Wire & Cable:
Handling and Installation Engineering Guide

Receiving and Handling Cable

In order to benefit from investing in underground cable (power cable), the purchaser should put into practice a complete visual inspection program that will help identify any cable that is damaged during shipment. If any cable is undesirable, it is then returned to the manufacturer instead of being installed. By recognizing and refusing damaged cable, one can considerably improve the dependability of the underground system.

Receipt of Cable Reels

Once the purchaser has received the cable shipments, they should carry out an approval inspection. A cable approval inspection involves some straightforward and low-cost steps that can yield significant dividends.

The following steps should be taken to insure proper acceptance of cable:

1. Visually check for shipment damage

Visually check cable reels for any damage that may have taken place during delivery. The purchaser should be mainly worried for cable damage if:

a. A reel is laying flat on its side, especially if it is a large conductor size, such as 500 kcmil, 750 kcmil, or 1,000 kcmil
b. Numerous reels are piled on top of each other
c. Other cargo is piled on the reel
d. Nails have been driven into the overhang to prevent overcrowding
e. A reel overhang is broken
f. A cable covering is detached, discolored, or broken
g. A cable end seal is detached or broken (a broken or absent end seal means that moisture may have come into the cable)
h. A reel has fallen (concealed damage likely)

2. Inspect reel tags

Visually check each reel to assure that it has the correct tags and labels as noted in the specifications. The reel should contain the subsequent minimum information:

a. Purchaser's name and address
b. Purchase order number
c. Conductor size and type
d. Insulation thickness and type
e. Jacket type
f. Quantity of cable on reel
g. Beginning and ending sequential footage numbers present on the jacket

Confirm that the cable description, reel size, and cable footage are equivalent to that specified. Any missing information should be acquired from the manufacturer.

3. Check dimensional tolerances

Make a straightforward measurement of the cable dimensions on one reel of each size of cable in a shipment to prove that the cable's dimensions meet the requirement.

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Handling of Cable Reels

To guarantee that material handling equipment does not touch or interfere with cable surfaces or with protective covering on the reel, the utmost care should be taken when moving the cable reels. **It is very important that cable reels not be dropped from any height, or be allowed to roll unrestrained**. Cable reels should be moved or lifted using the technique depicted at the end of this document.

1. For cranes, booms, or other overhead lifting equipment, a sturdy steel arbor or heavy rod or pipe should be placed in through the reel hubs so that the cable reel can be lifted by slings that make the most of spreader bars. This technique will assure that sling pressure against a reel flange, slanting of the reel, sliding of the sling, and other unstable situation will be reduced.
2. When lifting reels by fork truck type equipment, reels should only be lifted from the sides, and only if the blades of the fork truck are long enough to support both flanges. This way will make sure that the lift pressure is uniformly dispersed on both flanges and not on the cable itself.
3. Rolling reels containing cables should be kept to a minimum; if rolling is necessary, reels should always be rolled in the direction indicated by the “arrows” on the sides of the reel flanges or in the opposite direction to which the cable is wrapped onto the reel. Rolling the reels this way will avoid the release of the cable wraps, which may lead to problems during installation.
4. It is important that any debris be cleared from the path over which the cable reels are to be rolled since that might damage the cable if the reels were to roll over it. Cable reels should be rolled in the direction of the “Roll This Way” arrow and lowered in a controlled manner. The ramps should be spaced far enough apart so that they are touching the reel flanges at all times.

Storage of Cable Reels

Cable reels should not be stored on their sides if at all possible.

To prevent deterioration of the reels and moisture seeping into the cables, it is preferable to store cable reels indoors on a hard, dry surface.

If cable reels are stored outdoors they must be supported off the ground and protected with a suitable weatherproof material. The reel supports should be at least twice the width of the reel flange, long enough to provide a sufficient load bearing surface (to prevent sinking), and high enough to prevent the reel from sitting in free standing water in case of rain. Reel supports should be placed under each reel flange, and to prevent rolling each reel should be placed between the reel flange and the support at opposite sides of the flange.

All cable reels should be stored in such a way so as to allow easy access for lifting and moving, away from construction activities, falling or lying objects, sources of high heat, open flames, chemicals or petroleum products, etc. that may cause damage to the cable. It is also recommended to use fences or any other suitable barriers to protect cables and reels against damage by vehicles or other moving equipment in the storage area.

If the cable is stored on reels for future use after the factory applied end caps are removed, the exposed cable ends MUST be re-sealed using properly applied weatherproof end caps or by taping the ends with a tape designed to prevent moisture. PVC tapes or Duct Tape are not appropriate for preventing moisture. One must secure the loose ends of the cable reels to the reel flange and cannot lie on the ground.

Reels and end caps should be inspected from time to time if they will be stored outside for a long period of time. A once a month inspection is suitable at first but one should consider increasing this if storage time is extended since wooden reels tend to deteriorate over time and sealed end caps will lose their usefulness. Rates of deterioration will vary depending on the environment in which the reels are stored.

NOTE: If a specific method of shipping is used, such as shipping to a job site, etc., the manufacturer must be notified of these special requirements.

Installation Suggestions

Below you will find a general guide for the installation of shielded and unshielded cables, jacketed cables rated 600 to 35,000 volts in conduit, underground ducts, racks, trays or direct buried.

Safety Measures Prior to Pulling Cable

Temperature Considerations

AWG would follow and support the guidelines in the IEEE 576 Section 8 Minimum installation temperature.

Minimum installation temperature

When installing cables under cold ambient conditions, various insulations and jacket materials become brittle and cables may be damaged if worked at too low a temperature. Table 7 gives the recommended minimum temperatures for handling and installing cables. It should be noted that these are typical values for standard compound materials; minimum temperatures will vary with special compound designs and requirements as specifications dictate.

Applications

Table 7—Recommended minimum temperature for handling and installing cables

Type of Insulation or Jacket	Minimum Temperature for Installation
PVC	-10°C
PCP	-20°C
CSPE	-20°C
CPE	-20°C
XLPE	-40°C
PE	-40°C
EPR	-40°C

Duct Sizing

Select duct size in such a way that the difference between the hoop diameter of the cable(s) and the inside diameter of the duct will not be less than ½”. Also check that the cross-sectional area of the cable is not more than the percentage of the interior cross-sectional area of the conduit, as recommended by the National Electric Code (NEC). In addition, consider using larger ducts or additional pull boxes if long pulls are required.

Jam Ratio

Jamming might occur in bends if three cables are pulled in parallel in duct. This happens when the cables adjust from a triangular pattern to a cradled pattern as they are pulled in through the bend. This pattern change will force the two outer cables to move farther apart. The cables will also jam if the conduit diameter is too small to contain the wider pattern.

