Raceways and Conduit Systems

CONDUIT BENDING and FABRICATION

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Conduit as a practical raceway for electrical systems has been in use from the beginning of the electrical industry. Although the decades since the introduction of conduit have produced many alternative wiring methods, conduit offers a certain amount of flexibility and unmatched physical protection for conductors.

Early conduit designs included zinc tubes and spiral-wound paper tubes. These conduit designs were difficult to install because they could not be bent in the field. The development of lined iron gas pipe led to improvements in installation procedures because, to some extent, the iron pipe could be bent in the field.

The development of rubber insulation for conductors made the lined iron gas pipe conduit systems obsolete and unlined iron gas pipe was used. The development of enamel-coated steel conduit led to further improvements.

Rigid metal conduit is a threadable conduit with fairly thick walls. Intermediate metal conduit (IMC) is a threadable conduit with walls of intermediate thickness. Electrical metallic tubing (EMT) is a nonthreadable conduit with thinner walls than rigid or IMC. Because of its lighter weight and lack of threads, there are several restrictions on the use of EMT.

OBJECTIVES

1. *Briefly outline the history of raceways and conduit.*
2. *Describe the differences between rigid metal conduit and electrical metallic tubing.*
3. *Summarize the appropriate section of the NEC® for rigid, EMT, PVC, and IMC.*
4. *Describe the color coding of the thread protector caps used with rigid conduit and IMC.*

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RACEWAYS AND CONDUIT

The National Electrical Code® (NEC®) recognizes many different types of raceways for the protection and routing of electrical conductors. While some take the form of channels, troughs, gutters, or ducts, the most common raceways consist of conduit or tubing. Conduits such as rigid metal conduit (RMC), intermediate metal conduit (IMC), and rigid nonmetallic conduit (RNC) can be used in conjunction with electrical metallic tubing (EMT) and other raceways to form a system that allows conductors to be drawn into them after the conduit runs are completed.

When the NEC® uses the word conduit, it means only those raceways that contain the word "conduit" in their titles. However, by common usage, electrical metallic tubing (EMT) and other raceways are also called conduit.

Conduits are typically bundled for shipment in groups of 5 or 10 pieces. For large shipments, these bundles are banded onto large skids that may have as many as 50 bundles. Caution should be used when breaking these large shipping bundles open. The individual bundles can shift and fall, causing severe personal injury.

Early Wiring Methods

In 1879, Thomas Edison demonstrated the first practical incandescent lamp. **See Figure 1-1.** In many ways, developing the electric lamp was a major step in creating the electrical industry. Edison knew he would not be able to exploit this achievement unless methods of generating, distributing, and using electricity were developed.

Historians generally say that Edison's Manhattan Pearl Street generating station was the first practical commercial electrical system. **See Figure 1-2.** The Pearl Street generating station was built by the Edison Electric Illuminating Company in 1882 and was powered by a steam-powered DC generator. It originally provided power to about 50 buildings.

Eventually, the early Edison DC power systems were replaced by AC systems invented by Nikola Tesla and promoted by Westinghouse. The AC systems allowed for efficient transmission of power over greater distances. The expansion of the Westinghouse AC systems led to the increased use of electricity.

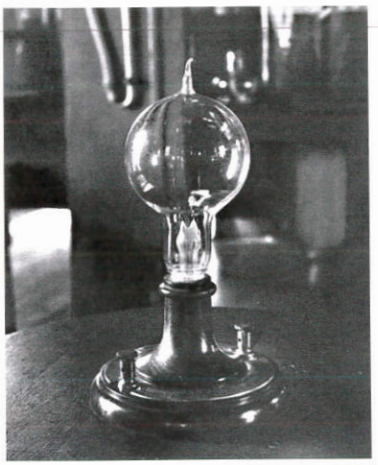
Architects designing buildings wanted the ability to install electrical power systems during construction. However, wire insulation was very poor, generally consisting of a braided fabric with a wax binder. This insulation deteriorated quickly and caused fires. In addition, the exposed wiring had the potential to cause personal injury from electrical shock.

From an aesthetic and safety point of view, it made sense to install the wires behind walls. Building owners needed the ability to protect people from the wires. However, the owners still needed to be able to replace the wires frequently to prevent fires. These problems led to the development of conduit to protect the wires and to make it easier to replace damaged wires.

