Cable Installation Manual for Power and Control Cables

Ninth Edition

General Cable

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Foreword

Welcome to the ninth edition of General Cable's ***Cable Installation Manual for Power and Control Cables***. This manual provides installation information for power and control cables for industrial. It covers 600 volts through 46 kV insulated copper conductors, however, the Cable Installation Manual is not a complete representation of the entire line of wire and cable products that General Cable manufactures. In addition to the general guidelines that are presented within this manual, General Cable's comprehensive Industrial Catalog provides in-depth information on the most wide-ranging line of products available today in the industry. It features the latest information on products, along with detailed technical and specification data in indexed sections. If you require any further information on any of your wire and cable needs, General Cable's Customer Service and Technical staff are available to provide the answers you need quickly and efficiently.

USING THIS MANUAL

The information contained herein is intended for evaluation and use by technically skilled and appropriately trained persons. Although the information is believed to be accurate as of the date of printing, General Cable makes no representations or warranties, expressed or implied, with respect to the accuracy or completeness of this document, nor does General Cable assume any obligation to update or correct the same in the future. You should always consult a trained professional for the most current industry practices and procedures unique to your application.

The numerical data, formulas and other calculations provided in this document are believed to be accurate and concise as of the date of printing. However, normal dimensional tolerances in actual cable constructions and variations in the installation conditions may lead to differences in the indicated values and actual measured values.

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1. INTRODUCTION

This manual provides installation methods commonly encountered in industrial and commercial applications and should be used in conjunction with the engineer's installation specifications and all applicable codes. These methods are recommended for all types of power and control cables.

This manual is intended for use by the design engineer and the installer in the field and is not a text on power system design or electrical circuit analysis. The information provided is concise and should be adequate for the majority of installations. If you require additional information, please contact General Cable at info@generalcable.com.

2. PRE-INSTALLATION

To ensure safety during cable installation and reliability once the cable is installed, you should confirm the following prior to installation.

- The cable selected is proper for your application
- The cable has not been damaged in transit or storage

Review all applicable local, state, provincial, and national codes to verify that the cable selected is appropriate for the installation job. Also consult the Authority Having Jurisdiction (AHJ).

Next, any existing cable damage must be identified and any further damage prevented from occurring. This is done through proper cable inspection, handling and storage.

2.1 CABLE INSPECTION

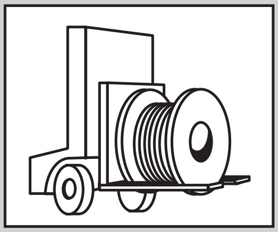
Inspect every reel of cable for damage before accepting the shipment. Be particularly alert for cable damage if:

- A reel is laying flat on its flange side
- Several reels are stacked on top of each other
- Other freight is stacked on top of a reel
- Nails have been driven into reel flanges to secure shipping blocks
- A reel flange is damaged
- A cable covering has been removed, or is stained or damaged
- A cable end seal has been removed or is damaged
- A reel has been dropped (hidden damage likely)

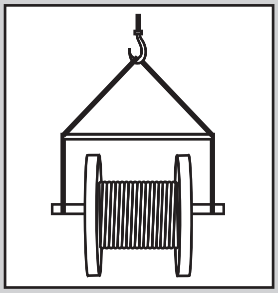
NOTE: All damages must be noted on the waybill upon receipt of the cable.

2.2 CABLE HANDLING

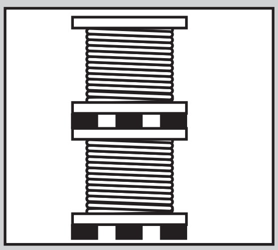
YES



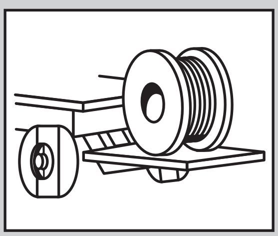
Cradle both reel flanges between forks.



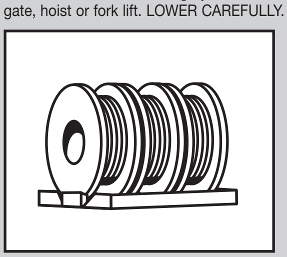
Reels can be hoisted with a shaft extended through both flanges.



Place spacers under the bottom flange and between reels to create a space to insert the forks.

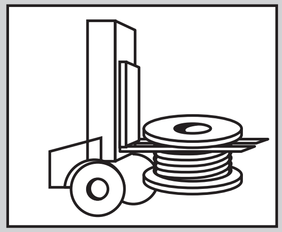


Lower reels from truck using hydraulic gate, hoist or fork lift. LOWER CAREFULLY.

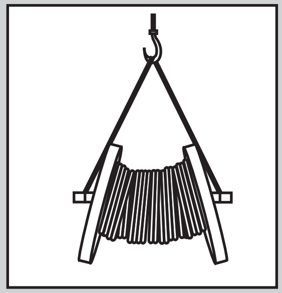


Always load with flanges on edge and chock and block securely.

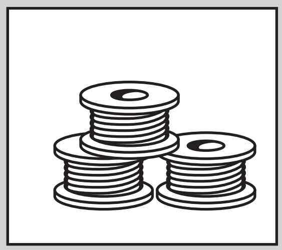
NO



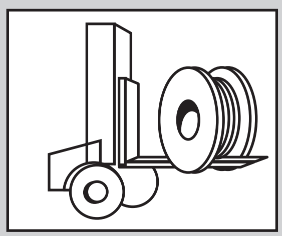
Do not lift by top flange. Cable or reel will be damaged.



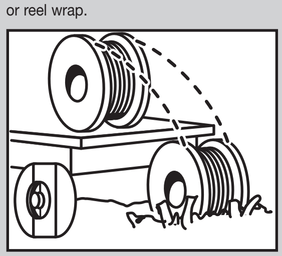
Use a spreader bar to prevent bending the reel flanges and mashing the cable.



Upended heavy reels will often arrive damaged. Refuse or receive subject to inspection for hidden damage.



Never allow forks to touch cable surface or reel wrap.



Never drop reels.

Remove all nails and staples from the reel flanges before moving a reel, and avoid all objects that could crush, gouge or impact the cable while it is being moved. NEVER use the cable as a means to move a reel. When unreeling, observe recommended bending radii, use swivels to prevent twisting, and avoid overruns.

2.3 CABLE STORAGE

Cables should be stored on hard surfaces so that reel flanges cannot sink. Small reels may weigh several hundred pounds while large reels can exceed several thousand pounds.

Impact damage can be prevented by the following precautions:
- Aligning reels flange to flange
- Using guards across flanges when different reel sizes are stored together
- Maintaining adequate aisles and barricades to prevent equipment from hitting the cable

Seal the ends of all cable stored outdoors, and re-seal both ends when a length is cut from the reel.

2.4 PRE-INSTALLATION CHECKLIST

Code Review

_____ Review all applicable local, state, provincial, and national codes relating to cable installation
_____ Consult local inspection authority

Cable Inspection

_____ Check for shipping damage before accepting shipment. Record any damage on the way bill
_____ Confirm that the cable specified was received
_____ Verify that the cable end seals are intact

Cable Handling

_____ Remove nails and staples from reel flanges
_____ Calculate and comply with recommended bending radii
_____ Use swivels, and avoid overruns when unreeling by utilizing a reel brake or back tension

Cable Storage

_____ Provide firm support for reels
_____ Protect cable from mechanical damage and from liquid spills
_____ Check cable end seals periodically
_____ Advise all splicers, installers and handlers of all special instructions

3. INSTALLATION

A high percentage of cable failures are due to mechanical damage, which typically occurs during transportation, handling and installation.

In fact, most cables are subjected to more mechanical stress during installation than they ever experience in actual operation. Needless to say, handling and installing the cable according to the manufacturer's recommendations is extremely important.

When cables are installed in a raceway, underground electrical duct or cable tray, the following factors must be considered.

- Conductor configuration
- Raceway or cable tray fill
- Physical limitations of cables
- Installation equipment
- Ambient temperature and conditions

Similarly, when cable is installed as exposed wiring or as messenger-supported wiring, all of the above factors except raceway or cable tray fill must be considered as well as the requirements for securing and supporting the cables.

Unless otherwise noted, the following references apply to the installation requirements:

NEC refers to NFPA 70: *National Electrical Code®* 2011 Edition, published by the National Fire Protection Association. The references apply to Sections in the NEC.

CEC refers to CSA Standard C22.1-06 *Canadian Electrical Code®*, Part I, Safety Standard for Electrical Installations, published by the Canadian Standards Association. The references apply to Rules in the CEC, Part I.

NEMA refers to the standards published by the National Electrical Manufacturers Association.

ICEA refers to the standards published by the Insulated Cable Engineers Association.

ANSI/ICEA S-93-639/NEMA WC 74, 5-46 kV *Shielded Power Cable for Use in the Transmission and Distribution of Electric Energy*

ANSI/ICEA S-94-649, *Standard for Concentric Neutral Cables Rated 5 through 46 kV*

ANSI/ICEA S-97-682, *Standard for Utility Shielded Power Cable Rated 5 through 46 kV*

AEIC refers to the standards published by the Association of Edison Illuminating Companies.

AEIC CS8, *Specification for Extruded Dielectric Shielded Power Cables Rated 5 through 46 kV*

AEIC CG5, *Underground Extruded Power Cable Pulling Guide*

3.1 INSTALLATION TEMPERATURE

Low temperatures are a cause for concern when installing cable. Cable should not be installed when temperatures are less than the cold bend temperature rating of the cable product plus 15°C (i.e., minimum installation temperature = cold bend temperature rating + 15°C). For example, when installing a cable with a cold bend temperature rating of -25°C, the minimum recommended installation temperature is -10°C.

The cold bend temperature ratings are indicated on the catalog spec sheets.

Prior to performing a low temperature (less than 10°F or -12°C) cable installation, cable should be pre-conditioned by storing it for a minimum of 24 hours at a temperature of 55°F (13°C) or higher.

Cable should be pulled more slowly and trained in place the same day it is removed from storage. Do not impact, drop, kink or bend cable sharply in low temperatures.

3.2 EQUIPMENT

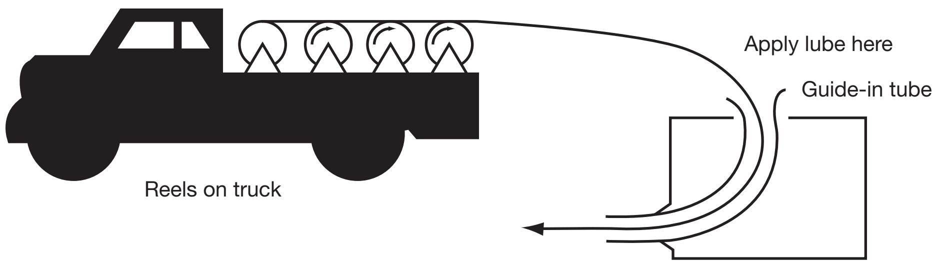
The proper use of appropriate equipment is crucial to a successful cable installation. The equipment recommended for a variety of installations is listed in the following checklist and the appropriate equipment should be selected for the particular installation requirements.

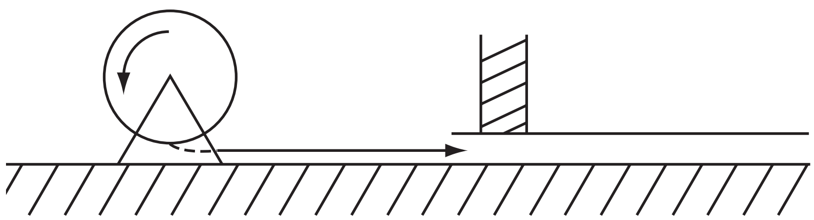
3.2.1 Checklist

- ☐ 0-1/5/10 kip dynamometer
- ☐ basket grip pullers
- ☐ cable cutter
- ☐ cable end seals
- ☐ cable pulling lubricant
- ☐ cable tray bend sheaves
- ☐ cable tray rollers
- ☐ capstan-type puller
- ☐ diameter tape
- ☐ duct cleaning mandrels
- ☐ electric safety blankets and clamps
- ☐ extension cords with GFCI protection
- ☐ fish tape or string blower/vacuum
- ☐ floodlights
- ☐ gang rollers: with at least 4 ft effective radius
- ☐ gloves
- ☐ guide-in flexible tubing (elephant trunks)
- ☐ hand winches (come-a-long)
- ☐ HiPot tester
- ☐ lint-free rags
- ☐ make-up air blower & hose
- ☐ manhole edge sheave
- ☐ measuring tape
- ☐ personal protection equipment (PPE)
- ☐ plywood sheets
- ☐ portable electric generator
- ☐ pre-lubing devices
- ☐ pulling rope
- ☐ pump, diaphragm
- ☐ radios or telephones
- ☐ reel arbor
- ☐ reel brakes
- ☐ reel jacks
- ☐ several wire rope slings of various lengths
- ☐ shackles/clevis
- ☐ short ropes for temp tie-offs
- ☐ cable end seals
- ☐ swivels
- ☐ warning flags, signs

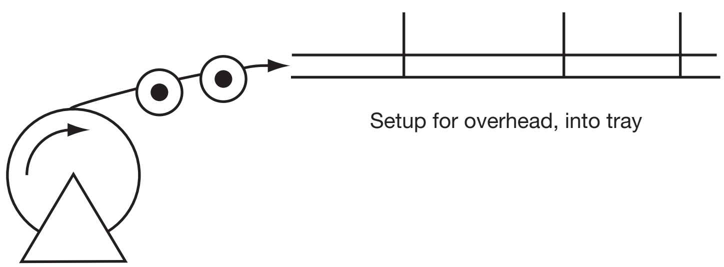
3.2.2 Cable Feed-In Setups

The following diagrams illustrate various cable feed-in setups:





Setup for duct close to floor



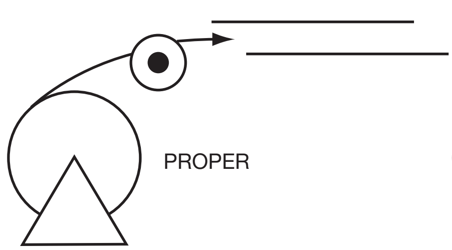


Fig. 3.2.2.1

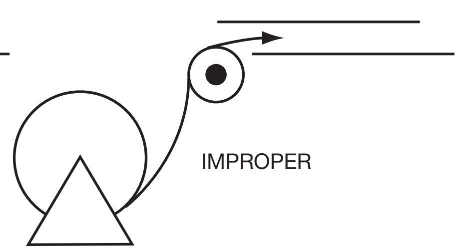
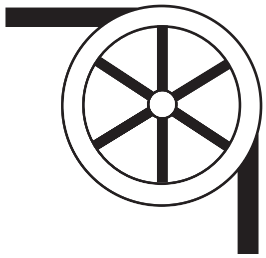


Fig. 3.2.2.2

The feed-in setup should unreel the cable with a natural curvature (Fig. 3.2.2.1) as opposed to a reverse “S” curvature (Fig. 3.2.2.2)

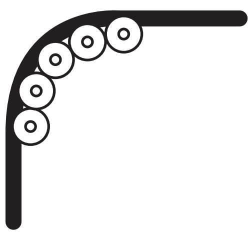
3.2.2 Cable Feed-In Setups (cont'd)

Single Sheave



Single sheaves should only be used for GUIDING cables. Arrange multiple blocks to maintain bending radii whenever cable changes direction or elevation.

Sheave Assembly



For pulling around bends, use conveyor sheave assemblies of the appropriate radius series.

The pulleys must be positioned to ensure that the effective curvature is smooth and changes direction or elevation evenly at each pulley. Never allow a polygon curvature to occur as shown in Fig. 3.2.2.3.

The fit of the pulley around the cable is also important when pulling heavy weights (e.g. pulleys at the top of a vertical drop).

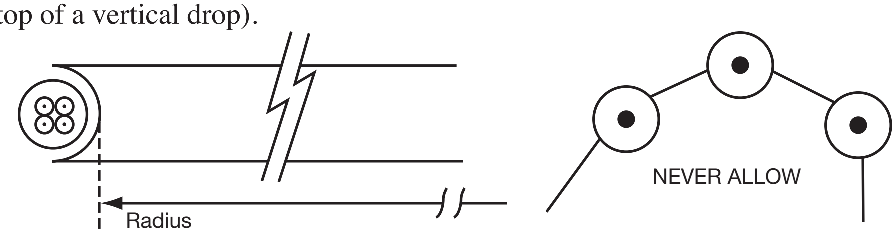


Fig. 3.2.2.3 Effective Curvature

Remember to use the radius of the surface over which the cable is bent, not the outside flange diameter of the pulley. A "10 inch" cable sheave typically has a 10 in. outside flange diameter with a 6 in. inside diameter that provides an inside (bending) radius of 3 in.

3.2.3 Wire-Pulling Compound Suppliers

Since it is not feasible to test every possible combination of cable material with every wire-pulling compound, the installer should check with the pulling compound manufacturer or the cable manufacturer to determine compatibility between specific cable materials and the pulling compound. It is recommended that the compatibility of the pulling compound with the cable comply with IEEE Std 1210, *Standard Tests for Determining Compatibility of Cable-Pulling Lubricants with Wire and Cable*.

The following manufacturers, who are listed in the 2010 Underwriters Laboratories (UL) Electrical Construction Equipment Directory, provide wire-pulling compounds intended for use as lubricants in installing electrical conductors in raceways. These manufacturers have had some of their products investigated by UL to determine their compatibility with specific conductor insulations and coverings.

The Listing Mark for these products includes the UL symbol, together with the word "LISTED", a control number, and the product name "Wire-Pulling Compound". Refer to the latest edition of the UL Electrical Construction Equipment Directory for the current listing of manufacturers of Wire-Pulling Compounds and their control numbers.

3M Company
American Bentonite International Inc.
American Polywater Corp.
Arnco Corp.
Dura-Line Corp.
Formulated Solutions LLC
Greenlee Textron
Ideal Industries Inc.*
J. C. Whitlam Mfg. Co.
Klein Tools Inc.
Madison Electric Products Inc.
Rainbow Technology Corp.
Rectorseal
Robinette Inc., DBA Electro Compound Co.
Thomas & Betts Corp.

* Yellow 77 is not recommended for use with UniShield® cables.

For Low-Smoke, Zero-Halogen (LSZH) jacketed cable, consult the wire-pulling compound manufacturers.

Other wire-pulling compounds may be suitable for use with General Cable constructions. Contact the wire-pulling compound manufacturer regarding the suitability of their products with specific General Cable products. Wire-pulling compounds should successfully pass IEEE Standard 1210, *Standard Tests for Determining Compatibility of Cable-Pulling Lubricants with Wire and Cable*.

3.3 EXPOSED RUNS (OPEN WIRING)

3.3.1 NEC

Exposed wiring is on or attached to the surface or behind panels designed to allow access, see NEC Article 100.

3.3.1.1 Wiring Methods

3.3.1.1.1 Metal Clad Cable. Type MC Cable may be installed in exposed runs for all voltages; refer to 330.10(A)(4) and 300.37.

3.3.1.1 Wiring Methods (cont'd)

3.3.1.1.2 Medium-Voltage Cable. Cables that are listed and marked as Type MC and Type MV may be installed as exposed runs in any installation; refer to 300.37. In locations accessible to qualified persons only, exposed runs of Type MV cables are also permitted; refer to 300.37.

3.3.1.1.3 Messenger-Supported Wiring. Refer to 396.10 and 396.12.

3.3.1.1.4 TC-ER Tray Cable. Refer to 336.10(7) and 3.4.1.1.2.

3.3.1.2 Securing and Supporting

Type MC Cables shall be secured and supported at intervals not exceeding 6 ft (1.8 m). Cables containing four or fewer conductors sized no larger than 10 AWG shall be secured within 12 in. (300 mm) of every box, cabinet, fitting, or other cable termination; Refer to 330.30(B) and (C).

Type TC-ER Tray Cable must be continuously supported and protected against physical damage and secured at intervals not exceeding 6 ft (1.8 m); Refer to 336.10(7) and 3.4.1.1.2.

3.3.1.3 Ampacity

The ampacity of Type MC Cables is based on the insulated conductors contained within the cable.

Where single Type MC conductors are grouped together in a triangular or square configuration and installed on a messenger or exposed with a maintained free airspace of not less than 2.15 times one conductor diameter (2.15 x O.D.) of the largest conductor contained within the configuration and adjacent conductor configurations or cables, the ampacity of the conductors cannot exceed the allowable ampacities in the following tables. Refer to 330.80(B) for additional information.

Table 310.15(B)(20) for conductors rated 0 through 2000 V

Tables 310.60(C)(67) and 310.60(C)(68) for conductors rated over 2000 V

Under engineering supervision, when the known installation conditions are different from those specified in the tables, ampacities may be calculated using the equations in 310.15(C) and 310.60(D).

Refer to 310.15(B)(2)(A)(3) for ampacity adjustment factors for conductors rated 2000 V or less.

3.3.2 CEC

Exposed (as applied to wiring methods) – not concealed, see the definition in Section 0 of the CEC, Part I.

3.3.2.1 Wiring Methods

Refer to CEC Section 12 – Wiring Methods, Rule 12-200 for open wiring and Rule 12-300 for exposed wiring on exteriors of buildings and between buildings on the same premises.

3.3.2.1 Wiring Methods (cont'd)

3.3.2.1.1 750 V or Less.

The provisions of Section 12 apply to all wiring installations operating at 750 V or less except for:

(a) Class 2 circuits unless otherwise specified in Section 16;
(b) community antenna distribution and radio television circuits unless otherwise specified in Section 54;
(c) optical fiber cables unless otherwise specified in Section 56;
(d) communication circuit conductors unless otherwise specified in Section 60; and
(e) conductors that form an integral part of factory-built equipment.

3.3.2.1.2 Over 750 V.

The provisions of Section 12 also apply to installations operating at voltages in excess of 750 V except as modified by the requirements of Section 36, high-voltage installations.

3.3.2.1.3 Installation Conditions.

Conductors installed in any location shall be suitable for the conditions indicated in Table 19 for the particular location involved and with particular respect to:

(a) moisture, if any;
(b) corrosive action, if any;
(c) temperature;
(d) degree of enclosure; and
(e) mechanical protection.

3.3.2.2 Hazardous Locations

The wiring methods and types of wires for hazardous locations are specified in Section 18 and Appendix B of the CEC.

3.3.2.3 Ampacity

The allowable (LV) ampacities (in air) are specified in Tables 1 through 4, 12, 12A, 36A and 36B of the CEC.

Refer to Table 19 for conditions of use and maximum allowable conductor temperatures of wires and cables other than flexible cords, portable power cables and equipment wires.

Refer to Table 11 for conditions of use, voltage and temperature ratings of flexible cords. Refer to Table 12 for ampacities of flexible cords and Table 12A for portable power cables.

3.3.3 Non-Code Installations

In the United States, the National Electrical Safety Code (NESC) has installation and design safe requirements that are not necessarily addressed in this document, please refer to this document for additional information and requirements.

3.3.3.1 Ampacity

Ampacities for non-code applications will require detailed installation conditions whereby the cable manufacture can calculate the cable ampacity rating for those conditions.

3.4 CABLE TRAY

3.4.1 NEC

A cable tray system is defined as a unit or assembly of units or sections and associated fittings forming a structural system used to securely fasten and support cables and raceways; see NEC 392.2.

Refer to Article 392 for specific installation requirements in cable trays.

3.4.1.1 Wiring Methods

The wiring methods permitted to be installed in cable tray for installations required to comply with the NEC are as follows. Also refer to the specific Article for the wiring method for other installation requirements.

3.4.1.1.1 General Industrial and Commercial.

Refer to 392.10(A) and Table 392.10(A) for wiring methods permitted to be installed in cable tray.

