EDITION 2/2025

Connecting
Globally

Guidelines Cable Installation

MC-HL · MV-105 · MV-90 · URD

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1. Cable installation

Cables placed in conduits or trays have specific installation parameters, including maximum pulling tensions, sidewall pressure which must be taken into account. Other types of installations, like buried or aerial, come with their own set of parameters. Damage to cables during installation can lead to service failures, as the mechanical stresses involved are typically more intense than those experienced during regular operation. The information below offers guidance on identifying these conditions and provides a methodology to help maintain them within acceptable limits.

2. General field practices

2.1 INTRODUCTION

Attention to detail is critical in determining whether an installation is successful or if damaged cables need to be removed, which may also impact warranty conditions. When preparing for a cable pull, it is essential to consider key factors such as maintaining sidewall pressure within allowable limits, adhering to the minimum bending radius, and ensuring that pulling tension does not exceed the specified maximum. Following best field practices helps facilitate the proper preparation of both large-scale and small-scale cable installations.

One of the most important aspects of a failure-free medium-voltage cable line is the proper technology of cable laying. It is important to pay attention to every stage of the process, as each of them carries the risk of potential cable damage.

Cleanliness
Cable manufacturing in the factory is carried out in accordance with high cleanliness standards to meet electrical insulation requirements. Reproducing the cable in field conditions, both during termination and splicing, must follow the same principles. Maintaining the cleanliness of materials, tools, and the workspace minimizes the risk of contamination and potential issues during the installation of cable terminations and joints.

Any dirt or foreign objects adhering to the sheath during cable laying should be removed using water or other biodegradable cleaning agents.

The highest level of cleanliness must be maintained during cable installation. It is essential that the installer strictly follows the accessory manufacturer's installation instructions and applies good installation practices.

2.2 TECHNICAL SUPPORT AND CUSTOMER SERVICE

In the event of issues with the supplied cable, promptly inform the manufacturer or seller. Each report will be accompanied by the manufacturer's declaration on the further course of action.

2.3 DELIVERY INSPECTION

Inspect the delivered drum and cable for any visible damage and ensure that heat shrink caps are present on both ends, or that the pulling head is properly installed if it was part of the order. If any damage is found, follow local procedures. Do not proceed with the installation if the cable or drum is damaged.

GUIDELINES - CABLE INSTALLATION

2.4 LOW AMBIENT TEMPERATURE

Low temperatures pose a significant concern during cable installation. Extra care should be taken in handling and pulling cables more slowly in cold weather, particularly below 0°C.

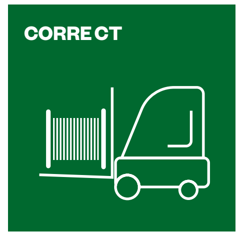
When planning cable installations in cold conditions, store the cables in a heated area for a minimum of 24 hours prior to installation. PVC jacketed cables should not be installed if the ambient temperature is below -10°C (14°F). This temperature guideline refers to the cable itself, not the surrounding environment.

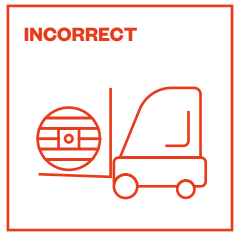
At ambient temperatures close to 0°C or lower, additional precautions should be taken to avoid damaging the cable's structural elements:
a. Reduce the unwinding speed,
b. Increase the diameter of the drum core on which the cable is wound,

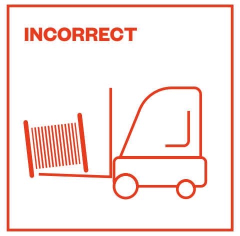
2.5 HANDLING AND STORAGE OF CABLE DRUMS

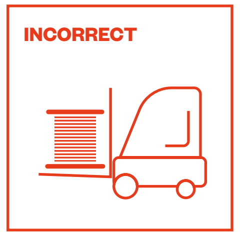
Unloading equipment should not come in contact with the cable or its protective covering. Drums should only be rolled in the direction indicated by the arrows on their side flanges.

a. Unloading using forklifts: the forklift forks must be positioned at a 90° angle to the plane of the drum's side flanges. They must be long enough to make contact with both flanges of the drum. Under no circumstances should the forklift forks come into direct contact with the cable.