Tech Fact

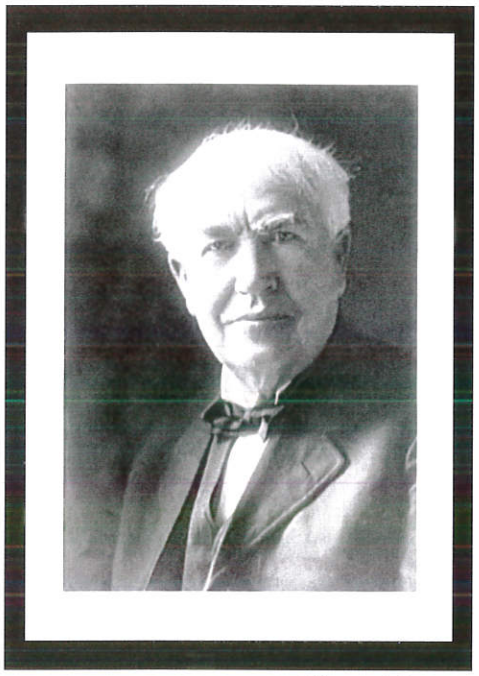
Conduit fittings, such as connectors and elbows, are the weak points of a raceway system. Fittings may loosen or corrode and destroy the grounding path.

Edison's Incandescent Lamp



National Park Service

Figure 1-1. *The electric lamp was a major step in creating the electrical industry.*



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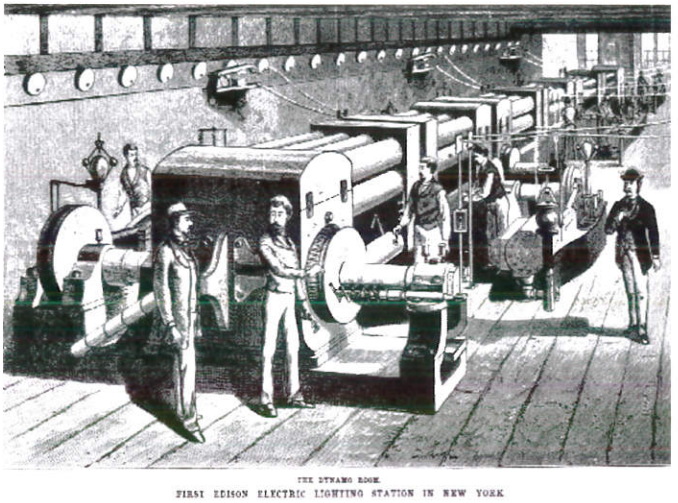
Thomas Edison was very important in the development of the commercial electric industry. His development of the incandescent light bulb led to the increased demand for electricity.

Pearl Street Station



THE DYNAMO ROOM.
FIRST EDISON ELECTRIC LIGHTING STATION IN NEW YORK

National Park Service

Figure 1-2. *The Pearl Street generating station was the first practical commercial electrical system.*

Early Conduit Designs

Conduit was present from the very beginning of the electrical industry. The electrical mains for customers of the Pearl Street generating station were installed underground. The mains were constructed of a rod conductor installed in an iron pipe. The pipe was filled with an asphalt-like substance to waterproof the conduit and act as an insulator.

Taps were made from these mains leading to the customers. Once inside the building, wires were installed on wooden cleats and connected to newly designed switches, lampholders, and other devices.

Zinc Tubes. In the 1880s, electricians began experimenting with lightweight zinc tubes to protect wires installed behind walls. These zinc tubes were very light and could not be bent on the job. However, the zinc tubes did provide a method of concealing the wires and allowed new wires to be pulled to replace deteriorated wires without damaging building finishes. One zinc tube was used for each wire.

Spiral-Wound Paper Tubes. Shortly after the development of the zinc tubes, a conduit system was introduced that used spiral-wound paper tubes covered with asphalt. This system included brass couplings and long-radius 45° and 90° elbows. The advantage of this system was that the conductor was protected within a raceway that was a better insulator than the wire insulation. A major disadvantage of this system was that it was difficult to install. In addition, the conduit had to be protected from moisture to prevent any deformation or other damage in the paper conduit.

Iron Gas Pipe. In the 1890s, iron gas pipe lined with wood, fiber, or paper became available. As with the paper conduit systems, long-radius 45° and 90° elbows were available. The couplings and fittings were threaded to allow a strong, durable connection. This iron gas pipe conduit system provided the best protection yet for the enclosed wires as well as a reliable ground path. It could be field bent to optimize routing, as long as the bends were kept to a small angle with a large radius.

The practice of using one conduit for each conductor was discarded when iron conduit was developed. Large, induced

magnetic fields are produced when a single alternating current conductor is installed in an iron raceway. This reduces the current carrying capacity of the conductor. Not only did installing multiple conductors in a single conduit make economic sense, it was required to improve the efficiency of an electrical distribution system.

