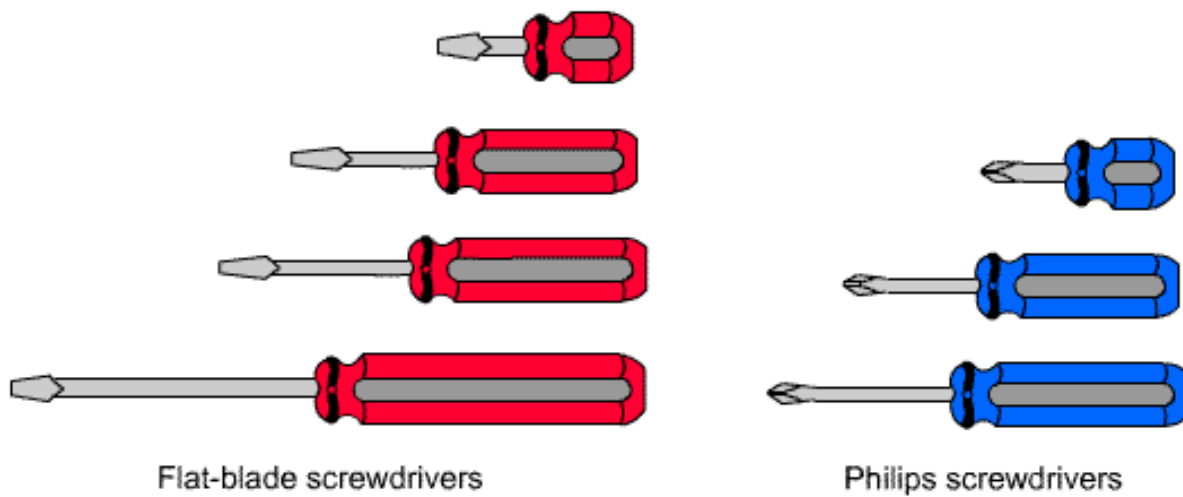


Figure 3.1. Screwdrivers. a) flat-blade Screwdrivers, b) phillips Screwdrivers

A very useful for electrical installations screwdriver is the one shown in Figure 3.2. It is basically a flat-blade screwdriver, but the blade is protected as shown to make easier fixing the connectors and couplings.



Figure 3. 2. Special Screwdriver for electrical wiring

Pliers.

Each type of work requires a specific type of pliers. Figure 3.3 shows a variety of the most employed in electrical installations.

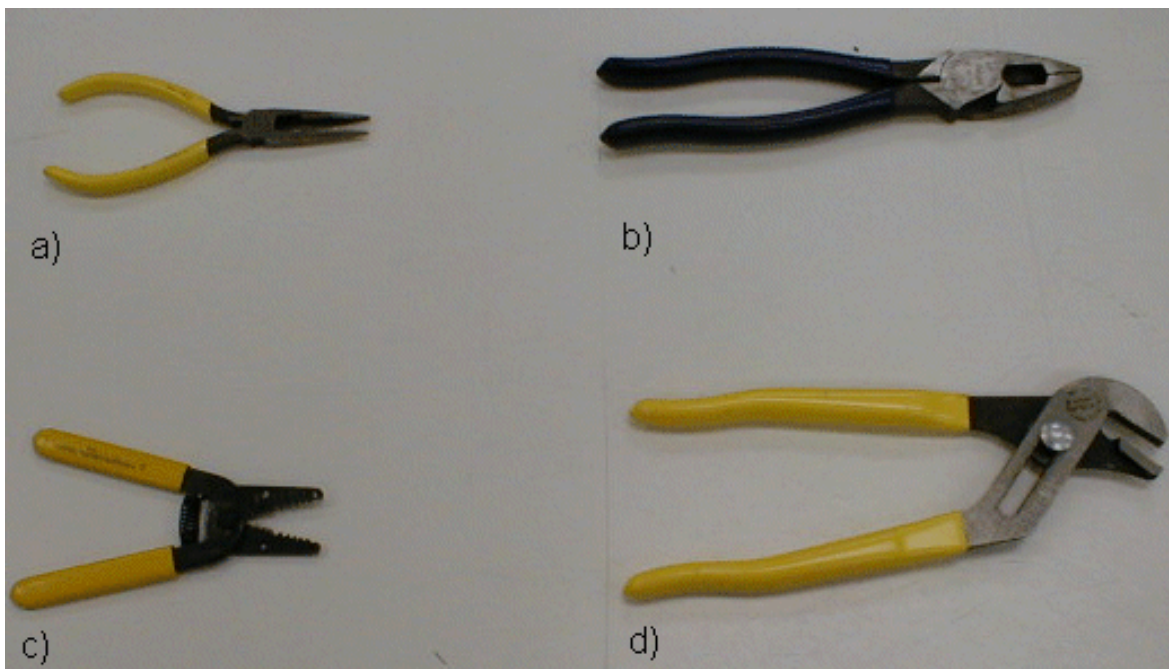


Figure 3.3. Pliers. a) long-nose; b) side cutting; c) crimping tool-wire stripper;
d) tongue & groove

Hammers.

