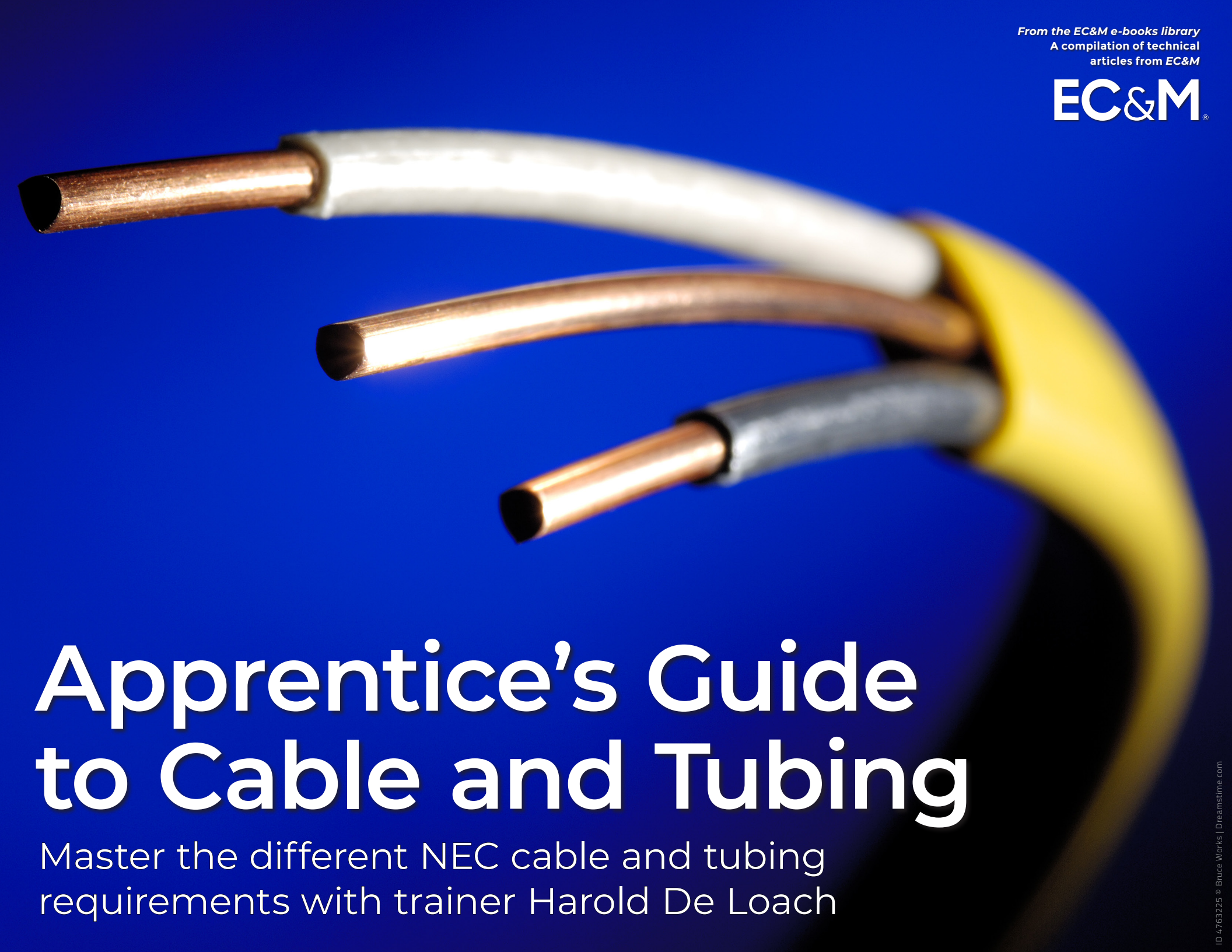
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Apprentice's Guide to Cable and Tubing

Master the different NEC cable and tubing requirements with trainer Harold De Loach

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EXECUTIVE SUMMARY

COMPREHENSIVE BASICS FOR INSTALLING CABLE AND TUBING

Harold De Loach breaks down various wiring method requirements in the NEC.

By Michael Morris, Editor, *EC&M*

We're back with the third installment in our "Apprentice's Guide" series of training e-books that highlight some of the most popular articles from *EC&M* contributor Harold De Loach, master electrician, electrical trainer/instructor, and founder/director of The Academy of Industrial Arts L.L.C.. The first e-book, "Apprentice's Guide to Entering the Electrical Industry," collected the best advice, tips, and tricks for anyone new to the trade. The second, "Apprentice's Guide to Calculations," focused on different types of electrical calculations. Both can be found in the e-book library available in the Members Only section of our website at ecmweb.com/ebook-library.

For this e-book, we chose to highlight training articles from Harold that focus on different cable and tubing requirements in the National Electrical Code (NEC). We kick off with an article about what Harold calls "one of the most essential Chapter 3 wiring methods for residential electricians." That wiring method, of course, is service entrance cable. This piece is a great introduction to Art. 338 requirements and sets the stage for the rest of the articles in this e-book.

