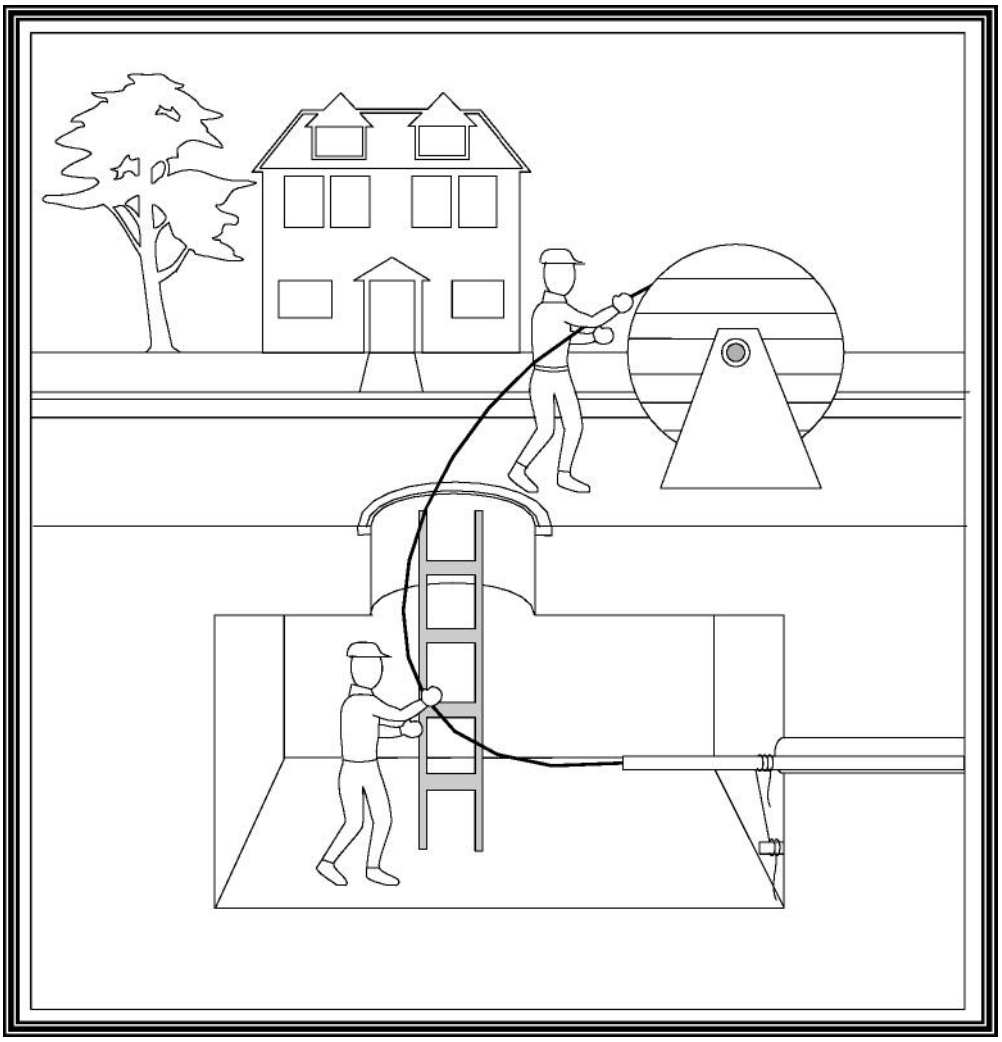
Underground Cable Installation Practices



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UNDERGROUND CABLE INSTALLATION PRACTICES

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1.0 GENERAL

1.01 The methods described in this document for placing cable in ducts are intended for use only as guidelines. It is impossible to cover all the various conditions that may arise during an installation. Individual company practices for placing fiber optic cable should supersede any conflicting instructions in this document when they do not exceed the cable's optical and mechanical performance specifications.

1.02 Methods used for placing fiber optic cables in ducts are essentially the same as those used for placing copper cable. However, fiber optic cable is a high capacity transmission medium which can have its transmission characteristics degraded when subjected to excessive pulling force, sharp bends, and crushing forces. These losses may not be revealed until long after installation is complete For these reasons extra care must be taken during the entire installation procedure.

1.03 Fiber optic cable is usually (but not always) installed in an innerduct that has been placed in a standard duct in advance of the fiber optic cable placing operation. An innerduct provides an efficient use of conduit space, a clean, low co-efficient of friction path and an added measure of mechanical protection for the fiber optic cable.

1.04 Fiber optic cables are usually ordered in specific lengths as calculated by an OSP (Outside Plant) Engineer. The lengths are determined by measuring between splice locations including allowances for racking at all manhole locations. Additional length to reach the splicing vehicle (truck or trailer) plus some minimum of excess cable should also be added. A fiber optic cable should never be cut without first consulting the OSP Engineer responsible for the work order.

2.0 PRECAUTIONS

2.01 The following are some suggested precautions that should be observed when working with fiber optic cables. Each individual company's safety precautions for working in manholes or underground vaults should be reviewed before work begins and practiced during the entire installation process.

2.02 Before cable installation begins, the cable reels should be carefully inspected for any imperfections such as nails, broken flanges, cable crossovers, or anything else that might cause damage to the cable as it is paid out. Precautions should be taken to protect stored reels from possible damage by vandals or other sources while left unattended. The thermal protective covering that is provided on each reel of fiber optic cable should always remain in place when storing reels.