The used by electricians hammer is the claw hammer, as shown in Figure 3.4. Typical used weights are 16 oz. and 20 oz. From the safety point of view, it is important to use non-conductive materials for the handle.

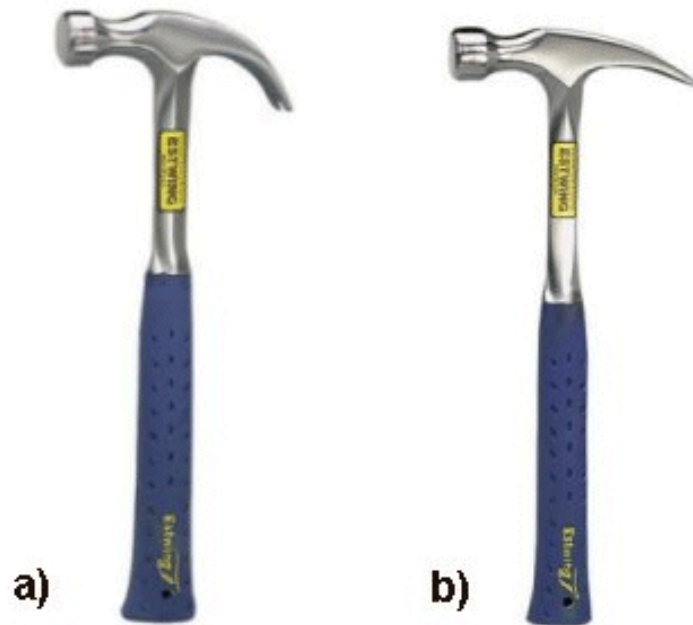


Figure 3.4. Hammers. a) curved claw, b) straight claw

Saws

Saws are widely used in electricians job. The more frequently employed are the hacksaw and the compass saw (Figure 3.5). The hacksaw is used to cut pipes, and the compass saw when the electrician has to cut an irregular shape in a wood or drywall structure.



a)

b)

Figure 3.5. Saws. a) Hacksaw. b) compass saw

Fish tape

It is a steel tape used for passing wires through pipes. The tape is passed through the pipe until it appears on the other end. The wires are tied to the tape end, and then the tape is pulled from the place where it was entered to the pipe, passing at the same time the wires through the pipe (Figure 3.6).



Figure 3.6. Fish tape

Measuring Tools

The preferred by most electricians measuring tool is the steel tape as can be seen in Figure 3.7. Different lengths are available depending on the job characteristics.



Figure 3.7. Steel Tapes

Wrenches

Several used wrenches are shown in Figure 3.8. The use of each type will depend on the work being realized and on the person preferences.





Figure 3.8. Wrenches. a) pipe; b) chain; c) open end; d) box end; e) adjustable; f) socket set; g) nut driver

Tubing Benders

When it is necessary to bend rigid metallic conduits, this can be made using special bending tools. Bends in 1/2 -inch, 3/4-inch, and 1-inch conduit can be made using hand benders, Figure 3.9. Hydraulic benders must be used to make bends in larger sizes of conduit.



Figure 3.9. Tubing benders.

Miscellaneous Tools

Besides the enumerated, there exist a big number of tools used in electrical jobs. Some of them are showed in Figures 3.10, 3.11, and 3.12.



Figure 3.10. Level



Figure 3.11. Chisel



Figure 3.12. Knife.

Power Tools

To increase productivity and reduce the needed effort in performing tasks, almost all the described hand tools have it electrical counterpart. The drill showed in Figure 3.13 is extremely important for the electrician job. The more frequently used is the cordless drill. Employed not only for drilling holes through walls or other parts of the structure, but also using special bits as powered screwdrivers, etc.



Figure 3.13. Cordless Drill. a) cordless drill; b) rechargeable power source

3.2 –WIRING METHODS AND MATERIALS

The *National Electrical Code® (NEC®)* permits the use of different wiring methods. Chapter 3 on the *National Electrical Code®* covers this part. The selection of some specific method depends on the type of building, location, desired quality, etc. Before analyzing the different wiring methods it is useful to pay attention to the used sizes and insulations in the conductors

for general wiring.

3.2.1. -CONDUCTORS FOR GENERAL WIRING

The material employed in the conductor construction, according to *NEC*®, shall be aluminum, copper-clad aluminum, or copper unless otherwise specified. Conductors shall be insulated. Table 310-13 of the *NEC*®-1999, lists various types of insulated conductors covered by the requirements of the code. From the table may be obtained information related to the trade name, type letter, maximum operating temperature, application, type of insulation and size. To clarify ideas, a partial reproduction of the table is presented in Figure 3.14.

Trade Name	Type Letter	Maximum Operating Temperature	Application Provisions	Insulation
Heat-resistant thermoplastic	THHN	90°C 194°F	Dry and damp locations	Flame- retardant, heat-resistant
Moisture- and heat-resistant thermoplastic	THHW	75° C	Wet location	Flame-retardant, moisture- and heat-resistant thermoplastic
		90°C 194°F	Dry location	
Moisture- and heat-resistant thermoplastic	THWN	75° C 167° F	Dry and wet locations	Flame-retardant, moisture- and heat-resistant thermoplastic

Figure 3.14. Partial Reproduction of Table 310.13 (Conductor Application and Insulation) from the *NEC*®-1999.