3.4.1.1.2 Industrial Establishments.

In industrial establishments only, where conditions of maintenance and supervision ensure that only qualified persons service the installed cable tray system, in addition to the wiring methods listed in 3.4.1.1.1, any of the cables in 392.10(B)(1) (single conductors 1/0 AWG and larger) and (B)(2) (Type MV Medium-Voltage) are permitted to be installed in ladder, ventilated trough, solid bottom, or ventilated channel cable trays.

Type TC tray cable that complies with the crush and impact requirements of Type MC cable and is identified for such use with the marking Type TC–ER is permitted to be installed in exposed runs between a cable tray and the utilization equipment or device, see 336.10(7). The cable must be continuously supported and protected against physical damage and secured at intervals not exceeding 6 ft (1.8 m). Equipment grounding for the utilization equipment must be provided by an equipment grounding conductor within the cable. In cables containing conductors size 6 AWG or smaller, the equipment grounding conductor must be provided within the cable or, at the time of installation, one or more insulated conductors may be permanently identified as an equipment grounding conductor in accordance with 250.119(B).

3.4.1.1.3 Hazardous Locations.

Cable trays in hazardous locations may only contain the cable types permitted in 501.10, 502.10, 503.10, 504.20, and 505.15.

3.4.1.2 Voltage Separation

3.4.1.2.1 600 V or Less.

Multi-conductor cables rated 600 V or less may be installed in the same cable tray with no separation required; refer to 392.20(A).

3.4.1.2.2 Over 600 V.

Cables rated over 600 V and those rated 600 V or less installed in the same cable tray must comply with either of the following; refer to 392.20(B).

(1) The cables rated over 600 V are Type MC.

(2) The cables rated over 600 V are separated from the cables rated 600 V or less by a solid fixed barrier of a material compatible with the cable tray.

3.4.1.3 Tray Fill

Refer to the NEC Sections and the Tables listed for the cable tray fill and installation requirements for the specific wiring method and the type of cable tray.

Table 3.4.1.3 Cable Tray Fill

Number of multi-conductor cables rated 2000 V or less	392.22(A) and Tables 392.22(A), 392.22(A)(5), and 392.22(A)(6)
Number of single conductor cables rated 2000 V or less	392.22(B) and Table 392.22(B)(1)
Number of Type MV and Type MC Cables rated over 2000 V	392.22(C)
Installation of single conductors – all voltages	392.20(D)
Installation of single conductors connected in parallel – all voltages	392.20(C)

3.4.1.4 Splices

Cable splices made and insulated by approved methods are permitted to be located within a cable tray, provided they are accessible. Splices shall be permitted to project above the side rails where not subject to physical damage. Refer to 392.56.

3.4.1.5 Ampacity

3.4.1.5.1 2000 V or Less.

Refer to 392.80(A)(1) for the ampacity of multi-conductor cables and 392.80(A)(2) for single conductors.

3.4.1.5.2 Over 2000 V.

Refer to 392.80(B)(1) for the ampacity of multi-conductor cables and 392.80(B)(2) for single conductors.

3.4.2 CEC

A cable tray is defined as a raceway consisting of troughing and fittings formed and constructed so that insulated conductors and cables may be readily installed or removed after the cable tray has been completely installed, without injury to either conductors or their covering, see Section 0 of the CEC, Part I.

Refer to Section 12 of the CEC and Rules 12-2202 through 12-2210 for installation requirements in cable trays. Also refer to Appendix B for additional information and clarification of the Rules regarding cable tray installations.

3.4.2.1 Conductors in Cable Trays

Conductors for use in cable trays are defined in Rule 12-2202 and shall be as listed in Table 19 and, except as permitted in 3.4.2.1.1 and 3.4.2.1.2, shall have a continuous metal sheath or interlocking armour.

3.4.2.1.1 Type TC Tray Cable.

Rule 12-2202(2) specifies that Type TC tray cable shall be permitted in cable trays in areas of industrial establishments that are inaccessible to the public provided that the cable is:

(a) installed in conduit, other suitable raceway or direct buried, when not in cable tray;
(b) provided with mechanical protection where subject to damage either during or after installation;
(c) no smaller than 1/0 AWG if a single conductor is used; and
(d) installed only where qualified persons service the installation.

3.4.2.1.2 Non-Armoured Jacketed (Sheathed) Cable.

Rule 12-2202(3) specifies that conductors having moisture-resistant insulation and flame-tested non-metal coverings or sheaths of a type listed in Table 19 shall be permitted in ventilated or non-ventilated cable trays where not subject to damage during or after installation in:

(a) electrical equipment vaults and service rooms; and
(b) other locations that are inaccessible to the public and are constructed as a service room where a deviation has been allowed in accordance with Rule 2-030.

3.4.2.2 Single Conductors

Rule 12-2202(4) specifies that single conductors shall be fastened to prevent excessive movement due to fault-current magnetic forces.

Rule 12-2202(5) specifies where single conductors are fastened to cable trays, precautions shall be taken to prevent overheating of the fasteners due to induction.

3.4.2.3 Ampacity

Ampacities listed in the CEC pertain to low-voltage cables. Ampacities for medium-voltage cables can be obtained from the IEE 835 standard.

3.4.2.3 Ampacity (cont'd)

Rule 12-2210 specifies the permitted ampacities of conductors in ventilated and ladder-type cable trays and Tables 1 through 4.

Rule 12-2210(3) defines the limitations when spacing is not maintained in ventilated and ladder-type cable trays and for any spacing in a non-ventilated cable tray.

CEC Table 5D provides the current rating correction factors based on the number of conductors or cables installed horizontally and vertically, where spacing is maintained in ventilated and ladder-type cable trays; refer to Rule 12-2210.

Derating for more than three conductors in a cable tray shall comply with Table 5C.

3.4.3 Non-Code Installations

For information on cable trays, refer to:
ANSI/NEMA–VE 1, *Metal Cable Tray Systems*
NEMA–VE 2, *Cable Tray Installation Guidelines*
NEMA–FG 1, *Fiberglass Cable Tray Systems*

3.5 MESSENGER-SUPPORTED WIRING

3.5.1 NEC

Messenger-supported wiring is defined in NEC 396.2 as an exposed wiring support system using a messenger wire to support insulated conductors by any one of the following:
(1) A messenger with rings and saddles for conductor support
(2) A messenger with a field-installed lashing material for conductor support
(3) Factory-assembled aerial cable
(4) Multiplex cables utilizing a bare conductor, factory assembled and twisted with one or more insulated conductors, such as duplex, triplex, or quadruplex type of construction

3.5.1.1 Wiring Methods

Refer to Article 396 for complete requirements on the use of messenger-supported wiring.

3.5.1.1.1 General Industrial and Commercial.

The cable types permitted to be installed in messenger-supported wiring are specified in 396.10 and Table 396.10(A). Refer to the NEC Article for the specific wiring method for any additional installation requirements.

3.5.1.1.2 Industrial Establishments.

In industrial establishments only, where conditions of maintenance and supervision ensure that only qualified persons service the installed messenger-supported wiring, any of the insulated conductors in Tables 310.104(A) (600 V) or 310.104(B) (2000 V), or Type MV medium-voltage single conductors or multi-conductor cables may be installed as messenger-supported wiring; refer to 396.10(B).

3.5.1.1 Wiring Methods (cont'd)

3.5.1.1.3 Hazardous Locations.

Messenger-supported wiring is permitted to be used in hazardous locations where the contained cables are permitted in 501.10, 502.10, 503.10, and 504.20.

3.5.1.2 Splices

Conductor splices and taps made and insulated by approved methods are permitted in messenger-supported wiring; refer to 396.56.

3.5.1.3 Ampacity

The ampacity of the messenger-supported wiring is determined by the insulated conductors or cables incorporated into the messenger-supported wiring.

3.5.1.3.1 2000 V or Less.

Refer to Table 310.15(B)(20) Ampacities of Not More Than Three Single Insulated Conductors, Rated 0 Through 2000 Volts, Supported on a Messenger, Based on Ambient Air Temperature of 40°C (104°F).

Refer to 310.15(B)(2) for ampacity adjustment factors.

Under engineering supervision, when the known installation conditions are different from those specified in the Table, ampacities may be calculated in accordance with 310.15(C).

3.5.1.3.2 Over 2000 V.

For single conductors, refer to Tables 310.60(C)(67) through 310.60(C)(70).

For three conductor cables, refer to Tables 310.60(C)(71) and 310.60(C)(72).

Under engineering supervision, when the known installation conditions are different from those specified in the tables, ampacities may be calculated in accordance with 310.60(D).

3.5.1.3.3 Type MC Cable.

Where single Type MC conductors are grouped together in a triangular or square configuration, and installed on a messenger or exposed with a maintained free airspace of not less than 2.15 times one conductor diameter (2.15 × O.D.) of the largest conductor contained within the configuration and adjacent conductor configurations or cables, the ampacity of the conductors shall not exceed the allowable ampacities in the following tables, see 330.80(B):

Table 310.15(B)(20) for conductors rated 0 through 2000 V

Table 310.60(C)(67) and Table 310.60 (C)(68) for conductors rated over 2000 V

Under engineering supervision, when the known installation conditions are different from those specified in the tables, ampacities may be calculated in accordance with 310.15(C) and 310.60(D).

3.5.2 CEC

3.5.2.1 Installation

CEC Rule 12-318 provides the requirements for the use and installation of Neutral Supported Cables (NS75 and NS90).

The maximum allowable span length is 38 meters.

Cables may be installed as a spun bus or field lashed arrangement. The construction of the phase conductors must satisfy the requirements for the installation conditions and are subject to approval from the local inspection authority.

3.5.2.2 Flame Spread

Rule 2-126 also applies with respect to Flame Spread requirements and the National Building Code of Canada.

3.5.2.3 Ampacity

The maximum allowable ampacities shall be in accordance with Rule 4-004(5) and Table 36A for aluminum conductors and Table 36B for copper conductors.

3.6 UNDERGROUND INSTALLATIONS

3.6.1 NEC

Underground installations include cables permitted to be direct buried and cables or conductors installed in raceways approved for direct burial.

An electrical duct, as used in Article 310, includes any of the electrical conduits recognized in Chapter 3 as suitable for use underground; other raceways round in cross section, listed for underground use, and embedded in earth or concrete, see 310.60(A).

3.6.1.1 Installation Requirements

For the requirements on underground installations of conductors and cables in raceways, ducts or direct buried, refer to 300.5 for conductors rated 600 V or less and 300.50 for conductors rated over 600 V. 310.10(F) specifies additional requirements for direct buried installations.

Figures 310.60 and B310.15(B)(2)(2) through B310.15(B)(2)(5) provide configurations of underground electrical ducts and direct burial arrangements for single conductors and multi-conductor cables.

3.6.1.2 Ampacity Calculations

Under engineering supervision, ampacities may be calculated in accordance with 310.15(C) or 310.60(D), when the known installation conditions are different from those specified in the tables.

Ampacities at ambient temperatures different from those specified in the tables may be calculated in accordance with 310.60(C)(4).

3.6.1.3 Ampacity Tables

The allowable ampacities for single conductors and three conductor cables installed underground are provided in the following tables.

3.6.1.3.1 2000 V or Less.

Refer to Table 310.15(B)(16) for the allowable ampacity of not more than three current-carrying conductors in an underground duct or direct buried.

Annex B provides additional application information for ampacities calculated under engineering supervision. Tables B.310.15(B)(2)(5) to B.310.15(B)(2)(7) apply to conductors installed in underground electrical ducts, and Tables B.310.15(B)(2)(8) to B.310.15(B)(2)(10) apply to direct buried conductors.

3.6.1.3.2 2001 V to 35 kV.

Tables 310.60(C)(77) to 310.60(C)(80) apply to conductors installed in underground electrical ducts, and Tables 310.60(C)(81) to 310.60(C)(86) apply to direct buried conductors.

3.6.2 CEC

Refer to Rule 4-004, Appendix B (Diagrams B4-1 to B4-4) and Appendix D (Tables D8A to D15B) of the CEC for underground cable configurations and ampacities for voltages not exceeding 2000 volts.

As an alternative to Rule 4-004(1) and (2) and related Tables 1, 2, 3 and 4, IEEE tables may be used to calculate the ampacities of copper and aluminum conductors if the electrical inspection department is agreeable and the data submitted is satisfactory to the department; refer to Appendix B.

3.6.2.1 Installation Requirements

For the requirements on underground installations of conductors and cables in raceways, ducts or direct buried, refer to Rule 12-012 and Table 53 Minimum Cover Requirements.

3.6.2.2 Ampacity

Underground installation configurations are shown in Appendix B Diagrams B4-1 to B4-4. The corresponding ampacities are listed in Appendix D Tables D8A to D15B.

3.7 RACEWAYS

For power cables, heat is generated as current passes through the conductor. The rate of dissipation of the heat to the surrounding environment is a major consideration for cable system designers and dictates allowable conduit fill.

3.7 RACEWAYS (cont'd)

Raceway fill is the percentage of cable cross-sectional area relative to the inside area of the raceway occupied by cable. It is a contributing factor in the maximum ampacity of the enclosed cables since an increase in the number of current-carrying conductors in the raceway decreases the amount of current each conductor can carry without exceeding its temperature rating.

Consult the applicable codes for the maximum specified raceway fill and for the limitations that fill has on circuit ampacity.

The effect of raceway fills on jamming, clearance and friction is covered in 3.7.3, Mechanical Fit of Cable in Raceway.

3.7.1 RMC Elbow Radius

Table 3.7.1 provides the inside radius for manufactured rigid steel conduit elbows, both standard and sweep. The elbow inside radius (ft) equals the centerline radius (in.) less half of the conduit inside diameter (in.) divided by 12.

Table 3.7.1 Manufactured RMC Elbow Dimensions

Metric Designator	Trade Size	Nominal Conduit ID (in.)	Conduit Area (in.^{2})	Standard Elbow	Sweep Elbow Centerline Radius (in.)							
					12	15	18	24	30	36	42	48
					Elbow Inside Radius (ft)							
16	½	0.632	0.31	0.33	0.97	1.22	1.47	1.97	2.47	2.97	3.47	3.97
21	¾	0.836	0.55	0.34	0.97	1.22	1.47	1.97	2.47	2.97	3.47	3.97
27	1	1.063	0.89	0.43	0.96	1.21	1.46	1.96	2.46	2.96	3.46	3.96
35	1¼	1.394	1.53	0.55	0.94	1.19	1.44	1.94	2.44	2.94	3.44	3.94
41	1½	1.624	2.07	0.62	0.93	1.18	1.43	1.93	2.43	2.93	3.43	3.93
53	2	2.083	3.41	0.70	0.91	1.16	1.41	1.91	2.41	2.91	3.41	3.91
63	2½	2.489	4.87	0.77	-	1.15	1.40	1.90	2.40	2.90	3.40	3.90
78	3	3.090	7.50	0.95	-	-	1.37	1.87	2.37	2.87	3.37	3.87
91	3½	3.570	10.01	1.10	-	-	1.35	1.85	2.35	2.85	3.35	3.85
103	4	4.050	12.88	1.16	-	-	-	1.83	2.33	2.83	3.33	3.83
129	5	5.073	20.21	1.79	-	-	-	-	2.29	2.79	3.29	3.79
155	6	6.093	29.16	2.25	-	-	-	-	-	2.75	3.25	3.75

3.7.2 Raceway Fill Calculations

Raceway fill is calculated as follows:

$$\% \text{ Fill} = \frac{\text{Total Cable Cross-sectional Areas}}{\text{Raceway Inside Area}} \text{ X } 100$$

For round raceways and cables with the same diameters:

$\% \text{ Fill} = (d/D)^2 \text{ x n x } 100$ Where:

d = overall diameter of one cable
D = inside diameter of raceway
n = number of conductors

3.7.3 Mechanical Fit of Cable in Raceway

Some of the factors that influence the mechanical fit of conductors or cables in a raceway or underground electrical duct are the conductor configuration, raceway fill, weight, clearance, jam ratio, and coefficient of friction.

3.7.3.1 Conductor Configuration

The configuration of the conductors or cables in the raceway is defined by the ratio (D/d) of the inner diameter of the raceway (D) to the overall diameter of one of the conductors or cables (d) within the raceway.

A cradled configuration occurs when conductors or cables with a ratio of 2.5 or greater are pulled in parallel from individual reels. A triplexed configuration occurs when conductors or cables with a ratio of less than 2.5 are pulled in parallel from individual reels or when the conductors are pre-assembled or bound together in a triangular configuration. Fig. 3.7.3.1 shows the various configurations.

Configuration directly effects drag and is calculated using the equations in Table 3.7.3.2.

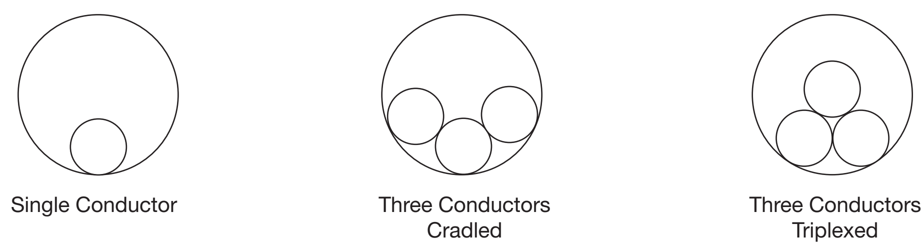


Fig. 3.7.3.1 Conductor Configurations within a Raceway

3.7.3.2 Weight Correction Factor

When making installation calculations, use the total weight per unit length of the conductors or cables being pulled. Cabled assemblies will weigh more than paralleled conductors unless the assembly was specially ordered to have several paralleled conductors wound on a reel.

Due to its geometric configuration, a conductor or cable is subjected to uneven forces when it is pulled into a raceway. This imbalance results in additional frictional drag, which is calculated as the Weight Correction Factor (w) using the equations in Table 3.7.3.2. When calculating the Weight Correction Factor, verify that all the cable diameters are equal. If in doubt, use the cradled configuration equation.

The conductors shown in Figure 3.7.3.1 may be either single conductors or multi-conductor cables. When only one cable, either a single conductor or a multi-conductor cable under a common overall jacket, is being pulled, no Weight Correction Factor is required.

Table 3.7.3.2 Weight Correction Factor Calculations

Number of Conductors	Configuration	Weight Correction Factor (w)
1	Single Conductor	1
3	Three Conductors Cradled	$1+\frac{4}{3}\left(\frac{d}{D-d}\right)^2$
3	Three Conductors Triplexed	$\frac{1}{\sqrt{1-\left(\frac{d}{D-d}\right)^2}}$

Where: d = cable OD
D = circular raceway ID

Refer to Fig. 3.7.3.1 for configuration

3.7.3.3 Clearance

Clearance refers to the distance between the uppermost conductor or cable in the raceway and the inner top of the raceway and is calculated using the equations in Table 3.7.3.3. Clearance should be at least ¼ in. and up to 1 in. for large cable installations or installations involving numerous bends.

When calculating clearance, verify that all the cable diameters are equal. If in doubt, use the triplexed configuration equation. The conductors shown in Figure 3.7.3.1 may be either single conductors or multi-conductor cables.

Table 3.7.3.3 Clearance Calculations

Number of Conductors	Configuration	Clearance
1	Single Conductor	D-d
3	Three Conductors Cradled	$D\text{-}d\text{-}\frac{d^2}{D\text{-}d}$
3	Three Conductors Triplexed	$\frac{D}{2}-1.366d+\frac{D-d}{2}\sqrt{1-\left(\frac{d}{D-d}\right)^2}$

Where: D = raceway ID
d = cable OD

3.7.3.4 Jam Ratio

Jamming is the wedging of three conductors or multi-conductor cables lying side by side in a raceway. This usually occurs when cables are being pulled around bends or when cables twist.

The jam ratio is calculated by slightly modifying the ratio used to measure configuration (D/d). A value of 1.05D is used for the inner diameter of the raceway since bending a cylinder creates an oval cross-section in the bend. The jam ratio is calculated using 1.05D/d, where D is the raceway ID and d is the OD of an individual conductor or multi-conductor cable.

When pulling three conductors or cables into a raceway, the following conditions can exist:

- If 1.05D/d is larger than 3.2, jamming is impossible.
- If 1.05D/d is between 2.8 and 3.2, jamming is probable.
- If 1.05D/d is between 2.5 and 2.8, jamming is possible.
- If 1.05D/d is less than 2.5, jamming is impossible but the clearance should be checked.

If the jam ratio results in a value between 2.8 and 3.2, one of the following alternatives should be considered to avoid jamming:

- use the next larger raceway,
- have the three conductors triplexed in the factory, or
- bind the conductors together, either in the factory or in the field, so a triangular configuration will be maintained during installation.

While jamming can occur when pulling four or more conductors or cables into a raceway, the probability is very low.

Table 3.7.3.4 provides the diameter ranges for single conductors or multi-conductor cables that will result in jamming in each size of RMC when three separate conductors or cables are pulled in together. The raceways in the shaded areas should be avoided when installing three conductors or cables of the same diameter and the larger raceways used to prevent jamming.

Since there are manufacturing tolerances on the conductors and cables, the actual overall diameter of the conductors or cables should be measured prior to installing the cable when considering the jam ratio.

Table 3.7.3.4 Jamming Possibilities

Three Conductors or Cables in RMC Based on 1.05D/d to Avoid Jam Ratio of 2.8 – 3.2

Trade Size		**½**	**¾**	**1**	**1¼**	**1½**	**2**	**2½**	**3**	**3½**	**4**	**5**	**6**
ID (in.)		**0.632**	**0.836**	**1.063**	**1.394**	**1.624**	**2.083**	**2.489**	**3.090**	**3.570**	**4.050**	**5.073**	**6.093**
Cable OD (in.)													
min.	max.												
0.000	0.206												
0.207	0.237	■											
0.238	0.273												
0.274	0.314		■										
0.315	0.348												
0.349	0.399			■									
0.400	0.456												
0.457	0.523				■								
0.524	0.532												
0.533	0.609					■							
0.610	0.682												
0.683	0.781						■						
0.782	0.816												
0.817	0.933							■					
0.934	1.013												
1.014	1.159								■				
1.160	1.170												
1.171	1.339									■			
1.329	1.519										■		
1.520	1.664												
1.665	1.902											■	
1.903	1.998												
1.999	2.285												■

3.7.3.5 Coefficient of Dynamic Friction

The Coefficient of Dynamic Friction (f) is a measure of the friction between the conductors or cables and the raceway or roller, and can vary from 0.03 to 0.8, even with lubrication.

The coefficient of friction of a duct or raceway varies with the type of cable covering, condition of the duct or raceway internal surface, type and amount of pulling lubricant used, and the ambient installation temperature.

Pulling lubricants must be compatible with the cable's components and be continuously applied while the conductors or cables are being pulled. See 3.2.3 for additional information on wire-pulling compounds.

Ambient temperatures over 80ºF (27°C) can increase the coefficient of dynamic friction for conductors or cables having a nonmetallic jacket.

Typical values for General Cable products in raceways are shown in Table 3.7.3.5. The values in Table 3.7.3.5 may be conservative and the lubricant manufacturer should be consulted for recommended coefficients of friction.