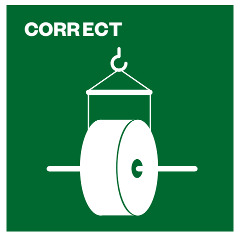




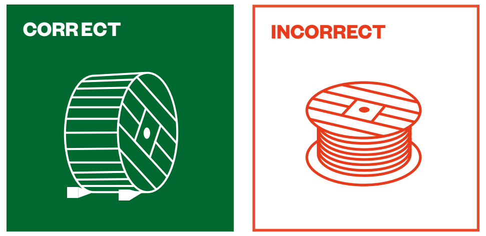


b. Unloading using a ramp: when using a ramp, keep in mind that it is inclined. Therefore, drums should be rolled down using ropes and winches. Ramps must be wide enough to support both reel flanges.

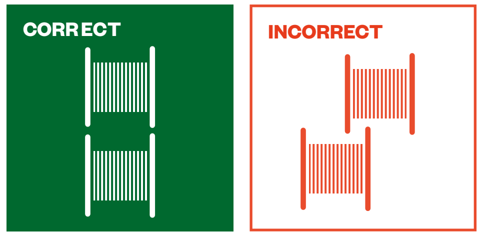
c. Unloading using a crane: when using a crane, the shaft must be suitable for the weight and width of the drum. A shaft through the arbor hole should be used. Under no circumstances should the sling ropes come into contact with the outer surface of the drum's side flanges.



Drums should be stored out of harm's way. Consider both physical and environmental hazards. Drums should be stored in an upright position on an area with a level, hard surface free of water, mud, stones, etc. The storage conditions should not deteriorate the technical condition of the drum with the wound cable. Store drums in a manner that prevents them from rolling spontaneously—use chocks.



Store drums in a way that prevents the flanges from coming into contact with the cable product, thereby avoiding potential cable damage.



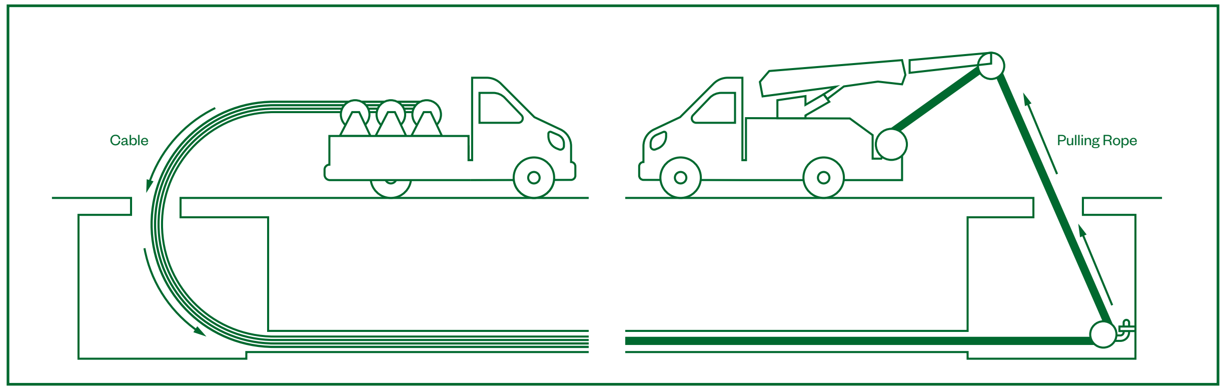
Over time, the condition of the wooden drums stored outdoors deteriorates. Therefore, it is recommended to rotate the drums by 90° every three months during the storage period.

Cable ends must always be sealed to prevent the entrance of moisture. After removing the cable termination, a heat-shrink cap should be placed on the cable end. Once the cable sock is removed, the section of the cable where it was applied must be cut off, and the end must be secured by placing a heat-shrink cap on it.