To prevent this, the jam ratio should be checked. The jam ratio corresponds to the inside diameter of the duct to the cable diameter, such that:

$$J = D \div d$$

Where:

J = Jam ratio

D = Inside diameter of duct (in)

d = Outside diameter of cable (in)

The proper cable configuration can be determined if the above jam ratio is calculated. The likely configurations are as follows:

Jam Ratio	Cable Configuration
J < 2.4	Triangular
2.4 < J < 2.6	More likely triangular
2.6 < J < 2.8	Either triangular or cradled
2.8 < J < 3.0	More likely cradled
J > 3.0	Cradled

Cable jamming tends to occur between J = 2.8 and J = 3.1. This is true if the sidewall bearing pressure (SWBP) in a bend surpasses the 1,000 lbs/foot.

Cable Clearance

In order to make sure that the cables can be pulled through the conduit, specifically in applications where the National Electric Code (NEC) limits on conduit fill do not apply, one needs to calculate the clearance between the cable(s) and conduit. The recommended calculated clearance should not be less than 0.5 inches. However, a lesser clearance, such as 0.25 inches, may be suitable for primarily straight pulls.

In addition, the clearance should contain the pulling eye or cable grip, which is used for the cable pull. The formulas below can be used to calculate the cable clearance for a single cable pull and for a three-cable pull. (Please Note: To allow for differences in cable and duct dimensions and ovality of the duct at bends, the nominal cable diameter “d” has been increased by 5%).

a. Single Cable Pull

$$C = D - 1.05 \times d$$

b. Three Cable Pull (triangular pattern)

$$C = \frac{D}{2} - 1.366\,(1.05 \times d) + \frac{(D - 1.05 \times d)}{2} \times \sqrt{1 - \left[\frac{1.05 \times d}{(D - 1.05 \times d)}\right]^2}$$

Where:

C = Cable clearance (in)

D = Inside diameter of duct (in)

d = Outside diameter of cable (in)

Please reference the following table in dealing with applications where the National Electric Code (NEC) is compulsory. The table shows the most ordinary scenarios concerning the fill ratio of many cable configurations in various duct sizes.

	Conductor Fill Per NEC							
Duct Sizes (in)	1 Conductor (53% Fill Ratio)		2 Conductors (31% Fill Ratio)		3 Conductors (40% Fill Ratio)		4 conductors (40% Fill Ratio)	
	Area (in2)	Dmax (in)	Area (in2)	Dmax (in)	Area (in2)	Dmax (in)	Area (in2)	Dmax (in)
½	0.16	0.453	0.09	0.245	0.12	0.227	0.12	0.197
¾	0.28	0.6	0.16	0.324	0.21	0.301	0.21	0.261
1	0.46	0.764	0.27	0.413	0.34	0.383	0.34	0.332
1 ¼	0.80	1.005	0.47	0.543	0.60	0.504	0.60	0.436
1 ½	1.08	1.172	0.63	0.634	0.82	0.588	0.82	0.509
2	1.78	1.505	1.04	0.814	1.34	0.755	1.34	0.654
2 ½	2.54	1.797	1.48	0.972	1.92	0.902	1.92	0.781
3	3.91	2.234	2.26	1.208	2.95	1.12	2.95	0.97
3 ½	5.25	2.583	3.07	1.397	3.96	1.296	3.96	1.122
4	6.74	2.931	3.94	1.585	5.09	1.47	5.09	1.273
5	10.60	3.674	6.20	1.987	8.00	1.843	8.00	1.596
6	15.31	4.415	8.96	2.388	11.56	2.215	11.56	1.918

Please Note: “*d_{max}(in)*” is the maximum single conductor diameter that will comply with the above requirements. “*Area (in^2)*” is the area of the conductor(s). Ground wires have not been considered in the above table. The NEC requires that *“Equipment grounding or bonding conductors, where installed, shall be included when calculating conduit or tubing fill. The actual dimensions of the equipment grounding or bonding conductor (insulated or bare) shall be used in the calculation.”*

The below formula can be used when a calculation must be made to comply with the NEC fill ratio requirements:

$$FR = [N_{PC} \times (PC_D \div 2)^2 + N_{GC} \times (GC_D \div 2)^2] \div (C_D \div 2)^2$$

Where:

FR = Fill Ratio (%)

N_{PC} = Number of Phase Conductors with the same diameter

PC_D = Diameter of Phase Conductor (in)

N_{GC} = Number of Ground Conductors with the same diameter

GC_D = Diameter of Ground Conductor (in)

C_D = Diameter of Conduit or Duct (in)

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Minimum Bending Radius (Static Conditions)
The following formula can be used to determine the minimum values for the radii to which such cables may be bent for permanent training:

$$MBR = OD \times M$$

Where:

MBR = Minimum radius of bend (in)

OD = Outside diameter of cable (in)

M = Diameter multiplier (Please see tables on the next page(s))

Note: The above calculation applies to STATIC conditions ONLY. Please reference the DYNAMIC conditions section below and the Sidewall Bearing Pressure section for the minimum bending radius of cable in motion.

Minimum Bending Radius (Dynamic Conditions)
The following formula can be used to determine the minimum values for the radii to which such cables may be bent while being pulled into an installation and while under tension. This value will largely depend on the tension the cable experiences as it exits the bend. The greater the exiting tension, the greater the minimum-bending radius will be for the cable.

$$MBR = (Te \div SWBP) \times 12 \text{ (in)}$$

Where:

MBR = Minimum radius of bend (in)

Te = Tension as cable exits the bend (pounds x force)

SWBP = Maximum allowable Sidewall Bearing Pressure (pounds x force per foot of bend radius)

Cable Training (Offset bending)
You may use the following formula to determine the minimum distance necessary for permanent cable training (offset bending) in a manhole:

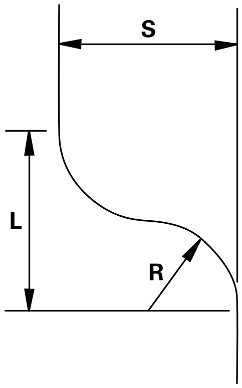
$$L = \sqrt{S\,(4R - S)}$$

Where:

L = Minimum distance required (in)

S = Offset (in)

R = Bending radius to cable centerline (in)



Allow a suitable length of straight cable at both ends of the offset bend.

Power and Control Cables without Metallic Shielding or Armor

Insulation Thickness (mil)	Overall Diameter of Cable (in)		
	1.000 and Less	1.001 to 2.000	2.001 and Over
	Minimum Bending Radius as a Multiple of Cable Diameter		
155 and less	4	5	6
156 to 310	5	6	7
310 and over	—	7	8

Note 1: The highest applicable multiplier should be used in all cases. The calculated minimum bend radius (applicable multiplier x outside diameter of cable) refers to the inner surface of the bent cable, and not the axis (centerline) of the cable conduit.
Note 2: Use the thickest of the insulations of the cables within the assembly and the diameter of the largest single cable within the cable assembly to determine the multiplier. Afterwards, apply that multiplier to the diameter of the overall assembly.