Table 3.7.3.5 Typical Coefficients of Dynamic Friction (f) with Adequate Cable Lubrication During Pull

Conductor or Cable Outer Surface	Type of Raceway		
	Metallic	PVC	Fiber
Polyvinyl Chloride (PVC)	0.4	0.4	0.55
Low density Polyethylene (PE)	0.35	0.35	0.5
Chlorinated Polyethylene (CPE)	0.35	0.35	0.5
Chlorosulfonated Polyethylene (CSPE)	0.5	0.5	0.7
Flame-Retardant Ethylene Propylene (FREP)	0.4	0.4	0.5
Cross-linked Polyethylene (XLPE)	0.35	0.35	0.5
Low-Smoke, Zero-Halogen (LSZH)	0.35	0.35	0.35

Metallic = Steel or Aluminum
PVC = Polyvinyl Chloride, Thinwall or Heavy Schedule 40
Fiber = Fiber Conduit

3.7.4 NEC

A raceway is defined in NEC Article 100 as an enclosed channel of metal or non-metallic materials designed expressly for holding wires or cables with additional functions as permitted in the NEC. Raceways include, but are not limited to, rigid metal conduit, rigid non-metallic conduit, intermediate metal conduit, liquid-tight flexible conduit, flexible metallic tubing, flexible metal conduit, electrical non-metallic tubing, electrical metallic tubing, underfloor raceways, cellular concrete floor raceways, cellular metal floor raceways, surface raceways, wireways, and busways. Underground ducts are also considered raceways. A cable tray is not considered a raceway.

3.7.4.1 NEC Chapter 9 Tables

Table 1 in Chapter 9 of the NEC permits 40% fill for 3 or more conductors in a raceway, 31% fill for 2 conductors and 53% fill for a single conductor. This Table applies only to complete raceway systems and is not intended to apply to sections of conduit or tubing used to protect exposed wiring from physical damage. Refer to 3.7.4.2 or Note (4) to the NEC Tables in Chapter 9 for conductors installed in raceway nipples having a maximum length not exceeding 24 in. (600 mm).

NEC Table 1 is based on common conditions of proper cabling and alignment of conductors where the length of the pull and the number of bends are within reasonable limits. It should be recognized that, for certain conditions, a larger raceway or a reduced conduit fill should be considered.

When pulling three conductors or cables into a raceway, if the ratio of the raceway inside diameter (D) to the conductor or cable outside diameter (d) is between 2.8 and 3.2, serious jamming is probable. While jamming can occur when pulling four or more conductors or cables into a raceway, the probability is very low. Refer to 3.7.3.4 for additional information related to conductor jamming.

Table 3.7.4.1 provides a summary of the inside diameters and cross-sectional areas of the raceways in NEC Chapter 9, Table 4, Dimensions and Percent Area of Conduit and Tubing. The inside diameters for RMC are shown in the Rigid Metal Conduit Fill tables in 3.7.4.3.

Table 3.7.1 provides the inside radius for manufactured RMC standard and sweep elbows. For additional information, refer to Chapter 9, Table 2, Radius of Conduit and Tubing Bends.

Refer to Chapter 9, Table 5, Dimensions of Insulated Conductors and Fixture Wires, for the approximate diameters and areas of standard 600 V insulated conductors. For dimensional information on General Cable insulated conductors, see 3.8.

Refer to Chapter 9, Table 8, Conductor Properties, for construction details and dc resistance of copper and aluminum conductors.

Table 3.7.4.1 Raceway Inside Diameter Dimensions

Metric Designator	Trade Size	EMT		ENT		FMC		IMC		LFMC	
		CONDUIT ID									
		mm	in.	mm	in.	mm	in.	mm	in.	mm	in.
12	⅜	-	-	-	-	9.7	0.384	-	-	12.5	0.494
16	½	15.8	0.622	14.2	0.560	16.1	0.635	16.8	0.660	16.1	0.632
21	¾	20.9	0.824	19.3	0.760	20.9	0.824	21.9	0.864	21.1	0.830
27	1	26.6	1.049	25.4	1.000	25.9	1.020	28.1	1.105	26.8	1.054
35	1¼	35.1	1.380	34.0	1.340	32.4	1.275	36.8	1.448	35.4	1.395
41	1½	40.9	1.610	39.9	1.570	39.1	1.538	42.7	1.683	40.3	1.588
53	2	52.5	2.067	51.3	2.020	51.8	2.040	54.6	2.150	51.6	2.033
63	2½	69.4	2.731	-	-	63.5	2.500	64.9	2.557	63.3	2.493
78	3	85.2	3.356	-	-	76.2	3.000	80.7	3.176	78.4	3.085
91	3½	97.4	3.834	-	-	88.9	3.500	93.2	3.671	89.4	3.520
103	4	110.1	4.334	-	-	101.6	4.000	105.4	4.166	102.1	4.020

Metric Designator	Trade Size	PVC Schedule 80		PVC Schedule 40		Type A Rigid PVC		Type EB PVC		LFNC-B	
		CONDUIT ID									
		mm	in.	mm	in.	mm	in.	mm	in.	mm	in.
12	⅜	-	-	-	-	-	-	-	-	12.5	0.494
16	½	13.4	0.526	15.3	0.602	17.8	0.700	-	-	16.1	0.632
21	¾	18.3	0.722	20.4	0.804	23.1	0.910	-	-	21.1	0.830
27	1	23.8	0.936	26.1	1.029	29.8	1.175	-	-	26.8	1.054
35	1¼	31.9	1.255	34.5	1.360	38.1	1.500	-	-	35.4	1.395
41	1½	37.5	1.476	40.4	1.590	43.7	1.720	-	-	40.3	1.588
53	2	48.6	1.913	52.0	2.047	54.7	2.155	56.4	2.221	51.6	2.033
63	2½	58.2	2.290	62.1	2.445	66.9	2.635	-	-	-	-
78	3	72.7	2.864	77.3	3.042	82.0	3.230	84.6	3.330	-	-
91	3½	84.5	3.326	89.4	3.521	93.7	3.690	96.6	3.804	-	-
103	4	96.2	3.786	101.5	3.998	106.2	4.180	108.9	4.289	-	-
129	5	121.1	4.768	127.4	5.016	-	-	135.0	5.316	-	-
155	6	145.0	5.709	153.2	6.031	-	-	160.9	6.336	-	-

For additional information, refer to NEC Chapter 9 for the applicable raceway.

Table 4, Dimensions and Percent Area of Conduit and Tubing
Article 358 – Electrical Metallic Tubing (EMT)
Article 362 – Electrical Non-metallic Tubing (ENT)
Article 342 – Intermediate Metal Conduit (IMC)
Article 344 – Rigid Metal Conduit (RMC)
Article 352 – Rigid Polyvinyl Chloride Conduit: Type PVC - Schedule 80 and 40, Types EB and A
Article 348 – Flexible Metal Conduit (FMC)
Article 356 – Liquidtight Flexible Non-metallic Conduit (LFNC-A and LFNC-B)
Article 350 – Liquidtight Flexible Metal Conduit (LFMC)
Article 353 – High Density Polyethylene Conduit (HDPE)

3.7.4.2 Notes to NEC Chapter 9 Tables

Equipment grounding or bonding conductors, where installed, must be included when calculating raceway fill. The actual dimensions of the equipment grounding or bonding conductor (insulated or bare) should be used in the calculation.

Where nipples having a maximum length not to exceed 24 in. (600 mm) are installed between boxes, cabinets and similar enclosures, the nipples shall be permitted to be filled to 60 percent of their total cross-sectional area, and 310.15(B)(3)(a) adjustment factors are not required to be applied for this application.

For conductors not included in Chapter 9, such as multi-conductor cables, the actual dimensions should be used.

For combinations of conductors of different sizes, use Table 5 for dimensions of conductors and Table 4 for the applicable raceway dimensions.

When calculating the maximum number of conductors, all of the same size (total cross-sectional area including insulation), permitted in a raceway, the next higher whole number may be used to determine the maximum number of conductors permitted when the calculation results in a decimal of 0.8 or larger.

Where bare conductors are permitted by other sections of the NEC, the dimensions for bare conductors in Table 8 should be used.

A multi-conductor cable or flexible cord of two or more conductors shall be treated as a single conductor for calculating the percentage raceway fill area. For cables that have elliptical cross-sections, the cross-sectional area calculation should be based on using the major diameter of the ellipse as a circle diameter.

3.7.4.3 Rigid Metal Conduit Fill Tables

The 3.7.4.3.1 and 3.7.4.3.2 series of Tables provide the maximum number of General Cable insulated single conductors permitted to be installed in Rigid Metal Conduit (RMC). The 3.7.4.3.3 series of Tables provide the maximum number of General Cable multi-conductor cables permitted to be installed in RMC.

The Raceway Fill Tables were developed in accordance with the 2011 NEC, Chapter 9, Tables 1 and 4, which permit 40% fill for 3 or more conductors, 31% fill for 2 conductors, and 53% fill for a single conductor. In accordance with Note 7 to the NEC Tables, the next higher whole number of conductors was used when the calculations resulted in a decimal of 0.8 or larger.

The highlighted boxes in the Tables indicate that jamming is highly probable if three single conductors or three multi-conductor cables, of the same diameter, are pulled into the raceway, particularly if it is not a straight run. If the jam ratio results in a value between 2.8 and 3.2, one of the following alternatives should be considered to avoid jamming:

(a) use the next larger raceway;
(b) have the three conductors triplexed in the factory; or
(c) bind the conductors together, either in the factory or in the field, so the triangular configuration will be maintained during installation.

3.7.4.3 Rigid Metal Conduit Fill Tables (cont'd)

The equipment grounding conductor in multi-conductor cables may be sectioned into 2 or 3 equal segments as permitted in NEC 310.15(5). The addition of a single equipment grounding conductor will increase the fill in a raceway while the addition of a sectioned equipment grounding conductor in a cabled assembly may not.

Refer to Table 3.7.4.1 in this Manual or NEC Chapter 9, Table 4 for dimensions of raceways other than RMC to calculate the maximum number of conductors or cables permitted to be installed in a specific raceway. Section 3.8 provides internet access information to obtain additional dimensional information on other General Cable insulated conductors and cables and tables showing the maximum allowable raceway fill in other commonly used raceways.

Refer to the 2011 NEC, Chapter 9, for the maximum allowable fill in raceways other than RMC or when installing insulated conductors or multi-conductor cables or assemblies with ODs different from those specified in this Manual.

For insulated conductors not included in this Installation Manual, refer to NEC Annex C for the maximum number of conductors or fixture wires, with compact conductors, and all of the same size (total cross-sectional area including insulation), permitted in trade sizes of the applicable raceway.

3.7.4.3.1 Single Conductor Nonshielded 600 V and 2400 V. Tables 3.7.4.3.1.1 through 3.7.4.3.1.3 provide the maximum number of General Cable nonshielded single conductors rated 600 V and 2400 V that may be installed in RMC.

3.7.4.3.2 Single Conductor Shielded 5 kV – 35 kV. Tables 3.7.4.3.2.1 through 3.7.4.3.2.6 provide the maximum number of General Cable shielded single conductors rated 5 kV through 35 kV that may be installed in RMC.

3.7.4.3.3 Three Conductor Shielded 5 kV – 35 kV. Tables 3.7.4.3.3.1 through 3.7.4.3.3.3 provide the maximum number of General Cable multi-conductor cables, containing three shielded conductors rated 5 kV through 35 kV under an overall non-metallic jacket, which may be installed in RMC.

The equipment grounding conductor in multi-conductor cables may be sectioned into 2 or 3 equal segments as permitted in NEC 310.13. The addition of a sectioned equipment grounding conductor in a cable or a multiplexed assembly usually will not increase the fill in a raceway.

Table 3.7.4.3.1.1 — Maximum Number of Single Conductors Permitted in RMC

1/C DuraSheath® 600 V (Spec 5050)

(The highlighted boxes indicate probable jamming, See 3.7.4.3)

RMC Trade Size			½	¾	1	1¼	1½	2	2½	3	3½	4	5	6	RMC Metric Designator		
			16	21	27	35	41	53	63	78	91	103	129	155			
Internal Area (in²)			0.314	0.549	0.887	1.526	2.071	3.408	4.866	7.499	10.010	12.882	20.212	29.158	Internal Area (mm²)		
			204	353	573	984	1333	2198	3137	4840	6461	8316	13050	18821			
Size (AWG/ kcmil)	O.D. (in.)	Area (in²)	Maximum Number of Conductors												Size (mm²)	O.D. (mm)	Area (mm²)
14	0.17	0.02	5	9	15	26	36	59	84	130	174	224	351	507	2.08	4.32	14.64
12	0.19	0.03	4	8	12	21	29	48	69	107	143	184	288	416	3.31	4.83	18.29
10	0.21	0.04	3	6	10	17	23	39	55	85	114	147	231	333	5.261	5.33	22.35
8	0.28	0.06	2	3	5	10	13	22	31	48	64	83	130	188	8.367	7.11	39.73
6	0.35	0.01	1	2	3	6	8	14	20	31	41	53	84	121	13.30	8.89	62.07
4	0.39	0.12	1	2	3	5	7	11	16	25	33	43	68	98	21.15	9.91	77.07
2	0.46	0.17	1	1	2	3	5	8	11	18	24	31	48	70	33.62	11.68	107.2
1/0	0.58	0.26		1	1	2	3	5	7	11	15	19	30	44	53.49	14.73	170.5
2/0	0.63	0.31		1	1	2	2	4	6	9	13	16	26	37	67.43	16.00	201.1
4/0	0.74	0.43			1	1	2	3	4	7	9	12	19	27	107.2	18.80	277.5
250	0.85	0.57			1	1	1	2	3	5	7	9	14	20	127	21.59	366.1
350	0.96	0.72				1	1	2	2	4	5	7	11	16	177	24.38	467.0
500	1.09	0.93				1	1	1	2	3	4	5	8	12	253	27.69	602.0
750	1.31	1.35					1	1	1	2	3	4	6	8	380	33.27	869.6
1000	1.46	1.67						1	1	1	2	3	5	7	507	37.08	1080

Notes:
(1) Raceway fill based on 2011 NEC, Chapter 9, Tables 1 and 4.
(2) 40% fill for 3 or more conductors, 31% for 2 conductors, and 53% for a single conductor.
(3) In accordance with Note 7 to the NEC Tables, the next higher whole number of conductors was used when the calculations yielded a decimal of 0.8 or larger.

Table 3.7.4.3.1.2 — Maximum Number of Single Conductors Permitted in RMC

1/C Unicon® FREP® 600 V (Spec 5100)

(The highlighted boxes indicate probable jamming, See 3.7.4.3)

RMC Trade Size			½	¾	1	1¼	1½	2	2½	3	3½	4	5	6			
			16	21	27	35	41	53	63	78	91	103	129	155	RMC Metric Designator		
Internal Area (in²)			0.314	0.549	0.887	1.526	2.071	3.408	4.866	7.499	10.010	12.882	20.212	29.158			
			204	353	573	984	1333	2198	3137	4840	6461	8316	13050	18821	Internal Area (mm²)		
Size (AWG/ kcmil)	O.D. (in.)	Area (in²)	Maximum Number of Conductors												Size (mm²)	O.D. (mm)	Area (mm²)
14	0.17	0.02	5	9	15	26	36	59	84	130	174	224	351	507	2.08	4.32	14.64
12	0.19	0.03	4	8	12	21	29	48	69	107	143	184	288	416	3.31	4.83	18.29
10	0.21	0.04	3	6	10	17	23	39	55	85	114	147	231	333	5.261	5.33	22.35
8	0.27	0.06	2	4	6	10	14	24	34	52	70	90	142	204	8.367	6.86	36.94
6	0.31	0.08	1	3	4	8	11	18	26	40	53	68	107	155	13.30	7.87	48.70
4	0.36	0.10	1	2	3	6	8	13	19	29	39	50	79	114	21.15	9.14	65.67
2	0.42	0.14	1	1	2	4	6	10	14	21	29	37	58	84	33.62	10.67	89.38
1/0	0.53	0.22		1	1	2	3	6	9	13	18	23	36	52	53.49	13.46	142.3
2/0	0.58	0.26		1	1	2	3	5	7	11	15	19	30	44	67.43	14.73	170.5
4/0	0.69	0.37			1	1	2	3	5	8	10	13	21	31	107.2	17.53	241.2
250	0.77	0.47			1	1	1	3	4	6	8	11	17	25	127	19.56	300.4
350	0.87	0.59				1	1	2	3	5	6	8	13	19	177	22.10	383.5
500	1.00	0.79				1	1	1	2	4	5	6	10	15	253	25.40	506.7
750	1.22	1.17					1	1	1	2	3	4	7	10	380	30.99	754.2
1000	1.37	1.47						1	1	2	2	3	5	8	507	34.80	951.0

Notes: (1) Raceway fill based on 2011 NEC, Chapter 9, Tables 1 and 4.
(2) 40% fill for 3 or more conductors, 31% for 2 conductors, and 53% for a single conductor.
(3) In accordance with Note 7 to the NEC Tables, the next higher whole number of conductors was used when the calculations yielded a decimal of 0.8 or larger.

Table 3.7.4.3.1.3 — Maximum Number of Single Conductors Permitted in RMC

1/C DuraSheath® 2400 V (Spec 6050)

(The highlighted boxes indicate probable jamming, See 3.7.4.3)

RMC Trade Size			¾	1	1¼	1½	2	2½	3	3½	4	5	6			
			21	27	35	41	53	63	78	91	103	129	155	RMC Metric Designator		
Internal Area (in²)			0.549	0.887	1.526	2.071	3.408	4.866	7.499	10.010	12.882	20.212	29.158			
			353	573	984	1333	2198	3137	4840	6461	8316	13050	18821	Internal Area (mm²)		
Size (AWG/ kcmil)	O.D. (in.)	Area (in²)	Maximum Number of Conductors											Size (mm²)	O.D. (mm)	Area (mm²)
8	0.59	0.27	1	1	2	3	5	7	11	14	19	29	42	8.367	14.99	176.4
6	0.63	0.31	1	1	2	2	4	6	9	13	16	26	38	13.30	15.88	197.9
4	0.67	0.35	1	1	1	2	4	5	8	11	14	23	33	21.15	17.02	227.5
2	0.72	0.41		1	1	2	$\boxed{3}$	4	7	9	12	19	28	33.62	18.39	265.6
1	0.76	0.45		1	1	2	$\boxed{3}$	4	6	9	11	18	26	42.41	19.25	291.1
1/0	0.80	0.50		1	1	1	2	4	6	8	10	16	23	53.49	20.19	320.3
2/0	0.84	0.55		1	1	1	2	$\boxed{3}$	5	7	9	14	21	67.43	21.26	355.0
3/0	0.92	0.66			1	1	2	$\boxed{3}$	4	6	8	12	17	85.01	23.29	426.1
4/0	0.97	0.74			1	1	2	2	4	5	7	11	16	107.2	24.59	474.8
250	1.07	0.89			1	1	1	2	$\boxed{3}$	4	5	9	13	127	27.08	575.8
350	1.16	1.06				1	1	2	3	3	5	7	11	177	29.52	684.2
500	1.28	1.29				1	1	1	2	$\boxed{3}$	4	6	9	253	32.56	832.8
750	1.52	1.81					1	1	1	2	$\boxed{3}$	4	6	380	38.51	1165
1000	1.67	2.19					1	1	1	2	2	$\boxed{3}$	5	507	42.37	1410

Notes:
(1) Raceway fill based on 2011 NEC, Chapter 9, Tables 1 and 4.
(2) 40% fill for 3 or more conductors, 31% for 2 conductors, and 53% for a single conductor.
(3) In accordance with Note 7 to the NEC Tables, the next higher whole number of conductors was used when the calculations yielded a decimal of 0.8 or larger.

Table 3.7.4.3.2.1 — Maximum Number of Single Conductors Permitted in RMC

1/C Uniblend® LF 5 kV (133%) or 8 kV (100%) (Spec 6155)

(The highlighted boxes indicate probable jamming, See 3.7.4.3)

RMC Trade Size			¾	1	1¼	1½	2	2½	3	3½	4	5	6			
			21	27	35	41	53	63	78	91	103	129	155	RMC Metric Designator		
Internal Area (in²)			0.549	0.887	1.526	2.071	3.408	4.866	7.499	10.010	12.882	20.212	29.158			
			353	573	984	1333	2198	3137	4840	6461	8316	13050	18821	Internal Area (mm²)		
Size (AWG/ kcmil)	O.D. (in.)	Area (in²)	Maximum Number of Conductors											Size (mm²)	O.D. (mm)	Area (mm²)
6	0.65	0.33	1	1	2	2	4	6	9	12	15	24	35	13.30	16.51	214.1
4	0.70	0.39		1	1	2	$\boxed{3}$	5	7	10	13	21	30	21.15	17.78	248.3
2	0.76	0.45		1	1	2	$\boxed{3}$	4	6	9	11	18	25	33.62	19.30	292.7
1	0.79	0.49		1	1	1	2	4	6	8	10	16	24	42.41	20.07	316.2
1/0	0.82	0.53		1	1	1	2	$\boxed{3}$	5	7	9	15	22	53.49	20.83	340.7
2/0	0.86	0.58		1	1	1	2	$\boxed{3}$	5	7	9	14	20	67.43	21.84	374.8
3/0	0.94	0.69			1	1	2	3	4	5	7	11	17	85.01	23.88	447.7
4/0	1.00	0.79			1	1	1	2	4	5	6	10	15	107.2	25.40	506.7
250	1.05	0.87			1	1	1	2	$\boxed{3}$	4	6	9	13	127	26.67	558.6
350	1.14	1.02				1	1	2	$\boxed{3}$	4	5	8	11	177	28.96	658.5
500	1.27	1.27				1	1	1	2	$\boxed{3}$	4	6	9	253	32.26	817.3
750	1.45	1.65					1	1	2	2	$\boxed{3}$	5	7	380	36.83	1065
1000	1.60	2.01					1	1	1	2	2	4	5	507	40.64	1297

Notes:
(1) Raceway fill based on 2011 NEC, Chapter 9, Tables 1 and 4.
(2) 40% fill for 3 or more conductors, 31% for 2 conductors, and 53% for a single conductor.
(3) In accordance with Note 7 to the NEC Tables, the next higher whole number of conductors was used when the calculations yielded a decimal of 0.8 or larger.

Table 3.7.4.3.2.2 — Maximum Number of Single Conductors Permitted in RMC

1/C Uniblend® LF 15 kV (133%) (Spec 6355)

(The highlighted boxes indicate probable jamming, See 3.7.4.3)

RMC Trade Size			1¼	1½	2	2½	3	3½	4	5	6			
			35	41	53	63	78	91	103	129	155	RMC Metric Designator		
Internal Area (in²)			1.526	2.071	3.408	4.866	7.499	10.010	12.882	20.212	29.158			
			984	1333	2198	3137	4840	6461	8316	13050	18821	Internal Area (mm²)		
Size (AWG/ kcmil)	O.D. (in.)	Area (in²)	Maximum Number of Conductors									Size (mm²)	O.D. (mm)	Area (mm²)
2	0.99	0.77	1	1	1	2	4	5	6	10	15	33.62	25.15	496.6
1	1.02	0.82	1	1	1	2	$\boxed{3}$	5	6	10	14	42.41	25.91	527.3
1/0	1.06	0.88	1	1	1	2	$\boxed{3}$	4	6	9	13	53.49	26.92	569.3
2/0	1.10	0.95	1	1	1	2	$\boxed{3}$	4	5	8	12	67.43	27.94	613.1
3/0	1.14	1.02		1	1	2	$\boxed{3}$	4	5	8	11	85.01	28.96	658.5
4/0	1.21	1.15		1	1	1	2	$\boxed{3}$	4	7	10	107.2	30.73	741.9
250	1.25	1.23		1	1	1	2	$\boxed{3}$	4	6	9	127	31.75	791.7
350	1.35	1.43			1	1	2	2	$\boxed{3}$	5	8	177	34.29	923.5
500	1.47	1.70			1	1	1	2	$\boxed{3}$	4	7	253	37.34	1095
750	1.65	2.14			1	1	1	2	2	3	5	380	41.91	1380
1000	1.86	2.72				1	1	1	2	$\boxed{3}$	4	507	47.24	1753

Notes:
(1) Raceway fill based on 2011 NEC, Chapter 9, Tables 1 and 4.
(2) 40% fill for 3 or more conductors, 31% for 2 conductors, and 53% for a single conductor.
(3) In accordance with Note 7 to the NEC Tables, the next higher whole number of conductors was used when the calculations yielded a decimal of 0.8 or larger.