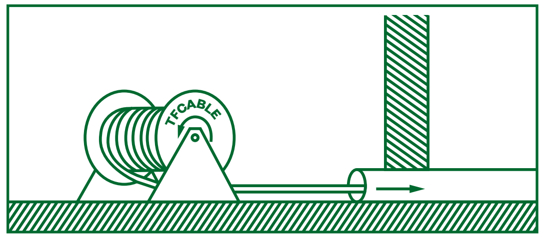
2.6 EQUIPMENT

The payout device should be equipped with a mechanism ensuring controlled unwinding. The pulling head or cable grip should be matched to the cable being pulled. The cable pulling device should allow for speed control and record the pulling force throughout the entire process. The technical condition of the rollers should be satisfactory.
The following figures illustrate some of the equipment and setups used for cable installation:

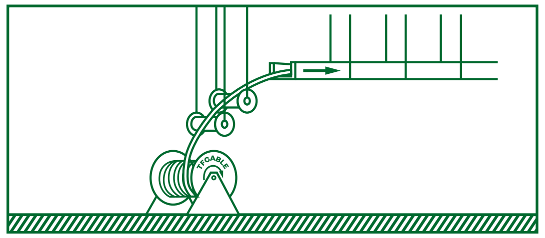
a. Pulling cable in duct: at the feed-in point, the cable's curvature follows a continuous arc with no reverse bends. At the pull-out point, the pulling rope exits the duct and goes directly to a pulling sheave.



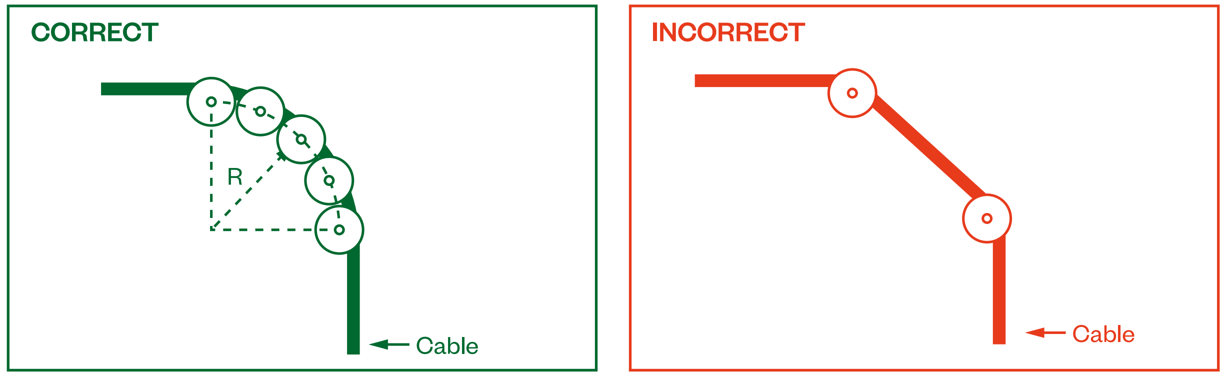
b. Cable feed into conduit at floor level: the cable is fed from the cable reel directly into the conduit at floor level. The cable is fed from the bottom of the reel so that its curvature is continuous with no reversed bends.

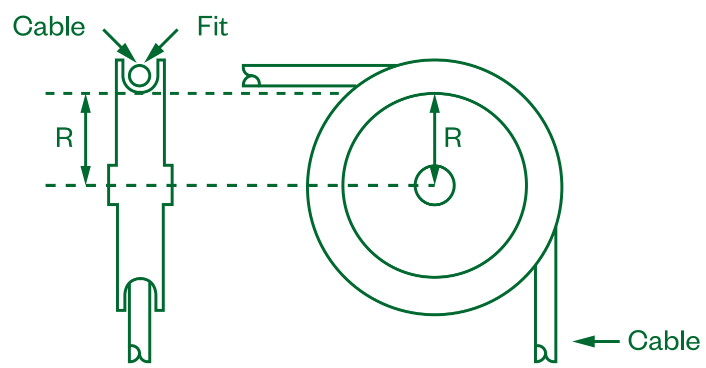


c. Cable feed into cable tray: from cable reel to cable tray, the cable is fed from the top of the reel to maintain required curvature. Sheaves, or a shoe, may be used to guide the cable into the tray.



d. Cable sheaves or shoes can be utilized to direct the cable, maintain the minimum bend radius, and minimize friction. The following figures illustrate examples of correct and incorrect sheave setups:



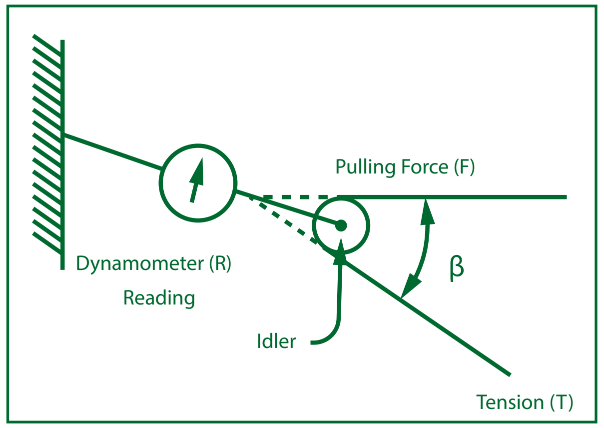


Single Sheave for 90° change of direction (R is radius used to calculate sidewall presure, SP)

e. The reading on the dynamometer (R) depends on the angle of the pulling line from the cable to the dynamometer idler and then to the pulling mechanism. As a result, a correction to the dynamometer reading may be necessary to determine the actual pulling tension (T).

$$T=R\bullet\left[\frac{1}{2\cos\left(\frac{\beta}{2}\right)}\right]-W$$

Where :
T - pulling tension, in pounds,
R - dynamometer reading, in pounds,
ß - angle between pulling line, in degrees,
W - tare weight of idler pulley assembly, in pounds.

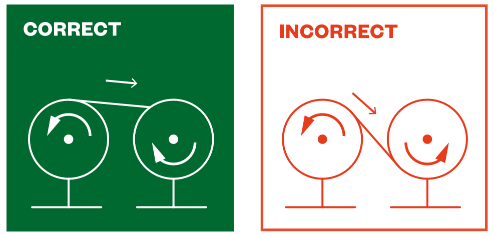


2.7 CABLE REWINDING

Check the condition of the inner sides of the drum's side discs; they should not contain any sharp elements.

a. The released outer end of the cable must be positioned in such a way that it can be attached to the second drum without bending the cable,
b. Straightening the cable should be done gradually without sudden actions,
c. Unwind the cable in the direction opposite to the arrow on the drum's side disc,
d. During the unwinding process, the inner end of the cable should be loosened but simultaneously secured against complete release,
e. The inner end must not undergo uncontrolled bends,
f. Rewinding the cable should be performed at a steady speed not exceeding 10 m/min,
g. The resumption of the rewinding process must proceed with a gradual increase in speed,
h. During the entire rewinding process, the cable must remain under tension.

The minimum diameter of the drum core onto which the cable is being rewound should not be less than 25*D.
The method of cable rewinding is presented in the following figure:

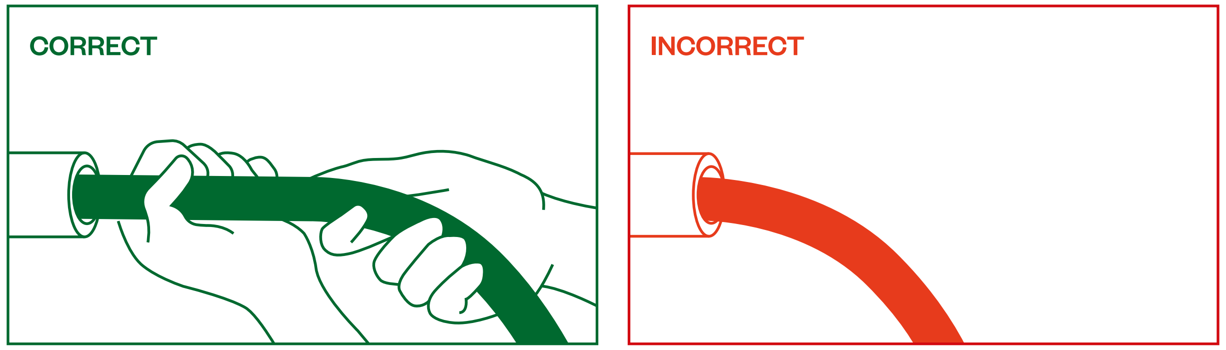


2.8 CABLE PULLING

If the condition of the drum, product, and protections raise no concerns, cable installation can proceed.

a. The released outer end of the cable must be positioned to allow connection to the pulling device without bending or kinking,
b. Straightening the cable should be done gradually without sudden actions,
c. Unwind the cable in the direction opposite to the arrow on the drum's side disc,
d. During the pulling process, the inner end of the cable should be loosened but simultaneously secured against complete release,
e. The inner end must not undergo uncontrolled bends,
f. Cable pulling should be performed at a steady speed not exceeding 10 m/min,
g. The resumption of the process must proceed with a gradual increase in speed,
h. During the entire pulling process, the cable must remain under tension.