Our next article on page 6 is called "The Apprentice's Guide to Electrical Metallic Tubing" where Harold looks at another essential wiring method. Following that article is a guide to metal-clad (MC) cable and then a guide to non-metallic (NM) sheathed cable. All of these articles are filled with great information regarding installation best practices.

Finally, we close out this compilation with "The Apprentice's Guide to Informative Annex C" on page 15. This piece offers a nice overview of Annex C, in which Harold explains why an apprentice (or any electrical worker for that matter) needs to be familiar with this part of the NEC. There are also a lot of tables and figures you can refer to at a glance.

Whether you're an apprentice or more experienced electrical professional, I know the information in this e-book will be useful for you. Read through it, and keep it handy for whenever you need a quick reference to the many different types of cable installations found in the NEC.

These articles reference the 2017 NEC because the Philadelphia area—the jurisdiction where Harold De Loach teaches and works—still operates under that version of the Code.

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THE APPRENTICE'S GUIDE TO SERVICE ENTRANCE CABLE

How to apply NEC Art. 338 requirements in the field

by Harold De Loach

One of the most essential Chapter 3 wiring methods for residential electricians in the National Electrical Code (NEC) is service entrance (SE) cable. Its primary purpose is to be used as a "main" feeder for the (building or premises) aerial service drop or underground feeder connection to dwelling units. This cable transports power from the utility company to the line side of the meter base — and then from the load side of the meter base to the breaker box or panelboard. It can be used in aerial (aboveground installations) as well as underground installations (if marked with SEU). Article 338 covers the use, installation, and construction specifications for SE cable, which is available as a single conductor or multiconductor assembly "with or without" an overall non-metallic sheathed covering.



ADDITIONAL USES (IT'S A MULTI-PURPOSE CABLE)

In specific conditions, SE and SER may be used for branch circuits and feeders to electrical equipment indoors and outdoors as approved by the NEC. For example, in Sec. 338.10 (B)(2), SE cable is approved to be used as a branch-circuit feeder

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in existing installations; when the uninsulated grounded conductor of the cable originates from the service equipment, the uninsulated conductors "shall be permitted" to be used as a grounded conductor. It can be used in cable trays and for feeding electrical equipment such as electrical ranges (Sec. 250.140, 210.19(A3) Exception No. 2). Just make sure the wire material and insulation rating match your device or receptacle requirements. Basically, SE cable can be used in any application where it's permitted by the NEC; it can be used in wet or dry locations; the installation is rated for 600V or less; and the temperature does not exceed 90°C.

IT HAS DIFFERENT STYLES

Service entrance cable Type SE is available as style SER and SE style U. Available in copper and aluminum, it's rated up to 600V, and the insulated (individual) conductors are covered with XHHW-2 or THHN/THWN. The gray jacketed-style cable has a flame-retardant, sunlight- and moisture-resistant polyvinyl chloride (PVC) outer jacket. In addition, a thin plastic reinforcement tape is wrapped around the conductors for added strength and conformity.

Type SEU cable has two insulated phase conductors surrounded by a concentric neutral. Type SER has three insulated conductors with an uninsulated grounding conductor. Type USE service-entrance cable is designed for underground use; it has a moisture-resistant covering but may not have a flame-retardant cover. For more information on the jacketing, see the **Table**.

CONDUCTOR SPECIFICATIONS	DESCRIPTIONS
AL	Conductor Material Type (Aluminum)
1 CDR 4 AWG 2 CDRS 2 AWG	Quantity, type, and size of conductor Quantity, type, and size of conductor
XHHW-2	Insulation Type for the (Ungrounded) Insulation Conductors
SE	Cable Type (Service Entrance)
U	Cable Style
600V	Cable Voltage Rating
XLPE SUN RES	Cable Jacket Insulation Type/Description (Sunlight Resistant)
2,344 FT	Cable Length Marker (Quantity of Cable Left on Spool)
CME Wire and Cable	Manufacturer
(UL) E98969	Standard: Underwriter Laboratories (Listing Number) (Approved)
12.04	Date of Manufacture
AA-8000	Conductors Construction Compact Stranded Aluminum Alloy 8000 Series ASTM STANDARD B800

YOU CAN USE IT HERE

SE cable is permitted for use in the following:

Type I or Type II structures —When installed within raceways approved to be used in Type I (fire-resistive) construction (i.e., a building constructed of non-combustible materials, such as reinforced concrete, brick, stone, etc., and having any metal members properly "fireproofed" with major structural members designed to withstand collapse and to prevent the spread of fire).

Type II (non-combustible) construction — (i.e., a building having all structural members, including walls, floors, and roofs, of non-combustible materials, such as reinforced concrete, brick, stone, etc.) and not qualifying as fire-resistive construction).

TYPE III-A-protected combustible applications — Known as "ordinary" construction with brick or block walls and a wooden roof or floor assembly, which is 1-hour fire-protected.