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The conductor **ampacity** is the maximum number of amperes allowed for that conductor under specified working conditions. The conductor used must have sufficient ampacity, or capacity, to carry the load being served. The limiting factor for the conductor ampacity is the heat dissipated in the wire due to the passing current, and calculated by $P = I^2R$ watts. The wire

insulation and location as well as the metal used for its construction will determine its capacity to carry the electrical current. Allowable ampacities of insulated conductors, rated 0 through 2000 Volts are presented in Tables 310-16 through 310-20 from *NEC*®-1999. Table 310-16, is partially shown for copper conductors and AWG values in Figure 3.15, is widely used in electrical wiring calculations, and will be given special attention.

Size	Temperature Rating of Conductor		
	60°C (140°F) Types TW, UF	75°C (167°F) Types FEPW, RH, RHW, THHW, THW, THWN, XHHW, USE, ZW	90°C (194°F) Types TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, ZW-2
18	--	--	14
16	--	--	18
14*	20	20	25
12*	25	25	30
10*	30	35	40
8	40	50	55
6	55	65	75
4	70	85	95
3	85	100	110
2	95	115	130
1	110	130	150
1/0	125	150	170
2/0	145	175	195
3/0	165	200	225
4/0	195	230	260

Figure 3.15. Partial Reproduction of Table 310-16 (Allowable Ampacities of Insulated Conductors) from *NEC*®-1999.

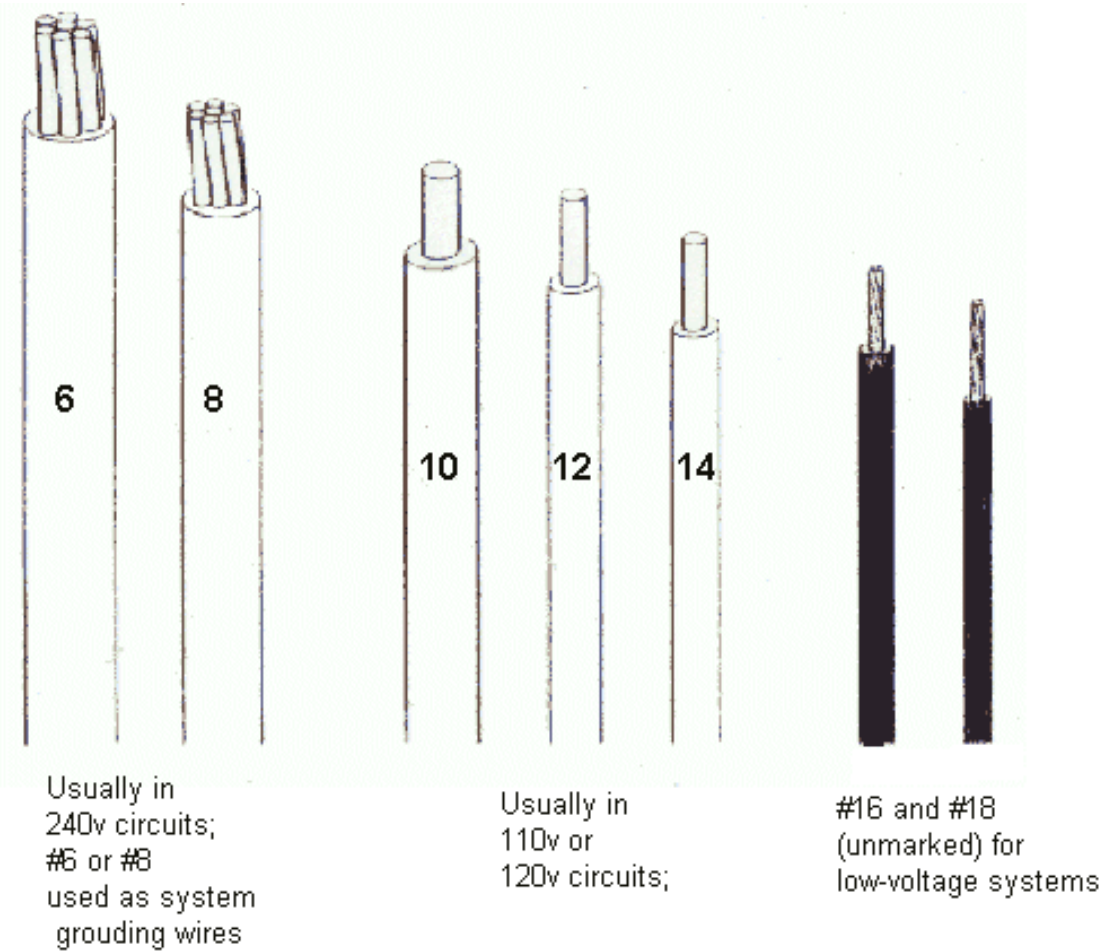
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The conductor size is expressed using the American Wire Gauge (AWG) denomination. Note that as the size increases, the number decreases until the # 1 denomination is reached. From # 1/0, there is an increase of the number with the size. For sizes bigger than 4/0(not represented in Figure 3.15), the size is expressed in cmil.

