NEMA RV 1

Application and Installation Guidelines for Armored Cable and Metal-Clad Cable

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Application and Installation Guidelines for Armored Cable and Metal-Clad Cable

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Foreword

These application and installation guidelines offer practical information on correct usage and industry recommended practices for the installation of Type AC and Type MC cables in accordance with the *National Electrical Code*®.

These guidelines have been developed by the NEMA Building Wire and Cable Section, which has committed to periodically reviewing them for any revisions necessary to address changing conditions, product listing and installation requirements, and technical progress. Comments for proposed revisions are welcomed and should be submitted to:

Vice President, Technical Services
National Electrical Manufacturers Association
1300 North 17th Street, Suite 1847
Rosslyn, VA 22209

At the time of approval, the Building Wire and Cable Section of the National Electrical Manufacturers Association had the following members:

AFC Cable Systems—New Bedford, MA
Alcan Cable—Atlanta, GA
Alflex Corporation—Long Beach, CA
Amercable—El Dorado, AR
American Insulated Wire Corporation—Pawtucket, RI
Colonial Wire & Cable, Inc.—Hauppauge, NY
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Section 1
APPLICATION GUIDELINES FOR ARMORED CABLE

1.1 CONSTRUCTION

1.1.1 General

Type AC cables are constructed in accordance with the *National Electrical Code*® (*NEC*®) and comply with the safety requirements of Underwriters Laboratories (UL) *Standard for Safety for Armored Cable*, UL 4. These cables employ copper, copper-clad, or acceptable aluminum alloy conductors. Copper conductors are of sizes 14–1 AWG. Aluminum or copper-clad aluminum conductors are of sizes 12–1 AWG. All conductors 6–1 AWG are stranded. The *NEC*® recognizes three AC Cable types—Types ACHH, ACTH, and ACTHH. Type ACTHH is the most common of these.

1.1.2 Circuit Conductors

Circuit conductors in Type ACHH are rated 90ºC and comply with UL 44, *Standard for Safety for Thermoset-Insulated Wires and Cables*. In Type ACTH Cable, circuit conductors are rated 75ºC and comply with UL 83, *Standard for Safety for Thermoplastic-Insulated Wires and Cables*. As with Type ACTH Cable, the circuit conductors of Type ACTHH Cable also comply with UL 83, but are rated 90ºC.

1.1.3 Equipment Grounding Conductors

Although not required in Type AC cables, one or more equipment grounding conductors are permitted. One bare copper or aluminum equipment grounding conductor is permitted and can have a paper covering. Insulated equipment grounding conductors are always of the same material as the circuit conductors. Type AC cable with an equipment grounding conductor is most commonly used where redundant, dedicated, or isolated grounding is required, such as in patient care areas.

1.1.4 Fibrous Coverings

Fibrous coverings (paper wrap) for Type AC cable consist of 30-pound or heavier paper, saturated with a preservative and moisture-resistant compound. Each of the thermoplastic-insulated circuit conductors and any insulated equipment grounding conductor in Type ACTH and ACTHH Cable have an individual paper covering applied directly over the insulation. The rubber-insulated conductors of Type ACHH Cable have an overall fibrous material over the grouped conductors.

Where Type ACTH and ACTHH Cable employ a bare equipment grounding conductor without a paper covering, an overall covering is applied directly over the grouped circuit and equipment grounding conductors to keep the bare conductor from contacting the armor.

1.1.5 Armor

The armor of Type AC cable is constructed of interlocked corrosion-resistant steel or aluminum strip, and is applied over the conductors. The external diameter of the armor is at least 0.415 in., but there are no requirements on the internal diameter.

1.1.6 Bonding Strip

The required bonding strip is made of aluminum, and is located between the armor and conductor assembly to enhance grounding ability. The bonding strip can be no smaller than 16 AWG.

1.1.7 Bushings

Type AC cable is constructed to allow an acceptable insulated bushing or its equivalent to be inserted readily between the conductors and the armor at each termination of the armor. The bushing is fully

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inserted so that the flange on the bushing comes in contact with the edge of the armor. At least 35 bushings will accompany each 250-ft length of cable, and are typically bright red.

1.2 GROUNDING

1.2.1 Armor

The finished armor assembly is comprised of the interlocked armor and bonding strip located between the armor and conductor assembly throughout the entire length of the cable. The finished armor assembly of Type AC cable is an acceptable equipment grounding conductor in accordance with Article 250 of the *NEC*©.

1.2.2 Equipment Grounding Conductor

One or more equipment grounding conductors are allowed but are not required. Each equipment grounding conductor is either insulated the same as the circuit conductors, or may be a bare copper or aluminum conductor.

1.3 MARKING

1.3.1 Armor

Armored cable is required to have a distinctive marking that identifies the factory where the cable was produced. The marking consists of a letter or symbol indented or embossed in the armor at intervals 12 in. or less. The armor may also include optional markings such as the UL logo.

1.3.2 Cable, Tag, or Package

The tag or package contains information on the identification and use of the cable, including the following:

Maximum voltage 600 V
Size and number of conductors
Optional markings for special applications
Manufacturer identification

If the cable employs aluminum armor, the following will also appear on the tag or package marking and on a marker tape under the armor at intervals of 24 in. or less:

- "ALUMINUM ARMORED CABLE"
- "NOT FOR USE ON DC CIRCUITS"
- "CAUTION: NOT TO BE USED WITH SETSCREW CONNECTOR"

1.3.3 Circuit Conductors

Circuit conductors are not required to be marked. Colored stripes, numerals, letters, or words may be used to provide identification. The neutral (grounded circuit) conductor within an armored cable is white, gray, or has three continuous white stripes throughout its entire length.

1.3.4 Equipment Grounding Conductors

Insulated equipment grounding conductors are green with or without one or more yellow stripes.

1.4 CODES AND STANDARDS

1.4.1 *National Electrical Code*®

Type AC cable is designed, manufactured and tested for use in accordance with the *National Electrical Code*®, Article 320, and with UL 4.

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1.4.1.1 Uses permitted

NEC® Section 320.10 specifies the permitted uses of Type AC as follows:

(1) In both exposed and concealed work
(2) In cable trays where identified for such use
(3) In dry locations
(4) Embedded in plaster finish on brick or other masonry, except in damp or wet locations
(5) To be run or fished in the air voids of masonry block or tile walls where such walls are not exposed or subject to excessive moisture or dampness

These permitted uses are not all inclusive, but only provide guidance on where and how the cable may be used.

The following provides additional guidance on the uses of Type AC cable:

General

A key provision of the permitted uses of Type AC is that Type AC cable is required to comply with all applicable Sections of the *NEC*©. While Section 320.10 permits Type AC to be used as branch circuits and feeders, other Articles of the NEC that apply to the particular installation must be reviewed to determine if additional requirements or restrictions apply. For example; Section 517.13(A) permits Type AC cable for use in patient care areas of Health Care Facilities however the cable must contain an insulated equipment grounding conductor.

Where not subject to physical damage

Type AC cable must be protected from physical damage. This includes installing the cable at heights and locations where the cable will not be exposed to damage. It also includes providing mechanical protection for the cable from nails and screws in accordance with section 300.4(D) by maintaining a 1-1/4 in. (32 mm) distance from the edge of a framing member or by providing a metal plate where the distance cannot be maintained.

In both exposed and concealed work

Type AC cable is permitted for installation in both exposed and concealed work however the cable must be protected from physical damage. Exposed work includes installations above suspended ceilings where installed behind panels designed to allow access. Where installed above suspended ceilings Section 300.11 should be consulted for requirements for securing and supporting the cable.

In cable tray where identified for such use

All UL Listed Type AC cable is identified for use in cable tray. There is no marking on the cable that indicates that the cable is identified for such use because the metallic armor enables the cable to meet the flame and sunlight resistance requirements for cables installed in cable tray. If documentation is required to show that Type AC is identified for use in cable trays, UL's General Information for Electrical Equipment Directory (White Book) contains the necessary information. *NEC*® Article 392 should be consulted for cable tray installation requirements.

In dry locations

Type AC cable is rated only for dry locations. The insulation used is not suitable for wet locations. The cable is permitted a limited exposure during building construction as defined in Article 100 under Dry Locations:

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Dry Location – A location not normally subject to dampness or wetness. A location classified as dry may be temporarily subject to dampness or wetness, as in the case of a building under construction.