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Type IV buildings that have non-combustible exterior walls and interior elements. These buildings are made from solid or laminated wood. All wooden members must meet specific dimensional requirements (e.g., wood columns, beams, and girders must be at least 8 in. thick; heavy planks for floors and roofs must be at least 6 in. thick).

Type V applications — Structural elements, walls, arches, floors, and roofs are wood or other approved material.

Harold De Loach, a master electrician and electrical trainer/instructor, is the founder of The Academy of Industrial Arts (www.taia-school.com) in Philadelphia. With more than 30 years of experience in the field, he writes regular exclusive content for the E-Train newsletter and can be reached at info@taia-school.com.

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THE APPRENTICE'S GUIDE TO ELECTRICAL METALLIC TUBING

Making sense of NEC Art. 358.

By Harold De Loach

This article covers the use, installation techniques, and a few NEC guidelines for electrical metallic tubing (EMT).

EMT is one of the essential wiring methods for all electricians. This raceway type is used and approved in almost every "special occupancy" (non-residential buildings) application in Chapter 5, single- and multi-family dwelling units. It is an unthreaded thin wall raceway permitted to be used for exposed, concealed, interior, and exterior use. Its primary function is to provide physical protection for conductors or cables (approved to be run in a raceway).

When EMT is installed with the proper fittings, the raceway/conduit system can also serve as the equipment grounding conductor for the branch circuits within it. In some cases, the installer does not have to run a separate green grounding conductor, which is why all fittings and connectors need to be "made up tight" or ironclad tight.

EMT is typically made of steel (ferrous) with protective coatings or aluminum (nonferrous). Available in 10-ft or 20-ft sections in trade sizes from ½ in. to 4 in., it can help reduce electromagnetic field levels of encased power distribution circuits, which shields computers and other sensitive electronic equipment from the effects of electromagnetic interference.



The tubing is required to be clearly and durably marked at least every 10 ft with the following information:

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- A UL listing mark
- Product identity type
- Manufacturers' name
- UL control number
- Batch number

EMT is available in red, white, blue, green, yellow, orange, purple, and black. This helps instantly identify different circuit systems. This color system can also eliminate the unnecessary labor and time of applying spray paints or tapes in the field. In addition, colored EMT raceway systems help building inspectors, electricians, and maintenance technicians separate and identify fire alarm circuits from power and control circuits during routine maintenance and emergencies.

The NEC does not require or designate any color for EMT raceway systems, but there is an established trade practice that you may see used in the field.

- Fire alarm (red EMT)
- Healthcare (green EMT)
- Data com (blue EMT)

Ferrous or nonferrous EMT, elbows, couplings, and fittings shall be permitted to be installed in concrete, in direct contact with the earth, or areas subject to severe corrosive influences. However, they must be coated or protected to resist corrosion and approved to be embedded in concrete. Electricians installing EMT raceways should avoid contact with dissimilar metals. This will reduce or eliminate the possibility of galvanic action. Galvanic action (accelerated corrosion) may occur if two dissimilar metals are in contact with each other for an indefinite amount of time (e.g., permanent installations).

Water and moisture can create a conductive path between the two raceways or metals. The electrons and ions move from one metal conduit to another; one metal begins to corrode as its ions are deposited onto the other metal, keeping dissimilar metals insulated from each other. Therefore, it is only permissible to make splices, taps, or install devices within EMT fittings if the manufacturer legibly and durably marked the body with the total volume on the fitting.

SECURING AND SUPPORTING THE RACEWAY

Keep these spacing requirements in mind:

- EMT is required to be securely fastened, strapped, or supported at least every 10 ft.
- EMT is required to be securely fastened, strapped, or supported within 3 ft of each conduit termination at an outlet box, junction box, device box, cabinet, or conduit body.

There are exceptions to these support requirements under specific conditions (Sec. 358.30):

Exception No. 1: Fastening of unbroken lengths shall be permitted to be increased to 5 ft where structural members do not readily permit fastening within 3 ft.

Exception No. 2: EMT in unbroken lengths shall be permitted to be fished in concealed work in finished buildings or prefinished wall panels where such securing is impracticable.

FILLING THE RACEWAY

When installing the same size conductors in a conduit, the permissible number of conductors installed in EMT shall not exceed the percentage fill in Table 1, specified in Chapter 9 or the tables in Annex C. When installing conductors of different sizes and insulation types in EMT, the combined approximate square inch area of conductor is found at Table 5.

BENDING THE RACEWAY

Bending raceways requires a lot of patience, practice, and good hand/eye coordination — it's an art form. This skill cannot be developed overnight. Always remember that between pull points, conduit bodies, and boxes, there shall not be more than 360° in a conduit run. This is the equivalent of four quarter

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bends 360°. Bends in the conduit or raceway shall be made so that the conduit is not damaged or pinched; you cannot reduce the internal diameter of the raceway when creating bends and offsets.

Typically, EMT is bent manually in the field using a hand bender. Although the size of a hand bender can range from ½ in. to 1¼ in., raceway sizes larger than this typically require a mechanical or hydraulic bender.