For conductors with an * sign, Section 240-3 of the *NEC*® does not allow (unless specifically permitted) overcurrent protection exceeding 15 amperes for #14, 20 amperes for #12, and 30 amperes for #10. This means that independently of the indicated ampacity for these conductors in Table 310-16, the number of amperes cannot exceed the specified in Section 240-3.

Table 310-16 also includes temperature correction factors (not shown in Figure 3.15). These correction factors shall be applied for ambient temperatures other than 30°C (86°F).

Figure 3.16 shows conductors of different sizes. All conductors are marked with the following information: the maximum rated voltage for which it is listed, letters that identify it as to type, the manufacturer's name, and the AWG size or circular mil area. No. 14 is the smallest wire size allowed for general wiring.



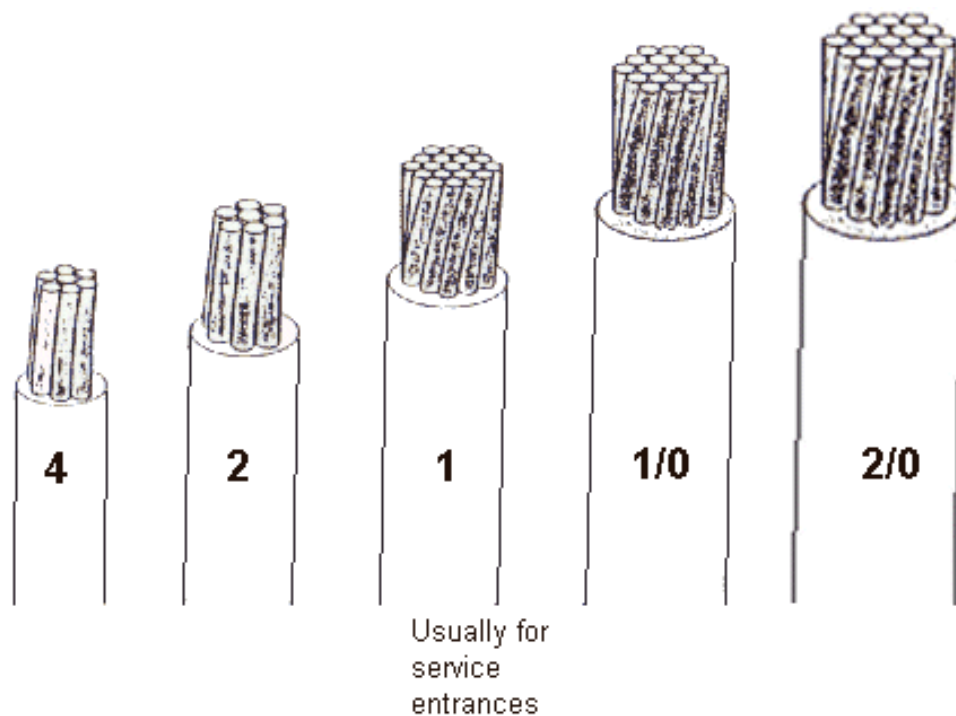


Figure 3.16. Sizes of Conductors

3.2.2. –ELECTRICAL RACEWAY

The term raceway is defined by the *NEC*[®] as any channel for holding wires, cables, or bus bars that is designed and used for this purpose. The following will cover some of the possible methods and used materials: electrical metallic tubing, rigid metal conduit, intermediate metal conduit, flexible conduit, rigid nonmetallic conduit, electrical nonmetallic tubing, etc.

Electrical metallic tubing (EMT)

(*NEC*[®], Article 348). It is a listed metallic tubing of circular cross section approved for the installation of electrical conductors when joined together with listed fittings.

Its use is permitted in exposed and concealed work. There it is necessary to use corrosion protection when galvanized steel EMT extend directly from concrete encasement to soil burial.

Its use is not permitted where it will be subject to severe physical damage, where protected from corrosion solely by enamel or subject to permanent moisture, and for the support of fixtures or other equipment except conduit bodies no larger than the largest trade size of the tubing.

The minimum permitted size is 1/2" and the maximum 4". In table 346-12(b)(2) can be found the maximum distance between metallic conduit supports. For 1/2" and 3/4" pipes, the distance may be up to 10', for 1" up to 12', and so on. The support from a box or other conduit termination point shall be within 3' Figure 3.17 shows an installation example.

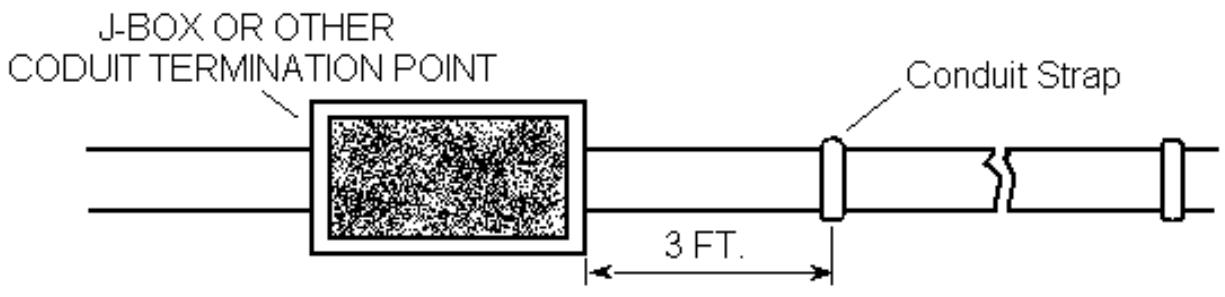


Figure 3.17. EMT installation

All cuts and ends of EMT shall be reamed to remove rough edges. The number of bends between outlets or fittings must not be greater than equivalent of four 90° bends or 360° total.