In addition to permitted uses covered in Section 320.10, Type AC is permitted for installation as follows:

- In other spaces used for environmental air in accordance with Section 300.22(C);
- Under raised floors of computer rooms in accordance with Section 645.5(D);
- In patient care areas of Health Care Facilities, Hospitals, and Nursing Homes in accordance with Section 517.13(A) where an insulated equipment grounding conductor is used;
- Isolated or dedicated ground circuits where an insulated equipment grounding conductor is used;
- Lighting whips; and
- Motor leads.

Based on the limitations of its construction, limited size range, number of conductors, and absence of an optional outer non-metallic jacket, Type AC is typically used as part of branch circuit wiring in multi-family residential/commercial and institutional applications. Industrial installations typically use Type MC cable, which does not have these limitations.

1.4.1.2 Uses not permitted

As with permitted uses, those uses not permitted by the *NEC*® are not all-inclusive. The Code language is intended to provide guidance on where and how the cable may be used. *NEC*® Section 320.12 specifies the uses of Type AC that are not permitted, which are as follows:

(1) In theaters and similar locations, except where permitted in 518.4
(2) In motion picture studios
(3) In hazardous (classified) locations except where permitted in
  a. 501.4(B), Exception
  b. 502.4(B), Exception No. 1
  c. 504.20
(4) Where exposed to corrosive fumes or vapors
(5) In storage battery rooms
(6) In hoistways, or on elevators or escalators, except where permitted in 620.21
(7) In commercial garages where prohibited in 511.4 and 511.7

Review of the uses not permitted shows a central theme that Type AC cable is not permitted where extreme or frequent flexibility is required and where corrosive environments may be present. For installations where frequent flexing or movement can be expected, flexible cord or specialty type cables such as Elevator Cable (e.g. Type ET) or Stage Lighting Cable (e.g. Type SC) are used. Similarly, where a corrosive environment exists, a cable with a protective outer covering such as Type MC with an outer nonmetallic jacket should be used.

1.4.1.3 Related *NEC*® Articles

The following *NEC*® Articles also contain provisions for the use of Type AC:

Wiring and Protection

- Article 250*, Grounding*
  250.118 (9), *Use of the Armor of Type AC as Equipment Grounding Conductor*

Wiring Methods and Materials

- Article 300*, Wiring Methods*
  300.15, *Boxes, Conduit Bodies, or Fittings—Where Required*
  300.16, *Raceway or Cable to Open or Concealed Wiring*
  300.22(C)(1), *Wiring in Ducts, Plenums, and Other Air-Handling Spaces*
  310.11, *Marking*

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- Article 392, *Cable Trays*
  392.3(A), *Wiring Methods*

Equipment for General Use
- Article 410, *Luminaires (Lighting Fixtures) Lampholders, and Lamps*
  410.14, *Connection of Electric-Discharge Luminaires (Lighting Fixtures)*
  410.67(C), *Wiring*
- Article 430, *Motors, Motor Circuits, and Controllers*
  430.145, *Method of Grounding*

Special Occupancies
- Article 517, *Health Care Facilities*
  517.13(A), *Grounding of Receptacles and Fixed Electric Equipment in Patient Care Areas*
- Article 518, *Places of Assembly*
  518.4, *Wiring Methods*
- Article 520, *Theaters, Audience Areas of Motion Picture and Television Studios, and Similar Locations*
  520.5(C), *Wiring Methods*
- Article 530, *Motion Picture and Television Studios and Similar Locations*
  530.11, *Permanent Wiring*
- Article 550, *Mobile Homes, Manufactured Homes, and Mobile Home Parks*
  550.16(A)(2), *Grounding*
- Article 551, *Recreational Vehicles and Recreational Vehicle Parks*
  551.47(G), *Wiring Methods*
  551.55(C), *Interior Equipment Grounding*
- Article 552, *Park Trailers*
  552.48(F), *Wiring Methods*
  552.56(C)(1), *Interior Equipment Grounding*

Special Equipment
- Article 610, *Cranes and Hoists*
  610.11, *Wiring Method*
- Article 620, *Elevators, Dumbwaiters, Escalators, Moving Walks, Wheelchair Lifts, and Stairway Chair Lifts*
  620.21, *Wiring Methods*
  620.81, *Metal Raceways Attached to Cars*
- Article 645, *Information Technology Equipment*
  645.5, *Supply Circuits and Interconnecting Cables*
- Article 668, *Electrolytic Cells*
  668.30(C), *Fixed and Portable Electrical Equipment—Wiring Methods*

1.4.2 Underwriters Laboratories (UL) Standards and Directories

UL publishes a number of Standards and Directories that provides detailed information on the construction, performance, application, ratings, and installation aspects of Type AC cable.

1.4.2.1 UL Standards

The UL standard for the construction and performance of Type AC cable is UL 4. According to *NEC*® Section 320.104, the insulated conductors for AC cable must be of the types listed in Table 310.13, or one identified for use in this cable. Practically all Type AC cable contains Type THHN, a thermoplastic insulated conductor covered in UL 83. Insulation types however, could be a thermosetting type such as Type XHH or RHH conductors covered in UL 44.

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1.4.2.2 UL Directories

UL publishes several directories that contain useful information on the products that it lists, recognizes, and certifies. The directories are frequently used by installers and by inspection authorities to gain a better understanding of how to specify and install products in accordance with their listing. All of this information is also readily available at the UL website.

These directories are helpful tools for understanding the details of how products, in this case Type AC cable, are constructed and marked as well as information on special or optional ratings, and terminations. One of the directories covers the UL approved methods for maintaining the fire resistive rating on walls, floors, and ceilings for fire-resistance rated construction, when cables must penetrate them and be fire stopped.

a) *UL General Information for Electrical Equipment Directory* (commonly called *White Book*)

The following information on Type AC cable is reprinted from the *UL General Information for Electrical Equipment Directory*, with permission from Underwriters Laboratories Inc., Copyright © 2003 Underwriters Laboratories Inc.:

ARMORED CABLE (AWEZ)

GENERAL
This category covers armored cable in sizes 14–1 AWG copper and 12–1 AWG aluminum or copper-clad aluminum and rated 600 V or less. Aluminum-armored cable is suitable for use in alternating current circuits only. Armored cable is for use in accordance with Article 320 of NFPA 70, *National Electrical Code®*.

ACTH — Indicates armored cable rated 75°C employing conductors having thermoplastic insulation.
ACTHH — Indicates armored cable rated 90°C employing conductors having thermoplastic insulation.
ACHH — Indicates armored cable rated 90°C employing conductors having thermosetting insulation.

Armored cable connectors (box connectors) other than the direct bearing setscrew type are suitable for use on cable employing aluminum armor. For conductor termination information, see Electrical Equipment for Use in Ordinary Locations (AALZ).

PRODUCT MARKINGS
Armored cable complies with the Flame and Limited Smoke Test requirements specified in UL 1685, ''Vertical-Tray Fire-Propagation and Smoke-Release Test for Electrical and Optical-Fiber Cables'' and may be marked with the suffix ''LS'' and/or ''For Use in Cable Trays.'' Cable with aluminum armor is identified with the words ''ALUMINUM ARMOR'' on a marker tape and tag on coils. Cable with copper-clad aluminum conductors is identified with the designation ''AL (CU-CLAD)'' or ''Cu-Clad Al.'' on a tag, on the carton or reel. Cable with aluminum conductors is identified with the designation ''AL'' on a tag, on the carton or reel. In addition, cable with compact-stranded copper conductors is identified with the designation ''Compact Copper'' or ''CMPCT CU'' following the conductor size and the words ''Terminate with connectors identified for use with compact-stranded copper conductors'' on a tag, on the carton or reel.

RELATED PRODUCTS
For fittings suitable as a grounding means, see Armored Cable Connectors (AWSX).

ADDITIONAL INFORMATION
For additional information, see Electrical Equipment for Use in Ordinary Locations (AALZ).

REQUIREMENTS
The basic standard used to investigate products in this category is UL 4, ''Armored Cable.''

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UL MARK
The Listing Mark of Underwriters Laboratories Inc. on the attached tag, the reel or the smallest unit container in which the product is packaged with or without the UL symbol on the product is the only method provided by UL to identify products manufactured under its Listing and Follow-Up Service. The Listing Mark for these products includes the UL symbol (as illustrated in the Introduction of [the] Directory) together with the word ‘‘LISTED,’’ a control number, and the product name as appropriate.