The cable can be laid in an open trench by unrolling it along the trench and laying it under control, or by pulling the cable into the trench. When pulling into a trench/pipe/duct, temporary rollers should be installed along the pulling length to avoid cable damage by stones and debris. When feeding the cable directly into a conduit, ensure it is clean and will not damage the cable sheath during pulling. During pulling, to prevent sharp bends and crossovers, ensure someone is guiding the cable(s) straight into the conduit by hand, or for larger cables, use a large diameter sheave.



When pulling the cable onto trays, ensure the path on which it is to be pulled is free of sharp edges that could damage the sheath. After removing the cable termination, a heat-shrink cap should be placed on the cable end. Once the cable sock is removed, the section of the cable where it was applied must be cut off, and the end must be secured by placing a heat-shrink cap on it.

2.9 BENDING RADII

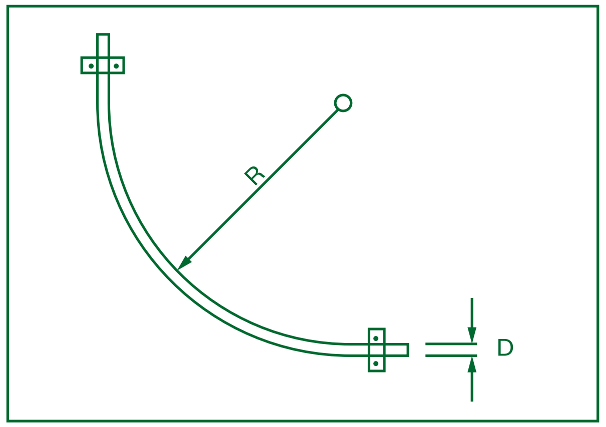
The minimum bending radius for power cables during installation shall be so made that the cable will not be damaged. The radius of the curve of the inner edge of any bend shall not be less than required:

12 x D for single-core cables[1]
7 x D for three-core cables[1]

In cases where the specified minimum bending radius prevents the installation of cable terminations or joints, a one-time reduction of the bending radius by 50% is allowed under the following conditions:

a. The cable is heated to approximately 25°C,
b. The bend is made in a single operation,
c. The bend is made using a template,
d. The bend is performed by a competent installer.

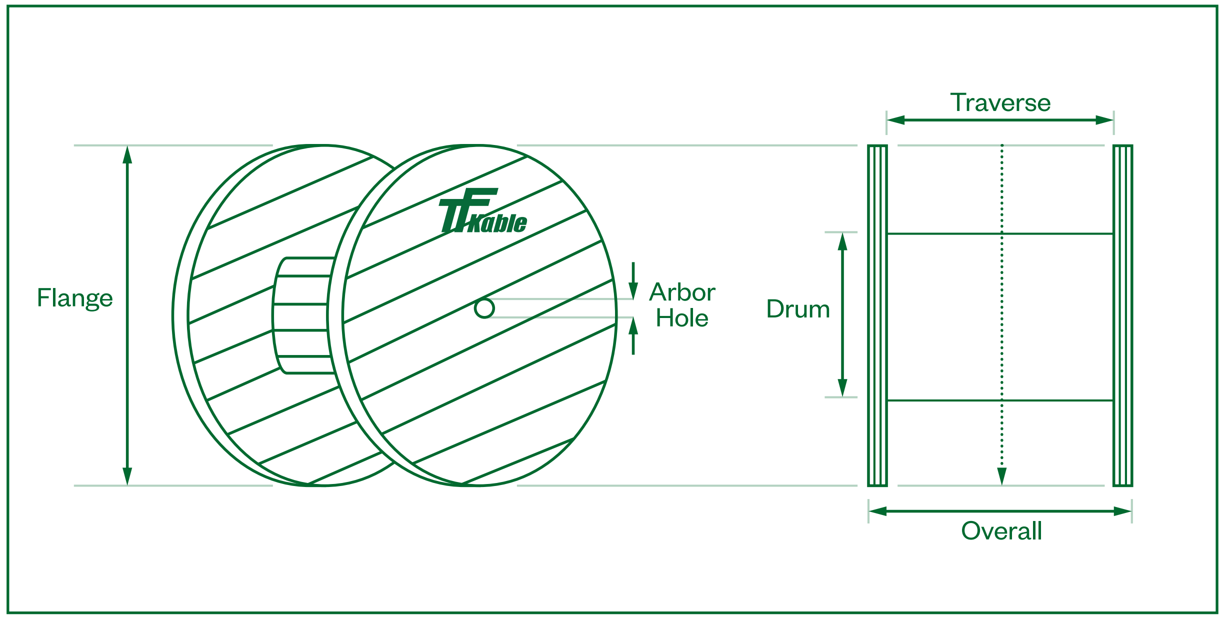
The minimum bending radius for transport on reels or in cases that cable is pulled under tension over curved surfaces as rollers or conduit should be increased to prevent damage of cable sheath etc. due to sidewall pressure limit (1, 000 lbs/ft).