A NOTE FROM THE AUTHOR

The ambitious apprentice should never forget that no matter what sector of the electrical industry you work in (e.g., commercial, industrial, maintenance, or construction), apprentices and journeymen that can bend pipe are indispensable. Most contractors would sacrifice a truck full of apprentices to get one good pipe bender.

If you are applying for a facility maintenance job, some employers may ask you to complete some simple bending tasks as part of the interview process. In some cases, if work gets slow, and the company must do layoffs — the boss will likely keep the employee skilled in pipe bending on staff — even if he must pay him/her his full rate to keep the shop organized until new work comes in. The boss is less likely to risk losing an apprentice or journeyman that is skilled at pipe bending.

Learning this craft can offer you some job security, opportunities, and advancement. Invest the time into learning how to bend conduit, even if you must practice on your own time and at your own expense.

Harold De Loach, a master electrician and electrical trainer/instructor, is the founder of The Academy of Industrial Arts (www.taia-school.com) in Philadelphia. With more than 30 years of experience in the field, he writes regular exclusive content for the E-Train newsletter and can be reached at info@taia-school.com.

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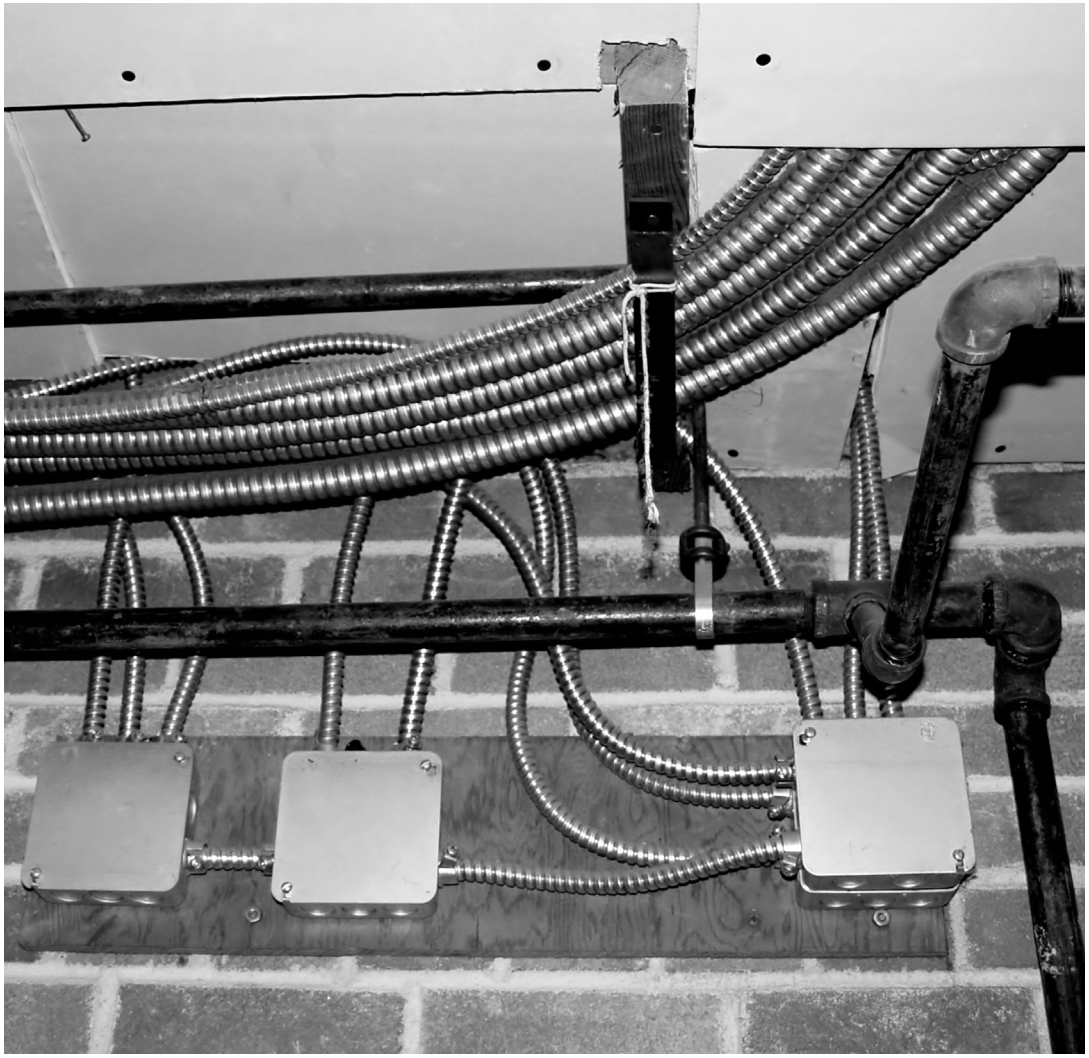
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THE APPRENTICE'S GUIDE TO MC-TYPE CABLE

Making sense of NEC Art. 330.