Armored cable that contains copper or copper-clad aluminum conductors has the product name ‘‘Armored Cable’’; armored cable that contains aluminum conductors has the product name ‘‘Armored Aluminum Cable.’’ Armored cable that has aluminum armor has the product name ‘‘Aluminum Armored Cable.’’

b) *UL Electrical Construction Equipment Directory* (commonly called *Green Book*)

UL’s *Electrical Construction Equipment Directory*, *Green Book*, contains the identical information that is contained in the *White Book* with the addition of the company name, address, and UL file number of those manufacturers that are authorized by Underwriters Laboratories to produce a listed product. The *Green Book* is frequently used to identify and locate listed manufacturers of Type AC cable, to verify if a manufacturer is authorized to produce UL Listed Type AC, and to identify the manufacturer of the cable when the cable is marked with the UL file number (E number) in place of the company name.

c) *UL Fire Resistance Directory* (commonly called *Orange Book*)

UL’s *Fire Resistance Directory* generally covers the construction detail necessary for constructing fire rated walls, floors, and ceilings. This directory also covers the listed materials and methods for sealing the wall ceiling or floor that has been penetrated by electrical cables, conduit, cable tray, or other equipment. The methods and materials are listed by UL under the category of “Through Penetration Fire Stop Systems.” The Directory should always be consulted for the proper method of sealing the opening. Any such opening that is not properly sealed in accordance with the UL listed “Through Penetration Fire Stop Systems” will be subject to rejection by the inspecting authority.

d) UL Listing on Website

Underwriters Laboratories operates a website at www.ul.com. This website contains an online version of the above directories as well as other general information relating to UL’s products and services.

Once logged onto the UL website, go to UL on line certification directory. This will lead you to a list of product categories. The following list, or one similar, will be presented:

- Company Name/Location
- UL File Number
- Appliance Wiring Material (AWM)
- Fire Resistance - Design or System Number
- Roofing Materials & Systems - Construction Number
- Building Materials - Assembly Number
- UL Category Control Number (CCN)/Guide Information
- Keyword Search

The category should be chosen based on the information available to you. The key word search is the easiest way to start if limited information is available. As an example, using “Armored Cable” as the key word opens the path to the information covered by the *UL Green and White Book Directories*.

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Section 2
APPLICATION GUIDELINES FOR METAL-CLAD CABLE

2.1 CONSTRUCTION

2.1.1 General

Type MC cables are constructed in accordance with the *National Electrical Code*® (*NEC*®) and comply with the safety requirements of *Underwriters Laboratories (UL) Standard for Safety for Metal-Clad Cables*, UL 1569. These cables employ conductors in sizes 18 AWG – 2000 kcmil copper, or 12 AWG – 2000 kcmil aluminum or copper-clad aluminum. Type MC cable referenced in this guideline can be rated for use up to 2000 V. The requirements in UL Standard 1569 for Metal-Clad cables cover round or flat Metal-Clad cables, with or without one or more optical fiber members enclosed in a metal sheath of interlocked tape or a corrugated or smooth metal tube. One or more insulated circuit conductors are permitted.

2.1.2 Circuit Conductors

The insulated conductors are of thermoplastic or thermoset type insulation, typically rated 90ºC. Thermoset-insulated conductors, typically XHHW, comply with UL 44 and thermoplastic-insulated conductors, typically THHN/THWN, comply with UL 83.

2.1.3 Equipment Grounding Conductors

The equipment grounding conductor required with interlocked sheath construction could be insulated or bare and may be sectioned. The required equipment grounding conductor can consist of the sheath of the smooth or corrugated tube Type MC cable, or a combination of the sheath and a supplemental bare or unstriped green insulated conductor. Any additional equipment grounding conductors will be insulated. The equipment grounding conductor for single conductor MC cable may be distributed helically (concentric).

2.1.4 Coverings

Interlocked armor cable will have a covering under the armor, typically a polyester or polypropylene tape. Smooth or corrugated cable with a bare equipment grounding conductor will also have a covering under the armor. A jacket may also be applied under the armor. Fillers under the jacket may be utilized to achieve roundness. In the case of direct burial use, the jacket will be applied over the armor and marked for such use.

2.1.5 Armor

The armor of Type MC cable is a metallic covering consisting of interlocked tape or a corrugated or smooth tube. Typically the sheath is aluminum alloy or galvanized steel. The sheath may be copper as well.

2.1.6 Cable Fittings

The combination of listed Type MC cable and listed MC cable fitting designs are such that the use of anti-short bushings is not required by the *NEC*®. MC cable fittings have a shoulder to protect the conductors from any sharp edge that may be present on the cut edge of the armor. Bushings may be used however (See Appendix A, or go to NEMA Engineering Bulletin 90).

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2.2 GROUNDING

2.2.1 General

NEC® Section 330.108 requires that Type MC cable provide an adequate path for equipment grounding. The metallic sheath, along with the equipment grounding conductors are the components in the cable that make up the equipment grounding conductor. The method used to achieve adequate grounding depends on the construction of the cable.

Interlocked armor construction requires an equipment grounding conductor in the cable. The conductor may be bare or insulated green.

Smooth or corrugated tube Type MC cable may only require the use of the armor as the equipment ground, or may require a combination of the armor and equipment grounding conductor, depending on the cable construction or application.

2.2.2 Sectioned Equipment Grounding Conductors

The equipment grounding conductor of Type MC cable is sized in accordance with the *NEC*®. This may be a single conductor or may be sectioned into a number of identically sized smaller conductors that as a whole add up to the equivalent of the required size.

2.2.3 Redundant Grounding

More than one equipment grounding conductor may be provided in the cable. The additional equipment grounding conductors may be used for isolated or redundant grounding.

2.2.4 Oversized Equipment Grounding Conductors for Cables in Parallel Circuits

NEC® Section 250.122 requires that parallel conductors have an equipment grounding conductor sized according to the rating or setting of the overcurrent device. When paralleling Type MC cables, the equipment grounding conductor size should be checked to make sure it is large enough to meet the requirements of *NEC*® 250.122. Manufacturers have special constructions available to meet these requirements for high ampacity circuits.

2.2.5 Color Code

Insulated equipment grounding conductors will always be identified with a green outer covering. Where multiple equipment grounding conductors are used, they will be identified with one or more yellow stripes, hash marks, or other surface markings indicating their intended use as equipment grounding, redundant grounding, or isolated grounding conductors.

2.3 GROUNDED CONDUCTOR

2.3.1 Identification

The grounded conductor is identified with a continuous white or gray outer finish or with three continuous white stripes along the entire length of conductor. Under specific conditions as described in *NEC*® Section 200.6(E), field marking is permitted at the time of installation.

2.3.2 Size and Number

MC cables used for feeders, services, and branch circuits typically contain a single grounded (neutral) conductor that is the same size as the ungrounded (circuit) conductors. Branch circuits installed where harmonics or power quality must be addressed may contain either a single grounded conductor sized 150 to 200% of the circuit conductors or may contain one grounded conductor for each phase sized the same as the circuit conductors.

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2.4 MARKING

Information regarding conductor type designation and AWG size, voltage, and temperature rating, manufacturers identification, date of manufacture, and additional listings are found on one or more locations, which include a marker tape under the armor, printing on individual conductors, printing on the nonmetallic jacket and packaging label or package. Additional markings may include:

- CT – suitable for use in cable trays
- Sun Res – direct sunlight
- Direct Burial – cables marked for direct burial are also acceptable for encasement in concrete
- LS – limited smoke
- FT4 / IEEE 1202 – vertical tray flame test
- –40°C – cold impact
- HL – UL 2225 hazardous location
- Oil Res I, Oil Res II – oil resistant for 75°C or 90°C

2.5 CODES AND STANDARDS

2.5.1 *National Electrical Code*®

Type MC cable is designed, manufactured, and tested for use in accordance with the *National Electrical Code*®, Article 330 and UL 1569.

2.5.1.1 Uses permitted

Section 330.10 of the *NEC*© specifies the permitted uses of Type MC as follows:

(A) General Uses

Where not subject to physical damage, Type MC cables shall be permitted:

(1) For services, feeders, and branch circuits

(2) For power, lighting, control, and signal circuits

(3) Indoors or outdoors

(4) Where exposed or concealed

(5) Direct buried where identified for such use

(6) In cable tray

(7) In any raceway

(8) As open runs of cable

(9) As aerial cable on a messenger

(10) In hazardous (classified) locations as permitted in Articles 501, 502, 503, 504, and 505

(11) In dry locations and embedded in plaster finish on brick or other masonry except in damp or wet locations

(12) In wet locations where any of the following conditions are met:
a. The metallic covering is impervious to moisture.

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b. A lead sheath or moisture-impervious jacket is provided under the metal covering.
c. The insulated conductors under the metallic covering are listed for use in wet locations.

(13) Where single-conductor cables are used, all phase conductors and, where used, the neutral conductor shall be grouped together to minimize induced voltage on the sheath.