Where:
R – bending radii,
D – outer diameter of cable.

[1] *NEC 2023 330.24(C)*

2.9.1 CABLE DRUMS



The minimum drum diameter is the smallest acceptable diameter of the reel drum. This requirement is specified in NEMA WC 26 and is based upon the cable construction. Excessive or extreme bending can damage the cable. Limitations on cable bending can best be expressed by identifying cable type and expressing the bending limit in terms of a multiplier of cable diameter.

Reels must have a drum diameter of not less than:

$$Dd = Dc \bullet F$$

Where :
Dd – minimum drum diameter,
Dc – diameter of cable,
F – the factor for specific cable constructions[2].

[2] *NEMA WC-26*

FACTORS FOR DETERMINING MINIMUM DRUM DISTANCES

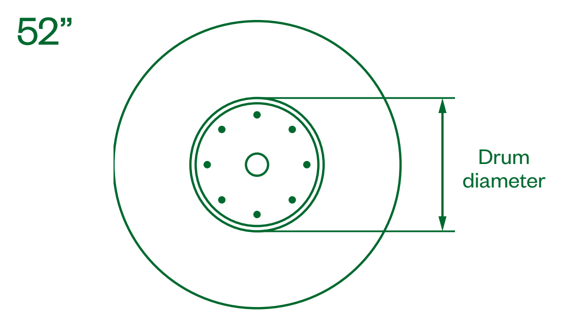
Type of cable	Factor
Single and multiple conductor nonmetalic covered cable – wire or tape shielded	14
Single and multiple conductor metallic covered cable – corrugated metallic sheathed	14

2.9.2 COMPARISON OF MIN DRUM DIAMETER AND MIN BENDING RADIUS

Example of calculations for drums:
For MC-HL 500MCM 15kV 133%, **the minimum drum diameter** is fourteen (14) times the cable overall diameter.

D = 3.71”
F = 14
3.71”x14 = 51.94”

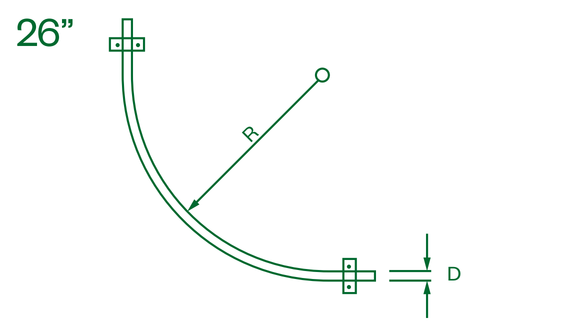
Minimum drum diameter packaging



Example of calculations for installation:
For MC-HL 500MCM 15kV 133%, **the minimum bending radius** is seven (7) times the cable overall diameter.

D = 3.71”
F = 7
3.71”x7 = 25.97”

Minimum bending radius installation



2.10 CABLE LUBRICATION SELECTION

Reducing the friction coefficient is the main consideration when choosing a lubricant. It is also crucial that the lubricant is compatible with both the cable and the conduit, ensuring it does not adversely affect the conduit or the physical and electrical properties of the cable’s insulation, semiconducting, or jacket materials. Additionally, the lubricant and any residue left behind should be non-flammable. It’s important that the lubricant is listed by UL or CSA and free of any waxes or greases.

The cable jacket and/or conduit walls must be fully lubricated. The lubricant should be applied right before or during the pulling process, and the amount used should be increased as necessary in challenging pulling conditions.

$$Q = 0.0015 \cdot L \cdot D$$[1]

Where:
Q - quantity, in gallons,
L - conduit length, in feet,
D - outside diameter of cable or inside diameter of conduit, in inches.