The number of conductors permitted in a single pipe can be calculated knowing the useful pipe area, the area of each insulated conductor and the number of conductors. The area of insulated conductors and fixture wires is obtained from the NEC® Table 5, chapter 9. Figure 3.18 shows the areas of some conductors, extracted from this table.

Size (AWG)	Approximate area (in. ²)
14	0.0097
12	0.0133
10	0.0211
8	0.0366
6	0.0507

Figure 3.18. Area of THHN, THWN, and THWN-2 conductors.

The maximum number of conductors in a pipe shall not exceed the percentage fill specified in Table 1, Chapter 9 of NEC®, represented down.

Number of Conductors	All Conductor Types
1	53 %
2	31 %
Over 2	40 %

From *NEC*®, table 4, chapter 9 it is possible to know the dimensions and percent area of conduits and tubing. A partial reproduction is presented in Figure 3.19.

Trade Size (in.)	Total Area (in. ²)	40% Area (in. ²)
½	0.304	0.122
¾	0.533	0.213
1	0.864	0.346
1¼	1.496	0.598
1½	2.036	0.814
2	3.356	1.342

Figure 3.19. Electrical Metallic Tubing areas

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Example 3.1.

Determine what EMT pipe size is it necessary to accommodate 4 # 8, 4 # 6, 7 #10, and 6 # 12 THHN conductors.

$$4 \times 0.0366 = 0.1464$$

$$4 \times 0.0507 = 0.2028$$

$$7 \times 0.0211 = 0.1477$$

$$6 \times 0.0133 = \underline{0.0798}$$

$$\text{Total area} = 0.5767$$

As there are more than 2 conductors in the pipe, the useful pipe area is 40% of its total area. The useful pipe area shall be greater than the conductors' area (0.5767). Checking for 1¼": $1.496 \times 0.4 = 0.5984$ (this number may be obtained directly from Table 4). As $0.5984 > 0.5767$, the selected pipe is acceptable.

The bending of EMT requires an EMT bender. EMT pipes are coupled together using EMT couplings. For connection to electrical boxes there are used several types of connectors. Figure 3.20 shows some of these fittings.



Figure 3.20 EMT couplings and connectors

Rigid Metal Conduit (RMC)

(*NEC*®, Article 346).. It is approved for use in all types of construction and atmospheric conditions. Also it is permitted as an equipment grounding conductor. The code permits its use in concrete, in direct contact with the earth, or in areas subject to severe corrosive influence where protected by corrosion protection and judged suitable for the condition. The minimum size approved is ½” and the maximum 6”. The number of conductors in a conduit is given by the percentage fill from Table 1, using the conduit dimensions of Table 4, Chapter 9 of the *NEC*®.

After the conduit is cut, it requires reaming to remove all burrs. The next step is threading the conduit with a die (Figure 3.21).



Figure 3.21. Pipe threaders.

The couplings and connectors used for the installation of rigid conduit may be threaded or threadless. The number of bends shall not be more than 360° total. Rigid conduit is supported at intervals not exceeding 10 ft or in accordance with Table 346-12(b)(2) of the *NEC*®.

Intermediate Metal Conduit (IMC)

(*NEC*®, Article 345). It is a thinner-walled rigid metal conduit that is satisfactory for use in all locations where rigid metal conduit is approved. All the fittings are interchangeable for either IMC or RMC. Galvanized IMC installed in concrete or in contact with soil does not generally require supplementary corrosion protection. The range of sizes are minimum ½", and maximum 4". The number of conductors in conduit, the support distance, and the number of bends follow the same rules as in previous cases. Figure 3.22 shows the minimum fastening requirements for intermediate metal conduit according to Section 345-12(a).

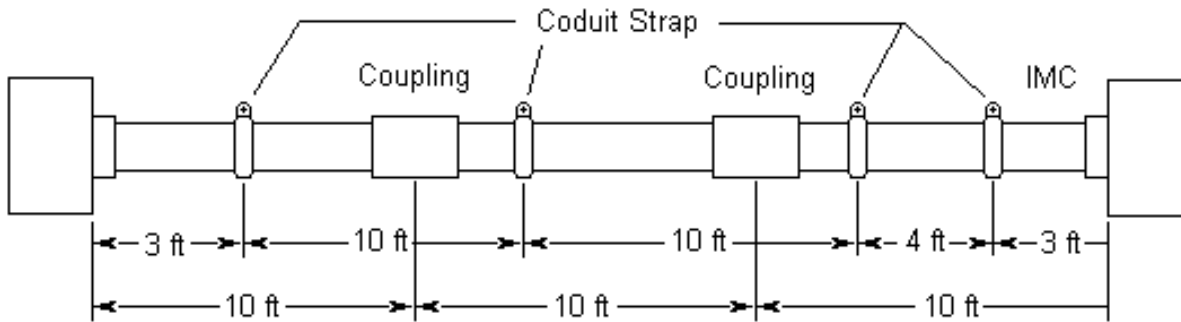


Figure 3.22. Minimum fastening requirement for IMC

Flexible Metal Conduit (FMC)

(*NEC*®, Article 350). Flexible metal conduit is known frequently as Greenfield.