By Harold De Loach



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Metal-clad (MC) cable is one of the essential wiring methods commercial electricians use in their daily work. This Chapter 3 wiring method is approved for use in dwelling units and "other than" building types (e.g., commercial, health care, and industrial). This article will give apprentices practical information on industry-recommended practices, installation tips, and NEC guidelines (Art. 330) for the correct application and use of MC cable (Type MC).

The metallic corrugated jacket of MC cable is constructed of interlocked corrosion-resistant steel or aluminum that provides electricians just the right amount of flexibility and abrasion resistance when pulled through wood or metal studs, nailed to joists, or strapped to the surface of walls and ceilings. MC cable is manufactured in various styles, colors, conductor sizes, and configurations. You can find customized cable configurations for specific purposes (e.g., fire protection, audio/video, health care equipment, and harmonic noise reduction).

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PLACES OF RELIGIOUS WORSHIP ARMORIES CLUB ROOMS ASSEMBLY HALLS AUDITORIUMS BOWLING LANES CONFERENCE ROOMS COURTROOMS DANCE HALLS DINING AND DRINKING FACILITIES EXHIBITION HALLS GYMNASIUMS MORTUARY CHAPELS MULTIPURPOSE ROOMS MUSEUMS RESTAURANTS SKATING RINKS PLACES OF AWAITING TRANSPORTATION POOL ROOMS CARNIVALS, CIRCUSES, FAIRS AND SIMILAR EVENTS CONTROL SYSTEMS FOR PERMANENT AMUSEMENT ATTRACTIONS MANUFACTURED BUILDINGS AND RELOCATABLE STRUCTURES MOTION PICTURE AND TELEVISION STUDIOS OR SIMILAR LOCATIONS PARKTRAILERS RECREATIONALVEHICLES AND RECREATIONALVEHICLE PARKS THEATRES, AUDIENCE AREAS MOTION PICTURE & TELEVISION STUDIOS, PERFORMANCE AREAS AND SIMILAR LOCATIONS AGRICULTURAL BUILDINGS MOBILE HOMES, MANUFACTURED HOMES, AND MOBILE HOME PARKS

To help resolve harmonic noise problems, the cable may contain either a single grounded conductor sized 150% to 200% of the circuit conductors (super neutrals) or multiple grounded conductors. MC cable can be used in, but is not limited to, dwelling units and the following Chapter 5 special occupancies (see **Photo** on page 9).

UNDERSTANDING CABLE DESIGN, DESCRIPTION, AND IDENTIFIERS

MC cable has a distinctive marker tape (print legend) under the armor that typically includes the following information at intervals of 24 in. or less:

- Voltage rating (maximum voltage 600V to 2,000V)
- Size and number of conductors (remember, do not count the ground wire)
- Conductors in 18 AWG to 2,000kcmil copper, or 12 AWG to 2,000kcmil aluminum or copper-clad aluminum
- Optional markings for special applications (e.g., hospital grade, direct burial, cable tray use, etc.)
- Wire insulation type and designation (e.g., THHN, THWN, XHHW)
- Manufacturer's name
- Time and date it was manufactured
- Temperature rating

MC cable typically has a fibrous (paper wrap) covering that consists of 30-lb paper saturated with a preservative and a moisture-resistant compound that reduces abrasion on the conductors when the cables are being pulled. The neutral (grounded circuit) conductor within MC cable is typically white or gray, or it can have a conductor with three continuous white stripes throughout its entire length. It may also contain an insulated equipment grounding conductor (EGC) that is green (with or without one or more yellow stripes if it is a multi-circuit cable). MC cables are available with multiple grounded and ungrounded conductors; the cable design can vary based on the electrician's needs.

THE ANTI-SHORT

MC cable is constructed to allow an insulated red bushing (anti-short) to be inserted between the conductors and the metallic (armored) jacket at each armor termination to protect the conductors from their sharp edges. When you purchase a coil (250 ft) or a spool (1,000 ft) of MC cable, there is typically a packet of anti-short bushings supplied with the wire.

It is a trade practice to install anti-short bushings at each cable termination at panels, junction box connections, equipment connections, etc. The bushing must be fully inserted so the flange on the bushing comes in contact with the armor's edge.

Anti-short bushings are optional; the NEC does not require them. However, fittings or connectors used with MC cable must be provided with a smooth, rounded end stop to prevent the wires from being damaged by the armored jacket when passing wires to the end stop. In addition, some MC cable fittings may include a red anti-short (insulated throat); these are acceptable in place of a separate anti-short.

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THE MC CABLE JACKET IS AN ACCEPTABLE GROUNDING CONDUCTOR

Depending on the cable construction or application, the jacket armor assembly of MC cable is an acceptable EGC per NEC Chapter 2, Art. 250. In addition, some cables have a supplemental bare silver wire used for redundant grounding of the jacket; this ensures continuity if the jacket breaks, becomes oxidized, or corroded.