[1] *Polywater, “Technical Talk”, volume 4*

3. Installation in conduit

It is essential to perform calculations to assess whether the pulling process appears “easy” or “impossible,” which will guide the decision-making. If a “marginal” situation arises, a comprehensive review of the entire pull is necessary. This review may involve more detailed calculations or conducting trial pulls. The final decision should be based on installation factors familiar to both the end user and the installer.
Pulling tensions can be evaluated by calculating the maximum tension based on the pulling equipment used and the highest tension that can be safely applied to the conductors. The smaller of these two values represents the maximum allowable tension (Tm).

Next, the pulling tension (T) needed to move the cable through the conduit is calculated and compared with the maximum allowable tension. If the pulling tension exceeds this limit, adjustments must be made to ensure a successful installation.

3.1 MAXIMUM TENSION ON CABLE CONDUCTORS

The conductors within the cable are usually the only components that can withstand pulling forces without sustaining damage. Avoid using metallic shielding wires, tapes, braids, or armor that are not intended for this purpose when calculating pulling tensions.

$$Tc = S \cdot A \cdot N$$

Where:
Tc - pulling tension, in pounds,
N - number of conductors,
S - allowable stress for Cu = 0.008; for Al = 0.005,
A - area of each conductor, in cmil.

In the case of simultaneously pulling two or three cables with the same cross-section of working cores, the pulling force should not exceed twice the value for a single cable.
It is not advisable to pull different sizes of conductors at the same time if their dimensions or other cable characteristics vary significantly.

Do not exceed the allowable tension:
a. 6000 lbs for single-core cable
b. 10000 lbs for three-core cable

3.2 PULLING TENSION

The pulling forces of cable lines are calculated using a special computational program.
Please remember that the calculations are based on the Cableizer program and our best experience. We are not a design office. Please treat them as a suggestion, not documentation constituting the basis for modifying the cable line layout. During installation, the role of the construction manager is to ensure that these parameters are not exceeded and to select the appropriate sections to be pulled for the complexity of the route.

The dynamic friction coefficient (μ) quantifies the friction between a moving cable and the conduit. This coefficient significantly influences tension calculations, ranging from 0.1 to 1.0 when lubrication is used and potentially exceeding 1.0 for unlubricated pulls. It’s important to avoid stopping and restarting pulls, as the static friction coefficient is always higher than the dynamic friction coefficient.

	Type of conduit	
Cable jacket	Metal	PVC
PVC	0.4	0.35
PE – LD HWM PE	0.35	0.35

Gene C. Neetz, "Coefficient of Friction Measurement Between Cable and Conduit Surfaces Under Varying Loads," in 1985 IEEE Transactions on Power Apparatus and Systems, vol. PAS-104, no. 1, pp. 16-21.

The friction coefficient between a cable's exterior (jacket/sheath) and the conduit depends on various factors, including the type of jacket or sheath, the type and condition of the conduit, the kind and quantity of pulling lubricant used, the temperature of the cable, and the ambient temperature. When the ambient temperature is high (80°F and above), the dynamic friction coefficient for cables with a non-metallic jacket can increase. It's essential that pulling lubricants are compatible with the cable components and are applied during the pulling process.

3.3 SIDEWALL PRESSURE

When a cable is pulled around a bend, sidewall pressure (SP) is applied to it. Excessive sidewall pressure can lead to cable damage and is often the most limiting factor in installations.

Sidewall pressure is calculated using the following formula.

For bending over a rollers:

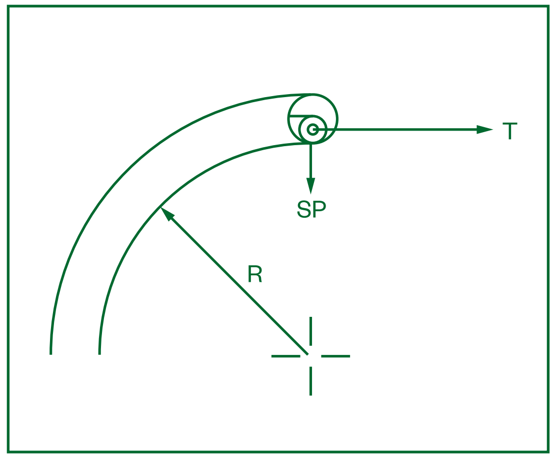
$$PSWP = T \cdot d / r$$

In this case, the limit is <= 500 lb/feet.