(B) Specific Uses. Type MC cable shall be installed in compliance with Articles 300, 490, 725, and 770.52 as applicable and in accordance with 330.10(B)(1) through (B)(4).

(1) Cable Tray. Type MC cable installed in cable tray shall comply with Article 392.
(2) Direct Buried. Direct-buried cable shall comply with 300.5 or 300.50, as appropriate.
(3) Installed as Service-Entrance Cable. Type MC cable installed as service-entrance cable shall comply with Article 230.
(4) Installed Outside of Buildings or as Aerial Cable. Type MC cable installed outside of buildings or as aerial cable shall comply with Article 225 and Article 396.

The permitted uses specified by the *NEC*® are not all-inclusive, but only provide guidance on where and how the cable may be used.

2.5.1.2 Uses not permitted

As with permitted uses, those uses not permitted by the *NEC*® are not all-inclusive. The Code language is intended to provide guidance on where and how the cable may be used. Section 330.12 of the *NEC*® specifies the uses of Type MC that are not permitted, which are as follows:

Type MC cable shall not be used where exposed to the following destructive corrosive conditions, unless the metallic sheath is suitable for the conditions or is protected by material suitable for the conditions:

(1) Direct burial in the earth

(2) In concrete

(3) Where exposed to cinder fills, strong chlorides, caustic alkalis, or vapors of chlorine or of hydrochloric acids

Type MC cable used in these applications will typically have a nonmetallic covering over the metallic armor.

2.5.2 Related *NEC*® Articles

The following *NEC*® articles also contain provisions for the use of Type MC:

Wiring and Protection

- Article 225*, Outside Branch Circuits and Feeders*
  225.10, *Wiring on Buildings*
- Article 230, *Services*
  230.43, *Services; Wiring Methods for 600 Volts, Nominal, or Less*
- Article 250, *Grounding*
  250.118 (11), *Equipment Grounding Conductor*

Wiring Methods and Materials

- Article 300*, Wiring Methods*
  300.3(3), *Nonferrous Wiring Methods (Single Conductor MC)*
  300.15*, Boxes, Conduit Bodies, or Fittings, Where Required*
  300.6, *Raceway or Cable to Open or Concealed Wiring*
  300.22 (B), *Ducts or Plenums Used for Environmental Air (Smooth or Corrugated MC)*
  300.22 (C)(1), *Wiring in Ducts, Plenums, and Other Air-Handling Spaces*

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300.50 (1), *Shielded Cables and Nonshielded Cables in Metal-Sheathed Cable Assemblies Underground Installations over 600 Volts*

- Article 310*, Conductors for General Wiring*
  310.11, *Marking*
  310.15 *Ampacities for Conductors Rated 0–2000 Volts*
- Article 330*, Metal-Clad Cable: Type MC*
- Article 392, *Cable Trays*
  392.3(A), *Wiring Methods*

Equipment for General Use

- Article 410, *Luminaires (Lighting Fixtures), Lampholders, and Lamps*
  410.14, *Connection of Electric-Discharge Luminaires (Lighting Fixtures)*
  410.67(C), *Wiring*

Special Occupancies

- Article 501, *Class I Locations (Hazardous Locations)*
  501.4 (A), *Class I, Division 1*
  501.4(B), *Class I, Division 2*
- Article 502, *Class II Locations (Hazardous Locations)*
  502.4(A), *Class II, Division 1*
  502.4(B), *Class II, Division 2*
- Article 503, *Class III Locations (Hazardous Locations)*
  503.3 (A), *Class III, Division 1*
  503.3 (B), *Class III, Division 2*
- Article 518, *Places of Assembly*
  518.4, *Wiring Methods*
- Article 520, *Theaters, Audience Areas of Motion Picture and Television Studios, and Similar Locations*
  520.5, *Wiring Methods*
- Article 550, *Mobile Homes, Manufactured Homes, and Mobile Home Parks*
  550.16(A) (2), *Grounding*
- Article 551, *Recreational Vehicles and Recreational Vehicle Parks*
  551.47(A), *Wiring Methods*
  551.55(C), *Interior Equipment Grounding*
- Article 552, *Park Trailers*
  552.48(A), *Wiring Methods*
  552.56(A)(1), *Interior Equipment Grounding*

Special Equipment

- Article 610, *Cranes and Hoists*
  610.11, *Wiring Methods*
- Article 620, *Elevators, Dumbwaiters, Escalators, Moving Walks, Wheelchair Lifts, and Stairway Chair Lifts*
  620.21, *Wiring Methods*
  620.81, *Metal Raceways Attached to Cars*
- Article 645, *Information Technology Equipment*
  645.5, *Supply Circuits and Interconnecting Cables*
- Article 668, *Electrolytic Cells*
  668.30(C), *Fixed and Portable Electrical Equipment – Wiring Methods*

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2.5.3 UL Standards and Directories

Underwriters Laboratories publishes a number of standards and directories that provide detailed information on the construction, performance, application, ratings, and installation aspects of Type MC cable.

2.5.3.1 UL Standards

The UL standard for the construction and performance of Type MC cable is UL 1569. According to *NEC*® Section 330.112, the insulated conductors for MC cable must be of the types listed in Table 310-13, or one identified for use in this cable for sizes larger than 16 AWG. Conductors sized 18 and 16 AWG shall be of a type listed in table 402.3. Practically all Type MC cable contains thermoplastic Type THHN/THWN conductors covered in UL 83 or thermoset type XHHW conductors covered in UL 44.

2.5.3.2 UL Directories

UL publishes several directories that contain useful information on the products that it lists, recognizes, and certifies. The directories are frequently used by installers and by inspection authorities to gain a better understanding of how to specify and install products in accordance with their listing. All of this information is also readily available at the UL website.

These directories are helpful tools for understanding the details of how products, in this case Type MC cable, are constructed and marked as well as information on special or optional ratings, and terminations. One of the directories covers the UL approved methods for maintaining the fire resistive rating on walls, floors, and ceilings for fire-resistance rated construction, when cables must penetrate them and be fire stopped.

a) *UL General Information for Electrical Equipment Directory* (commonly called *White Book*)

The following information on Type MC cable is reprinted from the *UL General Information for Electrical Equipment Directory*, with permission from Underwriters Laboratories Inc., Copyright © 2003 Underwriters Laboratories Inc.:

This category covers Type MC metal-clad cable. It is rated for use up to 2000 V, and Listed in sizes 18 AWG through 2000 kcmil for copper, 12 AWG through 2000 kcmil for aluminum, or copper-clad aluminum, and employs thermoset or thermoplastic insulated conductors. It is intended for installation in accordance with Article 330 of NFPA 70, *National Electrical Code*® (*NEC*®).

The cable consists of two or more insulated conductors; one or more equipment grounding conductors, if required; one or more optional optical fiber members; and an overall metal sheath. The metal sheath is an interlocked metal tape, a corrugated metal tube or a smooth metal tube. A nonmetallic jacket may be provided under and/or over the metal sheath. Cable with metal armor, rated 5000 to 35,000 V is covered under Medium-voltage Cable (PITY) and is marked "Type MV or MC."

The equipment grounding conductor required within a cable with interlocked metal tape sheath may be insulated or bare and may be sectioned. Any additional equipment grounding conductors have green insulation. One insulated equipment grounding conductor may be unmarked, one other may have only a yellow stripe and the balance have surface markings that indicate they are additional equipment grounding conductors or isolated grounding conductors.

The sheath of the smooth or corrugated tube Type MC cable or a combination of the sheath and a supplemental bare or un-striped green insulated conductor is suitable for use as the required equipment grounding conductor. The supplemental equipment grounding conductor may be sectioned. When sectioned, all sections are identical. Each additional green insulated equipment grounding conductor has either a yellow stripe or a surface marking or both to indicate that it is an additional equipment or isolated

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grounding conductor. Additional equipment grounding conductors, however marked, are not smaller than the required equipment grounding conductor.

PRODUCT MARKINGS

Information regarding temperature rating, voltage rating, cable, and conductor Type and AWG size is shown either on a marker tape under the armor or on the surface of a nonmetallic jacket, if used.

Copper-clad aluminum conductors are surface printed "AL (CU-CLAD)" or "Cu-clad Al." Aluminum conductors are surface printed "AL."

Cable employing compact-stranded copper conductors is so identified directly following the conductor size, wherever it appears (surface, tag, carton, or reel), by "compact copper." The abbreviations "CMPCT" and "CU" may be used for compact and copper, respectively.

Tags, reels, and cartons for products employing compact-stranded copper conductors have the marking: "Terminate with connectors identified for use with compact-stranded copper conductors."