YOU CAN USE IT HERE AND THERE (USES PERMITTED)

The uses permitted list is not all-inclusive. Type MC cable is rated only for dry locations, ones generally not subject to dampness or wetness. Dry locations may only be temporarily subject to dampness or wetness, "as in the case of a building under construction," which will only be temporarily exposed to dampness. The metallic jacket insulation used is not suitable for wet locations, so do not use it outside — or anywhere it will be exposed to:

- Installations underground
- In concrete slabs or masonry in direct contact with the earth
- In locations subject to saturation with water or other liquids (e.g., vehicle washing areas; unprotected locations exposed to weather)

MC cable can only be used in wet locations when coated with a PVC jacket that will provide added durability. The insulated conductors under the metallic covering are listed for use in wet locations as well. PVC-jacketed MC cable can be directly buried and used in wet locations or encased in concrete.

MC cable can be used for services, feeders, and branch circuits in the following conditions:

- For power, lighting, control, and signal circuits
- Exposed or concealed
- In any raceway
- As aerial cable on a messenger
- In plenums, spaces used for environmental air
- Under raised floors of computer rooms

PLEASE DO NOT USE IT HERE (USES NOT PERMITTED)

MC cable must be used/terminated with fittings identified for such use. When connecting cable to boxes, cabinets, or other equipment, do not use NM cable connectors or expose MC cable to physical damage. Do not expose the metallic sheath to destructive corrosive conditions (e.g., strong chlorides, caustic alkalis, or vapors of chlorine or hydrochloric acids) unless the cable is rated, listed, and resistant to these conditions or environments.

Do not put it in cinder fills, drainage-promoting fill material typically used around the foundation perimeter of a building or home. Cinder fill is where the land was built up or filled using the cinders from coal-burning furnaces; when cinders get wet, an acid is formed that can destroy raceways and metallic cable jackets. Cinders were also used in lightweight concrete to fill masonry blocks.

DISCLAIMER

How a wiring method is permitted to be used in a building is ultimately up to the Authority Having Jurisdiction. First, verify the edition of the NEC that has been adopted in the municipality, borough, or state you are working within. In Pennsylvania, where I live, there is no single edition of the NEC enforced; there are different editions of the NEC used throughout the state in the various counties, boroughs, and cities.

Jurisdictions such as Maryland, Delaware, and New Jersey have a statewide adoption of one edition of the NEC. Some jurisdictions may also have local electrical codes that may supersede the NEC guidelines. In some instances, inspectors may also have different interpretations of the rules.

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THE APPRENTICE'S GUIDE TO NON-METALLIC SHEATHED CABLE

Everything you need to know about this wiring method

By Harold De Loach

Non-metallic (NM) sheathed cable is one of the essential wiring methods found in Chapter 3 of the National Electrical Code (NEC) — see Art. 334. NM cable is used by electricians for wiring single-family dwellings, multifamily dwellings along with their attached or detached garages and storage buildings, mixed-use buildings, and light commercial applications. NM cable has a thermoplastic PVC-coated sheathing/jacket that provides electricians just the right amount of flexibility to pull it through studs, joists, and walls. It also has moderate abrasion resistance.

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HOW TO IDENTIFY WIRE SIZE, COLOR, AND AMPACITY

In 2001, NM cable with a color-coded jacket was introduced to the market to aid electrical inspectors in identifying the size of the branch-circuit conductors that contractors and electricians used in electrical projects. These color-coded jackets also benefited suppliers and other consumers of electrical wiring products; this system reduced mistakes resulting from the use of incorrect conductor sizes.

The jacket of NM type cable is typically marked with the following information:

- Wire type and designation (e.g., NM, NMC, or NMS)
- Conductor size
- Number of current-carrying conductors (remember, don't count the ground wire)
- Voltage rating (typically 600V)
- Manufacturer's name
- Time and date it was manufactured

There are no requirements specifying jacket color for a given cable size, but typically the following jacket color(s) are widespread throughout the industry:

- White 14 gauge [14/2, 15A]
- Yellow 12 gauge [12/2, 20A]
- Orange 10 gauge [10/2 (flat cable), 10/3 round cable, 30A]
- Black 8 gauge [8/2 (flat cable), 8/3 round cable, 40A]
- Black or Grey 6 gauge [6/2 (flat cable), 6/3 round cable, 60A]

YOU CAN USE IT HERE

Type NM cable is permitted for exposed and concealed work in normally dry locations; it cannot be used in wet or damp locations (see Sec. 334.10). When used in exposed work applications, it must not be subject to physical damage. It may be installed or "fished" in the air voids of masonry block or tile walls. When NM cable is used in structures other than dwellings (non-residential), it must be concealed in walls, floors, or ceilings that provide a thermal barrier of material that has at least a 15-min fire rating (e.g., ½-in. drywall), as identified in listings of fire resistance and their rated assemblies.