In the 1890s, the first viable rubber wire insulation was developed, making the lined iron gas pipe conduit unnecessary. A rubber compound was vulcanized to the wire to act as a dielectric. Linen fabric was braided around the rubber to protect the insulation from abrasion while the wire was being pulled into the conduit. While this type of insulation was not as good as modern insulation, it lasted for the life of the system.

Steel Conduit. Steel conduit was introduced at about the same time as insulated wire. Steel is more ductile than iron and can be bent with a fairly short bend radius and large bend angles. The steel conduit of the late 19th century was very different than modern conduit. One difference was that the early steel conduit had a heavier wall thickness than modern rigid conduit because it was manufactured to gas pipe standards.

Another major difference was the appearance of the conduit. While galvanizing was available at that time, it was not very effective. The older galvanizing methods left sharp edges on the conduit that would have damaged the wire as it was being pulled into the conduit. To avoid this, steel conduit of the day was enameled both inside and out. In about 1903, an effective electro-galvanizing process was developed and galvanized steel conduit quickly became the industry standard.

Tech Fact

There are many sections of the NEC® that describe the uses of conduit and raceways. One of the oldest sections says that there shall not be more than the equivalent of four quarter bends (360° total) between pull points, for example, conduit bodies and boxes. This is true for all types of conduit and tubing used as raceways.

CONDUIT AND THE NEC®

There are several sections of the NEC® that refer to conduit and raceways. Each of these raceways has its own article in the NEC®. The sections entitled "Uses Permitted" and "Uses Not Permitted" should be reviewed for the particular raceway being considered. Some of these articles require the raceway to be listed. If that is the case, the raceway shall be installed in accordance with any instructions included in the listing or labeling.

Rigid Metal Conduit (RMC)

Rigid metal conduit (RMC) is a threadable conduit with fairly thick walls. RMC is commonly called "rigid" in the field. In the early part of the 20th century, rigid steel conduit and galvanized rigid steel conduit were the only conduit systems allowed by the NEC®. Rigid is discussed in NEC® Article 344. Rigid is permitted under all atmospheric conditions and in all types of occupancies. When installing rigid, dissimilar metals that could cause galvanic action should be avoided.

Rigid is generally available in 10′ lengths with a coupling on one end. The NEC® allows lengths shorter or longer than 10′ to be shipped. However, it is relatively uncommon for a manufacturer to provide lengths other than the standard 10′ size. Therefore, prices for these lengths can be expected to be higher than for standard lengths.

Rigid is available in sizes from ½″ in diameter up to 6″ in diameter. **See Figure 1-3.** Sizes may be given in inches or millimeters. In addition, ⅜″ rigid may be used between a motor and its junction box when the junction box is not part of the motor housing.

Thread Protector Caps. Rigid is shipped with colored protector caps to protect the threads. The colored protector caps are blue for sizes 1″, 2″, 3″, 4″, 5″, and 6″. The caps are black for sizes ½″, 1½″, 2½″, and 3½″. The caps are red for sizes ¾″ and 1¼″. **See Figure 1-4.** In some parts of the country, the color code may

also be found on the nylon straps used to bundle the conduit.

The color of the protector caps is an added feature that aids in recognizing the size of the conduit. If at all possible, the caps should be left on the threads until the bending is complete. This provides added protection for the threads.

Tech Fact

According to the NEC®, a bushing shall be provided where a conduit enters a box, fitting, or other enclosure to protect the wire from abrasion, unless the design of the box, fitting, or enclosure is such as to afford equivalent protection.

Electrical Metallic Tubing (EMT)

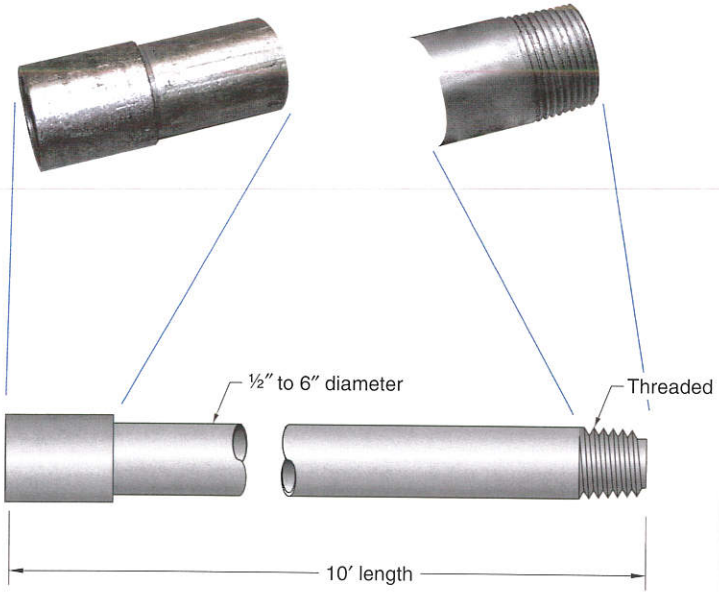
Electrical metallic tubing (EMT) is a lightweight tubular steel raceway without threads on the ends. In the 1928 revision to the NEC®, EMT was first approved in a very limited scope. EMT is discussed in NEC® Article 358. It is the lightest metallic raceway available. The lengths are typically joined together with setscrew couplings or compression fittings. **See Figure 1-5.**