It is a raceway of circular cross section made of helically wound, formed, interlocked metal strip. The minimum permitted size is ½", but under certain conditions, the code permits to use 3/8". A frequent case where 3/8" flexible metal conduit is used, in lengths not in excess of 6 ft, is for connecting vibrating equipment as the garbage disposal and fluorescent lights in residential wiring. Conduits larger than 4" are not permitted by the code. Figure 3.23 shows two places where FMC may be used.

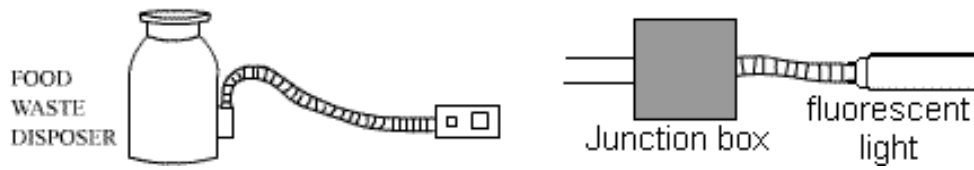


Figure 3.23. Some places where flexible metal conduit may be used.

FMC is permitted for use in wet locations under the condition of preventing water from entering enclosures or other raceways to which the conduit is connected. Often the use of FMC requires the inclusion of grounding conductors. For lengths under 6 ft, and circuits not exceeding 20 amperes, it is not necessary to install the grounding conductor. The maximum distance between flexible metal conduit supports is 4 ½ ft. Also shall be fastened in place within 12” of a box or other conduit termination. The number of conductors is calculated using Table 4, Chapter 9 of the *NEC*®. Figure 3.24 shows some of the common used fittings.



Figure 3.24. Fittings used with flexible metallic conduit.

Liquidtight Flexible Metal Conduit

(*NEC*®, Article 351). Liquidtight flexible conduit is recommended where conditions of installation, operation, or maintenance require flexibility or protection from liquids or vapors penetrating the conduit. It is composed of a liquidtight, nonmetallic, sunlight-resistant jacket over an inner flexible metal core. It is used outdoors for connecting air conditioning units or indoors for connecting machinery where oil leakage may be present.

Figure 3.25 shows a liquidtight conduit used in an air conditioning installation.



Figure 3.25. Installation of a liquidtight conduit.

Armored Cable (AC)

(NEC®, Article 333). Is a fabricated assembly of insulated conductors in a flexible metallic enclosure. It is listed in sizes # 14 through # 1 copper and # 12 through # 1 aluminum or copper-clad aluminum for use at 600V or less. Figure 3.27 shows an example of armored cable.

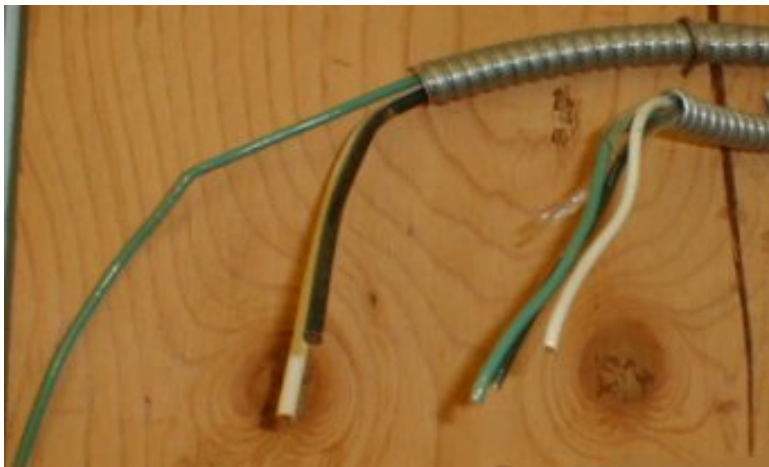


Figure 3.26. Armored cable

The support conditions are the same as for the FMC. It is permitted for branch circuits and feeders in both exposed and concealed work.

Metal-Clad Cable (MC)

(NEC®, Article 334). Type MC cable is a factory assembly of one or more insulated circuit conductors with or without optical fiber members enclosed in an armor of interlocking metal tape, or a smooth or corrugated tube. MC cable is listed in sizes from # 18 for copper conductors and # 12 for aluminum or copper-clad aluminum conductors. Its use is permitted for up to 2000 Volts.