Table 3.7.4.3.2.3 — Maximum Number of Single Conductors Permitted in RMC

1/C Uniblend® LF 25 kV (133%) & 35 kV (100%) (Spec 6555)

(The highlighted boxes indicate probable jamming, See 3.7.4.3)

RMC Trade Size			1½	2	2½	3	3½	4	5	6			
			41	53	63	78	91	103	129	155	RMC Metric Designator		
Internal Area (in²)			2.071	3.408	4.866	7.499	10.010	12.882	20.212	29.158			
			1333	2198	3137	4840	6461	8316	13050	18821	Internal Area (mm²)		
Size (AWG/ kcmil)	O.D. (in.)	Area (in²)	Maximum Number of Conductors								Size (mm²)	O.D. (mm)	Area (mm²)
1/0	1.31	1.35	1	1	1	2	3	4	6	8	53.49	33.27	869.6
2/0	1.35	1.43		1	1	2	2	3	5	8	67.43	34.29	923.5
3/0	1.40	1.54		1	1	2	2	3	5	7	85.01	35.56	993.1
4/0	1.45	1.65		1	1	2	2	3	5	7	107.2	36.83	1065
250	1.51	1.79		1	1	1	2	3	4	6	127	38.35	115
350	1.60	2.01		1	1	1	2	2	4	5	177	40.64	1297
500	1.78	2.49			1	1	1	2	3	4	253	45.21	1605
750	1.96	3.02			1	1	1	1	2	4	380	49.78	1947
1000	2.10	3.46				1	1	1	2	3	507	53.34	2235

Notes:
(1) Raceway fill based on 2011 NEC, Chapter 9, Tables 1 and 4.
(2) 40% fill for 3 or more conductors, 31% for 2 conductors, and 53% for a single conductor.
(3) In accordance with Note 7 to the NEC Tables, the next higher whole number of conductors was used when the calculations yielded a decimal of 0.8 or larger.

Table 3.7.4.3.2.4 — Maximum Number of Single Conductors Permitted in RMC

1/C UniShield® 5 kV (133%) or 8 kV (100%) (Spec 6100)

(The highlighted boxes indicate probable jamming, See 3.7.4.3)

RMC Trade Size			1	1¼	1½	2	2½	3	3½	4	5	6			
			27	35	41	53	63	78	91	103	129	155	RMC Metric Designator		
Internal Area (in²)			0.887	1.526	2.071	3.408	4.866	7.499	10.010	12.882	20.212	29.158			
			573	984	1333	2198	3137	4840	6461	8316	13050	18821	Internal Area (mm²)		
Size (AWG/ kcmil)	O.D. (in.)	Area (in²)	Maximum Number of Conductors										Size (mm²)	O.D. (mm)	Area (mm²)
2	0.71	0.40	1	1	2	3	5	7	10	13	20	29	33.62	18.03	255.4
1/0	0.78	0.48	1	1	1	3	4	6	8	10	17	24	53.49	19.81	308.3
2/0	0.83	0.54	1	1	1	2	3	5	7	9	15	21	67.43	21.08	349.1
3/0	0.88	0.61		1	1	2	3	5	6	8	13	19	85.01	22.35	392.4
4/0	0.93	0.68		1	1	2	3	4	6	7	12	17	107.2	23.62	438.3
250	1.01	0.80		1	1	1	2	3	5	6	10	14	127	25.65	516.9
350	1.11	0.97		1	1	1	2	3	4	5	8	12	177	28.19	624.3
500	1.24	1.21			1	1	1	2	3	4	6	9	253	31.50	779.1
750	1.44	1.63				1	1	2	2	3	5	7	380	36.58	1051
1000	1.61	2.04				1	1	1	2	2	4	5	507	40.89	1313

Notes:
(1) Raceway fill based on 2011 NEC, Chapter 9, Tables 1 and 4.
(2) 40% fill for 3 or more conductors, 31% for 2 conductors, and 53% for a single conductor.
(3) In accordance with Note 7 to the NEC Tables, the next higher whole number of conductors was used when the calculations yielded a decimal of 0.8 or larger.

Table 3.7.4.3.2.5 — Maximum Number of Single Conductors Permitted in RMC

1/C UniShield® 15 kV (133%) (Spec 6300)

(The highlighted boxes indicate probable jamming, See 3.7.4.3)

RMC Trade Size			1¼	1½	2	2½	3	3½	4	5	6			
			35	41	53	63	78	91	103	129	155	RMC Metric Designator		
Internal Area (in²)			1.526	2.071	3.408	4.866	7.499	10.010	12.882	20.212	29.158			
			984	1333	2198	3137	4840	6461	8316	13050	18821	Internal Area (mm²)		
Size (AWG/ kcmil)	O.D. (in.)	Area (in²)	Maximum Number of Conductors									Size (mm²)	O.D. (mm)	Area (mm²)
2	0.93	0.68	1	1	2	3	4	6	7	12	17	33.62	23.62	438.3
1/0	1.01	0.80	1	1	1	2	3	5	6	10	14	53.49	25.65	516.9
2/0	1.05	0.87	1	1	1	2	3	4	6	9	13	67.43	26.67	558.6
3/0	1.10	0.95	1	1	1	2	3	4	5	8	12	85.01	27.94	613.1
4/0	1.16	1.06		1	1	2	3	3	5	7	11	107.2	29.46	681.8
250	1.23	1.19		1	1	1	2	3	4	7	10	127	31.24	766.6
350	1.33	1.39			1	1	2	3	3	6	8	177	33.78	896.3
500	1.46	1.67			1	1	1	2	3	5	7	253	37.08	1080
750	1.67	2.19			1	1	1	2	2	3	5	380	42.42	1413
1000	1.86	2.72				1	1	1	2	3	4	507	47.24	1753

Notes: (1) Raceway fill based on 2011 NEC, Chapter 9, Tables 1 and 4.
(2) 40% fill for 3 or more conductors, 31% for 2 conductors, and 53% for a single conductor.
(3) In accordance with Note 7 to the NEC Tables, the next higher whole number of conductors was used when the calculations yielded a decimal of 0.8 or larger.

Table 3.7.4.3.2.6 — Maximum Number of Single Conductors Permitted in RMC

1/C UniShield® 25 kV (133%) & 35 kV (100%) (Spec 6500)

(The highlighted boxes indicate probable jamming, See 3.7.4.3)

RMC Trade Size			1½	2	2½	3	3½	4	5	6			
			41	53	63	78	91	103	129	155	RMC Metric Designator		
Internal Area (in²)			2.071	3.408	4.866	7.499	10.010	12.882	20.212	29.158			
			1333	2198	3137	4840	6461	8316	13050	18821	Internal Area (mm²)		
Size (AWG/ kcmil)	O.D. (in.)	Area (in²)	Maximum Number of Conductors								Size (mm²)	O.D. (mm)	Area (mm²)
1/0	1.29	1.31	1	1	1	2	3	4	6	9	53.49	32.77	843.9
2/0	1.36	1.45		1	1	2	2	3	5	8	67.43	34.54	937.2
3/0	1.41	1.56		1	1	2	2	3	5	7	85.01	35.81	1007
4/0	1.43	1.61		1	1	2	2	3	5	7	107.2	36.32	1036
250	1.51	1.79		1	1	1	2	3	4	6	127	38.35	1155
350	1.60	2.01		1	1	1	2	2	4	5	177	40.64	1297
500	1.74	2.38			1	1	1	2	3	5	253	44.20	1534
750	1.95	2.39			1	1	1	1	2	4	380	49.53	1927
1000	2.11	3.50				1	1	1	2	3	507	53.59	2256

Notes:
(1) Raceway fill based on 2011 NEC, Chapter 9, Tables 1 and 4.
(2) 40% fill for 3 or more conductors, 31% for 2 conductors, and 53% for a single conductor.
(3) In accordance with Note 7 to the NEC Tables, the next higher whole number of conductors was used when the calculations yielded a decimal of 0.8 or larger.

Table 3.7.4.3.3.1 — Maximum Number of Three Conductor Cables Permitted in RMC

3/C Uniblend® LF 5 kV (133%) or 8 kV (100%) with Equipment Grounding Conductor (Spec 6255)

(The highlighted boxes indicate probable jamming, See 3.7.4.3)

RMC Trade Size				1½	2	2½	3	3½	4	5	6				
				41	53	63	78	91	103	129	155	RMC Metric Designator			
Internal Area (in²)				2.071	3.408	4.866	7.499	10.010	12.882	20.212	29.158				
				1333	2198	3137	4840	6461	8316	13050	18821	Internal Area (mm²)			
Size (AWG/ kcmil)	Cable O.D. (in.)	Cable Area (in²)	Equipment Grounding (AWG/ kcmil)[4]	Maximum Number of Cables								Size (mm²)	Cable O.D. (mm)	Cable Area (mm²)	Equipment Grounding (mm²)[4]
6	1.29	1.31	6	1	1	1	2	$\boxed{3}$	4	6	9	13.30	32.77	843.2	13.30
4	1.39	1.52	6		1	1	2	2	$\boxed{3}$	5	7	21.15	35.21	979.0	13.30
2	1.51	1.79	6		1	1	1	2	$\boxed{3}$	4	6	33.62	38.35	1155	13.30
1/0	1.67	2.19	4		1	1	1	2	2	$\boxed{3}$	5	53.49	42.42	1413	21.15
2/0	1.82	2.60	4			1	1	1	2	$\boxed{3}$	4	67.43	46.23	1678	21.15
4/0	2.07	3.37	3				1	1	1	2	$\boxed{3}$	107.2	52.58	2171	26.67
250	2.15	3.63	2				1	1	1	2	$\boxed{3}$	127	54.61	2342	33.62
350	2.36	4.37	2				1	1	1	2	2	177	59.94	2822	33.62
500	2.64	5.47	1					1	1	1	2	253	67.06	3532	42.41
750	3.14	7.74	1/0						1	1	1	380	79.76	4996	53.49
1000	3.48	9.51	2/0							1	1	507	88.39	6136	67.43

Notes:
(1) Raceway fill based on 2011 NEC, Chapter 9, Tables 1 and 4.
(2) 40% fill for 3 or more conductors, 31% for 2 conductors, and 53% for a single conductor.
(3) In accordance with Note 7 to the NEC Tables, the next higher whole number of conductors was used when the calculations yielded a decimal of 0.8 or larger.
(4) The equipment grounding conductor may be sectioned into 2 or 3 equal segments as permitted in 310.13 of the 2008 NEC.

Table 3.7.4.3.3.2 — Maximum Number of Three Conductor Cables Permitted in RMC

3/C Uniblend® LF 15 kV (133%) with Equipment Grounding Conductor (Spec 6455)

(The highlighted boxes indicate probable jamming, See 3.7.4.3)

RMC Trade Size				3	3½	4	5	6				
				78	91	103	129	155	RMC Metric Designator			
Internal Area (in^2)				7.499	10.010	12.882	20.212	29.158				
				4840	6461	8316	13050	18821	Internal Area (mm^2)			
Size (AWG/ kcmil)	Cable O.D. (in.)	Cable Area (in^2)	Equipment Grounding (AWG/ kcmil)[4]	Maximum Number of Cables					Size (mm^2)	Cable O.D. (mm)	Cable Area (mm^2)	Equipment Grounding (mm^2)[4]
2	2.04	3.27	6	1	1	1	2	3	33.62	51.82	2109	13.30
1/0	2.20	3.80	4	1	1	1	2	3	53.49	55.88	2452	21.15
2/0	2.30	4.16	4	1	1	1	2	3	67.43	58.42	2680	21.15
4/0	2.52	4.99	3		1	1	1	2	107.2	64.01	3218	26.67
250	2.66	5.56	2		1	1	1	2	127	67.56	3585	33.62
350	2.94	6.79	2			1	1	1	177	74.68	4380	33.62
500	3.21	8.09	1			1	1	1	253	81.53	5221	42.41
750	3.61	10.24	1/0				1	1	380	91.96	6603	53.49
1000	3.99	12.50	2/0				1	1	507	101.35	8067	67.43

Notes:
(1) Raceway fill based on 2011 NEC, Chapter 9, Tables 1 and 4.
(2) 40% fill for 3 or more conductors, 31% for 2 conductors, and 53% for a single conductor.
(3) In accordance with Note 7 to the NEC Tables, the next higher whole number of conductors was used when the calculations yielded a decimal of 0.8 or larger.
(4) The equipment grounding conductor may be sectioned into 2 or 3 equal segments as permitted in 310.13 of the 2008 NEC.

Table 3.7.4.3.3.3 — Maximum Number of Three Conductor Cables Permitted in RMC

3/C Uniblend® LF 25 kV (133%) and 35 kV (100%) with Equipment Grounding Conductor (Spec 6605)

(The highlighted boxes indicate probable jamming, See 3.7.4.3)

RMC Trade Size				3½ 91	4 103	5 129	6 155	RMC Metric Designator			
Internal Area (in²)				10.010 6461	12.882 8316	20.212 13050	29.158 18821	Internal Area (mm²)			
Size (AWG/ kcmil)	Cable O.D. (in.)	Cable Area (in²)	Equipment Grounding (AWG/ kcmil)⁴	Maximum Number of Cables				Size (mm²)	Cable O.D. (mm)	Cable Area (mm²)	Equipment Grounding (mm²)⁴
1/0	2.73	5.85	4	1	1	1	2	53.49	69.34	3776	21.15
2/0	2.81	6.20	4	1	1	1	2	67.43	71.37	4001	21.15
4/0	3.10	7.55	3		1	1	1	107.2	78.74	4869	26.67
250	3.21	8.09	2		1	1	1	127	81.53	5221	33.62
350	3.42	9.19	2			1	1	177	86.87	5927	33.62
500	3.68	10.64	1			1	1	253	93.47	6862	42.41
750	4.10	13.20	1/0			1	1	380	104.14	8518	53.49

Notes:
(1) Raceway fill based on 2011 NEC, Chapter 9, Tables 1 and 4.
(2) 40% fill for 3 or more conductors, 31% for 2 conductors, and 53% for a single conductor.
(3) In accordance with Note 7 to the NEC Tables, the next higher whole number of conductors was used when the calculations yielded a decimal of 0.8 or larger.
(4) The equipment grounding conductor may be sectioned into 2 or 3 equal segments as permitted in 310.13 of the 2008 NEC.

3.7.4.4 Supporting Conductors in Vertical Raceways

Conductors or cables in vertical raceways must be supported if the vertical rise exceeds the lengths shown in Table 3.7.4.4. The conductors must be supported independently of the terminal connections and must not impose any damaging strain on the terminals of any electrical apparatus or device.

One cable support must be provided at the top of the vertical raceway or as close to the top as practical. Intermediate supports must be provided as necessary so the supported conductor length does not exceed the values in Table 3.7.4.4.

Supports must maintain the continuity of the raceway or cable system and not damage the conductors or their coverings. Conductors in raceways must not hang over the edges of bushings, bends or fittings of any kind in such a manner that the insulation or covering may be damaged.

Refer to 300.19 for additional information on support methods and the exception for steel wire armor cable.

For conductors over 600 V, use either the lengths in Table 3.7.4.4 or 70 lb per clamp for single conductor, whichever is the shortest length. Wrap the single conductors with two half-lapped layers of jacketing tape under the clamp.

Table 3.7.4.4 Maximum Spacing for Conductor Supports in Vertical Raceways

Conductor Size	Conductor Material			
	Copper		Aluminum or Copper-Clad Aluminum	
	(ft)	(m)	(ft)	(m)
18 to 8 AWG	100	30	100	30
6 to 1/0 AWG	100	30	200	60
2/0 to 4/0 AWG	80	25	180	55
Over 4/0 AWG to 350 kcmil	60	18	135	41
Over 350 to 500 kcmil	50	15	120	36
Over 500 to 750 kcmil	40	12	95	28
Over 750 kcmil	35	11	85	26

3.7.4.5 Ampacity

The allowable ampacity for insulated conductors, multi-conductor cables or multiplexed assemblies is limited to the conditions specified in the applicable NEC Tables in Article 310.

3.7.4.5.1 2000 V or Less. Refer to NEC 310.15 Ampacities for Conductors Rated 0–2000 Volts and Table 310.15(B)(16), for the allowable ampacities and limitations for single and multiple conductors and multi-conductor cables installed in raceways or underground electrical ducts.

Table 310.15(B)(16) Allowable Ampacities of Insulated Conductors Rated 0 Through 2000 Volts, 60°C Through 90°C (140°F Through 194°F), Not More Than Three Current-Carrying Conductors in Raceway, Cable or Earth (Directly Buried), Based on Ambient Temperature of 30°C (86°F).

Correction factors for ambient temperatures other than 30ºC (86°F) are provided in the NEC Tables and adjustment factors for more than three current-carrying conductors in a raceway or cable are provided in 310.15(B)(2).

NEC Annex B provides additional application information for ampacities calculated under engineering supervision, as permitted in 310.15(A)(1) and 310.15(C), and addresses installations in raceways in free air and in underground electrical ducts for insulated conductors rated 0 to 2000 volts.

3.7.4.5.2 Over 2000 V. Refer to NEC 310.60(B), (C), and (D) Ampacities of Conductors Rated 2001 to 35,000 Volts and the following Tables for the allowable ampacities and limitations for medium-voltage single conductors, triplexed assemblies and three conductor cables installed in raceways in air.

Table 310.60(C)(73) Ampacities of an Insulated Triplexed or Three Single-Conductor Copper Cables in Isolated Conduit in Air Based on Conductor Temperatures of 90°C (194°F) and 105°C (221°F) and Ambient Air Temperature of 40°C (104°F).

Table 310.60(C)(74) Ampacities of an Insulated Triplexed or Three Single-Conductor Aluminum Cables in Isolated Conduit in Air Based on Conductor Temperatures of 90°C (194°F) and 105°C (221°F) and Ambient Air Temperature of 40°C (104°F).

Table 310.60(C)(75) Ampacities of an Insulated Three-Conductor Copper Cable in Isolated Conduit in Air Based on Conductor Temperatures of 90°C (194°F) and 105°C (221°F) and Ambient Air Temperature of 40°C (104°F).

3.7.4.5.2 Over 2000 V. (cont'd)

Table 310.60(C)(76) Ampacities of an Insulated Three-Conductor Aluminum Cable in Isolated Conduit in Air Based on Conductor Temperatures of 90°C (194°F) and 105°C (221°F) and Ambient Air Temperature of 40°C (104°F).

Refer to NEC Figure 310.60 and the following Tables for the allowable ampacities and limitations for medium-voltage single conductors and three conductor cables installed in underground electrical ducts, see 310.60(A) definition.

NEC Annex B, Figures 310.3 through 310.5 may also be utilized under engineering supervision for conductors rated up to 5000 V installed in underground electrical ducts.

Table 310.60(C)(77) Ampacities of Three Single-Insulated Copper Conductors in Underground Electrical Ducts (Three Conductors per Electrical Duct) Based on Ambient Earth Temperature of 20°C (68°F), Electrical Duct Arrangement per Figure 310.60, 100 Percent Load Factor, Thermal Resistance (RHO) of 90, Conductor Temperatures of 90°C (194°F) and 105°C (221°F).

Table 310.60(C)(78) Ampacities of Three Single-Insulated Aluminum Conductors in Underground Electrical Ducts (Three Conductors per Electrical Duct) Based on Ambient Earth Temperature of 20°C (68°F), Electrical Duct Arrangement per Figure 310.60, 100 Percent Load Factor, Thermal Resistance (RHO) of 90, Conductor Temperatures of 90°C (194°F) and 105°C (221°F).

Table 310.60(C)(79) Ampacities of Three Insulated Copper Conductors Cabled Within an Overall Covering (Three-Conductor Cable) in Underground Electrical Ducts (One Cable per Electrical Duct) Based on Ambient Earth Temperature of 20°C (68°F), Electrical Duct Arrangement per Figure 310.60, 100 Percent Load Factor, Thermal Resistance (RHO) of 90, Conductor Temperatures of 90°C (194°F) and 105°C (221°F).

Table 310.60(C)(80) Ampacities of Three Insulated Aluminum Conductors Cabled Within an Overall Covering (Three-Conductor Cable) in Underground Electrical Ducts (One Cable per Electrical Duct) Based on Ambient Earth Temperature of 20°C (68°F), Electrical Duct Arrangement per Figure 310.60, 100 Percent Load Factor, Thermal Resistance (RHO) of 90, Conductor Temperatures of 90°C (194°F) and 105°C (221°F).

3.7.5 CEC

A raceway is defined as any channel designed for holding wires, cables, or busbars and, unless otherwise qualified in the Rules of the CEC, the term includes conduit (rigid and flexible, metal and non-metallic), electrical metallic and non-metallic tubing, underfloor raceways, cellular floors, surface raceways, wireways, cable trays, busways, and auxiliary gutters.

3.7.5.1 CEC Raceway Tables

3.7.5.1.1 Radii of Bends in Raceways. In accordance with Rule 12-922, where conductors are drawn into a raceway, the radius of the curve to the centre line of any bend shall be not less than shown in Table 3.7.5.1.1 and bends shall be made without undue distortion of the raceway and without injury to its inner or outer surfaces.

Table 3.7.5.1.1 Radius of Conduit Bends

Trade Size of Conduit or Tubing	Minimum Radius to Centre of Conduit or Tubing Bends (mm)
16	102
21	114
27	146
35	184
41	210
53	241
63	267
78	330
91	381
103	406
129	610
155	762

Ref: CEC Part 1, Table 7

3.7.5.1.2 Cross-Sectional Areas of Conduit and Tubing. The cross-sectional areas for each size conduit and tubing are shown in CEC Table 9. Refer to Rule 12-1014 for additional information.

3.7.5.2 CEC Raceway Fill Tables

3.7.5.2.1 Maximum Allowable Raceway Fill. The maximum allowable conduit and tubing fill is 53% for one, 31% for two, and 40% for three or more conductors or multi-conductor cables that are not lead-sheathed. Refer to Rules 12-1014 and 38-032 and Table 8 for additional information.

3.7.5.2.2 Maximum Number of Conductors. Refer to Rule 12-1014 and CEC Table 6 for the maximum number of conductors of one size allowed in trade sizes of conduit or tubing.

3.7.5.2 CEC Raceway Fill Tables (cont'd)

3.7.5.2.3 Cable Dimensions. The insulated conductor dimensions for calculating conduit and tubing fill are shown in CEC Table 10. Refer to Rule 12-1014 for additional information.

3.7.5.3 Supporting Conductors in Vertical Raceways

Conductors in vertical raceways must be supported independently of the terminal connections and at intervals not exceeding the lengths specified in Table 3.7.5.3.

Refer to Rule 12-120 for additional information on supporting of conductors.

Table 3.7.5.3 Maximum Spacing for Conductor Supports in Vertical Raceways

Conductor Sizes (AWG or kcmil)	Maximum Distance (m)	
	Copper	Aluminum
14 to 8	30	30
6 to 1/0	30	60
2/0 to 4/0	24	55
250 to 350	18	40
Over 350 to 500	15	35
Over 500 to 750	12	30
Over 750	10	25

3.7.5.4 Ampacity of Conductors Rated 2000 Volts or Less

The allowable ampacities for not more than 3 conductors in a raceway or cable, based on an ambient temperature of 30ºC are provided in CEC Table 2 for copper conductors and in Table 4 for aluminum conductors.