Note 3: The minimum values for the radii to which cables may be bent during installation may not apply to conduit bends, sheaves or other curved surfaces around which the cable may be pulled under tension while being installed. Larger radii bends may be required for such conditions. (Please reference "Precautions during Cable Pulling" in the "Sidewall Bearing Pressure" section).

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Power and Control Cables with Metallic Shielding or Armor

Cable Type	Minimum Bending Radius For Single Conductors	Minimum Bending Radius For Multiple Conductors†
Interlocked and Polymeric Armor (without shielded conductor)	7	7
Interlocked Armor and Polymeric Armor (with shielded conductor)	12	7
Wired Armored Cable	12	12
Metallic Tape Shielded Cable	12	7
Metallic Fine Wire Shield	12	7
Concentric Neutral Wire Shielded Cable	8	5
Lead Sheath Cable	12	7
LC Shielded Cable	12*	7

† Use the larger of the two minimum bending radii when considering the minimum-bending radius for multiple conductors.

**For conductor sizes 1500kcm and larger, the minimum bending radius for LC Shielded cable is 18X the cable diameter.*

Note 1: Multiply the diameter of the cable by the factor in the table above to attain the minimum-bending radius.

Note 2: These limits may not be appropriate for use with conduit bends, sheaves or other curved surfaces around which the cable may be pulled under tension while being installed due to sidewall bearing pressure limits. The minimum radius specified refers to the inner radius of the cable bend and not to the axis of the cable.

Clearing Ducts

Using a plug that is roughly the same diameter as the inside of the duct does not permit obstructions in the duct since it pulls the plug through the structure. After doing this, use a wire brush to clean and remove foreign matter from the duct. In order to prevent scratch damage to the cable jacket during pulling, it is important to smooth the interior.

Trench for Direct Burial

To prevent damage to the cable jacket during or after cable installation, the trench should be clean of sharp stone, glass, metal or wood debris. The trench bottom should be evenly covered with a layer of soil or sand that has been screened through a medium-to-fine mesh screen to remove all larger stones or other material. This will assure a smooth, soft-bedding surface for the cable(s). It is a good idea to lay a protective covering on the fill about 6-8 inches above the cable to protect it if working in an urban area or near where a lot of digging occurs. If working under highways or railroad rights-of-way, it is also a good idea to install the cable in a pipe or conduit to give added mechanical protection.

Rack/Trays

One should check the entire path that the cable will follow during pulling to make sure that the cable will have a smooth ride, free of all barriers or sharp edges. In checking this, one should consider the position the cable will take on when under tension.

Precautions During Cable Pulling

Cable Guides

All guides should be in the form of large diameter, smooth-surfaced, free-turning sheaves or rollers to prevent damage to the cable jacket when guiding the cable from the reel to the duct mouth or trench. Guide tubes or chutes must be smooth, burr-free working surfaces with the largest possible bend radii and be securely anchored if used. Mounting the cable reel in sturdy jacks, leveling the reel shaft and lubricating the reel arbor holes with grease will lead to low cable tension. If breaking the reel needs to happen, it should only be done to prevent reel over-run when the pull is slowed or stopped, or on steep downhill runs where cable weight is enough to overcome cable-duct friction.

This information also applies for rack or tray installations. The following points should be noted when making such pulls:

1. Cable support rollers should be spaced close enough so that the cable's normal sag, even when under tension, will not result in tray dragging.
2. The cable rollers should be contoured so that the cable will not ride off the end of the roller or be "pinched" into a sheave contour diameter that is smaller than that of the cable.
3. When rollers or sheaves are used to guide the cable through the bends, it is important that enough of them be used to guide the cable in a smooth curve of the desired radius from tangent point to tangent point. If this is not done, the cable may be "kinked" around the radius of each roller.

The cable may be paid off the reel and laid into the trench as the reel is moved along the length of the trench in cases of direct-burial installations. When this happens, the cable is laid on a bed of soil or sand.

If the cable needs to be pulled through the trench, the best way to do so is to support the cable on temporary rollers so that the cable does not drag over the soil or sand bed. If one does not have rollers handy, sacks filled with very fine sand or other fine powdery material may be used as an alternative to support the cable and keep it from dragging on the trench bed during the pulling process.

Cable Lubricant

To reduce pulling tensions and damage on cables, lubricants may be used in conduit. When using cable or pulling lubricants, one should avoid compounds that may contain oils or greases since they may damage the cable jackets. Also, pulling lubricants that contain micro-spheres or micro-balls should be avoided for medium-voltage cable installations. These kinds of lubricants are meant to be used on low-tension pulls that are not representative of power cable pulls.

Most commercially available pulling lubricants can be used with little worry for compatibility. But, one does need to keep in mind that some pulling lubricants react poorly to some cable jacket compounds, which may lead to ruining the cable jacket. It is best to avoid damage to the cable jacket by consulting the cable manufacturer regarding lubricant compatibility with specific jacket compounds.

Pulling Eyes & Grips

Pulling eyes attached to the cable conductor(s) are used for large, heavy cable, or for cables where the pulls are very long or contain numerous bends. To use the pulling eye, one must fasten it directly to the conductor(s) on the end of the cable by soldering the copper conductors into a socket-type eye, or by mechanically compressing the aluminum conductors into an aluminum eye. Then, a tape seal or heat-shrinkable tube is placed over the eye-cable joint to provide a reliable weather-tight seal for the cable during pulling. For armored cables, the armor needs to be properly secured to the eye to insure the reliability of the cable during pulling. Generally, pulling eyes tend to be installed at the factory; however, they can also be installed in the field.

Often times, woven wire pulling grips, generally called “baskets” are used to pull armored cables; they are well suited for pulling smaller size voltage cables, or where the pulls are fairly short. Special measures need to be taken if using “baskets” on Interlock Armored cables to avoid damage to the cable or problems in making the pull. The puling grip may tend to stretch the armor if the grip is not properly secured to the cable. The following method for preparing the cable and attaching the grip is advised:

1. Select the grip size that fits the cable diameter or armor best. Determine the length of the gripping portion of the grip.
2. Find two points on the end of the cable. The first is 75% of the grip length from the end; the second is 100% of the grip length from the end.
3. Get rid of the sheath/armor, and also the outer jacket if there, to the first mark. Do not damage the core of the armor. If need be, secure the armor at the cut point with friction tape before cutting.
4. Apply four, 3-inch long, tight wrappings of friction tape. Place this tape on a) the end of the core, b) on the core to the edge of the sheath/armor, c) on the jacket, or sheath/armor to the edge of same, and d) on jacket, or sheath/armor where the last 3 inches of grip will be.
5. If cable will be exposed to moisture during the pull, seal the cut ends of the conductors with sealing mastic and vinyl tape, or heat-shrinkable cap(s).
6. Place the grip on the cable and secure it tightly by “milking” it from the cable end towards the end of the grip.
7. Clamp the back end of the grip to secure it to the cable with a steel hose clamp, such as the “Band-It” types, or a tough steel wire that is firmly applied.
8. Over the clamp apply a tape wrapping to smooth it and prevent drag during the pull.