MC cable may be used for services, feeders, and branch circuits including power, lighting, control, and signal circuits outdoors or indoors. MC is not supposed to be used where exposed to destructive corrosive conditions or where submitted to physical damage. Most applications require that MC cable be supported and secured within 12" of a box or other conduit termination and at intervals not exceeding 6 ft (Figure 3.27).

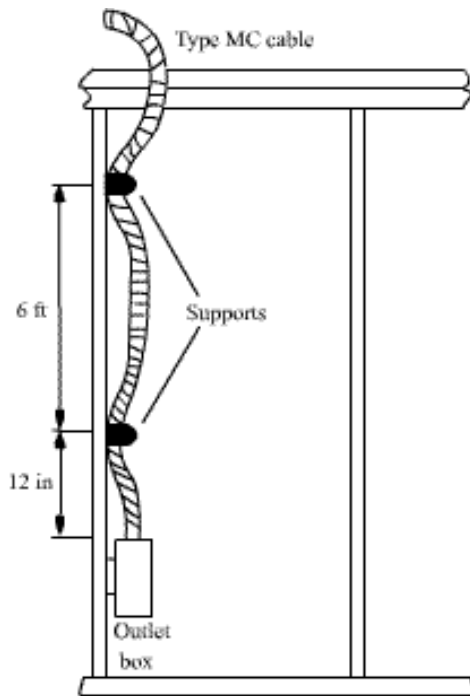


Figure 3.27. MC cable supports.

Rigid Nonmetallic conduit

(NEC®, Article 347) Generally known as PVC, refers to conduit and fittings of suitable nonmetallic material that is resistant to moisture and chemical atmospheres. There exist several types of rigid nonmetallic conduit that may be used according to the specific application. Its use includes aboveground and underground installations, as well as for direct burial without encasement in concrete. Is recommended for locations subject to severe corrosive influences and in wet locations. Nonmetallic conduits are not permitted in ducts, plenums, and other air-handling spaces that may contribute smoke and products of combustion during a fire.

Assembly of the conduit system is obtained cementing the various parts and fittings with a special solvent-type PVC cement. The bending is obtained by providing an even distribution of heat to make the conduit pliable. Nonmetallic rigid conduit shall be supported and secured within 3 ft of a box or other conduit termination and at intervals regulated by Table 347-8 from the NEC®, reproduced in Figure 3.28.

Conduit Size (in.)	Maximum Spacing Between Supports (ft)
½ – 1	3
1¼ – 2	5
2½ – 3	6
3½ – 5	7
6	8

Figure 3.28. Support of Rigid Nonmetallic Conduit

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Electrical nonmetallic Tubing (ENT)

(NEC®, Article 331). Is a pliable corrugated raceway of circular cross section with integral or associated couplings, connectors, and fittings listed for the installation of electric conductors. Because of the corrugation, the raceway may be bent by hand and has some degree of flexibility, but it is not intended for use in motors or other equipment to prevent transmission of vibrations.

The sizes range from ½” to 2”. Figure 3.29 shows the way ENT has to be supported. It may be used in buildings not

exceeding three floors above grade and for exposed work, where not subject to physical damage. In buildings over three floors, ENT shall be concealed within walls, floors, and ceilings, providing a thermal barrier material protecting the pipe from high temperatures.

Nonmetallic –sheathed cable

(*NEC*®, Article 336) Is a factory assembly of two or more insulated conductors having an outer sheath of moisture-resistant, flame retardant, nonmetallic material. It may be used for either exposed or concealed wiring. Where exposed, can not be subject to physical damage. There are three types of Nonmetallic –sheathed cable: NM, NMC, and NMS. Each type has characteristics making it suitable for different electrical installations.

Nonmetallic –sheathed cable shall be supported and secured within 12” of a box or other conduit termination and at intervals not exceeding 4 ¼ ft. figure 3.29 shows an example of Nonmetallic –sheathed cable.

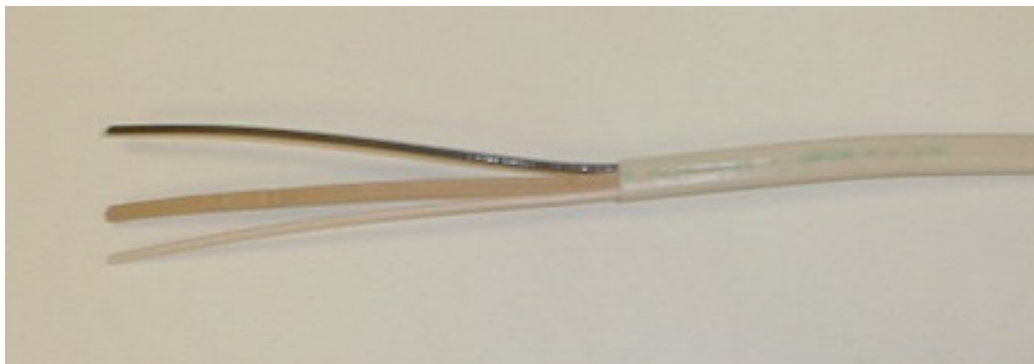


Figure 3.29. Nonmetallic –sheathed cable

Metallic and Nonmetallic Wireways

(*NEC*®, Article 362). Are sheet metal (for metallic), or flame-retardant nonmetallic troughs with removable covers for housing and protecting electric wires and cables and in which conductors are laid in place after wireway has been installed as a complete system. Frequently are used for exposed work, and its use is not permitted where subject to severe physical damage or corrosive vapor.