The allowable ampacities for single conductors in a raceway or cable, based on an ambient temperature of 30ºC are provided in CEC Table 2 for copper conductors and in Table 4 for aluminum conductors.

The maximum allowable conductor temperature for wires and cables is provided in Table 19.

Refer to Rules 4-004, 8-104, 26-142, 42-008, and 42-016 and Tables 5A, 5C, 19, and D3 for additional information.

3.7.5.5 Ampacity Correction Factors

Table 5A provides the ampacity correction factors applying to Tables 1, 2, 3 and 4 for ambient temperatures above 30°C, refer to Rules 4-004(8) and 12-2210.

Where from 2 to 4 single conductors are present and in contact, Table 5B provides the ampacity correction factors for Tables 1 and 3; refer to Rule 4-004(9).

Table 5C provides ampacity correction factors for Tables 2 and 4 when there are more than 3 conductors in a raceway or cable. Refer to Rules 4-004 and 12-2210 for additional information.

3.7.5.5 Ampacity Correction Factors (cont'd)

The maximum allowable ampacities for neutral supported cables are provided in Table 36A for aluminum conductors and Table 36B for copper conductors.

3.7.6 Non-Code Installations

This information is provided for those installations where an electrical code is not applicable or not enforced.

3.7.6.1 Schedule 40 PE/PVC Conduit

The dimensional data in Table 3.7.6.1 is in accordance with ASTM D1785-06, Standard Specification for Polyvinyl Chloride (PVC) Plastic Pipe, Schedules 40, 80, and 120 and ASTM D2447-03, Standard Specification for Polyethylene (PE) Plastic Pipe, Schedules 40 and 80, Based on Outside Diameter.

Table 3.7.6.1 Schedule 40 PE/PVC Conduit Information

Conduit Size											
Metric Designator	Trade Size (in.)	ID (in.)	ID (mm)	OD (in.)	OD (mm)	WALL (in.)	WALL (mm)	AREA [1] (in²)	AREA [1] (mm²)	40% AREA [2] (in²)	40% AREA [2] (mm²)
16	½	0.622	15.80	0.840	21.34	0.109	2.77	0.30	196	0.12	78
21	¾	0.824	20.93	1.050	26.67	0.113	2.87	0.53	344	0.21	138
27	1	1.049	26.64	1.315	33.40	0.133	3.38	0.86	557	0.35	223
35	1¼	1.380	35.05	1.660	42.16	0.140	3.56	1.49	964	0.60	386
41	1½	1.610	40.89	1.900	48.26	0.145	3.68	2.03	1313	0.81	525
53	2	2.067	52.50	2.375	60.33	0.154	3.91	3.35	2164	1.34	866
63	2½	2.469	62.71	2.875	73.03	0.203	5.16	4.79	3087	1.92	1235
78	3	3.068	77.93	3.500	88.90	0.216	5.49	7.39	4767	2.96	1907
91	3½	3.548	90.12	4.000	101.60	0.226	5.74	9.88	6375	3.95	2550
103	4	4.026	102.26	4.500	114.30	0.237	6.02	12.72	8209	5.09	3284
129	5	5.047	128.19	5.563	141.30	0.258	6.55	20.00	12900	8.00	5160
155	6	6.065	154.05	6.625	168.28	0.280	7.11	28.88	18629	11.60	7452
–	8	7.981	202.72	8.625	219.08	0.322	8.18	50.00	32259	20.00	12904
–	10	10.020	254.51	10.750	273.05	0.365	9.27	78.81	50848	31.50	20339
–	12	11.930	303.02	12.750	323.85	0.406	10.31	111.73	72081	44.80	28832

[1] Area = $(\pi/4) \times (ID)^2$
[2] 40% Area = $(\pi/4) \times (ID)^2 \times (0.4)$

3.7.6.2 Duct Information

The dimensional information in Table 3.7.6.2 for underground ducts is in accordance with data published by the duct manufacturers.

Table 3.7.6.2 Rigid Duct Dimensional Data

Trade Size	EMT			IMC Type I		IMC Type II		PVC = EPC 40			PVC = EPC 80	
	O.D. (in.)	Wall (in.)	Elbow	O.D. (in.)	Wall (in.)	O.D. (in.)	Wall (in.)	O.D. (in.)	Wall (in.)	Elbow	O.D. (in.)	Wall (in.)
3/8	0.577	0.042	-	-	-	-	-	-	-	-	-	-
½	0.706	0.042	4.0	0.815	0.070	0.084	0.094	0.84	0.109	4	0.84	0.147
¾	0.922	0.049	4.5	1.029	0.075	1.05	0.098	1.05	0.113	4.5	1.05	0.154
1	1.163	0.057	5.75	1.29	0.085	1.315	0.118	1.315	0.133	5.75	1.315	0.179
1 ¼	151	0.065	7.37	1.638	0.085	1.66	0.122	1.66	0.140	7.25	1.66	0.191
1 ½	1.74	0.065	8.62	1.883	0.090	1.9	0.123	1.9	0.145	8.25	1.9	0.2
2	2.197	0.065	9.5	2.361	0.095	2.375	0.125	2.375	0.154	9.5	2.375	0.218
2 ½	2.875	0.072	10.5	2.857	0.140	2.875	0.171	2.875	0.203	10.5	2.875	0.276
3	3.5	0.072	13	3.476	0.140	3.5	0.176	3.5	0.216	1.3	3.5	0.3
3 ½	4	0.083	15	3.971	0.140	4.0	0.176	4.0	0.226	15	4	0.318
4	4.5	0.083	1.6	4.466	0.140	4.5	0.178	4.5	0.237	16	4.5	0.337
5	-	-	-	-	-	-	-	5.563	0.258	24	5.563	0.375
6	-	-	-	-	-	-	-	6.625	0.28	30	6.625	0.432

Fibre			
Size	Enc.	O.D. (in.)	DB
1	1.38	-	-
1 ½	2	-	2.22
2	2.5	-	2.8
2 ½	3	-	3.36
3	3.5	-	3.9
3 ½	4.06	-	4.46
4	4.6	5	3
4 ½	5.12	5.56	-
5	5.75	-	-
6	6.75	-	-

PVC = EPT		
Size	O.D. (in.)	Wall
½	0.84	0.06
¾	1.05	0.06
1	1.32	0.06
1 ¼	1.66	0.07
1 ½	1.9	0.08
2	2.375	0.1
2 ½	2.875	0.11
3	3.5	0.125
4	4.5	0.15

PVC = Utilities-EB			
Size	O.D. (in.)	Wall	Elbow
2	2.375	0.06	18
3	3.5	0.067	18
3 ½	4.0	0.090	24
4	4.5	0.089	18
5	5.563	0.112	-
6	6.625	0.135	-

PVC = Utilities-DB			
Size	O.D. (in.)	Wall	Elbow
1 ½	1.9	0.073	18
2	2.375	0.065	18
3	3.5	0.100	18
3 ½	4.0	0.107	24
4	4.5	0.131	18
5	5.563	0.164	36
6	6.625	0.196	36

Transite = EB			
Size	O.D. (in.)	Wall	Elbow
3	3.58	0.29	36
3 ½	4.1	0.3	36
4	4.6	0.3	36
5	5.66	0.33	48
6	6.88	0.34	48

Transite = DB			
Size	O.D. (in.)	Wall	Elbow
3	3.75	0.37	36
4	4.74	0.37	36
5	5.8	0.4	48
6	6.8	0.4	48

All sizes and dimensions are in inches.

3.7.6.3 Supporting Conductors in Vertical Raceways

For installations not subject to Code installation requirements, the following equa-tion may be used to calculate the maximum vertical distance between supports.

$$F = \frac{AT}{LW}$$

Where: A = conductor area (sq in.)
T = conductor tensile strength (lb/in.^{2})
L = length (ft)
W = cable weight (lb/ft)
F = minimum safety factor = 7, unless otherwise required by the Authority Having Jurisdiction (AHJ)

$$A = \frac{\text{cmil } \pi}{4000000}$$

Where: cmil = circular mil area of the conductor

Example: Suspend 470 ft of 15 kV cable containing three 4/0 AWG soft-drawn copper conductors, 1080 lb/1000 ft weight, each supported at the top, with full tension terminals:

$$F = \frac{[(211600)\ (\pi/4)/1\ 000\ 000]\ 24\ 000}{[(470)\ (1080/1000)]} = 7.9 = \text{OK}$$

For additional information, refer to 7.4.4 in ANSI/ICEA S-93-639/WC 74, 5-46 kV *Shielded Power Cable for Use in the Transmission and Distribution of Electric Energy.*

3.8 GENERAL CABLE INSULATED CONDUCTOR AND CABLE DIMENSIONS

Additional information on the General Cable products included in this Manual and information on other General Cable products is available on the General Cable website at www.generalcable.com or in the General Cable Industrial Catalog.

3.9 PHYSICAL LIMITATIONS OF CABLES

Another major consideration in any cable installation is the physical limitations of the cable as it is being pulled into position. The cable is subjected to extreme stress during pulling and, if not done properly, can distort or displace cable components and affect its integrity and performance. Therefore, it is very important that the following guidelines be observed.

- Calculate and do not exceed the maximum pulling tension, maximum sidewall bearing pressure or the minimum bending radius.
- Verify that the raceway or cable tray system is completely installed prior to cable installation and that the wiring space is adequate.
- Train the cable to avoid dragging it on the edge of the raceway or cable tray.
- When using a basket grip, it must be securely fastened to the cable. Once the cable is installed, cut the cable behind the location of the basket grip.
- The elongation characteristics of the pull rope should provide a constant and smooth pulling tension.

3.9 PHYSICAL LIMITATIONS OF CABLES (cont'd)

- Pull no faster than 40 ft (12 m) per minute.
- Pull with a capstan, whenever possible.
- Do not stop a pull unless absolutely necessary.
- Never pull the middle of the cable.
- Seal the cable ends of medium-voltage cable with an end seal with mastic coating inside.

3.9.1 Maximum Pulling Tensions

Excessive pulling tension can cause separation and displacement of cable components. This can cause voids that become the focal points for corona deterioration in medium-voltage cables.

Pulling Tension should not be greater than the smallest of the maximum allowable pulling tensions for conductors shown in Table 3.9.1.2.2 or for multi-conductor cables in Table 3.9.1.2.3 or the following values:

- Allowable Tension on Pulling Device (3.9.1.1)
- Allowable Tension on Conductor (3.9.1.2)
- Allowable Sidewall Bearing Pressure (3.9.2)

3.9.1.1 Allowable Tension on Pulling Device

The working load specified by the manufacturer of the pulling devices (pulling eyes, ropes, anchors, basket grips, etc.) should not be exceeded.

The maximum allowable tension when pulling with a basket grip is 1000 lbs or the appropriate values in 3.9.1.2.2 and 3.9.1.2.3, whichever is smaller. Exceptions to this limitation are the following General Cable products, for which the upper limit is 1250 lbs – DuraSheath® EPR, Unicon® FREP®, and Unicon® XLPE.

3.9.1.2 Allowable Tension on Conductor

The metal in the conductor is the strength member and should bear all the pulling forces. Therefore, the maximum pulling tensions are proportional to the conductor cross-sectional area. Equipment grounding conductors, shielding drain wires or braids should never be used for pulling or included in the calculations.

Table 3.9.1.2 provides the tensile strength per unit area of the metallic conductor. Three-quarter (3/4) hard aluminum is permitted for power cable. AWM, which is a UL aluminum designation, is required for UL Listed 600 V solid aluminum conductors 8 AWG and smaller; it may be used for larger sizes.

Table 3.9.1.2 Conductor Pulling Tensions

Material	Cable Type	Temper	lb/cmil
Copper	All	Soft	0.008
Aluminum	Power	Hard	0.008
Aluminum	Power	¾ Hard	0.006
Aluminum	Power and Control	AWM	0.005

3.9.1.2 Allowable Tension on Conductor (cont'd)

The maximum pulling tension, based on the conductor tensile strength, may be calculated using the following equations, where T_{total} is the total allowable pulling tension, n is the number of conductors, and $T_{1/C}$ is the maximum allowable tension for one conductor.

$T_{1/C}$ = conductor size (cmil) x lb/cmil factor in Table 3.9.1.2

Single Conductors in Parallel

The maximum pulling tension for single conductors pulled in parallel may be calculated using the formulas below. When pulling three single conductors of equal size that are not cabled or triplexed, n = 2 rather than 3, since two of the conductors may be subjected to the total pulling tension.

$n < 3 \quad T_{total} = n \times T_{1/C}$

$n = 3 \quad T_{total} = 2 \times T_{1/C}$

$n > 3 \quad T_{total} = n \times T_{1/C} \times 0.8$

Three-Conductor or Triplexed Assembly

The maximum pulling tension for a three-conductor or triplexed assembly.

$T_{total} = 3 \times T_{1/C}$

Cabled or Multiplexed Assemblies

The maximum pulling tension for cabled or multiplexed assemblies.

For cables 8 AWG (8.37 mm^2) and larger with 3 to 5 conductors.

$T_{total} = n \times T_{1/C}$

For cables smaller than 8 AWG (8.37 mm^2), or cables 8 AWG (8.37 mm^2) and larger with 6 or more conductors, that do not contain any twisted subassemblies.

$T_{total} = n \times T_{1/C} \times 0.8$

For cables with twisted subassemblies.

$T_{total} = n \times T_{1/C} \times 0.6$

Reduce the maximum pulling tension by 20% to 40% if several conductors are being pulled simultaneously since the tension is not always evenly distributed among the conductors.

While General Cable does not recommend the practice, we recognize that some users pull a combination of conductor sizes simultaneously, observing the maximum pulling tension of the largest conductors. During such a pull, the smaller cables may get crushed at bends or may have the pulling forces transferred to them momentarily, which greatly exceeds their tensile strength.

3.9.1.2.1 Conductor Diameters

The following Tables provide the data necessary to calculate the maximum allowable tensions on the conductors. The nominal conductor diameters are provided in inches in Table 3.9.1.2.1.1 and in mm in Table 3.9.1.2.1.2.

Table 3.9.1.2.1.1 Nominal Conductor Diameters (in.)

For Copper and Aluminum Conductors

Conductor Size		Solid	Concentric Lay Stranded		Unilay Compressed
AWG	kcmil		Compact [1]	Compressed	
18	1.62	0.0403	-	-	-
16	2.58	0.0508	-	-	-
14	4.11	0.0641	-	-	-
12	6.53	0.0808	-	-	-
10	10.38	0.1019	-	-	-
9	13.09	0.1144	-	-	-
8	16.51	0.1285	0.134	0.141	-
7	20.82	0.1443	-	0.158	-
6	26.24	0.1620	0.169	0.178	-
5	33.09	0.1819	-	0.200	-
4	41.74	0.2043	0.213	0.225	-
3	52.62	0.2294	0.238	0.252	-
2	66.36	0.2576	0.268	0.283	-
1	83.69	0.2893	0.299	0.322	0.313
1/0	105.60	0.3249	0.336	0.362	0.352
2/0	133.10	0.3648	0.376	0.406	0.395
3/0	167.80	0.4096	0.423	0.456	0.443
4/0	211.60	0.4600	0.475	0.512	0.498
-	250	0.5000	0.520	0.558	0.542
-	300	0.5477	0.570	0.611	0.594
-	350	0.5916	0.616	0.661	0.641
-	400	0.6325	0.659	0.706	0.685
-	450	0.6708	0.700	0.749	0.727
-	500	0.7071	0.736	0.789	0.766
-	550	-	0.775	0.829	0.804
-	600	-	0.813	0.866	0.840
-	650	-	0.845	0.901	0.874
-	700	-	0.877	0.935	0.907
-	750	-	0.908	0.968	0.939
-	800	-	0.938	1.000	0.969
-	900	-	0.999	1.061	1.028
-	1000	-	1.060	1.117	1.084

[1] Diameters shown are for compact round, compact modified concentric and compact single input wire.

Table 3.9.1.2.1.2 Nominal Conductor Diameters (mm)

For Copper and Aluminum Conductors

Conductor Size		Solid	Concentric Lay Stranded		Unilay Compressed
AWG	kcmil		Compact [1]	Compressed	
18	0.82	1.02	-	-	-
16	1.31	1.29	-	-	-
14	2.08	1.63	-	-	-
12	3.31	2.05	-	-	-
10	5.26	2.59	-	-	-
9	6.63	2.91	-	-	-
8	8.37	3.26	3.40	3.58	-
7	10.60	3.67	-	4.01	-
6	13.30	4.11	4.29	4.52	-
5	16.80	4.62	-	5.08	-
4	21.10	5.19	5.41	5.72	-
3	26.70	5.83	6.05	6.40	-
2	33.60	6.54	6.81	7.19	-
1	42.40	7.35	7.59	8.18	7.95
1/0	53.50	8.25	8.53	9.19	8.94
2/0	67.40	9.27	9.55	10.3	10.0
3/0	85	10.40	10.7	11.6	11.3
4/0	107	11.70	12.1	13.0	12.6
250	127	12.70	13.2	14.2	13.8
300	152	13.90	14.5	15.5	15.1
350	177	15.00	15.6	16.8	16.3
400	203	16.10	16.7	17.9	17.4
450	228	17.0	17.8	19.0	18.5
500	253	18.0	18.7	20.0	19.5
550	279	-	19.7	21.1	20.4
600	304	-	20.7	22.0	21.3
650	329	-	21.5	22.9	22.2
700	355	-	22.3	23.7	23.0
750	380	-	23.1	24.6	23.9
800	405	-	23.8	25.4	24.6
900	456	-	25.4	26.9	26.1
1000	507	-	26.9	28.4	27.5

[1] Diameters shown are for compact round, compact modified concentric and compact single input wire.

3.9.1.2.2 Conductors in Parallel or in Assemblies.

Table 3.9.1.2.2 provides the maximum allowable pulling tensions when conductors are pulled in parallel or as multiplexed assemblies using a compression type attachment secured directly to the conductors.

When a basket grip is used over paralleled conductors or a multiplexed assembly, the maximum allowable pulling tension is limited to 1000 lbs or the values in Table 3.9.1.2.2, whichever is less.

Exceptions to this limitation are the following General Cable products, for which the upper limit is 1250 lbs - DuraSheath® EPR, Unicon® FREP®, and Unicon® XLPE.

Since the pulling tensions shown in Table 3.9.1.2.2 are maximum values and a cable pull is a complete system, it is limited by the weakest link. Under no circumstances, should the pulling tension exceed the smallest value of (1) conductor maximum allowable pulling tension, (2) sidewall bearing pressure, (3) the tension capability of the pulling device or tugger, or (4) 10,000 lbs.

The values are based on soft drawn copper or hard drawn aluminum conductors. The Table may also be used for hard temper (H-19) aluminum conductors. For all other UL Listed cables with other aluminum conductor characteristics, use one-half of the values in the Tables.

When more than two conductors are pulled in parallel in an installation containing bends, the maximum allowable pulling tension is limited to the two conductor column, regardless of the number of conductors that are being pulled. Tension forces for paralleled or cradled cables are assumed to be evenly distributed among the three conductors only when pulling in a straight line. Since most pulls involve bends, the forces are not evenly distributed, and it is conservative to assume that tension forces are shared by only two conductors. Therefore, the number of conductors [value of n in the Equation] is equal to two for the paralleled or cradled cable case. For triplexed cables, the value of n can remain as 3 since due to the cabling of the conductors, the pulling force will distribute evenly. A factory-assembled triplexed cable should be treated the same as a multi-conductor cable with regard to pulling tension, sidewall pressure, and weight correction factor.

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Table 3.9.1.2.2 Maximum Allowable Pulling Tensions (lb) for Conductors in Parallel or in Assemblies [1]

AWG/ kcmil	Number of Conductors					
	1	2	3	4	5	6
18	13	26	39	41	52	62
16	20	40	60	65	81	97
14	33	66	99	105	132	158
12	52	104	157	167	209	251
10	83	166	249	266	332	399
8	132	264	396	423	528	634
6	210	420	630	672	840	1008
4	334	668	1002	1069	1336	1603
2	531	1062	1593	1699	2124	2548
1	670	1339	2009	2142	2678	3214
1/0	845	1690	2534	2703	3379	4055
2/0	1065	2130	3194	3407	4259	5111
3/0	1342	2685	4027	4296	5370	6444
4/0	1693	3386	5078	5417	6771	8125
250	2000	4000	6000	6400	8000	9600
350	2800	5600	8400	8960	10000	10000
500	4000	8000	10000	10000	10000	10000
750	6000	10000	10000	10000	10000	10000
1000	8000	10000	10000	10000	10000	10000

[1] The maximum allowable pulling tensions are for direct attachment to the conductor.

$T = 0.008 \times \text{cmil} \times n$, if $n \leq 3$
$T = 0.008 \times \text{cmil} \times n \times 0.8$, if $n > 3$

3.9.1.2.3 Multi-Conductor Cables

Table 3.9.1.2.3 provides the maximum allowable pulling tensions when multi-conductor cables are pulled into a raceway or cable tray using a basket grip or similar device secured directly to the cable jacket. The pulling tensions are for multi-conductor cables with all the same size conductors and no subassemblies.

The maximum allowable pulling tension must not exceed the values in Table 3.9.1.2.3, the sidewall bearing pressure, the pulling device tension capability, or 1000 lbs, whichever is lower. The pulling tensions are based on soft drawn copper conductors.

Table 3.9.1.2.2 may be used for multi-conductor cables with all the same size conductors and no subassemblies when a compression type attachment is secured directly to the conductors.

Contact General Cable for the maximum allowable pulling tensions for cables containing a number of conductors not shown in the Table or when the cable includes subassemblies.

Table 3.9.1.2.3 Maximum Allowable Pulling Tensions (lb) for Multi-Conductor Cables[1]

Number of Conductors	Conductor Size (AWG)				
	18	16	14	12	10
2	26	40	66	104	166
3	39	60	99	157	249
4	41	65	105	167	266
5	52	81	132	209	332
6	62	97	158	251	399
7	73	113	184	293	465
8	83	129	210	334	531
9	93	145	237	376	598
10	104	161	263	418	664
12	124	194	316	502	797
14	145	226	368	585	930
15	156	242	395	627	996
16	166	258	421	669	1000
18	187	290	473	752	1000
19	197	306	500	794	1000
20	207	323	526	836	1000
22	228	355	549	919	1000
24	249	387	631	1000	1000
25	259	403	658	1000	1000
30	311	484	789	1000	1000
37	383	596	974	1000	1000

[1] The maximum allowable pulling tensions are for multi-conductor cables pulled into a raceway or cable tray using a basket grip or similar device secured directly to the cable jacket. It is recommended that a combination of basket grips and pulling eyes be used whenever possible.

$T = 0.008 \times cmil \times n$, if $n \leq 3$
$T = 0.008 \times cmil \times n \times 0.8$, if $n > 3$

3.9.1.3 Tension Calculations

These tension calculations are for estimating the forces due to dynamic friction; they do not take into account bending forces. The bending forces will vary with cable construction and material stiffness, especially with conductor hardness.

The following symbols are used in this section:

cmil = circular mil = area of a circle having diameter of 0.001 inch = $D^2 \times 10^6$

d = overall diameter of a single conductor or a multi-conductor cable

D = inside diameter of circular raceway

f = coefficient of friction

Degree	Radians
360ºC	2π
180ºC	π
90ºC	$\pi/2$
45ºC	$\pi/4$
30ºC	$\pi/6$

L = length of duct run (ft)

L_m = maximum length (ft)

kcmil = thousands of circular mils

n = number of conductors

P_m = sidewall load limit (lb/ft)

R = radius of bend (ft)

SWBP = sidewall bearing pressure (lb/ft)

T_n = pulling tension at point “n”

T_{max} = maximum tension (lb)

W = cable weight (lb/ft)

w_c = weight correction factor

θ = angle of deviation = radians = degree x π /180

$e = 2.718$

$\pi = 3.142$

$\sqrt{2} = 1.414$

$\sqrt{3} = 1.732$

$\sinh x = (e^x - e^{-x})/2$ $\pi/4 = 0.7854$ $\cosh x = (e^x - e^{-x})/2$

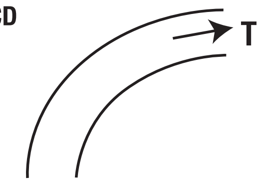
If $T_{out} < 0$, use zero as tension for next section of raceway.