For bending inside a conduit:

$$PSWP = T/r$$

In this case, the limit is <= 1000 lb/feet.



Where:
PSWP - pressure at the bend point of the cable [lb/feet],
T - pulling force behind the bend point [lb],
d - distance between rollers [feet],
r - bending radius of the cable [feet].

4. Installation in cable tray

The same method used for installing cables into conduits should be applied when pulling cables into cable trays. It's essential to consider the length of the runs, the number of cable turns, and the size of the cable sheaves to ensure that the cable's maximum pulling tension, minimum bending radius, and maximum allowable sidewall pressure are not exceeded, which could potentially damage the cable.

4.1 ROLLERS AND SHEAVES

When navigating bends in cable trays, excessive sidewall pressure can damage the cable. This pressure can be minimized by using a sheave with a large radius. However, when a large radius sheave is not feasible, an assembly of multiple smaller sheaves is often used. Care must be taken to avoid damage caused by high sidewall pressure on each sheave. The sheaves should have a minimum inside radius of 1.25 inches, with at least one sheave for every 20° of the bend. A three-sheave assembly for a 90° bend is not recommended; minimum of 5 rollers in the frame should be used.
Rollers and sheaves should be well-maintained and lubricated to achieve the lowest possible coefficient of friction.

Rollers mounting:
a. Rollers must be properly spaced to prevent the cable from touching the tray,
b. Rollers must turn freely,
c. When the tray changes direction, either vertically or horizontally, the sheave radii must be large enough to comply with the minimum bending radius and maximum allowable sidewall pressure limits.

Roller spacing will vary with:
a. Cable weight,
b. Cable tension,
c. Cable construction,
d. Roller height above the tray.

To estimate roller spacing, the following equation can be used:

$$s = \sqrt{\frac{8 \cdot h \cdot T}{w}}$$

where:
s - distance between rollers, in feet,
h - height of top roller above the tray bottom, in feet,
T - tension, in pounds,
w - weight of cable, per foot.

4.2 PULLING TENSION

Calculations of pulling tensions for cable trays are similar to those for pulling cable in conduit, adjusting the coefficient of friction to reflect using rollers and sheaves.

5. Field Testing

Manufacturers conduct a range of electrical tests on finished cables to ensure they can safely handle their rated voltage and current levels. However, certain installation procedures—such as pulling cables through conduit, laying them in cable trays, or integrating them into structural components—can potentially cause damage severe enough to create electrical hazards. For instance, miscalculations in pulling tension, sidewall pressure, or conduit fill ratios may compromise the conductor's insulation when pulling it through a raceway.
Since post-installation testing is considered a best practice, some installation contracts may require the installer to perform specific tests.

Safety Considerations
Electrical testing carries inherent risks and should only be performed by qualified personnel. Both low-voltage and high-voltage testing present potential dangers to workers and equipment. A thorough understanding of safety protocols, testing instruments, cable systems, and connected devices is essential to prevent equipment damage, cable failures, and electric shock hazards. IEEE Standard 510 outlines industry best practices for conducting field tests safely.

Test Preparation
Before testing begins, the cable system must be properly disconnected from its power source. If it was previously energized, appropriate procedures for de-energization, lockout, tagging, and grounding should be followed. High-voltage cables that remain energized can induce voltage in nearby ungrounded conductors. To ensure both safety and test accuracy, it is advisable to disconnect cables from unrelated equipment and ground all conductors that are not being tested.
Additionally, sufficient physical clearance should be maintained between cable ends and other components, such as live conductors and grounded structures. At remote ends of the cable system—away from the test equipment—protective barriers or designated personnel should be in place to prevent unauthorized access to the test area.

Conducting the Test
Testing should be carried out in accordance with the procedures specified by the test equipment manufacturer. Adhering to established protocols and recording test results ensures reliability and provides documentation for future reference.

Completing the Test
After testing, all cables should remain grounded until the test equipment is fully disconnected and secured. Special caution is required when performing HVDC (high-voltage direct current) tests, as residual voltage can persist on the cables after the test is completed. As a general rule, grounding should be maintained for a period equivalent to one to four times the test duration before it is removed and the cables are reconnected to the circuit.

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