NM cable is permitted for use in:

- Type I or Type II structures when installed within raceways approved to be used in Type I (fire-resistive) construction [i.e., a building constructed of noncombustible materials (reinforced concrete, brick, stone, etc.) and having any metal members properly "fireproofed" with major structural members designed to withstand collapse and to prevent the spread of fire].
- Type II (noncombustible) construction [i.e., a building having all structural members (including walls, floors, and roofs) of noncombustible materials (reinforced concrete, brick, stone, etc.) and not qualifying as fire-resistive construction].
- TYPE III-A-protected combustible applications (also known as "ordinary" construction with brick or block walls and a wooden roof or floor assembly, which is 1-hour fire-protected).

Inspector's Choice

How a wiring method is permitted "to be used" in a building is ultimately up to the Authority Having Jurisdiction (AHJ). Inspectors interpret and enforce the requirements outlined in the NEC. It's your job to verify which edition of the NEC has been "adopted" in the municipality, borough, or state you are working within. In some states, there is no single edition of the NEC being enforced; the various counties, boroughs, and cities use different editions. Other states like Maryland, Delaware, and New Jersey have adopted the NEC on a statewide basis. Some jurisdictions may also have local electrical codes that may supersede the NEC requirements. In some instances, inspectors may have different interpretations of the rules.

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- Type IV buildings that have noncombustible exterior walls and interior elements. These buildings are made from solid or laminated wood. All wooden members must meet specific dimensional requirements (e.g., wood columns, beams, and girders must be at least 8 in. thick; heavy planks for floors and roofs must be at least 6 in. thick).
- Type V applications: Structural elements, walls, arches, floors, and roofs are wood or other approved material.

DON'T USE IT HERE

As per Sec. 334.12, NM cable cannot be used as open runs in drop or suspended ceilings in (non-residential) applications other than one- and two-family and multifamily dwellings. It cannot be used in wet or damp locations or as service-entrance cable. It cannot be exposed to corrosive fumes or vapors. It cannot be embedded in masonry, concrete, adobe, fill, or plaster. You cannot install it in a shallow chase in masonry, concrete, or adobe, where covered with plaster, adobe, or similar finish.

Always verify or check the building construction type in consideration or in Annex E of the NEC. If the construction type is approved for NM cable *only* in raceways, verify the wiring methods permitted in Chapter 5 Special Occupancies. If the building occupancy (Type) allows raceways, you may have an exception to use it; always check with the Authority Having Jurisdiction (AHJ) first before proceeding.

The use of NM cable is also prohibited in these specific NEC Chapter 5 special occupancies:

- Motion picture studios, theaters, and similar locations, except where permitted in Sec. 518.4
- Commercial garages where Class 1 hazardous location liquids or gaseous fuels are stored, handled, or transferred. In these locations, electrical wiring (wiring methods used) and electrical utilization equipment shall be designed following the requirements for Class I, Division 1 or 2 hazardous (classified) locations
- Storage battery rooms
- Hazardous (classified) locations except as permitted in Sec. 501.10(B)(3), Sec. 502.10(B)(3), and Sec. 504.20
- Hoistways or on elevators or escalators

Harold De Loach, a master electrician and electrical trainer/instructor, is the founder of The Academy of Industrial Arts (www.taia-school.com) in Philadelphia. With more than 30 years of experience in the field, he writes regular exclusive content for the E-Train newsletter and can be reached at info@taia-school.com.

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THE APPRENTICE'S GUIDE TO INFORMATIVE ANNEX C

Why you must know how to use the conduit and tubing fill tables for conductors and fixture wires of the "same size."

By Harold De Loach

As an electrician, no matter what sector of the electrical industry you work in (e.g., residential, commercial, or industrial), the tables found in "Annex C" are a handy reference source or guideline when you are performing basic electrical installations for equipment, devices, and fixtures found in residential houses (i.e., dwelling units), commercial buildings (i.e., special occupancies), and industrial facilities. Neatly tucked away in the rear of the NEC are 12 Informative Annexes, alphabetically arranged A-J that provide additional information for inspectors, electricians, and engineers. Note: The information in this part of the Code book is NOT part of the requirements for NFPA 70; it is included for informational purposes only.

WHY YOU NEED ANNEX C

As your responsibilities grow as an apprentice, you may need to determine the number of (single or stranded) conductors for the electrical circuit and the safe or recommended percentage area "inside" the conduit taken up by the circuit conductors/wires. Informative Annex C, which has 26 reference tables, provides a quick and easy reference for conduit fill after you select the type

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of electrical conduit or raceway for your electrical project. But remember, all the conductors must be the same size and insulation type to use this table.

NAVIGATING THE TABLES

The tables in Annex C are strategically organized by the schedule or weight of the raceway/conduit — from the lightest to the heaviest. The first eight tables are "thin-wall" raceways or "lightweight" metallic raceways and nonmetallic "light schedule" raceways and lightweight flexible conduits [C.1 through C.4(A)*]. I have included the Article numbers for quick reference in the field in **Table 1**. Note: An asterisk (*) denotes where this table is used in conjunction with Tables C.1 through C.13, the conductors installed must be of the compact type.