3.9.1.3.1 Vertical Bend, Pulling Up

Convex Bend – Upward Pull (VUCD)

$$T_{out} = T_{in}e^{w_c f\theta} + \frac{WR}{1+(w_c f)^2}\left[2w_c f e^{w_c f}\sin\theta + (1-w_c^2 f^2)(1-e^{w_c f\theta}\cos\theta)\right]$$

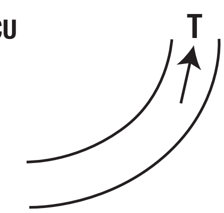
Fig. 3.9.1.3.1 VUCD



Concave Bend – Upward Pull (VUCU)

$$T_{out} = T_{in}e^{w_c f\theta} - \frac{WR}{1+(w_c f)^2}\left[2w_c f\sin\theta - (1-w_c^2 f^2)(e^{w_c f\theta}-\cos\theta)\right]$$

Fig. 3.9.1.3.1 VUCU

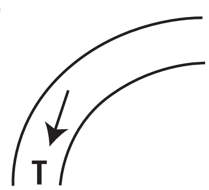


3.9.1.3.2 Vertical Bend, Pulling Down

Convex Bend – Pulling Down (VDCD)

$$T_{out} = T_{in}e^{w_c f\theta} + \frac{WR}{1+(w_c f)^2}\left[2w_c f\sin\theta - (1-w_c^2 f^2)(e^{w_c f\theta}-\cos\theta)\right]$$

Fig. 3.9.1.3.2 VDCD

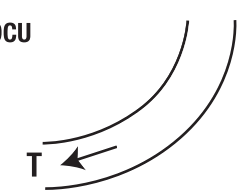


Concave Bend – Downward Pull (VDCU)

$$T_{out} = T_{in}e^{w_c f\theta} - \frac{WR}{1+(w_c f)^2}\left[2w_c e^{w_c f}\sin\theta + (1-w_c^2 f^2)(1-e^{w_c f\theta}\cos\theta)\right]$$

If T in $\leq$ WR, use the equation for concave down.

Fig. 3.9.1.3.2 VDCU



3.9.1.3.3 Horizontal Pull

Straight section $T = w_c fWL + \text{(Prior tension)}$

Maximum length $L_m = \dfrac{T_m}{w_c fW}$

3.9.1.3.4 Incline Pull

Upward $T = WL(\sin\theta + w_c f\cos\theta) + \text{(Prior tension)}$

Downward $T = -WL(\sin\theta - W_c f\cos\theta) + \text{(Prior tension)}$

3.9.1.3.5 Horizontal Bend

$T_{out} = T_{in}\cosh w_c f\theta + (\sinh w_c f\theta)\sqrt{(T_{in})^2 + (WR)^2}$

3.9.1.3.6 Bend Approximation

If $T_{in} > 10\ WR$ then $T_{out} = T_{in}e^{w_c f\theta}$

3.9.1.3.7 Arches

$$R = \frac{Z^2 + 4H^2}{8H}$$

$$\theta^o = \frac{360}{\pi}\sin^{-1}\frac{Z}{2R}$$

$$S = 2R\cos^{-1}\frac{R-H}{R}$$

$$\beta = \tan^{-1}\frac{2H}{Z}$$

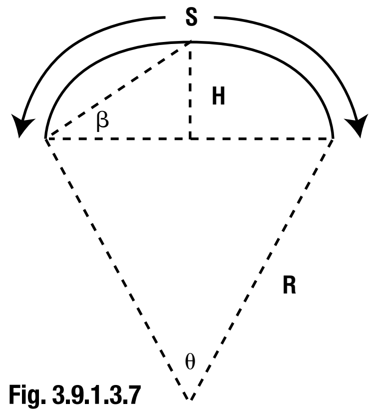
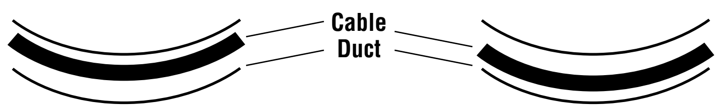


Fig. 3.9.1.3.7

The preceding equations for vertical bends assume that the conductor(s) or cable(s) are sliding on the inside surface of the bend. This would not occur on concave up bends when the sidewall bearing pressure is less than the weight of the cable.



Standard equations are valid $T_{in} > 10\ WR$

Standard equations are not valid $T_{in} < 10\ WR$

Typical installations where the cable drags on the bottom of the raceway or duct are in large industrial facilities, river crossings or up and downhill pulls of long lengths.

3.9.1.3.8 Bend Multiplier

Pulling around bends increases the tension required to pull the cable into a raceway. The following example illustrates the significant increase in pulling tension required due to pulling around a single 90º bend; the tension approximately doubles.

Straight horizontal pull: $T_{out} = w_c fWL + T_{in} = 610$ lb
Pull around a 90º bend: $T_{out} = T_{in}\, e^{w_c f\theta} = 1200$ lb
Where: $w_c = 1.1$ $W = 2$ $f = 0.5$ $T_{in} = 500$ lb $L = 100$ ft

Because of this multiplying effect, it is recommended that the cable be fed into the end of the raceway having the greater number of bends. However, the tensions should be calculated for pulling in either direction to determine which direction will actually require the lower tension.

3.9.1.3.9 Calculations Correlation

Even though the previous equations using the parameters provided result in exact values, these values may not correspond to actual conditions because of variations in installation techniques. THESE CALCULATIONS MUST BE USED ONLY AS GUIDELINES TO PREDICT “NORMAL” OR “DIFFICULT” CABLE PULLS.

The equations provided do not consider forces required to bend the cables, and the coefficient of friction has been arbitrarily selected; in fact, it may change during the pull if the lubricant is not spread continuously and evenly. The bends are seldom located exactly as shown on the engineer’s drawing, nor are the exact bend angles or radii known.

CAUTION – the equations provided for calculating pulling tensions do not take into account:

(1) Weight Correction Factor when there are more than 6 cables (use $w_c = 1.4$)
(2) Sidewall Bearing Pressure when there are more than 3 cables
(3) Bending forces encountered in short pulls of large cables through several bends.

Care should be taken to measure pulling tension during installation of the cable.

3.9.2 Allowable Sidewall Bearing Pressure

Sidewall bearing pressure (SWBP), or sidewall loading, is the radial force exerted on a cable being pulled around a conduit bend or sheave. Excessive SWBP can crush a cable and is, therefore, one of the most restrictive factors in installations having bends and requiring high pulling tensions. SWBP can be reduced by increasing the radius of bends.

3.9.2 Allowable Sidewall Bearing Pressure (cont'd)

The maximum tension that can safely be applied to the cable during installation can be calculated using the maximum SWBP for the cable and the radius of the bend it is traversing. For example, a cable having a maximum SWBP of 300 lb/ft that is being pulled around a bend having a radius of 2 ft should have no more than 300 lb/ft x 2 ft or 600 lb tension applied to it as the cable exits the bend.

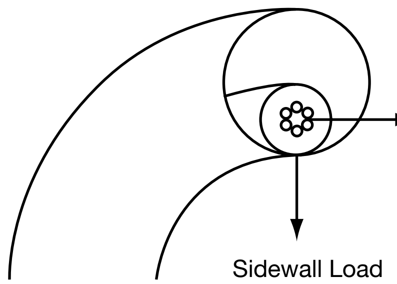


Fig. 3.9.2 Sidewall Loading

Sidewall bearing pressure (SWBP) may be calculated using the following equations:

1/C in a raceway: $$SWBP = \frac{T}{R}$$

3-1/C cradled: $$SWBP = \left[\frac{3w_c - 2}{3}\right]\frac{T}{R}$$

3-1/C triangular: $$SWBP = \left[\frac{w_c}{2}\right]\frac{T}{R}$$

Where: T = tension (lb) out of the bend
R = radius (ft) of the bend
w_c = weight correction factor

Table 3.9.2 Sidewall Bearing Pressure (Sidewall Loading)

Cable Type	SWBP (lb/ft)
300 V Nonshielded, 300 V & 600 V shielded control & instrumentation	500
600 V Nonshielded control & instrumentation	500
600 V and 2400 V Nonshielded power	1000
5 kV–35 kV Shielded power	1000
Interlocked armored cable (All Voltages)	300
CCW® MC-HL Armored Cable	500

3.9.3 Training and Bending

Training is the positioning of cable when it is not under tension. Bending is the positioning of cable when it is under tension. When installing cable, the object is to limit the mechanical forces so that the cable's physical and electrical characteristics are maintained for the expected service life. Bends in conductors, multi-conductor cables, or assemblies of conductors shall be made so that the cable will not be damaged.

A nonshielded cable can tolerate a sharper bend than a shielded cable. This is especially true for cables having helically applied metallic shielding tapes which, when bent too sharply, can separate or buckle and cut into the insulation. Remember that offsets are bends.

The problem is compounded by the fact that most tapes are under jackets that conceal such damage. The extruded polymers used for insulation shields have sufficient conductivity and coverage initially to pass acceptance testing and then fail prematurely due to corona at the shield/insulation interface.

3.9.3.1 NEC

The radius of the curve of the inner edge, not the centerline, of any bend shall not be less than the dimensions specified in Table 3.9.3.1 during or after installation.

The minimum bending radii shown in the Table are in compliance with 300.34 for cables rated over 600 V, 330.24 for Type MC cable, and 336.24 for Type TC cable. The values shown for other constructions are not defined in the NEC and ICEA recommendations are included.

Since UniShield® is a unique construction, there are no applicable values for the bending radius in the NEC, however, in accordance with ANSI/ICEA S-93-639/ NEMA WC 74-2000, General Cable recommends 8X for single conductors and, for multiplexed or multi-conductor cables, 8X the diameter of an individual conductor or 5X the overall diameter of the cable assembly, whichever is greater.

For constructions or voltages not shown, see 3.9.3.3 Non-Code Installations.

For messenger-supported wiring, use the applicable minimum bending radius for the overall cable assembly and conductors contained within the assembly.

The applicable minimum bending radius for the individual conductors must be used where the conductors in a multi-conductor or multiplexed cable are separated out for termination.

Table 3.9.3.1 Minimum Bending Radius in Accordance with National Electric Code

Voltage	Conductors	Shielding	Cable Types	Minimum Bending Radius as a Multiple of Conductor/Assembly Diameter		
600 V	Single	Nonshielded	All	5X		
601V-2000 V			All	8X		
600 V or 2000 V	Multi-Conductor or Multiplexed	Nonshielded	TC or TC-ER	1 in. (25 mm) or less	Over 1 in. to 2 in. (>25 mm to 50 mm)	Over 2 in. (>50 mm)
				4X	5X	6X
			MC [3]	7X		
		Shielded	All	12X		
			TC or TC-ER	12X		
			MC	12X/7X [1]		
Over 2000 V	Single	Nonshielded	MV	8X		
			MC [3]	7X		
		Shielded	MC and MV	12X [2]		
	Multi-Conductor or Multiplexed	Nonshielded	MC and MV	8X		
		Shielded	MC and MV	12X/7X [1,2]		

[1] 12 times the diameter of an individual shielded conductor or 7 times the overall cable diameter, whichever is greater.

[2] Since UniShield® is a unique construction, there are no applicable values for the bending radius in the NEC, however, General Cable recommends 8 times for single conductors, and for multiplexed or multi-conductor cables, it is 8 times the diameter of the individual conductors or 5 times the overall diameter, whichever is greater, in accordance with ANSI/ICEA S-93-639 5-46kV *Shielded Power Cable for Use in the Transmission and Distribution of Electric Energy*.

[3] Per 330.24B Interlocked-Type Armor or Corrugated Sheath.

3.9.3.2 CEC

The minimum bending radius for 600 V armoured cable is 6X the external diameter of the armoured cable; refer to CEC, Part I, Rule 12-614.

Table 3.9.3.2 provides the minimum bending radii for over 600 Volts and is in accordance with CEC, Part I, Table 15. During installation, the radius of the curve of the inner edge of any bend must not be less than the dimensions specified in the Table.

For constructions or voltages not shown, see 3.9.3.3 Non-Code Applications.

Table 3.9.3.2 Minimum Bending Radius – High-Voltage Cable

Cable Construction	Overall Cable Diameter Multiplying Factor: Up to and including 25 mm (1 in.) diameter	Over 25 mm (1 in.) diameter and up to and including 50 mm (2 in.) diameter	Over 50 mm (2 in.) diameter
Corrugated aluminum-sheathed	10X	12X	12X
Tape shielded Flat tape armoured Wire armoured	12X	12X	12X
Nonshielded Wire shielded	7X	7X	7X

Note: The bending radius is that measured at the innermost surface and equals the overall diameter of the cable multiplied by the appropriate number shown in the Table.

3.9.3.3 Non-Code Applications

Tables 3.9.3.3.1 and 3.9.3.3.2 provide the minimum values to calculate the radii to which insulated conductors or cables may be bent for permanent training during installation. These limits do not apply to raceway bends, sheaves or other curved surfaces around which the cable may be pulled under tension while being installed. Larger radii bends are required during installation due to sidewall bearing pressure limitations. In all cases, the minimum radius calculated refers to the inner surface of the cable and not to the axis of the cable.

Table 3.9.3.3.1 Minimum Bending Radii

Single and Multiple Nonshielded Conductors without Metallic Sheath or Armor

Thickness of Conductor Insulation		Overall Cable Diameter					
		inches	mm	inches	mm	inches	mm
		1.000 and less	25.4 and less	1.001 – 2.000	25.41 – 50.8	Over 2.000	Over 50.8
inches	mm	Minimum Bending Radius as a Multiple of Cable Diameter					
0.169 and less	4.31 and less	4X		5X		6X	
0.170 to 0.310	4.32 – 7.87	5X		6X		7X	
0.311 and over	7.88 and over	—		7X		8X	

Table 3.9.3.3.2 Minimum Bending Radii
Single and Multiple Shielded Conductors without Metallic Sheath or Armor

Voltage	Conductors	Shielding	Minimum Bending Radius as a Multiple of Conductor/Assembly Diameter
Over 2000 V	Single	Tape	12X
		Wire	8X
	Multi-Conductor or Multiplexed	Tape	12X
		Wire	5X

3.9.4 Sample Calculations

Symbols are defined Section 3.9.1.3, Page 63.

Example 1 – Maximum length $\xleftrightarrow{\quad L_{max} \quad}$

Problem: Find the maximum manhole spacing for a feeder.

Cable: 3 -1/C 350 kcmil Cu, 15 kV, 0.220″ EP – Uniblend®; to be installed in parallel.

Cable Data: Weight = 1.783 lb/ft for a single conductor and d = 1.35 in.

Raceway Selection = 4 in. (Table 3.7.4.3.3.1)
This size raceway avoids jamming and is in conformance with the NEC.

Raceway Inside Diameter (D) = 4.050 in. for RMC conduit.

The inside radius for a 4 in. standard RMC conduit elbow is 1.16 ft (Table 3.7.1)

$$\text{Clearance} = 0.5D - 1.366d + 0.5\,(D\text{-}d)\sqrt{1-\left(\frac{d}{D-d}\right)^2}$$

=((0.5*4.05)-(1.366*1.35)+((0.5)*(4.05-1.35)))*((SQRT(1-POWER((1.35/(4.05-1.35)),2))))

$$= \left[(0.5\,(4.05)) - (1.366\,(1.35)) + (0.5\,(4.05 - 1.35))\right]\sqrt{1-\left(\frac{1.35}{4.05-1.35}\right)^2}$$

= 1.33 in. which is acceptable; it must be at least 0.5 in.

Maximum pulling length

$$L_{max} = T_{max} / w_c fW$$

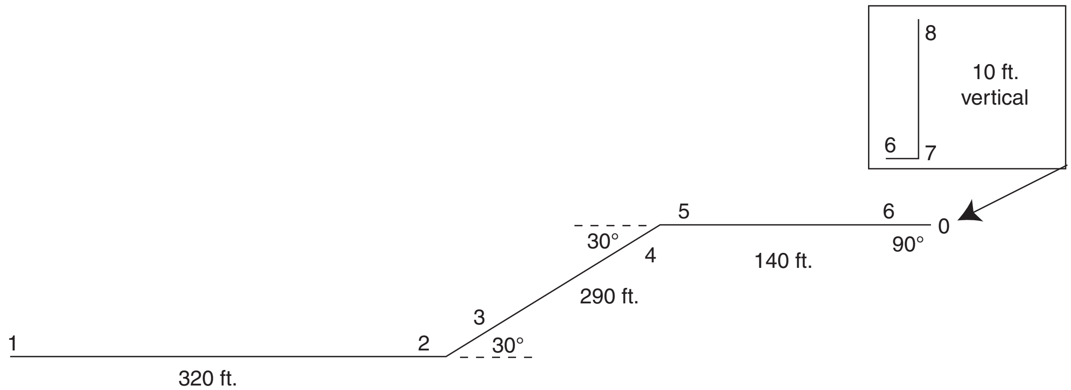
$$L_{max} = \frac{T_{max}}{w_c f W} = \frac{T_{max}}{\left[1+\frac{4}{3}\left(\frac{1.35}{4.05-1.35}\right)^2\right] fW}$$

T_{max} = 8400 lb for 3/C 350 kcmil (Table 3.9.1.2.2)

$$L_{max} = \frac{8400}{\left[1+\frac{4}{3}\left(\frac{1.35}{4.05-1.35}\right)^2\right](0.5)\left(3\,x\,\frac{1783}{1000}\right)} \approx 2350$$

3.9.4 Sample Calculations (cont'd)

Example 2 – Calculate Pulling Tension for the Following Installation



Problem: Install 15 kV feeder in rigid metal conduit between Points 1 and 8

Cable Data: 3 - 1/C, 1 AWG Cu 15 kV, 0.220″ Uniblend® with one 4 AWG bare copper equipment grounding conductor cabled

Uniblend® weight = 733 lb/kft and d = 1.02 in.

Conductor: Bare Class B = 128.9 lbs/kft

Grounding Conductor: d = 0.232 in.
area = 0.0423 in^2

Maximum Conductor Tension = 2009 for 3/C (Table 3.9.1.2.2)

Rigid Metal Conduit Selection:

Total Cable Area = $\left[3 \times \left(\frac{\pi\ (1.02)^2}{4}\right)\right] + 0.0423 = 2.49\ in^2$

For fill ≤ 40% use 3" RMC (Table 3.7.4.3.2.2)

3" RMC has a 40% fill area of 3.000 in^2 (= 7.499 x 0.40) and 3.090 in. nominal ID

Grounding Conductor Fit:

Calculate if 4 AWG bare grounding conductor will fit in an outer interstice between the current carrying conductors.

Interstice factor = 0.483 (Annex 6.2.6)

Interstice Fit = 0.483 x 1.01 = 0.488 in.

Since the interstice fit is greater than the bare grounding conductor diameter (0.232 in.), the grounding conductor will fit within the interstice and the 3/C multiplying factor of 2.155 can be used.

3.9.4 Sample Calculations (cont'd)

Clearance (CI):

$$CI = \frac{D}{2} - 1.366d + \frac{D-d}{2}\sqrt{1-\left(\frac{d}{D-d}\right)^2}$$

$$CI = \frac{3.09}{2} - 1.366 \text{ x } 1.02 + \frac{3.09-1.02}{2} \text{ x } \sqrt{1-\left(\frac{1.02}{3.09-1.02}\right)^2} = 1.052$$

$$CI = 1.545 - 1.393 + (1.035 \text{ x } 0.9006) = 1.052$$

Bending and Training:

Training and Bending Radius: (See 3.9.3)

1/C = 1.02 x 12 = 12.2 in. = 1 ft

Cabled Assembly = 1.02 x 2.155 x 7 = 15.4 in. = 1.3

Since the minimum bending radius for the assembly is greater than the minimum bending radius for the single conductor, the requirements for the assembly will determine the elbow selection.

Elbow Selection: An RMC sweep conduit elbow having at least an 18 in. centerline radius (R = 1.37 ft) must be used to exceed the 1.3 ft minimum training and bending limitation for the assembly.

Weight Correction (See 3.7.3.2)

$$w_c \approx 1.17 \quad \frac{1}{\sqrt{1-\left(\frac{d}{D-d}\right)^2}}$$

Calculate the weight correction factor times the friction factor

$w_c f \approx (1.16)(0.5) = 0.58$

Calculate the total weight of the cable

W = 3(0.733) + 0.1289 = 2.33 lb/ft

Calculate a constant K

$K = w_c fw = (0.58)(2.33) = 1.36$

Calculate 10WR which will be used later

10WR = 10(2.33)(1.37) = 31.9

$SWBP_{max} = 1000$ lb/ft

$w_c/2R = 1.17/(2 \text{ x } 1.37) = 0.43$

Calculate $e^{w_c f \theta}$ for θ = 30° (π/6) and 90° (π/2)

For θ = 30° = 1.36

For θ = 90° = 2.5

3.9.4 Sample Calculations (cont'd)

Pulling from Point 1 to 8:

$T_2 = w_c fWL = KL = (1.36)(320) = 435$ lb

since T_2>10WR then $T_3 = T_2 e^{w_c f \theta}$, likewise for T_5 & T_7

$T_3 = T_2\ e^{w_c f \theta} = (435)(1.36) = 590$ lb

$SWBP_3 = [w_c /2R]\ T_3 = (0.43)(590) = 255$ lb/ft = since 255 lb/ft is less than 1000 lb/ft, this is OK

$T_4 = KL + T_3 = (1.36)(290) + 590 = 984$ lb

$T_5 =$ T4 $e^{w_c f \theta} = (984)(1.36) = 1335$ lb

$SWBP_5 = [w_c /2R]\ T_5 = (0.43)(1335) = 575$ lb/ft, which is less than 1000 lb/ft, so it is OK

$T_6 = KL + T_5 = (1.36)(140) + 1335 = 1525$ lb

$T_7 = T_6\ e^{w_c f \theta} = (1525)(2.5) = 3813$ lb of tension

This tension is not acceptable since it is greater than the maximum tension of 2009 pounds specified in Table 3.9.1.2.2.

$SWBP_7 = [w_c /2R]T_7 = (0.43)(3813) = 1640$ lb/ft This is not OK since it is more than the allowable tension of 1000 lb/ft

The pull cannot be made from T_1 to T_8 since both the maximum tension and sidewall bearing pressure would be exceeded at T_7.

Pulling from Point 8 to 1

The tension is zero at T_8 and because the drop down into the conduit is negative at T_6 and T_7 the calculations can begin at T_5. The weight of the cable and gravity exert a downward or negative tension on the cable.

$T_5 = KL = (1.36)(140) = 190$ lb

$T_4 = T_5\ e^{w_c f \theta} = (190)(1.36) = 258$ lb

$SWBP_4 = [w_c /2R]\ T_4 = (0.43)(258) = 110$ lb/ft This value is far less than 1000 lb/ft so it is OK.

$T_3 = KL + T_4 = (1.36)(290) + 258 = 652$ lb

$T_2 = T_3\ e^{w_c f \theta} = (652)(1.36) = 885$ lb

$SWBP_2 = [w_c /2R]\ T_2 = (0.43)(885) = 380$ lb/ft This value is also less than 1000 lb/ft so it is OK.