Cable suitable for use in cable trays, direct sunlight, or direct burial application is so marked.

Cable marked for direct burial is also considered acceptable for encasement in concrete.

Cable marked "Oil Resistant I" or "Oil Res I" is suitable for exposure to mineral oil at 60°C.

Cable suitable for exposure to mineral oil at 75°C is marked "Oil Resistant II" or "Oil Res II."

Cable containing one or more optical fiber members is marked "MC-OF."

Cable with a nonmetallic outer jacket that complies with the Limited Smoke Test requirements specified in UL 1685, "Vertical-Tray Fire-Propagation and Smoke-Release Test for Electrical and Optical-Fiber Cables," and all unjacketed metal-clad cable may be marked with the suffix "LS."

b) *UL Electrical Construction Equipment Directory* (commonly called *Green Book*)

UL's *Electrical Construction Equipment Directory* contains the identical information that is contained in the *White Book* with the addition of the company name, address, and UL file number of those manufacturers that are authorized by Underwriters Laboratories to produce a listed product. The *Green Book* is frequently used to identify and locate Listed manufacturers of Type MC cable, to verify if a manufacturer is authorized to produce UL listed Type MC, and to identify the manufacturer of the cable when the cable is marked with the UL file number (E number) in place of the company name.

c) *UL Fire Resistance Directory* (commonly called *Orange Book*)

UL's *Fire Resistance Directory* generally covers the construction detail necessary for constructing fire rated walls, floors, and ceilings. The *Directory* also covers the listed materials and methods for sealing the wall, ceiling, or floor that has been penetrated by electrical cables, conduit, cable tray, or other equipment. The methods and materials are listed by UL under the category of "Through Penetration Fire Stop Systems." The *Directory* should always be consulted for the proper method of sealing the opening. Any such opening that is not properly sealed in accordance with the UL listed "Through Penetration Fire Stop Systems" will be subject to rejection by the inspecting authority.

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d) UL Listing on Website

Underwriters Laboratories can be found on the Internet at www.ul.com. This website contains an online version of the above directories as well as other general information relating to UL's products and services.

Once logged onto the UL website, go to the UL online certification directory. This will lead you to a list of product categories. The following list, or one similar, will be presented:

- Company Name/Location
- UL File Number
- Appliance Wiring Material (AWM)
- Fire Resistance - Design or System Number
- Roofing Materials & Systems - Construction Number
- Building Materials - Assembly Number
- UL Category Control Number (CCN)/Guide Information
- Keyword Search

The category should be chosen based on the information available to you. The keyword search is the easiest way to start if limited information is available. As an example, using "MC cable" as the keyword opens the path to the information covered by the *UL Green and White Book Directories*.

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Section 3
INSTALLATION GUIDELINES FOR ARMORED CABLE AND METAL-CLAD CABLE

3.1 FUTURE CAPACITY

The demands that may be placed on power and lighting installations in the future should be carefully considered. The layout, equipment, and lighting in industrial and commercial buildings change frequently. These changes often involve increased load requirements. It is recommended that an allowance for a growth of 50% of the initial load be used.

3.2 HOMERUNS

3.2.1 Definition

The term “Homerun” comes from the run back to home. Home is the load center or panelboard. The Homerun ends at the first distribution or junction box. The number of conductors in a Homerun cable is a minimum of four, and is most often for a three-phase four-wire application. The cable could include as many circuits as is practical.

3.2.2 Advantages

The advantage of utilizing a “Homerun” installation is the economy of not having to run individual branch circuits back to the load center. Homeruns also provide for good workmanship by eliminating the “messy” appearance of multiple cable runs. When utilizing a Homerun cable, consideration must be given to sizing the conductors based on the total number of current carrying conductors in the cable and the ampacity derating factors specified by the *NEC*®. See section 3.5 of this guide for information on ampacity derating.

3.3 HARMONICS

3.3.1 Definition

When an end-user connects a non-linear load drawing short pulses of current (such as non-continuous load currents that are switched on and off for part of the cycle), the current wave becomes distorted and harmonic currents begin to flow.

In electrical terms, harmonics are AC voltages or currents whose frequency is some integral multiple of the fundamental frequency. The fundamental frequency (the lowest possible frequency in a complex wave) in North America is 60 Hz. For example, the Third Harmonic is 180 Hz or (3 x 60 Hz) and the Fifth Harmonic is 300 Hz. (5 x 60 Hz)

In balanced, three-phase 60 Hz systems, currents are equal and when they return in the neutral they cancel each other adding to zero at any point (the neutral current is zero).

When odd order harmonics are present, the three phase return currents remain in phase with one another and are additive. As a result, the sum of the 3rd, 9th, 15th, etc. harmonic phase currents and all odd multiples of the third harmonic combine for a total possible neutral current of 1.73 times the phase current. The effect of odd order harmonic currents is shown in Figure 3-1.

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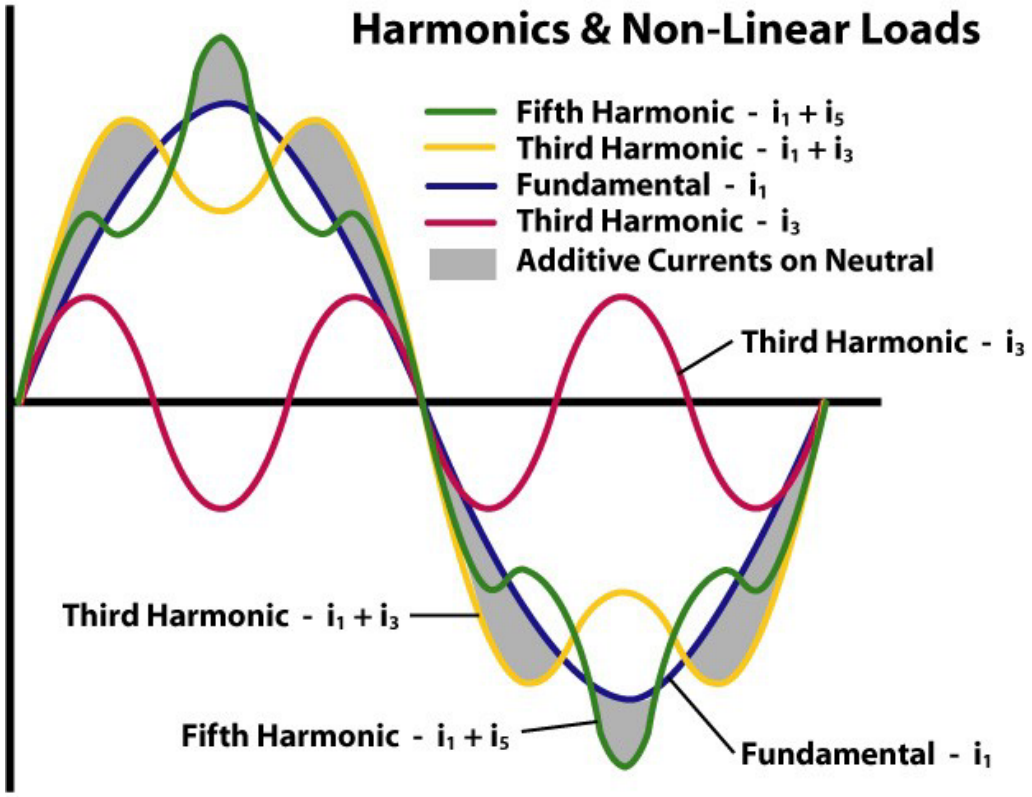

Figure 3-1
EFFECT OF ODD ORDER HARMONIC CURRENTS

3.3.2 Effect of Harmonics on Neutral Conductors

The resulting adverse effects from harmonics on shared neutrals are overheated neutral conductors on three-phase, four-wire circuits, e.g., 120/208V circuits feeding PCs, laser printers, etc., 277V lighting circuits, and higher than normal voltage drop between the neutral conductor to ground at 120V receptacles.

3.3.3 Major Causes of Harmonics

The following are major causes of harmonics for various types of equipment:

Electronic Switching Power Converters:
Adjustable - speed motor drives (AC and DC)
Uninterruptible power supplies (UPS)
Switch mode power supplies (SMPS)
Electronic lighting ballasts
Electronic process control equipment, PLCs, etc.
Personal computers and printers
Reduced voltage motor controllers
Solid-state rectifiers

Ferromagnetic Devices:
Transformers operating near saturation level
Ballasts (saturated iron core) of fluorescent lights
Induction heating equipment

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Arcing Devices:
Arc-discharge lighting, e.g., fluorescent,
HID, sodium, and mercury vapor
Electric arc furnaces
Electric welding equipment

3.3.4 *NEC*® Rules on Harmonic Currents in Neutral Conductors

The *NEC*® requires that the Neutral conductor for circuits that generate harmonic currents be considered as current carrying conductors. They must be counted for purposes of derating according to *NEC*® 310.15(B)(4)(c), which states:

> "On a 4-wire, 3-phase wye circuit where the major portion of the load consists of nonlinear loads, harmonic currents are present in the neutral conductor; the neutral shall therefore be considered a current-carrying conductor."