Rigid Thread Protector Caps

Color	Sizes	Examples
Blue	Inch sizes	1″, 2″, 3″, 4″, 5″, 6″
Black	½″ sizes	½″, 1½″, 2½″, 3½″
Red	¼″ sizes	¾″, 1¼″

Figure 1-4. *Thread protector caps protect the threads and use color coding to help with identification.*

Rigid Metal Conduit (RMC)



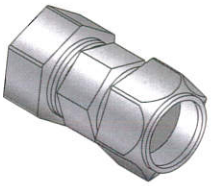
Sizes

10′ Lengths

Inches	Metric Designator
½	16
¾	21
1	27
1¼	35
1½	41
2	53
2½	63
3	78
3½	91
4	103
5	129
6	155

Figure 1-3. *Rigid metal conduit (RMC) is available in sizes from ½″ to 6″ in diameter with threaded ends.*

Electrical Metallic Tubing (EMT)



COMPRESSION COUPLING

SETSCREW COUPLING

COMPRESSION CONNECTOR

SETSCREW CONNECTOR

Sizes

10′ Lengths	
Inches	Metric Designator
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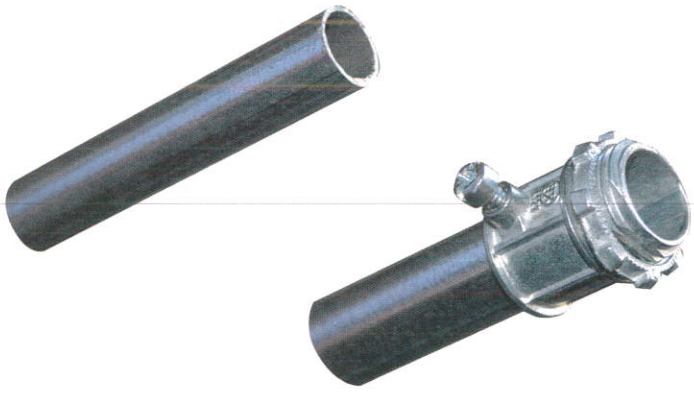

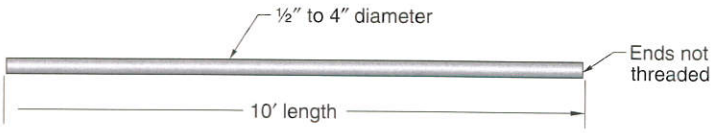

EMT SHALL NOT BE USED

- Where subject to severe physical damage
- In corrosive atmospheres
- Where buried in cinder fill
- In hazardous locations (with exceptions)
- For support of equipment except conduit bodies no larger than largest trade size of EMT
- Where practicable, in contact with dissimilar metals

EMT IS AVAILABLE

- In 10′ lengths
- In ½″ to 4″ diameters

Figure 1-5. *Electrical metallic tubing (EMT) is unthreaded thinwall tubing. The lengths are typically joined together with setscrew couplings or compression fittings.*

EMT has a much thinner wall thickness than rigid and does not require threading. Therefore, it supplies a degree of protection to the conductors while being cost effective. EMT is about 40% thinner in wall thickness than rigid and is commonly called "thinwall" in the field. There are six restrictions on the use of EMT. It cannot be used in the following situations:

- where subject to severe physical damage
- in corrosive atmospheres
- where buried in cinder fill
- in hazardous locations, except as specifically permitted
- for the support of fixtures or other equipment except conduit bodies no larger than the largest trade size of the EMT
- where practicable, in contact with dissimilar metals

Carlon

Figure 1-6. *PVC conduit is a common type of rigid nonmetallic conduit. PVC is available in thinwall and thickwall grades with many types of couplings and fittings.*

Rigid Nonmetallic Conduit (RNC)

Rigid nonmetallic conduit (RNC) is a conduit made of materials other than metal. RNC is discussed in NEC® Article 352. These materials are recognized as having suitable physical characteristics for direct burial in the earth. One of the more common types of RNC is polyvinyl chloride (PVC). **See Figure 1-6.**

Originally, PVC water pipes were given a number designation depending on the wall thickness. The thinnest wall thickness was designated as 10. The next thicker size was 20, then 30, 40, and up to 100. When PVC was presented to the electrical industry, the three sizes adopted were Schedule 20, 40, and 80.