CAUTION: The ends of cable pulled this way will not be entirely safe from water. If this is an issue, properly applied pulling eyes should be used.

****NOTE: The force applied by pulling a grip may damage or disrupt the underlying cable, so it is best to cut off the section immediately below the grip as well as the three feet of cable behind the grip before fixing together.***

Maximum Pulling Tensions

To prevent damage to the cable, pulling tensions for installing electrical cables should be maintained as low as possible. This may be done through proper use of size ducts or conduits, by avoiding long pulls, and avoiding runs that may contain sharp bends or severe changes in elevation.

The following maximum allowable pulling tension must not be passed when pulling cable by the method indicated.

A. Pulling Eye

The maximum tension for cables pulled with a pulling eye should not exceed the value calculated using the following formula:

$$T_{max} = CTC \times CA \times N$$

Where:

T_{max} = Maximum pulling tension (lb)

CA = Conductor Area (cmil)

N = Number of conductors being pulled

CTC = Conductor Tension Constant

For CTC with aluminum compression eyes or blots use:

0.011 – Copper conductor

0.008 – Aluminum Stranded conductor

0.006 – Aluminum Solid conductor

For CTC with filled eyes or bolts use:

0.013 – Copper conductor

0.011 – Aluminum Stranded conductor

0.008 – Aluminum Solid conductor

NOTE: When calculating the maximum pulling tension, DO NOT consider the area of neutral or grounding conductors in cable(s). The number of conductors should be reduced by one (1) when calculating the maximum tension for parallel cable assemblies. The “N” can equal the number of cables in the assembly, excluding ground wires. This number can also be reduced by one (1) as an extra measure.

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Pulling Eye Maximum Pulling Tension (lbs)

Size	Copper 1/C Single	Copper 3-1/C Parallel	Copper 3-1/C Triplex	Stranded Aluminum 1/C Single	Stranded Aluminum 3-1/C Parallel	Stranded Aluminum 3-1/C Triplex
8 AWG	181	362	543	132	264	396
7 AWG	229	458	687	166	332	498
6 AWG	288	576	864	209	418	627
5 AWG	363	726	1089	264	528	792
4 AWG	459	918	1377	333	666	999
3 AWG	578	1156	1734	420	840	1260
2 AWG	729	1458	2187	530	1060	1590
1 AWG	920	1840	2760	669	1338	2007
1/0 AWG	1161	2322	3483	844	1688	2532
2/0 AWG	1464	2928	4392	1064	2128	3192
3/0 AWG	1845	3690	5535	1342	2684	4026
4/0 AWG	2327	4654	6981	1692	3384	5076
250 kcmil	2750	5500	8250	2000	4000	6000
300 kcmil	3300	6600	9900	2400	4800	7200
350 kcmil	3850	7700	11550	2800	5600	8400
400 kcmil	4400	8800	13200	3200	6400	9600
450 kcmil	4950	9900	14850	3600	7200	10800
500 kcmil	5500	11000	16000	4000	8000	12000
550 kcmil	6050	12100	18150	4400	8800	13200
600 kcmil	6600	13200	19800	4800	9600	14400
650 kcmil	7150	14300	21450	5200	10400	15600
700 kcmil	7700	15400	23100	5600	11200	16800
750 kcmil	8250	16500	24750	6000	12000	18000
800 kcmil	8800	17600	26400	6400	12800	19200
900 kcmil	9900	19800	29700	7200	14400	21600
1000 kcmil	11000	22000	33000	8000	16000	24000

B. Cable Grips

When using a cable grip to pull cables, the maximum tension should not exceed the value shown in the following two tables, or the formula used in the table above.

Pulling Grips Maximum Pulling Tension (lbs)

Type of Cable	PE, XLPE Single Cable	Insulated Multiple Cables	EPR Insulated Single Cable	EPR Insulated Multiple Cables
Unshielded, with or without Jacket	2000	2000	2000	2000
Concentric Wire URD with Jacket	10000	5000	10000	10000
Concentric Wire URD without Jacket	10000	5000	6000	3000
Taped Shielded with Jacket	10000	5000	10000	10000
Fine Wire Shielded with Jacket	10000	5000	10000	10000
LC Shielded with Jacket	8000	4000	5000	2500
Polymeric Armored Cables ***(See Note 3)***	–	–	10000	10000
Interlock Armor with PVC Jacket	5000†	–	5000†	–
Interlock Armor with PE Jacket	5000†	–	5000†	–
Lead Sheathed Cables	See Subsequent Table			

† Interlock Armor pulling tension using pulling grips should be limited to the lesser of the value provided above or 50% of value of T_{max} calculated using "Pulling Eye" formula.

Note 1: The above tensions correspond to three cables in one grip. The stress on the cable conductor should not exceed 16,000 psi (0.013 lbs/cmil) for annealed copper conductors when using a grip. For stranded ¾ and full hard aluminum conductors the stress should not exceed 14,000 psi (0.011 lbs/cmil) and 10,000 psi (0.008 lbs/cmil) for solid ½ to full hard aluminum conductors. The allowable conductor stress should be based on two cables sharing a load for three single conductor cables in parallel and triplexed configurations.

Note 2: The manufacturer of the cable(s) used should be contacted to determine the mechanical limitations of the cable(s).

Note 3: It is recommended that pulling grips be used during installation of Polymeric Armored Cables, due to their higher sidewall bearing pressure capabilities.

Pulling Grips Maximum Pulling Tension (psi)

Type of Cable	PE, XLPE Single Cable	Insulated Multiple Cables	EPR Insulated Single Cable	EPR Insulated Multiple Cables	Paper Insulated Single Cable	Paper Insulated Multiple Cables
Lead Shielded	16000 ***(Note 4)***	16000 ***(Note 4)***	8000 ***(Note 5)***	8000 ***(Note 5)***	1500 ***(Note 6)***	1500 ***(Note 6)***

Note 4: The maximum pulling tension stress limit for pulling grips on lead sheathed cable with XLPE or TR-XLPE insulation is 16,000 psi of lead sheath area for a single cable as well as one grip on three cables (per AEIC CG5-2005).