3.3.5 Minimizing the Effects of Harmonic Loads on Neutral Conductors

Type MC and AC cable are available with an oversized neutral conductor or one neutral per phase for three-phase/four-wire power supply systems to computers (with DC drive fan motors, tape, and disk drives) office machines, programmable controllers, and similar electronic equipment where harmonic currents may create overloaded neutral conductors.

The oversized neutral conductor(s) are sized 150% to 200% of the phase conductor ampacity to minimize the effects of harmonics generated by the non-linear loads. The neutral per phase (striped with color to match the phase conductor) accomplishes the same objective.

3.4 VOLTAGE DROP

Improper voltage due to a voltage drop in supply conductors is a major source of trouble and inefficient operation in electrical equipment. Under-voltage conditions reduce the capability and reliability of motors, lighting sources, heaters, and solid-state equipment.

The resistance or impedance of conductors may cause a substantial difference between voltage values at service equipment and voltage values at the point-of-utilization equipment. In addition to resistance or impedance, the type of raceway or cable enclosure, the type of circuit (AC, DC, single-phase, 3-phase), and the power factor may contribute to the voltage drop.

Reasonable operating efficiency is achieved if the voltage drop of a feeder or the voltage drop of a branch circuit is limited to 3 percent. However, the total voltage drop of a branch circuit plus a feeder can reach 5 percent and still achieve reasonable operating efficiency.

One method of reducing the voltage drop of a circuit is to increase the size of the circuit conductors. Where this method is used, the *NEC*® requires that the equipment grounding conductors, where installed, be increased in size proportionately according to the circular mil area of the circuit conductors.

3.5 AMPACITY AND DERATING

3.5.1 General

The ampacity of a cable is the maximum amount of current it can carry in a given situation without exceeding its temperature rating. Most AC and MC cables have a temperature rating of 90°C.

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3.5.2 Cable Ampacity and Derating

3.5.2.1 AC or MC Cable with Three or Less Current Carrying Conductors

The ampere rating of an AC or MC cable containing three current carrying conductors or less can be found in Table 310.16 of the *NEC*®. These values are based on an ambient temperature of 30°C (86°F). For other ambient temperatures, the correction factors at the bottom of Table 310.16 must be used.

Next to the 14, 12 and 10 AWG sizes, a * appears. The note at the bottom of the table directs you to *NEC*® Section 240.4(D). This section explains the overcurrent protection required for these gauge sizes. Section 240.4(D) states that unless it is specifically permitted in Section 240.4(D) through 240.4(G), "the overcurrent protection shall not exceed 15 amperes for 14 AWG, 20 amperes for 12 AWG, and 30 amperes for 10 AWG copper" conductors.

For example, according to *NEC*® Table 310.16, a cable with three 12 AWG copper, 90°C insulated conductors is rated at 30 amp. If the ambient temperature is 38°C (100°F) rather than 30°C (86°F), the correction factor of .91 found at the bottom of the table is used to derate the conductors to 91%. This is done by multiplying the .91 correction factor by the 30 amp, for a resulting ampacity of 27.3 amp.

Because there is a * next to the 12 AWG conductor in the table, Section 240.4(D) must be consulted. Even though the wire itself is rated at 30 amperes, according to Section 240.4(D) the overcurrent protection is only rated at 20 amp. Therefore, the circuit can only be used for up to 20 amp, not 30.

3.5.2.2 AC or MC Cable With More Than Three Current Carrying Conductors

When utilizing a multi-conductor cable assembly of more than three current carrying conductors, the conductor ampacity must be derated. To derate the conductor ampacity, use the adjustment factors in *NEC*® Table 310.15(B)(2)(a). If harmonic loads exist, the neutral conductors must also be considered to be "current carrying" and included in the derating process. Again, refer to *NEC*® Section 240.4(D) for AWG sizes with an * beside them to determine the ampacity limitation.

For example, a 12 AWG cable with 4 to 6 conductors has an available ampacity of 30, but per Table 310.15(B)(2)(a) must be reduced to 80% (multiplied by .80) leaving the available ampacity at 24. Because there is an * next to this size, Section 240.4(D) must be consulted for the 20 amp limitation.

When 7 to 9 conductors are used in a raceway or cable per Table 310.15(B)(2)(a), the value of ampacity from the table must be reduced using a 0.70 multiplier. Refer to Table 310.15(B)(2)(a) for quantities greater than 9 conductors.

3.5.3 Double Derating

When installing an MC cable consisting of more than three current-carrying conductors in an area where the ambient temperature is other than 30°C (86°F), the correction factors at the bottom of *NEC*® Table 310.16 are used with the adjustment factors in *NEC*® Article 310.15(B)(2)(a). This is considered double derating of the conductor ampacity.

For example, an 8 AWG cable with four 90°C insulated conductors is run through an ambient temperature of 123°F. Using the adjustment factors in *NEC*® Section 310.15(B)(2)(a), each conductor must be derated to 80% of the ampacity of 55 amp taken from Table 310.16. An additional derating of 76% must also be applied using the correction factors in the bottom of Table 310.16 to account for the high ambient temperature. The resulting ampacity is therefore limited to 33.44 amp per conductor.

3.5.4 Bundled Type AC and MC Cables

Where multiconductor cables are stacked or bundled for more than 24 in., without maintaining spacing, the conductor ampacities must be derated according to 310.15(B)(2)(a). An exception is allowed for 12

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AWG Type AC and MC Cables. The derating of bundled 12 AWG AC and MC cables is determined by Exception No. 5 to *NEC*® Section 310.15(B)(2) as follows:

"Exception No. 5: Adjustment factors shall not apply to Type AC cable or to Type MC cable without an overall outer jacket under the following conditions:

(a) Each cable has not more than three current-carrying conductors.
(b) The conductors are 12 AWG copper.
(c) Not more than 20 current-carrying conductors are bundled, stacked, or supported on "bridle rings."

A 60 percent adjustment factor shall be applied where the current-carrying conductors in these cables that are stacked or bundled longer than 24 in. (600 mm) without maintaining spacing exceeds 20."

3.6 INSTALLATION REQUIREMENTS

3.6.1 Installing AC and MC Cable

Type AC and MC cable is installed after the rough-in phase of locating and setting all boxes and enclosures. Rough-in occurs when all interior and exterior walls are framed, but before the dry wall or other building finish is installed.

The first step in the rough-in phase is to determine the number of home run circuits and from where the wiring will originate. Once this is done, time should be taken to determine the best and shortest routes for each cable run. Long runs of spider web type routing not only require more cable but increase voltage drop. This is very important to consider when locating boxes for receptacles, lights, and switches. If long runs are required, over-sizing the circuit conductors is recommended to limit voltage drop.

AC and MC cables are available on reels and in coils. If using a reel, simply draw the cable from the end of the reel. If using a coil, draw the cable from the center of the coil to prevent kinking and to help prevent the corrugations from getting caught on steel framing members.

Prior to pulling the MC cable, the installer prepares the end by stripping the armor back to expose the conductor. One method of stripping the armor is to cut a ring around the cable with an armored cable cutter being careful to not cut deep enough to damage the insulation on the conductors. Another method is to cut two adjacent ribs of the armor utilizing a rotary cutter and slide the armor off the conductors. Always pull the cable by the conductors and not the armor.

For larger sizes, slide a basket grip over the conductor assembly and tape the basket, conductors, and armor together. The pulling force is to be applied to the conductors and not the armor. The installer prepares the route of the cable pull by placing sheave wheels or pulleys at adequate distances to pull the cable without damage. Short distance pulls may not require wheels or pulleys but only smooth surface with which to pull the cable over. The route of the pull may include many turns and vertical and horizontal distances, but always pull the cable by the conductors and not the armor.

3.6.2 Installation Considerations

3.6.2.1 Through or Parallel to Framing Members

Type MC and AC cable must comply with the rules of *NEC*® Section 300.4 for protection against physical damage, where installed through or parallel to joists, studs, rafters, or similar wood or metal members.