The next eight tables contain the lightweight, thin-wall, flexible nonmetallic raceways first and then the heavier (wall or gauge) flexible raceways [C.5 through C.8(A)*]. I have included the Article numbers for quick reference in the field in **Table 2**:

The last 10 tables contain the heavy-weight schedule/heavy wall, metallic raceways first and then the heavier (wall or schedule) nonmetallic raceways [C.9 through C.13(A)*]. I have included the Article numbers for quick reference in the field in **Table 3**:

Annex C tables are typically used for basic installations, short runs of pipe, average conditions, or non-adverse environments. In some cases, the size and number of conductors pulled into a raceway are selected after cross-referencing the tables in Chapter 9 when electricians or engineers are required to perform or applyderating factors such as adjustment factors or ambient temperature corrections factors.

Light or "Thin-Wall" Conduits/Raceways	
C.1 — Electrical Metallic Tubing (EMT)	**Article 358**
C.1(A)* — Electrical Metallic Tubing (EMT)	
C.2 — Electrical Nonmetallic Tubing (ENT)	**Article 362**
C.2(A)* — Electrical Nonmetallic Tubing (ENT)	
C.3 — Flexible Metal Conduit (FMC)	**Article 348**
C.3(A)* — Flexible Metal Conduit (FMC)	
C.4 — Intermediate Metal Conduit (IMC)	**Article 342**
C.4(A)* — Intermediate Metal Conduit (IMC)	

Table 1

Flexible Conduits and Raceways	
C.5 — Liquidtight Flexible Nonmetallic Conduit (Type LFNC-A)	**Article 356**
C.5(A)* — Liquidtight Flexible Nonmetallic Conduit (Type LFNC-A)	
C.6 — Liquidtight Flexible Nonmetallic Conduit (Type LFNC-B)	
C.6(A)* — Liquidtight Flexible Nonmetallic Conduit (Type LFNC-B)	
C.7 — Liquidtight Flexible Nonmetallic Conduit (Type LFNC-C)	
C.7(A) — Liquidtight Flexible Nonmetallic Conduit (Type LFNC-C)	
C.8 — Liquidtight Flexible Metal Conduit (Type LFMC)	**Article 350**
C.8(A)* — Liquidtight Flexible Metal Conduit (Type LFMC)	

Table 2

Additional calculations must be performed using the tables in Chapter 9 and other tables in Chapter 3 if the conductors will be installed in a raceway subject to the following:

- More than three circuit conductors.
- The conductors' sizes and insulation types are different.
- Longer than usual conduit runs for branch circuits or feeders.

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- Direct sunlight (e.g., harsh weather conditions: extreme heat or cold).
- Harsh environments (bakeries, steel plants, manufacturing facilities).
- Large or very diverse electrical loads that cause excessive heat on circuit conductors.
- Repair, avoid, or identify a problem in an electrical circuit due to malfunctioning equipment.

SAMPLE ELECTRICAL EXAM QUESTION

Here is an example of a question typically used in an electrical license examination, continuing education course, or journeyman exam related to these concepts:

The maximum number of 8 AWG THW conductors permitted in a ¾-inch, liquid-tight flexible metallic conduit is _____.

A. 3
B. 4
C. 5
D. 6

Step 1. Locate the appropriate table listed in the directory of Annex C, and identify the "type" of wiring method referenced in the question. Is it light or heavy? Is it a tube conduit or a flexible raceway? I have arranged the type of wiring methods with colored rows in the **Tables** above to identify them quickly by weight and type. If you use my system, you'll save time and energy.

"HeavyWall" Conduit and Raceways	
C.9 — Rigid Metal Conduit (RMC)	**Article 344**
C.9(A)* — Rigid Metal Conduit (RMC)	
C.10 — Rigid PVC Conduit, Schedule 80	**Article 352**
C.10(A)* — Rigid PVC Conduit, Schedule 80	
C.11 — Rigid PVC Conduit, Schedule 40, and HDPE Conduit	**Article 353**
C.11(A)* — Rigid PVC Conduit, Schedule 40, and HDPE Conduit	
C.12 — Type A, Rigid PVC Conduit	**Article 352**
C.12(A)* — Type A, Rigid PVC Conduit	
C.13 — Type EB, PVC Conduit	
C.13(A)* — Type EB, PVC Conduit 789	

Table 3

Step 2. We are selecting Table C.8 — Maximum Number of Conductors or Fixture Wires in Liquid-Tight Flexible Metallic (LFMC).

Step 3. Locate the insulation material type on the conductor in the question from the vertical column on the left side of the table. The question uses "THW" conductors.

Step 4. Locate the vertical column (right next to the insulation type) with the conductor size or (awg) gauge. Our question lists the size to be #8 AWG.

Step 5. Next, you must locate the raceway or conduit size referenced in the question from the row of trade sizes at the top of the table (metric designator). In our question, the trade size is ¾ in.

Step 6. Next, drop down to the insulation type/conductor size and slide over to the raceway size. Where the column and rows meet are the number of conductors recommended to install in this type of conduit or raceway, so (#8 size) THW conductors + ¾ in. LFMC = 5. Bam! Our answer is C.

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