Note 5: The maximum pulling tension stress limit for pulling grips on lead sheathed cable with EPR insulation is 8,000 psi of lead sheath area for a single cable as well as one grip on three cable (per AEIC CG5-2005).

Note 6: The maximum pulling tension stress limit for pulling grips on lead sheathed cable with Paper insulation is 1,500 psi of lead sheath area for a single cable as well as one grip on three cables (per IPCEA P-41-412-1958).

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Sidewall Bearing Pressure (Static Conditions)
The dynamic radial pressure of cable which is pulled around a bend under pulling tension should be kept as low as possible and not exceed the following values listed in the table. To calculate these values use the following formula:

$$P_{SW} = T_e \div B_r$$

Where:

P_{SW} = Sidewall Bearing Pressure in pounds per foot of bend radius

T_e = Pulling Tension as cable exits the bend (lbs)*

B_r = Bend radius, in feet

****Note: The maximum pulling tension determined by the above formulas must be observed.***

Sidewall Bearing Pressure (Dynamic Conditions)
To calculate the minimum bending radii for dynamic conditions, use the following formula:

$$MBR = (T_e \div P_{SW}) \times 12$$

Where:

MBR = Minimum Bending Radius (in)

T_e = Pulling Tension as cable exits the bend (lbs)*

P_{SW} = Maximum Sidewall Bearing Pressure in pounds per foot of bend radius from following table

****Note: The maximum pulling tension determined by the above formulas must be observed.***

Sidewall Bearing Pressure (lbs/ft of bend radius)*

Type of Cable		PE, XLPE Insulated	EPR Insulated
Unshielded, without Jacket		1200	500
Unshielded, with Jacket		1200	1000
Interlock Armor with PVC Jacket Single Conductor & Three Conductor having round core (100% fillers)		800	800
Interlock Armor with PE Jacket Single Conductor & Three Conductor having round core (100% fillers)		1000	1000
Concentric Wire URD, without Jacket		1200†	1000†
Concentric Wire, Encapsulating Jacket		2000	2000
Concentric Wire, with Sleeved Jacket		1500	1500
LC Shielded with Jacket		1500	1500
Taped Shielded with Jacket		1500	1500
Fine Wire Shielded with Jacket		1500	1500
TECK90 Cable, Single Conductor & Three Conductor having round core (100% fillers)		800	800
TECK90 Cable, Three Conductor with minimal or no fillers		350	350
Lead Sheathed (Solid Dielectric)		2000**	2000**
Polymeric Armored Cables	Air Bag®	2400	
	AirGuard®	3000	
Lead Sheath (PILC)		400	

† Value shown corresponds to a single conductor cable pull. Maximum Sidewall Bearing Pressure limits of 750 and 200 lbs. per foot, respectively, are recommended for a three-conductor pull.

** For a pulling eye/pulling grip, the maximum pulling tension must be observed in addition to the maximum sidewall bearing pressure limit.*

*** These values are based on the cross-sectional area of one lead sheath.*

Note 1: It is recommended that the manufacturer of the cable(s) in question be contacted concerning the mechanical limitations of the cable.

Special Conditions for Metallic Armored Cables

Sheath Currents and Voltages in Single Conductor Cables

A voltage is induced in the concentrically applied wires of the grounding conductor and the armor in a single conductor cable with an interlocking armor.

A current will flow in the completed path if the armor and the concentric grounding conductor are bonded or grounded at more than one (1) point. The magnitude of the induced voltage is relative to the magnitude of the current in the phase conductor. The magnitude of the sheath currents is a function of the induced voltage and the sheath impedance. The armor and the grounding conductor can become very hot if the sheath current is large. If this occurs, the conductor insulation will also be subjected to temperatures that may cause electrical failure or reduce the life expectancy of the cable.

One will have to derate the cable if sheath currents are large enough to raise the temperature of the insulation above its rated value.

In a single conductor cable carrying currents less than 180 amps, sheath currents will not pose a problem since induced voltages and sheath impedances minimize sheath losses.

In single conductor cables carrying currents between 180 and 425 amps, sheath currents will not pose a problem if the cables are spaced about one (1) cable diameter apart. When this spacing is done, mutual heating is minimized and the induced voltage is reduced by virtue of field cancellation.

In single conductor cables carrying currents larger than 425 amps, it is normally necessary to derate the cables to avoid overheating unless the sheath currents are removed.

Armor of magnetic material (such as galvanized steel) should not be used on single conductor cables intended for use in AC circuits.

Eliminating Sheath Currents

One needs to make sure that all paths by which sheath currents circulate are kept open in order to prevent the current from flowing. One should ground and bond cable armors and concentrically applied grounding conductors at the supply end only and afterwards isolated from ground and each other. Isolation may be established when installing cables in individual ducts by using cables with PVC jackets or other insulating materials, or also by mounting cables.

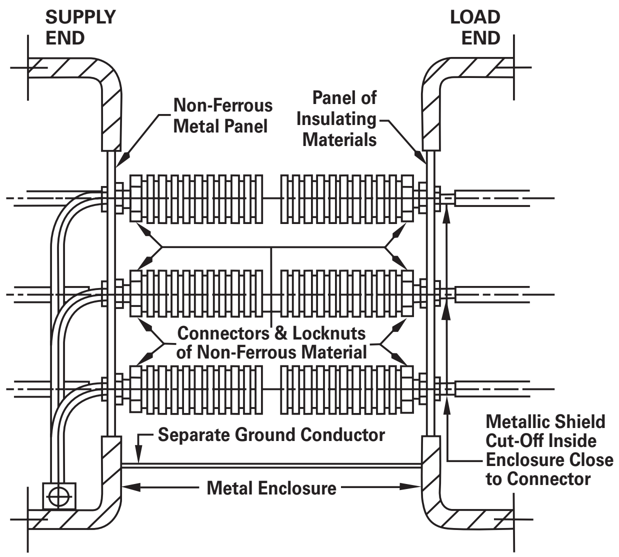
No sheath current will flow if the armors and concentrically applied grounding conductors are bonded and grounded at the supply end through a non-ferrous metal panel and mounted on an insulated panel at the load end. For an illustration of this, please see the figure down below.

a) Cables enter supply end enclosure through metallic non-ferrous panel to avoid overheating. Cable armors are bonded through panel.
b) Cable enters load end enclosure through panel of insulating material. The insulating material maintains the open circuit of the armors.
c) Cable armors and concentrically applied grounding conductors are bonded and grounded at the supply end only. When installed in this way, the armor and concentric grounding conductor do not form a part of the system ground circuit and a separate ground conductor should be installed, following the proper electrical code.
d) All cable connectors and lock nuts are made of non-magnetic metal (aluminum or other).