3.6.2.2 In Accessible Attics

The installation of Type MC and AC cable in accessible attics or roof spaces must comply with the rules of 300.4 for protection against physical damage. In addition, Type MC cable must meet the same requirements for Type AC cable, found in the rules of *NEC*® Section 320.23 for installation across floor joists and parallel to framing members in attics.

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3.6.3 Securing and Supporting AC and MC Cables

According to *NEC*® Section 320.30, AC cable must be supported and secured at intervals of 4.5 ft (1.4 m) or less (unless routed through a framing member) and within 12 in. (300 mm) of every termination.

According to *NEC*® Section 330.30, MC cable must be supported and secured at intervals of 6 ft or less (unless routed through a framing member) and cables containing four or fewer conductors sized no larger than 10 AWG must be secured within 12 in. (300 mm) of every termination.

AC and MC cable support requirements are waived when the cable is fished. This is a major advantage of AC and MC cable in remodeling work over other wiring products that cannot be fished.

AC and MC cable may also be installed in cable tray, per *NEC*® Article 318. Securing of the cable is only required in this installation for vertical runs.

Supports may include strut, trapeze, and rack or cable tray. Generally, the same support systems utilized for metal conduit are used for MC cable except that they are installed at 6-ft. (1.8 m) intervals instead of 10 ft (3 m) as required for conduit installations.

3.6.4 Unsupported Cables

In general, the cable must closely follow the surface it is wired over. The *NEC*® allows cable to be installed unsupported under the following conditions:

1. When the cable is fished.
2. When flexibility is required, a box may be installed near a motor or appliance using a short piece of Type AC cable up to 24 in. (600 mm) long, between the box and motor or appliance.
3. Lengths of not more than 6 ft (1.8 m) from the last point of support for connections within an accessible ceiling to lighting fixtures or equipment.
4. When installed in cable trays.
5. For **Type AC** cable in other than vertical runs through framing members where distance between members does not exceed 4.5 ft (1.4 m).
6. For **Type MC** cable in other than vertical runs through framing members where the distance between members does not exceed 6 ft (1.8 m).

3.6.5 Bending Radius

Care should be taken not to exceed the bending radius of the cables during installation, such as when routing around corners. According to *NEC*® Section 320.24, for AC cable, the radius of the curve of the inner edge of any bend shall not be less than 5 times the diameter of the cable. *NEC*® Section 330.24(B) states that for interlocked type MC cable, the radius of the curve of the inner edge of any bend shall not be less than 7 times the external diameter of the armor. AC and MC cables have no restrictions on the number of bends.

3.6.6 Stripping the Armor

Specialized tools are available and widely used for stripping the armor sheath from MC cable (MCI). These tools are efficient and effective in safely removing the necessary armor to expose the conductors necessary for making connections. Unfortunately, their use always results in a sharp angle cut on the end of the sheathing and often cuts partially through the next remaining full convolution of the armor. Whether or not one of these specialized tools is used, the best and most effective fitting assembly is ensured when the armor sheath is squared by carefully cutting off the angled edge and any damaged convolutions with a pair of diagonal pliers, a hacksaw, or the like. If this important step is not taken, complete seating of the cable into the fitting, and a secure bearing surface for the securement screw, clamp, or bonding means cannot be assured (See Figures 3-3 and 3-4). Take care not to cut or scar the insulation on individual conductors when stripping the armor sheath.

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Figure 3-2
TERMINATION OF BONDING STRIP FOR TYPE AC CABLE

3.6.7 Terminating AC and MC Cables

When terminating or splicing at a junction, outlet, or switch box, cut the cable so that 6 in. (150 mm) of free conductor is left for connections or splices. Use an approved connector and insure a proper bond by firmly tightening the connectors to both the box and the cable.

NOTE—Set screw connectors **cannot** be used with **aluminum armor** Type AC cable, because the screw may penetrate the armor, damaging the cable.

To terminate an AC cable, insert an anti-short bushing and bend back the exposed length of bonding strip. The bonding strip can be bent back before **or** after the bushing is inserted. There are several techniques used for this procedure shown in Figure 3-2.

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3.6.7.1 **Preparing AC Cable for Termination**

Insert the cable into the connector and secure the connector into the box. Be sure that the anti-short bushing is plainly visible in the connector for easy inspection.

- ❑ Square the end of the metal jacket.
- ❑ Insert appropriate sized anti-short (armored cable) bushing.
- ❑ Insert cable armor so that it is flush with the fitting's end stop.
- ❑ Assure seating of clamp on armor jacket before torquing.
- ❑ Take care when torquing the fitting's securement screw.

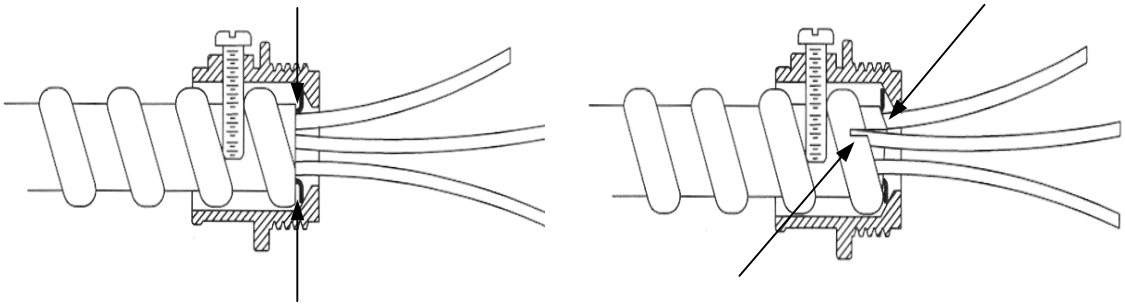
3.6.7.2 **Preparing MC Cable for Termination**

The most efficient assembly of a Metal-Clad cable and fitting system can be achieved, and optimum performance ensured, by adherence to a few simple cable preparation and assembly techniques:

- ❑ Square the end of the metal jacket.
- ❑ Insert cable so that it is flush with the fitting's end stop.
- ❑ Ensure seating of clamp on armor jacket before torquing.
- ❑ Take care when torquing the fitting's securement screw.

Selecting the correct size fitting requires the installer to know:

(1) the dimensions of the MC cable conductor assembly;
(2) the armor diameter;
(3) the fitting dimensions of the throat opening for the conductors; and
(3) the clamping range for securing the MC cable armor in the fitting.



Correct seating
(Cut end squared with pliers or hacksaw)

Incorrect seating
(Cut end not properly squared)

Figure 3-3
CUT ENDS OF CABLE

In addition, when installing a fitting suitable for jacketed metal-clad cable and listed as suitable for wet locations:

- ❑ Strip the polymeric jacket to the length stated in the manufacturer's assembly instructions, if provided.
- ❑ Remove oils or solvent by-products from the outer jacket of the cable.
- ❑ Ensure seating of clamp on armor jacket before torquing.
- ❑ Torque the fitting's gland nut to manufacturer's specifications.

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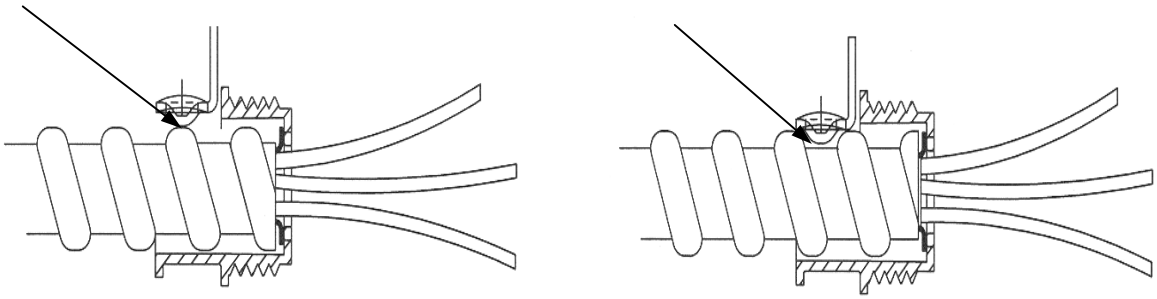
For cable preparation always follow the manufacturer's instructions. In addition, we recommend thorough adherence to the recommendations described in NEMA FB 2.20, *Selection and Installation Guidelines for Fittings for use with Flexible Conduit and Cable.* This document can be downloaded free of charge from the NEMA website at www.nema.org.

When assembling an MC fitting, be certain that the cable is completely inserted in the fitting and is flush against the end stop. This ensures that the cable is secure, the sharp cut end of the armor sheath is bushed, and that the armor on interlocking-type armor MC will not open under pressure when torquing the direct-bearing or clamp securement screw. The diameter of the end stop of the fitting is not restricted to a specific range, but must be of a size that will prohibit the cable armor sheath from being pulled through. Selection of the proper fitting to match the trade size of the cable cannot be overemphasized.