$T_1 = KL + T_2 = 1.36 * 320 + 885 = 1319$ lb

In summary, calculating the tension from T1 to T7 results in a tension of T7 = 3813 lb, and a sidewall pressure SWBP7 = 1623 lb/ft and pulling from T8 to T1 results in a tension at T1 of 1319 pounds and a SWBP of 377 lb/ft.

The cable should be pulled in the direction of T8 to T1

3.9.5 Installation Checklist

3.9.5.1 Raceways

- Bending – Check sidewall loads; the use of long sweeps over 6 ft (1.8 m) allows longer pulls of shielded medium-voltage cable. Avoid bends and offsets at the ‘pulling’ end of a raceway section.
- Training – Make sure to meet or exceed the minimum training radius.
- Size – Consider Weight Correction Factor and Clearance.
- Jam Ratio – Avoid a raceway to cable ratio which may cause jamming; elbows may be out of round.
- Raceway Fill – Raceways that are too full cause pull-in problems and possible cable damage.
- Heat Transfer – Route raceways to avoid high ambient temperatures and high thermal resistivity locations. Separate cables in raceway seals, and fire and draft stops.
- Abrasion – Use duct end-bells, raceway bushings, and rack saddles to prevent abrasion.
- Grounding – Be sure metallic raceways are grounded.
- Expansion – Thermal expansion of raceways should be considered in the duct layout.
- Spacing – Heat dissipation improves with greater spacing between raceways.
- Manhole/Splice Box –

  Allow enough working space for pulling and splicing.
  Install anchor bolts and grounding electrode during box fabrication.
  Provide cable supports.
  Chamfer concrete edges at openings.
  Provide drainage holes in bottom of boxes and adequate lips on covers.
- Support raceway system – during system and cable installation.
- Provide for gang rollers to be used during pulling.
- Ties – Allow for radial expansion of cable during electrical loading

3.9.5.2 Direct Buried

- Backfill – Use screened backfill to keep rocks and debris from damaging cables.
- Crossovers – Do not lay one cable directly on top of another.
- Cable Slack – Allow for earth movement due to freezing, drying or settling.
- Depth – Stay below frost line; check Building Code requirements.
- Protection – Use marker tape and post warning signs.

3.9.5.3 Cable Pulling

- Raceway Cleanout – Provide clean smooth concentric inner surface; test with a mandrel for obstructions and swab to remove any debris.
- Bending – Bends during pulling must be larger than those permitted for final training, especially the last bend, which may be temporary for installation. If possible, it is recommended that bends should be at the beginning of the pull to minimize the Sidewall Bearing Pressure. Refer to Section 3.9.2
- Edges – Install temporary guides, tubes, sheaves, etc., as necessary to prevent cutting the cable on sharp edges, such as at panelboards.
- Maximum Tension –
  Keep sidewall loads below specified maximum limits.
  Check maximum allowable pulling tension. Monitor with the use of a dynamometer.
  Check limitation for type of pulling attachment used. A swivel should be employed to avoid twisting.
- Lubrication –
  Use pulling compound liberally.
  Be sure it is compatible with the particular cable being installed.
  Pre-lube just before making a pull.
- Temperature – Check for minimum allowable installation temperature. Allow for change of the coefficient of friction with temperature.
- End Seals – Keep moisture out of cable.
- Special Instructions – Check shipping container for special instructions.

4. POWER CABLES

4.1 SHIELDING

All electrically insulated conductors are capacitors. When a changing voltage is applied across a capacitor, a charging current will flow through that capacitor.

4.1.1 Nonshielded Cables

In most cable installations, the cable's surface makes only random casual contacts with its grounded physical supports or with the surfaces of other cables. Except at these points of actual physical contact, there are air gaps that are also capacitors. The result is a series circuit consisting of the capacitance of the cable and the capacitance of the air gap. The surface of the cable then becomes the "floating" tap of a capacitive voltage divider. Consequently, the voltage on the cable surface can vary from almost zero to nearly the phase-to-ground voltage of the insulated conductor, depending upon the size of these external air gap capacitors.

4.1.1 Nonshielded Cables (cont'd)

If the voltage along the cable surface or across the air gap capacitors is sufficiently high, the surface of the cable may be deteriorated by surface tracking, and/or there can be corona and sparking discharges across the air gaps, and the surface may be a shock hazard.

4.1.2 Shielded Cables

Insulation shielding properly applied and grounded eliminates electrostatic charges external to the cable shield and provides a fixed known path to ground for the charging current. Shields are recommended on cables operating over 2 kV. The National Electrical Code requires cables operating above 2400 V to be shielded except as indicated in Section 310.10(E) of the 2011 NEC.

The shield of a power cable provides a fixed electrical path to ground that is in intimate contact with the external surface of the cable insulation. The shield eliminates the surface discharge problems associated with nonshielded cables.

In addition, shielding assures uniform electrical stress distribution within the cable insulation. Because of the fixed conductor-to-ground capacitance per unit length of cable, shielding minimizes voltage surge reflections along the cable.

Carefully designed and grounded shields provide personal safety by eliminating surface potential, as well as minimizing shield losses and insulation stress. The size of the shield should be determined based on the available short circuit current of the circuit within the time frame as indicated in the "fuse" co-ordination assessment. The shield can be open circuit or (closed circuit) grounded at both ends, depending on the design of the system. While open circuited shields provide higher ampacities, they also generate a standing voltage in the shield that increases with distance from the grounded point. General Cable recommends the use of multi-point grounding of shields to insure personal safety.

4.2 SPLICING AND TERMINATING

A shielded power cable termination must be properly designed and applied or the termination may fail within a short time. A splice in a cable run is essentially two shield terminations.

As described in 4.1.2, the shield is always grounded.

Splices also introduce the problem of heat dissipation.

When specifying or purchasing a splice or termination kit, be sure that it is the correct one for the specific cable construction.

Carefully review and follow the instructions provided by the manufacturer of the splice or termination kit, particularly regarding the cable preparation.

Recommended Preparation Procedure for Termination or Splicing of Shielded Cable

This procedure is to be considered a supplement rather than a replacement for the instructions provided by the manufacturer of the termination or splice kit. This procedure is designed to provide recommendations and guidelines on good practices for the cable preparation for installation of the termination and splice materials. All surfaces must be clean and free of contaminants.

4.2 SPLICING AND TERMINATING (cont'd)

A. Termination or Splice Material

Confirm that the termination or splice material is correct for the application and construction of cable and system requirements. Ensure that all the required tools and components, including the ground strap, are available. Review the manufacturer's instructions before proceeding any further.

If deemed necessary, practice cable cutbacks on a scrap piece of cable.

B. Cable Cut-Off

Ascertain the end cut-off point for the cable based on the final connection point, the length of the connector or splice sleeve and the expansion or growth due to compression. Cut off the end of the cable.

C. Removal of Jacket, (Black) Semi-Conducting Layer and Insulation (except for UniShield®, see ANNEX 7.5)

The termination or splice manufacturer's instructions must be maintained with respect to cut-back distances for the jacket, insulation semi-conducting layer and the insulation.

The jacket, insulation semi-conducting layer and insulation can be removed with the use of cable stripping tools or a cable stripping knife. It is recommended that cable stripping tools be used for this requirement.

The use of a (sharp) knife requires practice, experience and extreme care to prevent scoring of the metallic shield, semi-conducting layer, insulation and conductor strands. It is extremely important that the cut edge of the semi-conducting layer must be straight and clean and must remain bonded to the insulation; otherwise, "corona" or partial discharge will occur upon energizing of the cable, resulting in failure of the termination. If a knife is used, the removal of the semi-conducting layer can be controlled by the use of a hose clamp or constant tension spring secured at the cut-off point. Circumferentially score the surface of the semi-conducting layer and taper the score mark to the outer edge. Lift the edge of the semi-conducting layer and peel off against the edge of the hose clamp.

The semi-conducting layer should be easily stripped off the insulation, but any remaining residue on the surface of the insulation must be removed by very light sanding and cleaned with isopropyl (rubbing) alcohol or other approved cleaning solution. It is normal to see indentations or impressions in the (black) semi-conducting insulation shield due to the (metallic) copper tape, wire shield, or concentric neutral wires.

It is also imperative that there are no score marks or grooves in the surface of the insulation, especially under the edge of the semi-conducting layer. Any residue or marks on the surface of the insulation must be removed by very light sanding and subsequent cleaning using rubbing alcohol or other cleaning solvent approved by the manufacturer of the termination or splice manufacturer. It is recommended that a 120 grit aluminum oxide or electrician's abrasive roll material be used for sanding. Excessive sanding of the insulation is not acceptable.

Scoring of the wire shield or conductor strands will create notch sensitivity and possible loss of conductor material, resulting in overheating.

4.2 SPLICING AND TERMINATING (cont'd)

Cable stripping tools such as spiral cutters are recommended, but removal of the layers should be conducted on a scrap piece of material, as the required settings depend on the thickness of the layer or depth of cut.

Upon completion of removal of the jacket, insulation semi-conducting layer and insulation, the prepared surfaces must be cleaned with isopropyl (rubbing) alcohol or other approved cleaning solvent before attempting to apply any stress control material.

4.3 EMERGENCY OVERLOAD CURRENT GUIDELINES

The increase or decrease of the load current does not produce an instantaneous change of the cable temperature. Therefore, during emergency conditions, the cable may be overloaded for short periods of time at the maximum overload temperature of 130ºC/140ºC for cable rated at 90ºC/105ºC continuous operation.

Operations at the emergency overload temperature must not exceed 1,500 cumulative hours during the lifetime of the cable. Lower temperature for emergency overload conditions may be required due to the type of material used in the cable splices and terminations or environmental conditions.

5. TESTING GUIDELINES FOR LOW-VOLTAGE CABLES

5.1 NONDESTRUCTIVE INSULATION RESISTANCE (IR) TESTING FOR LOW-VOLTAGE CABLES

The insulation resistance test is not recommended for verification of the insulation level of medium-voltage cables. However, it can be performed prior to the application of a dc Hi Pot test.

The dc voltage applied during an insulation resistance (IR) test on cables rated 2400 volts or less is relatively low, 500 to 1000 volts, and the test is nondestructive. Typically, a portable high-range resistance ohmmeter is used for this test.

This low-voltage IR test is particularly useful in detecting dead shorts as well as indicating grossly deteriorated insulation.

The limitation for this low-voltage IR test is its interpretation. The significance of such testing on nonshielded, non-metallic sheathed cable is very dependent upon the environment because the characteristics of the return circuits are unknown.

Even though the test voltage is lower, safety precautions must be observed.

Again, low resistance readings may be caused by contaminated or moist cable ends or variable test voltage. Failure to clean water-based cable pulling lubricants from the cable test ends will cause erroneous rejection of good cable as tracking may occur back to a ground plane.

5.1 NONDESTRUCTIVE INSULATION RESISTANCE (IR) TESTING FOR LOW-VOLTAGE CABLES (cont'd)

Insulation Resistance:

The value of the insulation resistance at a temperature of 15.6°C (60°F), or when corrected to this temperature, shall not be less than the value of R calculated as follows:

$$R = K * \log_{10}\left(\frac{D}{d}\right)$$

Where:

R = insulation resistance (Megohms-kft)
K = insulation constant
D = diameter over insulation (in)
d = diameter under insulation (in)

6. TESTING GUIDELINES FOR MEDIUM-VOLTAGE CABLES

This section provides general guidelines for high potential "Hi-Pot" dc testing of power cables.

All tests made following cable installation and during the warranty period must be performed in accordance with the applicable specifications.

Testing should be performed by qualified personnel taking all appropriate safety precautions. The responsible safety officer should be consulted regarding the equipment and the appropriate personnel protection requirements.

The significance of performing dc high-voltage tests on nonshielded, nonmetallic sheathed cable is dependent upon the environment in which it is installed because the characteristics of the return circuits are unknown. The environment must be carefully considered or the test results may not be significant. In fact, these tests can result in damage to the cable insulation.

Humidity, condensation and actual precipitation on the surface of a cable termination can increase the leakage current by several orders of magnitude. Humidity also increases the corona current, which is included in the total leakage current. Wind prevents the accumulation of space charges at all bare energized terminals. This results in an increase of corona. It is desirable to reduce or eliminate corona current at the bare metal extremities of cable or terminations. This may be accomplished by covering these areas with plastic envelopes, plastic or glass containers, plastic wrap, or suitable electrical putty.

6.1 PRE-TEST GUIDELINES

6.1.1 Testing Equipment

Direct current test equipment is commercially available with a wide range of voltages. The Operator's Manual for the particular test set being used should be read and understood.

Accessory equipment necessary to safely conduct high voltage tests such as safety barriers, rubber gloves, nonconducting hard hats, and, where necessary, arc flash protection must be used.

6.1.2 Recommended Testing Procedures

Acceptable procedures for conducting Hi-Pot testing, although varying slightly in technique, have been standardized as either a "withstand test" or a "time-leaking current test." IEEE Std 400 provides additional information on dc testing and evaluation of the insulation of shielded power cable systems.

6.1.3 Preparation for Testing

Before conducting any Hi-Pot testing, the following steps should be taken.

(1) All equipment, such as transformers, switches, taps, motors, circuit breakers, surge arrestors, etc., must be disconnected from the cable circuit to prevent damage to equipment and will prevent test interruptions due to flashovers or trip-outs resulting from excessive leakage current.

(2) Provide adequate clearance (about 2.5 ft) between the circuit test ends and any grounded object, and to other equipment not under test.

(3) Ground all circuit conductors not under test including the cable shields and nearby equipment.

Test equipment should be supplied from a stable, constant voltage power source. Do not use the same source that is supplying arc welders or other equipment that may cause line voltage fluctuations. The output voltage of the test set must be filtered and regulated. The use of a portable, motor driven alternator to provide power to the test set is recommended.

6.2 HI-POT TESTING PROCEDURES

The dc test voltage may be applied either continuously or in predetermined steps up to the maximum value in accordance with the applicable specifications.

6.2.1 Continuous Method

The test voltage is applied at an approximate rise rate of 1 kV per second or 75% of the rated current output of the equipment, whichever is less. Some equipment will take longer to reach the maximum test voltage because of the amount of charging current.

6.2.2 Step Method

The test voltage is applied slowly in 5 to 7 increments of equal value up to the maximum specified. Allow sufficient time at each step for the leakage current to stabilize.

6.2.3 Recommended Testing Procedure

Maintain the test voltage at the prescribed value for the time specified in the applicable specifications.

At the end of the test period, set the test set voltage to zero, allow the residual voltage on the circuit to decay, disconnect the power supply and then ground and "drain" the conductor just tested.

6.2.3 Recommended Testing Procedure (cont'd)

After testing, maintain solid grounds on the cable for at least 4 times the duration of the test since dc charges can build up on the cable to potentially dangerous levels if grounds are removed too quickly. On exceptionally long cable lengths, it may be necessary the increase the grounding time. It is also advantageous to maintain these grounds longer and while reconnecting circuit components.

6.2.3.1 Acceptance Testing

Acceptance testing is performed to detect any defects in cable insulation and terminations which may have resulted from poor workmanship or mechanical damage. This proof test confirms the integrity of the insulation and accessories before the cable is placed into service.

After installation and before the cable is placed in regular service, the test voltages specified in Table 6.2.3.1 should be applied for 15 consecutive minutes. Record the leakage current at one minute intervals for the duration of the test.

Table 6.2.3.1 ICEA dc Field Test Voltages
ICEA S-97-682 Utility Shielded Power Cables Rated 5,000-46,000 Volts

Rated Voltage Phase-to-Phase (kV)	Conductor Size		Nominal Insulation Thickness (Insulation Level)				Maximum dc Field Test Voltages (kV)			
							During or After Installation		First 5 Years	
	AWG/kcmil	mm^2	100%		133%		100%	133%	100%	133%
			mils	mm	mils	mm				
5	8 – 1000	8.4 - 507	90	2.29	115	2.92	28	36	9	11
	> 1000	> 507	140	3.56	140	3.56				
8	6 – 1000	13.3 – 507	115	2.92	140	3.56	36	44	11	14
	> 1000	> 507	175	4.45	175	4.45				
15	2 – 1000	33.6 - 507	175	4.45	220	5.59	56	64	18	20
	> 1000	> 507	220	5.59						
25	1 – 2000	42.4 – 1013	260	6.60	320	8.13	80	96	25	30
28	1 – 2000	42.4 – 1013	280	7.11	345	8.76	84	100	26	31
35	1/0 – 2000	53.5 - 1013	345	8.76	420	10.7	100	124	31	39
46	4/0 - 2000	107.2 - 1013	445	11.3	580	14.7	132	172	41	54

6.2.3.2 Maintenance Testing

At any time during the warranty period, the cable circuit may be removed from service and tested at a reduced voltage (normally 65% of the original acceptance value) for 5 consecutive minutes. Record the leakage current at one minute intervals for the duration of the test.

Routine periodic dc maintenance testing of cables for the evaluation of the insulation strength is not a common practice. Some power cable users, particularly in the continuous process industries, have adopted a program of testing circuits during planned outages, preferring breakdowns during testing rather than experiencing a service outage during regular operations.

It is nearly impossible to recommend test voltage values for maintenance testing without having a history of the cable circuit. An arbitrary test voltage level could result in a cable failure in a circuit that would otherwise have provided long trouble-free service at normal operating ac voltage. Periodic off-line partial discharge testing at very low frequencies (VLF) is a diagnostic method for monitoring the insulation degradation of medium-voltage cable. This type of testing is discretionary and neither endorsed nor recommended by General Cable.

6.3 COMMON TESTING PROBLEMS

Some common problems that may be encountered during testing are listed below.

Extra Leakage Current:
- Failure to guard against corona
- Failure to clean insulation surface
- Failure to keep cable ends dry
- Failure to provide adequate clearance to ground
- Failure to isolate the cable from other equipment
- Improper shield termination

Erratic Readings:
- Fluctuating voltage to test set
- Improper test leads

Environmental Influences:
- High Relative Humidity
- Dampness, Dew, Fog
- Wind, Snow

No correlation has yet been established between dc test results and cable life expectancy.

6.4 FAULT LOCATING

Time Domain Reflectometer (TDR) units are portable commercially available devices which can be used in the field to locate some types of conductor breaks or shorts. They connect to the end of the cable and echo back when an open, short or tap is encountered. The device can usually locate faults within ± 2 in. of the cable length. However, TDRs are only capable of locating breaks or shorts having an impedance different than that of a cable. For most cables shorts having a resistance of less than a few ohms and opens having a resistance greater than several hundred ohms splices, taps, etc sometimes distort the echo and can mask the fault. Nevertheless, the method is nondestructive and is used successfully on faults having characteristics within the capabilities of the method. Note that the conductor may be in a low-voltage or medium-voltage cable, shielded or nonshielded, or it may even be the shield.

6.5 TESTING CHECKLIST

- Safety – FOLLOW TEST EQUIPMENT SUPPLIER'S INSTRUCTIONS. Operators should be familiar with the test equipment. Stay clear of energized cable ends. Ensure that shields are grounded! Insulated conductors are capacitors.
- Voltages – CHECK CABLE AND TERMINATION MANUFACTURER'S GUIDELINES.
- Records – keep detailed records and provide copy to owner.

7. ANNEX

7.1 DEFINITIONS

The definition of terms applicable to this Manual are listed below.

7.1.1 NEC

Unless indicated otherwise, definitions are contained in Article 100 of the NEC.

Conductor, Bare. A conductor having no covering or electrical insulation whatsoever.

Conductor, Covered. A conductor encased within material of composition or thickness that is not recognized by this Code as electrical insulation.

Conductor, Insulated. A conductor encased within material of composition and thickness that is recognized by this Code as electrical insulation.

Cable Tray System. A unit or assembly of units or sections and associated fittings forming a structural system used to securely fasten and support cables and raceways (NEC 392.2).

Electrical Ducts. As used in Article 310, electrical ducts shall include any of the electrical conduits recognized in Chapter 3 as suitable for use underground; other raceways round in cross section, listed for underground use, and embedded in earth or concrete (NEC 310.60) (A).

Exposed (as applied to wiring methods). On or attached to the surface or behind panels designed to allow access.

7.1.1 NEC (cont'd)

Grounding Conductor, Equipment (EGC). The conductive path installed to connect normally non-current-carrying metal parts of equipment together and to the system grounded conductor, to the grounding electrode conductor, or both.

FPN No. 1: It is recognized that the equipment grounding conductor also performs bonding.
FPN No. 2: See 250.118 for a list of acceptable equipment grounding conductors.

Location, Damp. Locations protected from weather and not subject to saturation with water or other liquids but subject to moderate degrees of moisture. Examples of such locations include partially protected locations under canopies, marquees, roofed open porches, and like locations, and interior locations subject to moderate degrees of moisture, such as some basements, some barns, and some cold-storage warehouses.

Location, Dry. 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.

Location, Wet. Installations underground or in concrete slabs or masonry in direct contact with the earth; in locations subject to saturation with water or other liquids, such as vehicle washing areas; and in unprotected locations exposed to weather.

Messenger-Supported Wiring. (NEC 396.2) An exposed wiring support system using a messenger wire to support insulated conductors by any one of the following:

(1) A messenger with rings and saddles for conductor support

(2) A messenger with a field-installed lashing material for conductor support

(3) Factory-assembled aerial cable

(4) Multiplex cables utilizing a bare conductor, factory assembled and twisted with one or more insulated conductors, such as duplex, triplex, or quadruplex type of construction

Raceway. An enclosed channel of metal or nonmetallic materials designed expressly for holding wires, cables, or busbars, with additional functions as permitted in this Code. Raceways include, but are not limited to, rigid metal conduit, rigid nonmetallic conduit, intermediate metal conduit, liquidtight flexible conduit, flexible metallic tubing, flexible metal conduit, electrical nonmetallic tubing, electrical metallic tubing, underfloor raceways, cellular concrete floor raceways, cellular metal floor raceways, surface raceways, wireways, and busways.

7.1.2 CEC

Definitions are contained in Section 0 of the CEC, Part I.

Aluminum-sheathed cable – a cable consisting of one or more conductors of approved type assembled into a core and covered with a liquid- and gas-tight sheath of aluminum or aluminum alloy.

Ampacity – the current-carrying capacity of electric conductors expressed in amperes.

7.1.2 CEC (cont'd)

Cable tray – a raceway consisting of troughing and fittings formed and constructed so that insulated conductors and cables may be readily installed or removed after the cable tray has been completely installed, without injury to either conductors or their covering.

Conduit – a raceway of circular cross-section, other than electrical metallic tubing and electrical non-metallic tubing, into which it is intended that conductors be drawn.

Electrical metallic tubing – a raceway of metal having circular cross-section into which it is intended that conductors be drawn and that has a wall thinner than that of rigid metal conduit and an outside diameter sufficiently different from that of rigid conduit and an outside diameter sufficiently different from that of rigid conduit to render it impractical for anyone to thread it with a standard pipe thread.

Electrical non-metallic tubing – a pliable non-metallic corrugated raceway having a circular cross-section.

Exposed (as applied to wiring methods) - not concealed.

Grounding conductor – the conductor used to connect the service equipment or system to the grounding electrode.

Industrial establishment – a building or part of a building (other than an office or exhibit space) or a part of the premises outside the building where persons are employed in manufacturing processes or in the handling of material, as distinguished from dwellings, offices and similar occupancies.

Location –

Damp Location – an exterior or interior location that is normally or periodically subject to condensation of moisture in, on, or adjacent to electrical equipment and includes partially protected locations under canopies, marquees, roofed open porches, and similar locations.

Dry Location – a location not normally subject to dampness, but that may include a location subject to temporary dampness as in the case of a building under construction, provided that ventilation is adequate to prevent an accumulation of moisture.