Standing Voltage

An induced voltage will exist between ground and both the armor and the concentric grounding conductor throughout the length of the cable when single conductor cables are installed, as shown in the figure below:

The magnitude of this voltage is proportional to the phase conductor current, the cable length and the spacing between the cables. The magnitude of the “standing voltage” is usually limited to about 25 volts. Please be aware that some Electrical Inspection Authorities limit this voltage to a lower amount.



By grounding the armor and the concentric grounding conductor at the midpoint of the cable run, one can limit the standing voltage and also increase the circuit length. If doing this, the cable must go through a junction box at the midpoint of the run and must be connected on each side of the junction box as shown on the supply end of the figure above. In this case, the cables at both the supply and load ends must be connected through panels of insulating material to prevent the flow of sheath currents. Nevertheless, when two (2) or more single conductor cables are installed in parallel per phase, grounding at the midpoint is not allowed. For more on installing single conductor armor cables in parallel please see the diagram below, which depicts symmetrical configurations:

Installation of Single Conductor Cables in Parallel

SINGLE PHASE	THREE PHASE
TWO (2) CONDUCTORS PER PHASE	TWO (2) CONDUCTORS PER PHASE
ABBA	ABCCBA OR ABC CBA OR C C AB ←S→ AB
THREE (3) CONDUCTORS PER PHASE	THREE (3) CONDUCTORS PER PHASE
NOT RECOMMENDED	C C C AB ←S→ AB ←S→ AB
FOUR (4) CONDUCTORS PER PHASE	FOUR (4) CONDUCTORS PER PHASE
AABBBBAA OR ABBA ABBA	ABCCBA ABCCBA OR C C C C AB ←S→ AB ←S→ AB ←S→ AB

Notes:

1. S = Separation of groups. This equals the width of one group.
2. Horizontal and vertical separation between adjacent cables should be a minimum of one (1) cable diameter to benefit from the ampacity in free air in a ventilated cable tray.
3. Neutral conductors can be located outside of the above groups.

Reel Capacities

NEMA Method

The formula for calculating footage capacities of reels for round cable is shown below. A 5% factor and 95% traverse utilization have been built into the formula. Cables must be wound evenly to obtain consistency.

$$F = \frac{\pi}{12}\left\{\left[B + \left(\frac{A - 2 \times X - B}{1.9 - D}\right)^{*} 0.95 \times D\right]\left[\frac{A - 2 \times X - B}{1.9 - D}\right]^{*}\left[\frac{0.95 \times C}{D}\right]^{*}\right\}$$

** Round off the result to the nearest whole number.*

Where:

F = Feet of cable on reel

A = Flange diameter, in inches

B = Drum diameter, in inches

C = Inside traverse, in inches

D = Cable diameter, in inches

X = This variable is defined as the distance between the cable and the outside edge of the reel flange. Clearance is equivalent to 1 inch or 1 cable diameter, whichever is the larger quantity.

Note: The NEMA formula does not cover paralleled or triplexed assemblies. Contact the cable manufacturer for the maximum footages of these assemblies.

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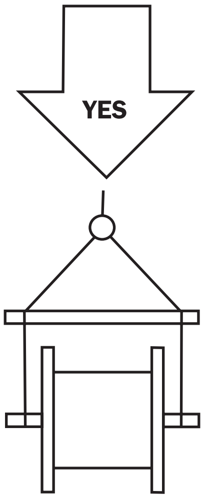
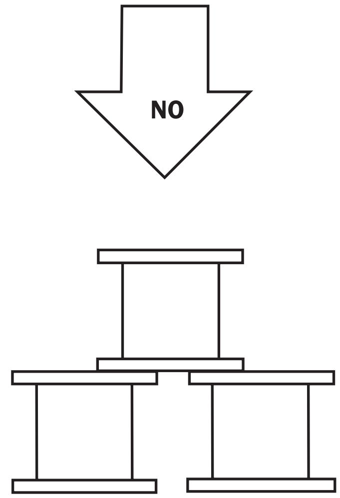
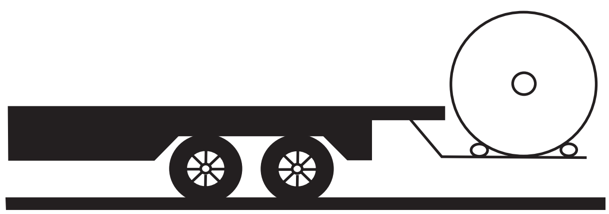
Handling of Cables Reels



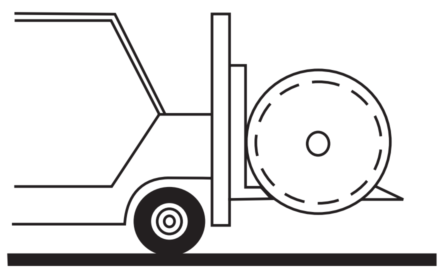
Reels should be lifted with a shaft extending through both flanges.



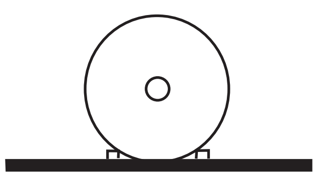
Inspect all reels. Reels laying flat should be refused or received subject to inspection.



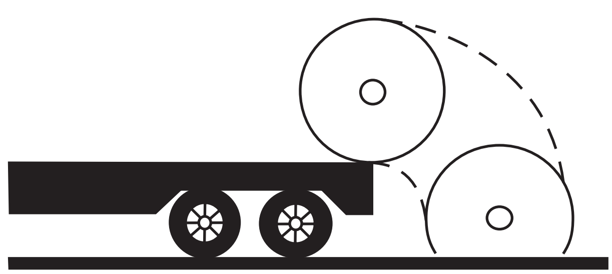
Reels should be lowered using hydraulic gate, hoise or forklift. LOWER CAREFULLY.



Do NOT allow forks to touch cable or reel wrap.

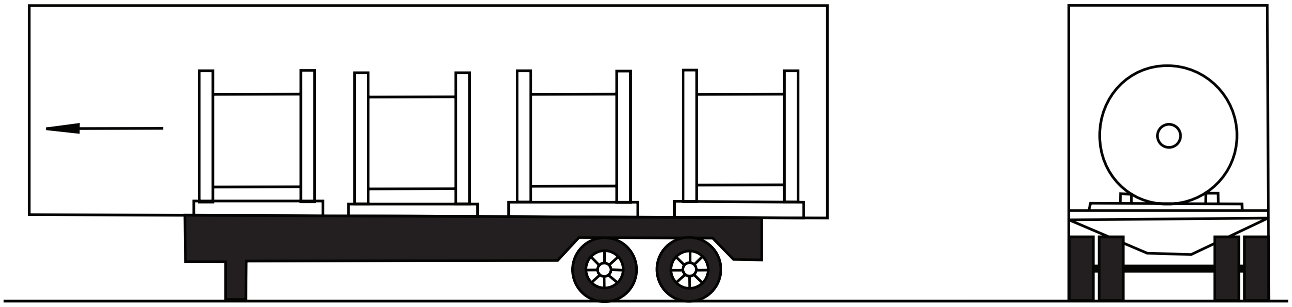


Load with flanges on edge and chock securely..