The number of current-carrying conductors in the wireway is limited to 30, and the total cross-sectional area of all conductor

will not exceed 20% of the interior cross-sectional area of the wireway. Exception No. 1 permits the number of current-carrying conductors to exceed 30, where the adjustment factor for more than three current-carrying conductors [NEC® Table 310-15(b)(2)(a)] is applied, maintaining the cross-sectional area of all conductors less than 20% of the interior cross-sectional area of the wireway.

Metallic and nonmetallic wireways shall be supported at each end, and according to:

	Metallic	Nonmetallic
Horizontal support	5 ft	3ft
Vertical support	15 ft	4 ft

3.2.3. -ELECTRICAL BOXES

Electrical boxes are available in a variety of shapes and sizes, for its use according to the particular application. It is possible to find metal and plastic boxes. All metal boxes need to be grounded. Article 370 from the NEC® covers the installation and use of all boxes and conduit bodies used as outlet, junction, or pull boxes.

Switch boxes are 2" x 3" in size and may be found in ranges from 1 ½ in. to 3 ½ in. Some metal boxes are gangable, that means that they have removable sides and can be mounted side by side to accommodate two or more switches or receptacles. Plastic and many metallic boxes don't have this possibility, but they are manufactured in one-gang, two-gang, three-gang, or four-gang styles.

Round and octagonal metal boxes are generally used with ceiling fixtures. Metal and plastic square boxes are often used as junction boxes. When rectangular boxes are used for holding switches or receptacles, they use a flat cover with switch or receptacle shaped openings called plaster ring. Figure 3.30 shows some of the more frequently used boxes.



Figure 3.30. Types of boxes

The box volume gives the number of conductors inside a box. In no case the volume of a box can be smaller than the calculated volume of the conductors filling it. The box volume is given in Table 370-16(a) for metal boxes, and the volume allowance required per conductor is presented in Table 370-16(b) from the *NEC*®. In Figure 3.31, a partial reproduction of Table 370-16(a) is presented, and Figure 3.32 shows Table 370-16(b).

Box Dimension in Inches, Trade Size, or Type	Minimum Capacity (in.3)
4 x 1¼ round or octagonal	12.5
4 x 1½ round or octagonal	15.5
4 x 21/8 round or octagonal	21.5
4 x 1¼ square	18.0
4 x 1½ square	21.0
4 x 21/8 square	30.3
4 11/16 x 1¼ square	25.5
4 11/16 x 1½ square	29.5
4 11/16 x 21/8 square	42.0

Figure 3.31. Volume of metal boxes

Size of Conductor(AWG) Each Conductor (in ³)	Free Space Within Box for
18	1.50
16	1.75
14	2.00
12	2.25
10	2.50
8	3.00
6	5.00

Figure 3.32. Volume allowance required per conductor

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For calculating the box it is necessary to take into account:

1. Each conductor is counted once.
2. Where one or more internal cable clamps, fixture studs or hickey are present in the box, a single conductor will be counted, based on the largest conductor present in the box.
3. Where one or more equipment grounding conductors or equipment bonding jumpers enters a box, a single conductor will be counted, based on the largest equipment grounding conductor or equipment bonding present in the box.

Example 3.2.

Select the rectangular box necessary to accommodate: 3 # 12, 2 # 10, and 2 # 8 conductors, one # 12, and one #10 ground.

$$3 \times 2.25 = 6.75$$

$$2 \times 2.5 = 5.0$$

$$2 \times 3.0 = 6.0$$

$$1 \times 2.25 = 2.25$$

$$1 \times 2.5 = 2.5$$

Total 22.5 cu. in.

A (4 11/16 x 1¼) square is acceptable

3.3. REVIEW QUESTIONS

3.1. Insulated handles are important on many electrician's tools because_____.

3.2. Why must all joints, connections, and splices be contained in a box?

3.3. List four shapes of boxes

1. _____

2. _____

3. _____

4. _____

3.4. *NEC*® requires a grounding bushing wherever conduit enters a non-threaded opening on a box.

a) True b) False

3.5. A #8 copper wire THWN has an ampacity of _____Amps.

3.6. What size box is needed when there are two #10 AWG conductors, six #12 AWG conductors, and four #14 AWG conductors?

3.7. What size box is needed to install four # 12 conductors, two # 14 conductors, four grounding conductors, and three cable clamps?

3.8. When a receptacle is installed in a metallic box it must always be connected to ground through the grounding hex screw.

a) True b) False

3.9. As the AWG number becomes smaller, the wire size becomes

a) Larger b) Smaller

3.10. When using a #12 THWN copper wire in a branch circuit, the over-current protection shall not exceed _____Amps.

3.11. The maximum number of conductors # 12 that can be allocated in a 4 x 1¼ square box is _____.

3.12. The allowable ampacity for a # 2/0 THHN copper wire is _____Amps.