Hazardous Location – premises, buildings or their parts which the hazard of fire or explosion exists due to the fact that

(a) highly flammable gases, flammable volatile liquid mixtures or other highly flammable substances are manufactured or used, or are stored in other than original containers;

(b) combustible dust or flyings are likely to be present in quantities sufficient to produce an explosive or combustible mixture, or it is impracticable to prevent such dust or flyings from being deposited upon incandescent lamps or from collecting in or upon motors or other electrical equipment in such quantities as to produce overheating through normal radiation being prevented;

7.1.2 CEC (cont'd)

(c) easily ignitable fibres or materials producing combustible flyings are manufactured, handled, or used in a free open state; or

(d) easily ignitable fibres or materials producing combustible flyings are stored in bales or containers but are not manufactured or handled in a free open state.

Qualified person – one familiar with the construction and operation of the apparatus and the hazards involved.

Raceway – any channel designed for holding wires, cables, or busbars and, unless otherwise qualified in the Rules of the CEC, the term includes conduit (rigid and flexible, metal and non-metallic), electrical metallic and non-metallic tubing, underfloor raceways, cellular floors, surface raceways, wireways, cable trays, busways, and auxiliary gutters.

Underfloor raceway – a raceway suitable for use in the floor.

Utilization equipment – equipment that utilizes electrical energy for mechanical, chemical, heating, lighting, or similar useful purposes.

Voltage –

Extra-low voltage – any voltage up to and including 30 V.

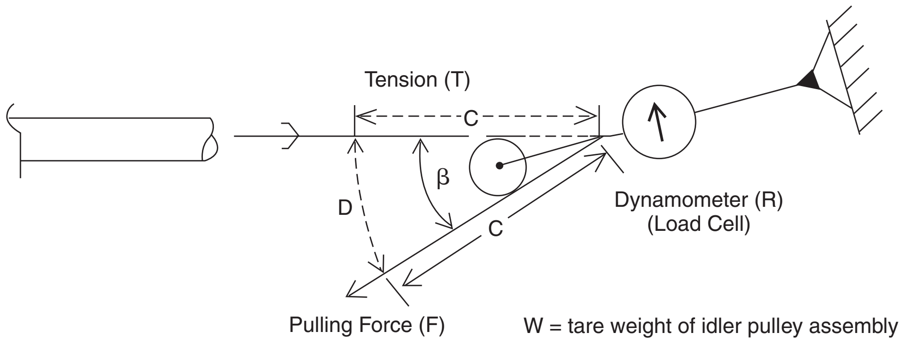
Low-voltage – any voltage from 31 to 750 V inclusive.

High-voltage – any voltage above 750 V.

Wireway – a raceway consisting of a completely enclosing arrangement of metal troughing and fittings formed and constructed so that insulated conductors may be readily drawn in and withdrawn, or laid in and removed, after the wireway has been completely installed, without injury either to conductors or to their covering.

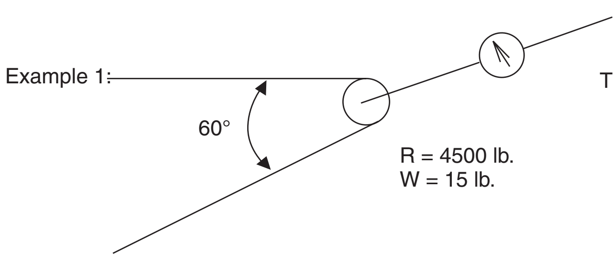
7.2 DESIGN CONSIDERATIONS

7.2.1 Dynamometer Correction

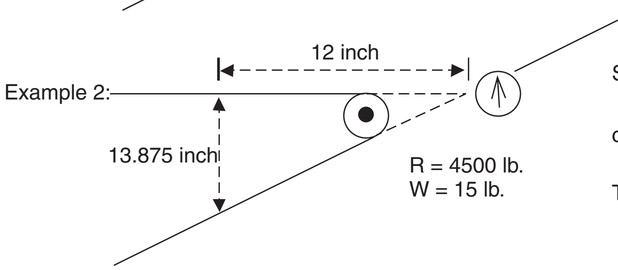


$S = C + D/2 \qquad \cos(\beta/2) = \sqrt{\frac{S\,(S-D)}{C^2}} \qquad T = R \left[\frac{1}{2\cos(\beta/2)}\right] - W$

β (degrees)	$\frac{1}{2\cos(\beta/2)}$	β (degrees)	$\frac{1}{2\cos(\beta/2)}$	β (degrees)	$\frac{1}{2\cos(\beta/2)}$
0	0.500	120	1.00	150	1.93
30	0.518	125	1.08	155	2.31
45	0.541	130	1.18	160	2.88
60	0.577	135	1.31	165	3.83
90	0.707	140	1.46	170	5.74
100	0.778	145	1.66	175	11.5
105	0.821				
110	0.872				
115	0.931				



$T = (4500)\,(0.577) - 15 = 2580$ lb.



$S = 12 + 13.875/2 = 18.9$ inch

$\cos(\beta/2) = \sqrt{\frac{18.9\,(18.9 - 13.875)}{12^2}} = 0.816$

$T = \frac{4500}{2\,(0.816)} - 15 = 2740$ lb.

7.2.1 Dynamometer Correction (cont'd)

To Size Dynamometer:

R = (T+W) [2 Cos (β/2)]

Example: estimated T = 1800 lb W = 15 lb β = 45º
R = (1800 + 15) [2 Cos (45/2)] = 3350 lb
A 5,000 lb dynamometer is required.

Limitations:

(1) The forces of friction at the pulley must be negligible
(2) "Tare" weight of the idler assembly must be zeroed out
(3) Angle is constant and accurately known
(4) Dynamometer is swinging free so its line bisects β; but avoids drag on the duct opening

7.2.2 Diameter of Multi-Conductor Assemblies

Table 7.2.2 provides the multiplying factor that can be used to calculate the diameter over a multi-conductor assembly containing all the same diameter conductors. The calculated diameter over the assembly does not include any overall metallic or nonmetallic coverings.

Diameter over Assembly = Multiplying Factor x Single Conductor Diameter
Table 7.2.2 Multiplying Factor for Multi-Conductor Assembly

Number of Conductors	Multiplying Factor
1	1.00
2	2.00
3	2.16
4	2.42
5	2.70
6	3.00
7	3.00
8	3.31
9	3.61

7.2.3 Diameter of Outer Interstice in Multi-Conductor Assembly

The diameter of the largest conductor that will fit in the outer interstice of a multi-conductor assembly containing all the same size conductors and still remain within a circumscribing circle can be determined by multiplying the diameter of a single conductor in the assembly by the appropriate factor from Table 7.2.3.

Table 7.2.3 Outer Interstice Conductor Diameter Factor

Number of Conductors	Configuration	Factor
2	Flat	0.250
2	Round	0.667
3	Round	0.483
4	Round	0.414
5	Round	0.377
6	Round	0.354

7.3 PURGING WATER FROM CONDUCTOR STRAND OR SHIELD

On all cables, purge the shield separately from the insulated strands, otherwise the gas will only flow through the path offering the lease resistance.

If the cable is on a reel, unlash the cable ends, drain any excessive water from the cable and position the inside end of the cable to its lowest possible elevation.

7.3.1 Cables Not Installed

Remove the end seals. At the cable end with the highest elevation, apply two layers of half-lapped HV insulating tape to act as a sealing cushion. Interconnect the cable ends to the dry gas supply using hoses, valves, pipe fittings, and pressure regulators (10 to 25 psig range), as necessary.

Attach a one gallon plastic bag to the exhaust end of the cable. Secure the bag with tape or clamps. Make a small vent hole by cutting one bag corner.

As shown in Fig. 7.3, several cables may be connected to a single manifold with a gas supply. Dry nitrogen is available from a welding gas supplier. Apply 15-25 psig and maintain the pressure for at least eight hours after all indications of moisture have stopped.

Water vapor may be readily detected by sprinkling one tablespoon of Anhydrous Cupric Sulfate in the plastic bag. The Sulfate will change color from “off white” to blue if moisture is present. The Sulfate should be available from a scientific laboratory supply distributor.

7.3.2 Installed Cables

Splices and terminations may be removed and the cable purged.

To remove water from the strand, the cable can be lightly loaded to drive the moisture out one end of the cable, providing the cable's termination design has an open strand. The termination may also be removed and low-voltage and low-current applied to drive out the moisture.

A shield system may be purged by attaching a truck air valve, with the stem removed, over ½ in. (13 mm) holes cut into the jacket at both ends of the cable section. Apply a maximum of 15 psig of dry nitrogen and maintain the pressure for at least eight hours after all indications of moisture have stopped. Do not try to purge across or through splices!

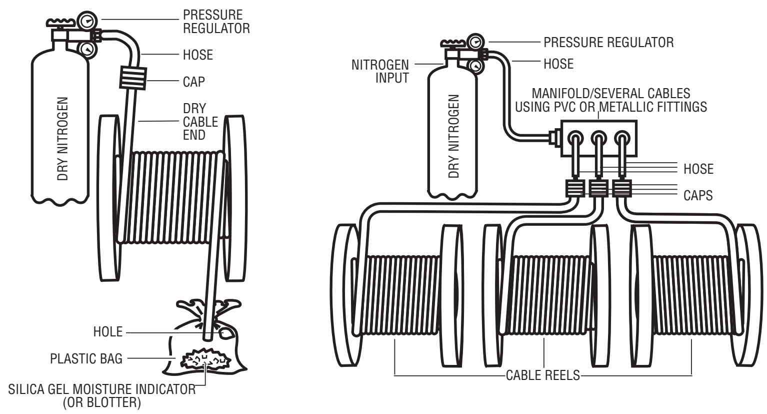


Fig. 7.3 Setup for Purging Water from Strand or Shield

7.4 TYPE MC METAL CLAD (CCW®) , 300 V – 35 KV ARMORED CABLE FOR HAZARDOUS LOCATIONS SHEATH REMOVAL GUIDELINES

The following procedures provide a simple, safe means of removing the non-metallic jacket and the corrugated, continuously welded (CCW) aluminum sheath from Type MC cable for terminating or splicing without damaging the insulated conductors. These procedures are not recommended for use on TECK 90, HVTECK or interlocked armor MC.

Tool Kit:

- Kett-Tool Metal-Clad Cable Saw
- 2"/44 teeth Cutting Blades
- Cable Saw Spindle and Allen Wrenches
- MC Cable Guide
- Tubing and Pipe Cutter
- 12" V-Jaw Channel-Lock Pliers
- 10" Hacksaw Frame
- 10"/24 teeth/in. Hacksaw Blades
- 10 ft. Tape Measure
- Utility Knife with Blades
- 5/16" Screwdriver
- Tool Box

Safe working practices should be observed, including safety glasses and adequate work gloves. Cable installers should be properly trained in cable termination procedures.

Installation Note 1:
Work Prior to Removing Sheath

Measure twice, cut once. Ensure that the pull of cable, in addition to the termination used, and the amount of cable required are adequate for the installation. Make sure that you have the correct size and style glands to properly marry the cable to the equipment.

Step 1:

Using the utility knife, remove the jacket to expose the required length of unarmored cable within the enclosure.

Step 2:

Refer to the instructions of the gland manufacturer for the length of aluminum sheath required to be exposed beyond the jacket for fitting the glands to the sheath. Mark the sheath at the nearest crown (high point). This is the **cutting point**.

7.4 TYPE MC METAL CLAD (CCW®) , 300 V – 35 KV ARMORED CABLE FOR HAZARDOUS LOCATIONS SHEATH REMOVAL GUIDELINES (cont'd)

Installation Note 2:
Review Sheath Outside Diameters

For diameters less than or equal to 1.625", use Steps 3-9.

For diameters greater than 1.625", use Steps 10-15.

Installation Note 3:
Using the Kett Model KS-226 Cable Saw

When using the cable saw, it is important to read and understand the manufacturer's instructions and to be familiar with the Kett Cable Saw cutting equipment prior to operating.

For Small-Diameter CCW® Cable (diameter of sheath less than or equal to 1.625")

Step 3:

Using a hacksaw blade or tubing cutter, score the CCW aluminum sheath around the entire sheath at the **cutting point**. Gripping the cable with a hand on either side of the **cutting point**, flex the cable until the metal opens. Carefully remove the freed armored sheath from the end of the cable, being careful not to score or damage the cabled core.

Step 4:

For CCW cables with an inner jacket or tight-fitting sheath, it may be necessary to use the Kett-Tool Metal-Clad Cable Saw with the optional red cable guide. Attach the cable guide to the Kett Cable Saw and secure the cable.

Step 5:

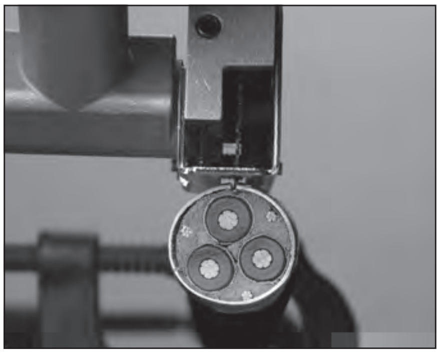
Now that your cross-cut is complete, sheath removal via the Kett-Tool Metal-Clad Cable Saw must be done longitudinally down the cable sheath.

7.4 TYPE MC METAL CLAD (CCW®) , 300 V – 35 KV ARMORED CABLE FOR HAZARDOUS LOCATIONS SHEATH REMOVAL GUIDELINES (cont'd)

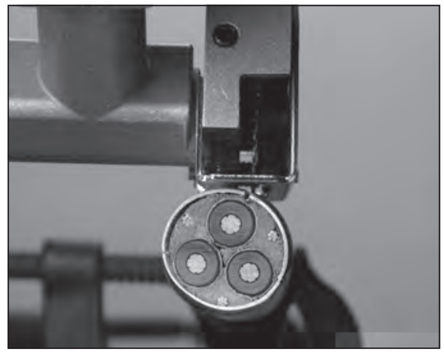
Step 6:

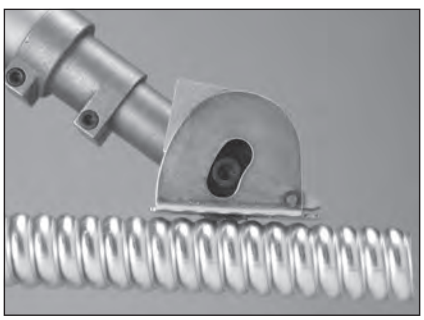
When setting up to cut CCW cable, the cable saw blade must be placed to cut perpendicular to the cable along the cable. See below:

CORRECT



NOT CORRECT





Depth of the saw blade and use of the guides are critical to the proper cutting operation. Do not cut through the entire sheath, as damage to the core is likely. It is suggested that the saw depth be adjusted so that 80-95% of the metal in the valley (low point) of the CCW® sheath is cut.

Step 7:

With downward pressure being applied to the Kett Cable Saw, make a longitudinal cut down the length of the sheath to be stripped (from the cut end) to the end you hacksawed earlier. Do not attempt to use the cable saw to plunge cut, as this could result in injury.

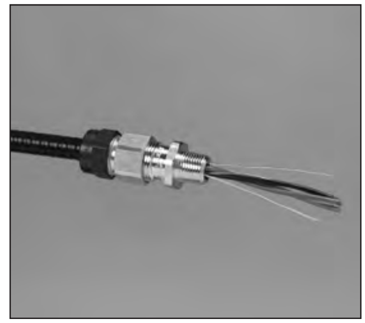
Step 8:

Insert the wide flat-head screwdriver into the cut at the free end and twist. This will cause the remaining metal in the valleys to break. Repeat until the sheath completely separates from the core.

7.4 TYPE MC METAL CLAD (CCW®) , 300 V – 35 KV ARMORED CABLE FOR HAZARDOUS LOCATIONS SHEATH REMOVAL GUIDELINES (cont'd)

Step 9:

Remove the cable fillers and marker tape from the cabled core, separating the conductors and the equipment grounding conductor(s) for ease in termination. Install the appropriate gland suited to the application per the manufacturer's instructions. The cable is now ready to be terminated into the enclosure.

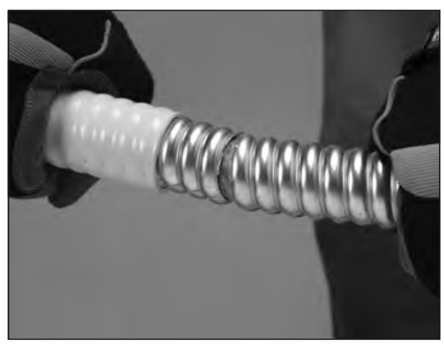


For Large-Diameter CCW® Cable (diameter of sheath greater than 1.625")

Step 10:

Using a hacksaw with the appropriate blade for cutting metal, cut through the crown (high point) of the CCW sheath at your marked **cutting point** to connect the valley (low point) of the CCW sheath.

Once this cut is made, mark the sheath around the balance of the cable, making additional cuts for a completed circle. If you cannot complete the circle entirely through cutting, then flex the cable end until the metal separates as shown at the far right.



Step 11:

Now that your cross-cut is complete, sheath removal via the Kett-Tool Metal-Clad Cable Saw must be done longitudinally down the cable sheath.

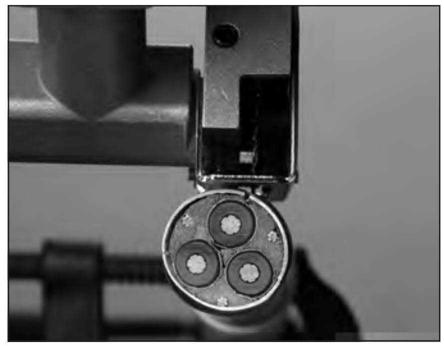
7.4 TYPE MC METAL CLAD (CCW®) , 300 V – 35 KV ARMORED CABLE FOR HAZARDOUS LOCATIONS SHEATH REMOVAL GUIDELINES (cont'd)

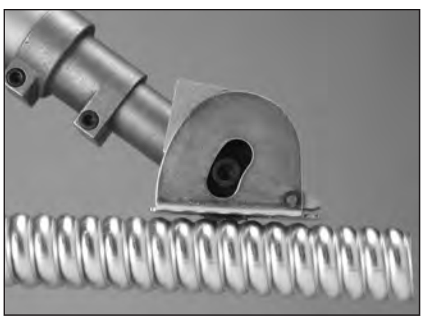
Step 12:

When setting up to cut CCW cable, the cable saw blade must be placed to cut perpendicular to the cable along the cable. See below:

CORRECT

NOT CORRECT





Depth of the saw blade and use of the guides are critical to the proper cutting operation. Do not cut through the entire sheath, as damage to the core is likely. It is suggested that the saw depth be adjusted so that 80-95% of the metal in the valley (low point) of the CCW® sheath is cut.

Step 13:

With downward pressure being applied to the Kett Cable Saw, make a longitudinal cut down the length of the sheath to be stripped (from the cut end) to the end you hacksawed earlier. Do not attempt to use the cable saw to plunge cut, as this could result in injury.

At this point, you should have a completed cut with noticeable connections in the valleys of the sheath.

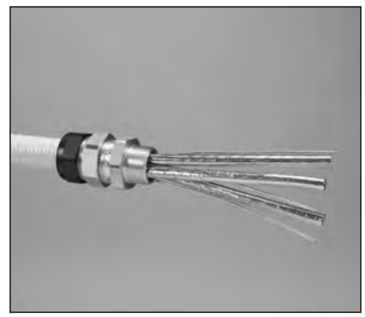
7.4 TYPE MC METAL CLAD (CCW®) , 300 V – 35 KV ARMORED CABLE FOR HAZARDOUS LOCATIONS SHEATH REMOVAL GUIDELINES (cont'd)

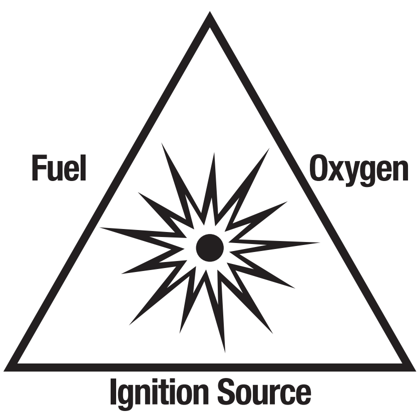
Step 14:

Insert the wide flat-head screwdriver into the cut at the free end and twist. This will cause the remaining metal in the valleys to break. Repeat until the sheath completely separates from the core.

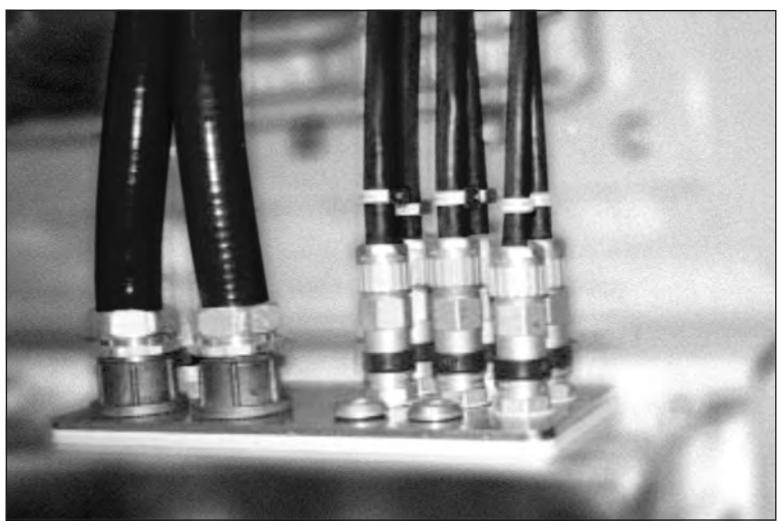
Step 15:

Remove the cable fillers and marker tape from the cabled core, separating the conductors and grounds/shields for ease in termination. Install the appropriate fitting/gland suited to the application per the manufacturer's instructions. The cable is now ready to be terminated into the enclosure.





Areas with a high propensity for ignitable environments, including presence of liquids, gases or dust.



7.5 TYPE MV-105, EPR 5 – 35 KV WIRE SHIELD POWER CABLE (UNISHIELD®) TERMINATION AND INSTALLATION PREPARATION GUIDELINES

UniShield® is the easiest MV cable to prep for termination and to install

- UniShield provides labor-saving costs of up to 30% when compared to tape shield designs.
- Unique metallic shield helps to more effectively separate the semi-conducting jacket/insulation shield from the EPR insulation for easier stripability and quicker cable preparation time.
- No longitudinal scoring is needed, minimizing potential damage to the underlying conductor insulation, eliminating costly repair time.
- UniShield's light weight and flexibility allow for ease of handling, splicing and termination and permit longer pulls from terminal to terminal.

How to Prepare UniShield for Termination and Installation

1 Affix tape collar guide for drain wire removal in accordance with the information provided by the accessory manufacturer.

2 Pull drain wire back to tape.

3 Affix metal collar in accordance with specified manufacturer's instructions.

4 Cut through shield to insulation layer, no more than 1" from the end of the cable.

5 Grasp shield layer only and pull back to loosen.

6 Loosen shield around entire circumference of cable.

7 Wind shield on tip of needle-nose pliers to collar.

8 Cut shield material circumferentially.

9 Clean insulation surface with solvent, working from free end to shield cutoff.

Global Reach

General Cable serves customers through a global network of 47 manufacturing facilities in 25 countries and sales representatives and distribution centers worldwide. The Company is solely dedicated to the production of high-quality energy, industrial, specialty and communications wire and cable products. In addition to its breadth of product line and strong brand recognition, the Company offers competitive strengths in such areas as technology, manufacturing, distribution and logistics, and sales and customer service. This combination enables General Cable to better serve its customers as they expand into new geographic markets.

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