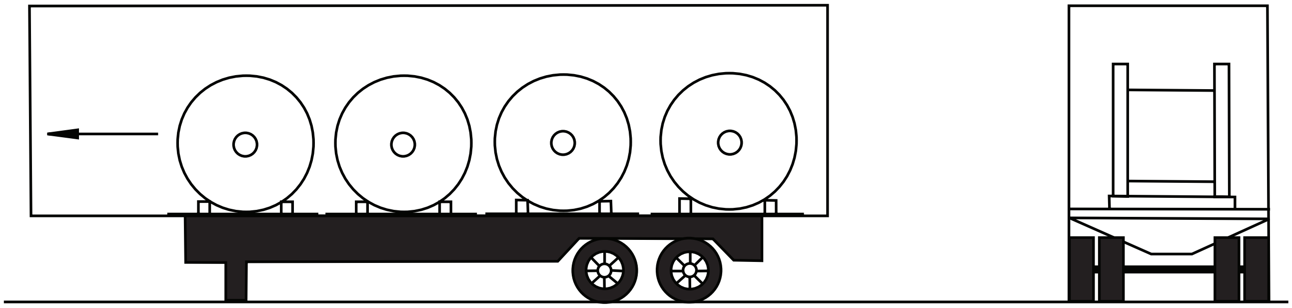


Never drop reels from trailer.

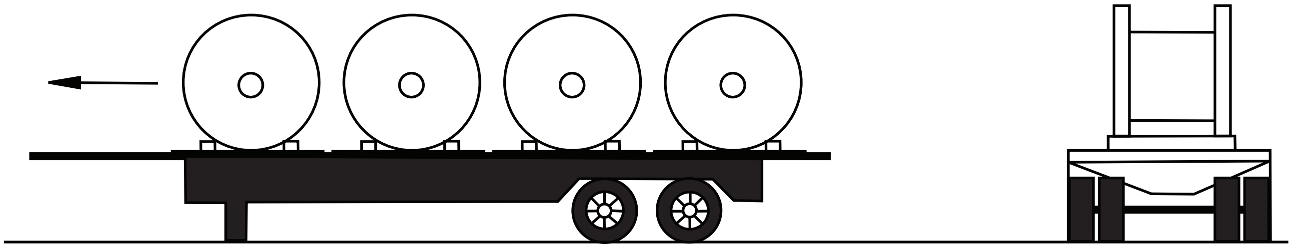
Shipment for unloading with a forklift at dock