Where a fitting employs a clamp as the means to secure the cable, proper seating of the clamp to the cable's metal jacket must be assured. Using the following method, the fitting's clamp will seat between the convolutions of the cable:

Hand tighten the fitting screw(s). Then slightly rotate the cable in the fitting. Where two screws are provided, they are to be alternately tightened until both are secure. The assembly shall then be visually inspected prior to applying the final torque to the screws to be certain the metal jacket at the end of the cable remains flush with the fitting's end stop (see Figure 3-4).



Incorrect Seating **Correct Seating**

Figure 3-4
PROPER ORIENTATION OF CABLE FITTING CLAMP SECUREMENT SCREW

The designed performance of an MC cable fitting is dependent on adequately torquing the fitting's securement means, screw, clamp, or gland nut. By nature of its design, the interlocked construction of interlocking armor type metal-clad cable (MCI) can be susceptible to collapse from overtorquing of the fitting's securement means. The experienced electrician has typically relied on the "measured by feel" approach over the years. Performance will not typically be enhanced and may even be reduced when excessive torque is applied. Performance tests in the product standards for MC cable fittings prescribe testing under specific assembly torque (e.g. average hand tightening of a No. 10 screw with a screwdriver is represented by 35 lb·in. (3.95 N·m). Some fitting designs include a raised screw boss (see Figure 3-4). It is usually not necessary or intended that the screw be tightened to the point that its head be in contact with the boss. The screws on certain fitting designs, particularly larger trade sizes, may offer more than one tightening option, including screwdriver (slot, Phillips, or Robertson-square drive) and bolt head for wrench application (hex or square). Greater mechanical advantage and torque can generally be achieved with a wrench. Where both screwdriver and wrench application options are offered, torque should be limited to that which can be applied by the screwdriver.

Fittings employing a "gland" design are intended to be wrench tightened. When the appropriate torque is applied, the gland is uniformly compressed and secured to the cable. Typically, most compression gland nuts achieve maximum securement after 1 to 2 turns past the hand-tightened torque.

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Use torque-indicating tools for the assembly of MC cable fittings. Care should be taken during the assembly of fittings not to puncture or deform the cable's armor, which may result in the presence of sharp edges in the wireway. See NEMA FB 2.20 provides a complete reference of standard assembly torque for AC and MC cable fittings. If a manufacturer prescribes a tightening torque other than that in the standard as a condition of listing, that recommended torque value will be marked on the installation instructions or the smallest unit shipping container of the fitting.

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3.6.8 Cable support, fittings, and attachment to boxes and enclosures

3.6.8.1 Attachment to Non-threaded Entries

Where Metal-Clad cable is used, electricians usually fasten the boxes into position on the framing members before attaching the raceway assembly. Metal-Clad cable and fittings manufacturers caution installers to be sure to allow for sufficient length of cable to enable sufficient armor to be removed, to expose the prescribed length of conductor and complete seating of the armor against the fitting's end stop. This will minimize stress on the cable's interlocked armor (MCI) or the cable to fitting connection during attachment to a box.

Metal-Clad cable fittings supplied with locknuts for attachment to a box or enclosure may be assembled first to either the cable or the box; attachment first to the cable is the preferred method. A secure attachment to a box or enclosure can be made when the locknut is hand tightened and then further tightened 1/4 turn using an appropriate tool. When securing the locknut, care is to be taken to avoid excessive pressure where gripping the body of the fitting is necessary. Assemble fittings supplied without locknuts to the cable and the box according to the manufacturer's installation instructions.

NOTE—Locknuts are not to be relied upon to penetrate nonconductive coatings on enclosures. Such coatings are to be removed in the locknut area prior to raceway assembly to assure a continuous ground path is achieved.

3.6.8.2 Attachment to Threaded Entries

Metal-Clad cable connectors having external threads may be installed into the threaded entries provided in certain boxes, enclosures and conduit bodies. Cast boxes and conduit bodies with threaded conduit entries or integral hubs, designed to ANSI/NEMA FB 1 have taper threads (NPT). The external threads of MC Cable fittings conforming to ANSI/NEMA FB 1 have straight threads (NPS). Threaded openings where these fittings are intended to be used may have taper (NPT) or straight (NPS) threads, but care should be taken to ensure that the threaded entry will accommodate a minimum of 3 full engaged threads.

3.6.8.3 Supports

NEC® Article 334 requires Metal-Clad cable to be secured at intervals not to exceed 6 ft (1.83 m). For cables containing 10 AWG and smaller conductors, support within 12 in. (305 mm) of each box is required (note exceptions in Article 334). Securement in this manner prior to assembly to a box or enclosure assures a minimum of strain will be placed on the cable to fitting and fitting to box connection during assembly and throughout the lifetime of the installation. Metal-Clad Cable shall be supported at least at the frequency required by the *NEC*®, using raceway supports intended for the purpose, and mounted by hardware acceptable to the authority having jurisdiction.

A variety of straps, clamps, staples, and hangers are available which are specifically intended to secure Metal-Clad Cable and similar raceways. These supports shall be installed only on cable of the trade size indicated on the support or its smallest unit shipping container. The variability of mounting surfaces, expected loads, and application environments will determine the appropriate support options and mounting hardware. Design specifications usually calculate requirements based on maximum spacing intervals given in the *NEC*®. Closer support intervals than are required in the *NEC*® are an acceptable option to heavier supports and mounting hardware in some applications.

Metal-Clad cable fittings and typical support hardware are not designed to perform the function of conductor support in long vertical installations of large size armored cable (*NEC*® 300-19). Often, bends are designed in such long vertical runs to relieve the strain on the conductor terminations. Consult with the MC cable manufacturer for alternative solutions.

3.7 VERIFICATION OF INSTALLATION

Once the cable system is fully installed, a visual check should be made to determine if adjustments are needed. This is necessary to determine if there is any loosening of system components, which

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sometimes may occur during construction that involves other trades. The following steps should be taken:

1) Conductors, cables, and cable assemblies shall be properly terminated and supported at panelboards, boxes, and devices.

2) The conductor size shall be not less than the ampere rating of the circuit unless otherwise permitted for specific types of utilization equipment.

3) Splices and taps shall be made in an approved manner.

4) Cables and cable assemblies shall be properly secured and supported.

5) Conductors, cables, and cable assemblies shall not show evidence of damage or physical abuse.

In addition, an insulation test may be conducted prior to devices being installed, to detect any possible unseen damage that a visual inspection might not reveal.

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Appendix A
NEMA ENGINEERING BULLETIN 90
Use of Anti-Short Bushings for Terminating Type MC Cable

There has been much confusion within the installation and inspection communities regarding the use of anti-short bushings for terminating Type MC cable. The confusion stems from the fact that some MC cable manufacturers include anti-short bushings with their cable. The inclusion of anti-short bushings with coils or reels of MC cable is based on historical practice relating to the requirements of 320.40 of the *NEC*®, which mandates the use of anti-short bushing or its equivalent protection for Type AC cable.

Fittings used with Type MC cable are required to be listed per 330.40 of the *NEC*®. NEMA supports the use of listed fittings for MC cable. The design of these fittings may or may not include an insulated throat. However, they are required to be provided with a smooth, rounded end stop so that the metal sheath of the cable will not pass through and the wires will not be damaged in passing over the end stop. Whether or not an insulated throat is part of the listed product, these listed MC fittings do not require an additional anti-short bushing. Anti-short bushings that may be supplied by MC cable manufacturers are for optional use by the installer. However they are not required.

ROP #7-116 from the May 2001 Report on Proposals (ROP) for the 2002 *NEC*® was a proposal seeking to require anti-short bushings on all MC cable termination installations. The following is an excerpt from the Panel statement rejecting the proposal:

> "Anti-short bushings are not required for Type MC cable in accordance with the listing for the product. The termination fittings approved for use with Type MC cables are designed such that the wires will not come in contact with the cut edge of the armor; the throat of the fitting is small enough to prevent contact with the armor. Type MC termination fittings perform the same function for Type MC cable as Type AC terminations plus the anti-short bushing do for Type AC cable."

NEMA supports the uniform adoption and enforcement of the *NEC*® and recommends that local authorities having jurisdiction follow the requirements of *NEC*® Section 330.40, *Boxes and Fittings for MC Cable*. Section 330.40 requires that the fitting be listed, but does not mandate the use of an anti-short bushing.

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