PVC is waterproof, rustproof, and does not corrode in most locations. Because Schedule 40 PVC does not have the strength of metal conduits, it cannot be used where subject to physical damage. Schedule 80 PVC has a heavier wall thickness and is suitable for most locations where RMC is used. PVC must be supported as required in the NEC®. If the length change in a run of PVC exceeds ¼″ due to thermal expansion, an expansion fitting must be provided.

Permitted Uses. RNC, including PVC, was first approved in the 1960s. There are many permitted uses listed in the NEC®. Because of its nonmetallic, noncorrosive nature and ease of installation, PVC conduit is commonly used in underground installations. It is also used aboveground for carrying and protecting grounding electrode conductors. Because of the nonmetallic nature of PVC, grounding conductors can carry extremely high fault currents safely without inducing the large magnetic fields that would be found in a steel conduit raceway system.

As a general note, the use of PVC in extremely cold environments should be carefully evaluated. Extreme cold can make PVC brittle and therefore susceptible to physical damage. PVC is one of the few raceways that can be installed in cinder fill without the use of additional protective measures. It is also permitted for exposed work if it is identified as sunlight resistant and will not be subject to physical damage.

Uses Not Permitted. The NEC® lists the prohibited uses for rigid nonmetallic conduit.

Temperature considerations should always be considered when selecting RNC for a specific application. In general, RNC should not be installed where there are significant temperature extremes. RNC is prohibited from use where it is subjected to ambient temperatures in excess of 122°F and RNC is only permitted in hazardous locations under very specific conditions.

Intermediate Metal Conduit (IMC)

Intermediate metal conduit (IMC) is a raceway of circular cross-section with an intermediate wall thickness designed for protection and routing of conductors. IMC is discussed in NEC® Article 342. The NEC® requires that IMC and all associated fittings, elbows, and couplings be listed. The NEC® has specific requirements when IMC is installed in corrosive environments or is in indirect contact with cinder fill.

The wall thickness of IMC is between the wall thicknesses of EMT and rigid conduit. IMC is available in trade sizes ½″ through 4″. Like rigid conduit, IMC is generally available in 10′ lengths with a coupling on one end. It is made of steel, is threadable, and is frequently used because of its excellent protective qualities, large internal diameter, and ease of installation.

IMC is composed of a less-ductile grade of steel than rigid. This can cause some problems when bending IMC. It is not unusual for IMC to split when bent against the seam. This conduit also has much more springback than other metal conduits and requires adjustment when bending to specific angles.

Thread Protector Caps. IMC is shipped with colored protector caps to protect the threads. The colored protector caps are orange for sizes 1″, 2″, 3″, and 4″; yellow for sizes ½″, 1½″, 2½″, and 3½″; and green for sizes ¾″ and 1¼″. **See Figure 1-7.**

Tech Fact

A bushing is a fitting placed on the end of a conduit to protect the conductor's insulation from abrasion.

IMC Thread Protector Caps

Color	Sizes	Examples
Orange	Inch sizes	1″, 2″, 3″, 4″
Yellow	½″ sizes	½″, 1½″, 2½″, 3½″
Green	¼″ sizes	¾″, 1¼″

Figure 1-7. *Thread protector caps protect the threads and use color coding to help with identification.*

SUMMARY

- Conduit has been used from the beginning of the electrical industry.
- Early conduit designs included zinc tubes, spiral-wound paper tubes, and iron gas pipe.
- The development of rubber insulation for conductors and galvanized steel conduit made the lined iron gas pipe systems obsolete.
- Galvanized steel conduit can be bent in the field to improve installation procedures.
- Rigid conduit is a threadable conduit with fairly thick walls.
- Rigid can generally be used in all atmospheric conditions and all types of occupancies.
- Color-coded thread protector caps help protect the threads and help identify the size.
- EMT has thinner walls than rigid and does not require threading.
- EMT has several restrictions on its use.
- PVC conduit is waterproof, rustproof, and does not corrode in most locations.
- IMC is a conduit with intermediate wall thickness.