Shipment for unloading down an inclined ramp

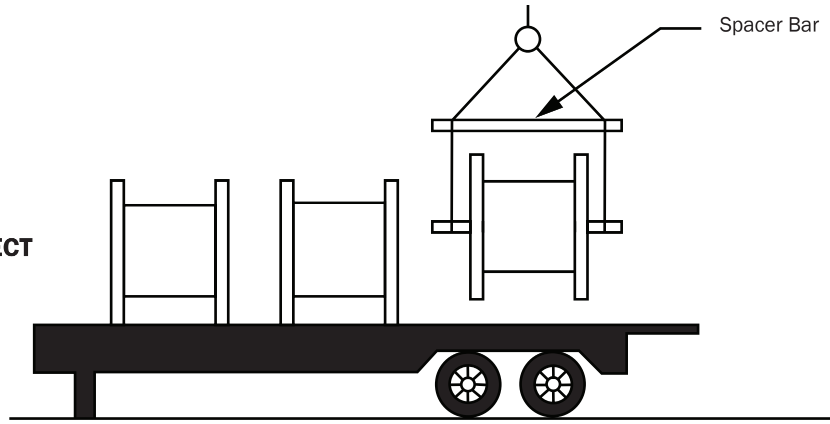


Shipment for unloading with a forklift at jobsite

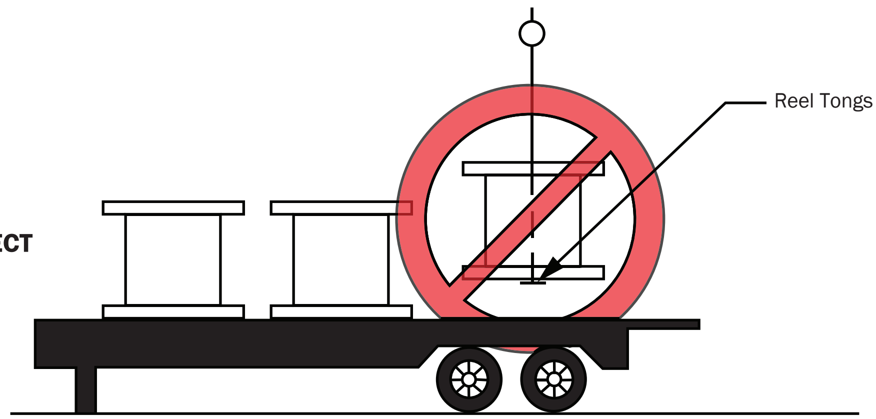


Unloading from Open Flat Bed Trailers

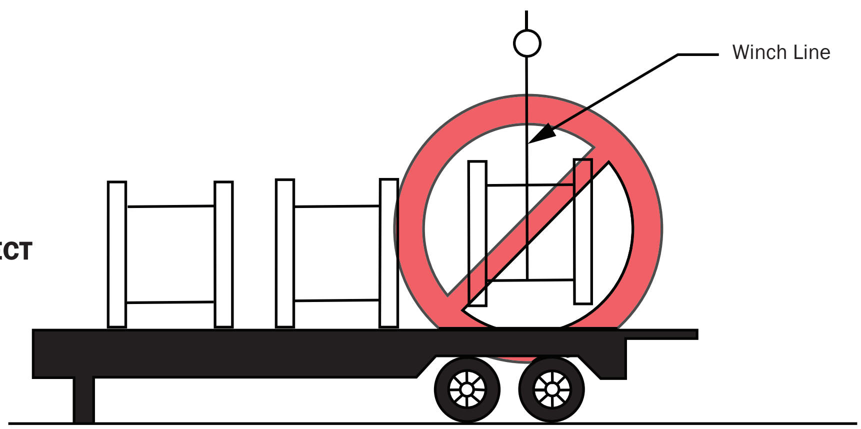
CORRECT



INCORRECT



INCORRECT



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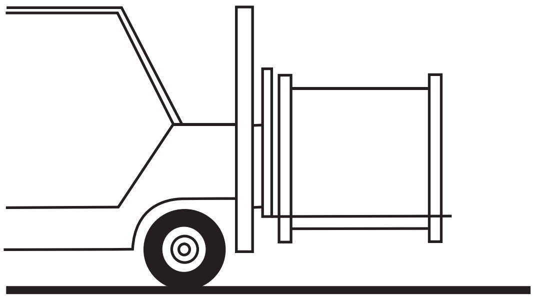
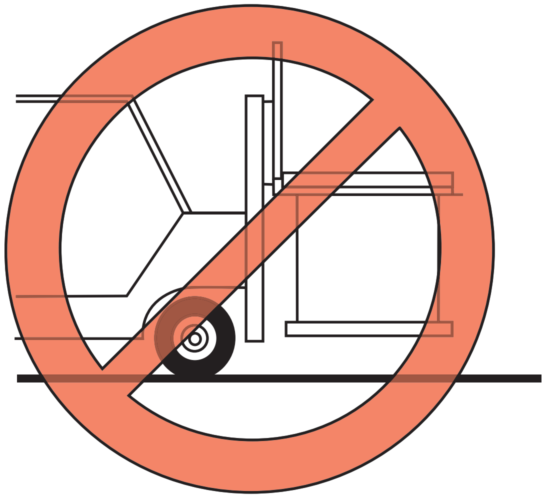
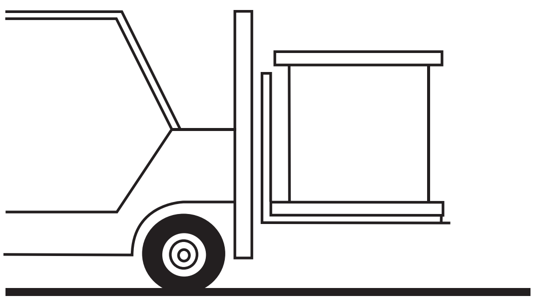
Cable Reel Handling



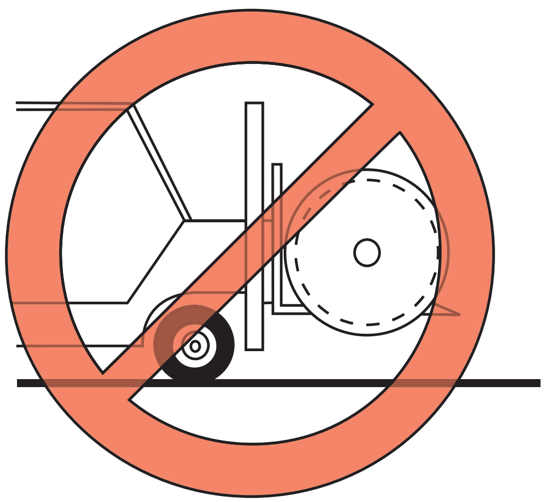
Do NOT allow forks to touch cable or reel wrap.



Do NOT allow forks to touch cable or reel wrap.



Do NOT allow forks to touch cable or reel wrap.
This method OK for Low Voltage Cable only!



Do NOT allow forks to touch cable or reel wrap.

Wire & Cable: Handling and Installation Engineering Guide

Excavating, Trenching, Backfilling, and Surface Restoration

PRODUCTS

Excavated Backfill Materials

- Backfill shall be free of roots, stumps, rubbish, and stone, concrete and clay lumps larger than one-third cubic foot.
- Remove and dispose of unsuitable material in backfill.

EXECUTION

Preparation

- Verify location of existing underground utilities.
- Protect all existing underground facilities.
- Protect all existing above ground facilities and structures.
- Provide for continuance of use of all utilities.

Trenching

- Cut existing surfaces to expose area for trenching.
- Bore below all asphalt surfaces.
- No classification of excavated material will be made.
- Strip topsoil and stockpile for replacement/restoration
- Excavate trench to required line and grade.
- Keep trench width to a minimum to allow proper jointing of utility and compaction of bedding and backfill.
- Organize operations to keep time of open trench to a minimum.
- Excavation by blasting will not be allowed.
- Trench bottom shall be firm for entire length and width.
- Remove unstable material from trench bottom and replace with approved bedding.
- Remove rock, shale and hardpan to one foot below bedding elevation and replace with approved foundation material.
- Keep trenches free from water.
- Dispose of excavated material not used or suitable for use as backfill.
- Stabilize unstable trench walls.
- Protect bottom of trench from frost. Do not place structures or conduit on frozen ground.

Backfilling and Compacting

- Do not start encasement backfilling until work which will be covered is completed and areas are free of foreign material.
- Restore underground facilities interfered with to original condition.
- Place minimum of two feet of backfill over initial encasement before beginning compaction operations.
- Compaction by flooding will not be allowed.
- Level depressions in finished trench.
- Replace topsoil.
- Backfill compaction - 85% of standard proctor density unless otherwise specified on drawings.
    - Testing fees will be paid by the Contractor.

Surface Restoration

- Provide surface restoration to match existing conditions.

Drain Tile Repairs

Contractor shall use good engineering and construction practices to minimize damage to existing drainage tiles and waterways in order to minimize damage to existing drainage. Contractor shall consult with landowners to determine locations of existing tiles, if known, prior to construction.

In the event that Contractor damages drainage tiles or waterways during construction, Contractor shall repair or replace the damaged tiles and restore the damaged waterways, either at their original location or at such other location as will accomplish their original purpose.

Suitable fill material shall be placed under the repaired or replaced tile to minimize settling.

Contractor shall coordinate drainage tile repair such that Landowner's representative may observe such work by Contractor, provided such representative must be available in accordance with Grantee's construction schedule.

All underground power lines (including ground cables) shall be installed at least 4 feet below finished ground elevation. During construction, if Contractor encounters underground drainage tiles while trenching for underground lines, Contractor shall install underground lines below the drainage tiles unless the drainage tiles are 6 feet or more below the surface, in which case the underground lines shall be installed above the drainage tiles.

Upon Completion of the work, Contractor shall provide a site map showing the "as built" location of the underground transmission lines on the Property.

TESTING

Backfill Compaction Test

Compaction tests shall be performed at a depth of one and 1.5 feet above the cables and 3 feet above the cables.

Compaction tests shall be performed every 500 feet for the first mile and every mile thereafter.

Care is to be taken when compacting under, alongside, and immediately above the cable to avoid crushing the insulation and to preserve the trefoil configuration of the cable.

Compaction Test Failure

If the required state of compaction is not obtained, it shall be the responsibility of the Contractor to re-compact or rework the material to the required state of compaction. In cases where there is a failure to achieve the required state of compaction it may be required that the backfill be removed and re-compacted or replaced at the discretion of Engineer and/or Owner.