2.03 Whenever cable is placed on pavement or other surfaces, it should be protected with barricades or cones to prevent possible vehicular or pedestrian traffic damage. A "figure-eight" configuration should be used when the cable is removed from the reel and piled on the ground. This prevents kinking and twisting of the cable which could cause damage. *Fiber optic cable should not be coiled in a continuous direction except for lengths of 30 meters (100 ft) or less. The minimum size for the "figure-eight" is about 4.5 meters (15 ft) in length with each loop 1.5 meters (5 ft) to 2.4 meters (8 ft) in diameter.*

Note Figure 8 machines should not be used without approval from Prysmian. Many machines violate the cable bend radius which can flatten buffer tubes. They are also problematic with central tube designs which contain radial strength members.

2.04 *Standard Prysmian fiber optic cable has a maximum recommended pulling tension of 600 lb. The maximum pulling tensions are not to be exceeded.* Please consult Prysmian's Methods and Procedures for the proper installation and use of pulling grips. Prysmian cables may be ordered from the factory with pulling eyes already installed.

2.05 Fiber optic cables are more susceptible to performance degradation due to tight bending than are copper cables. The minimum bend radius of each cable is relative to the cable's diameter. *A general guideline is that a cable under tension should not be exposed to a bend radius less than 20 times the cable diameter and a cable with no tension should not be exposed to a bend radius less than 10 times the cable diameter.*

2.06 If, during the course of the placing operation, the tension reading approaches the maximum limit it may be necessary to stop the pull and determine the cause. The following lists some of the reasons for a high pulling load:

a) Unaccounted for bends in the conduit run.
b) Obstruction against which the pulling hardware is catching.
c) Insufficient lubricant being used (only use lubricants approved for polyethylene sheaths).
d) The conduit is partly clogged with earth, roots which have grown into the duct or other debris.
e) Sub-ducts were severely twisted during installation.

Once a cable encounters one of the problems above it will need to have the pull halted and the cable pulled back until the problem can be corrected. Care must be exercised during the pull-back to prevent kinking or crushing of the cable. The pulled back slack must be carefully stored in a safe location. The cable must not be exposed to the possibility of damage or present a hazard to workers or the public.

3.0 PREPARATION

3.01 A pre-survey of the fiber cable route is an integral part of the total project. Engineering and Installations should jointly pre-survey the job site and cable route to ensure all problem areas are uncovered before pulling begins. Problem areas should be located and any special requirements identified during the planning stages of the project.

3.02 Manholes in which splicing will take place should be inspected and plans made for closure and cable slack racking. Racking space should be carefully chosen so that a minimum bend radius for the cable can be provided. Accessibility of manholes by splicing vehicles should be considered.

3.03 With the cable route survey completed, and knowing the equipment/manpower resources that are available, a cable-pulling plan should now be developed. Reel and winch locations should be determined and their suitability confirmed. Changes in elevation and locations of bends and offsets should enter into these decisions. Elevation, bends and offsets will greatly increase pulling tension. To minimize their effect, pulls should begin at the end of the innerduct section nearest their location.

4.0 TOOLS AND MATERIALS

4.01 The following sections are intentionally generic in tools and material application. Each company provides their own unique practices outlining the proper tools and materials to install fiber optic cables in their own cable systems. Prysmian Cables and Systems does not intend for the following tools and materials list to supplant the individual's tools and materials as defined by their company's practices. The

following generic list is offered only as an overview of the tools and material required for pulling cable into ducts.

4.02 Innerduct provides a high quality path for the fiber optic cable. Innerduct has a lower friction factor than regular duct and allows the main 4" duct to be subdivided. Typical subdivisions may be three 1.25" sub-ducts or two 1.5" and one 1" sub-ducts.

4.03 Innerduct couplings are used to join sections of innerduct to form a continuous duct through intermediate manholes, to extend innerduct in a manhole, to repair innerduct or extend innerduct out of a manhole for other placing operations.

4.04 A pulling eye or grip may be used to provide a connection point between the cable and the pulling line. The pulling eye may be factory installed by Prysmian. A pulling grip may be field installed provided Prysmian Methods and Procedures are followed.

4.05 A winch or capstan is the device used to provide the cable pulling power. A winch or capstan that cable will be pulled around must have a diameter that does not exceed the minimum bend radius for the cable when under tension. The winch or capstan should contain a tension-monitoring device so that the recommended pulling tension of 600 pounds for the cable can be monitored. The winch or capstan must be designed so that it is capable of maintaining tension on the cable/pulling line when not taking up cable.

4.06 A fiber cable pulling sheave should be used at the pulling end to maintain the proper bending radius as the fiber optic cable enters the pulling manhole and exits towards the pulling device.

4.07 A swivel should be used on the winch line to prevent twisting of the fiber optic cable and winch line. The swivel must have a 600 pound breakaway pin to prevent pulling damage to the cable.

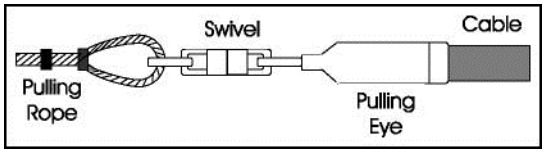

Figure 1 - 600# Break-away Swivel and Pulling Eye

4.08 Various pull lines are available for use with fiber optic cables. Typical pull line materials are wire rope, polypropylene, or aramid tape. The cross section of the pull line can be flat or round. Smaller diameter pull lines have a tendency to cut the innerduct when under tension. A pull line with low elasticity is preferred as it will minimize surge-induced fluctuations in pull-line tension when used with winches.

4.09 Proper cable lubrication is necessary to minimize tension on the fiber optic cable during the pulling operation. Proper cable lubrication can reduce cable pulling tension by 50% or more. Only use lubricants specifically designed for lubricating fiber optic cables. Bentonite or wax base lubricants must not be used nor should liquid detergent be used. Use of the wrong lubricant will result in poor pulling characteristics and can possibly result in long-term breakdown of the fiber optic cable's polyethylene sheath. The amount and method of lubricant required and proper application techniques will vary with conditions and company practices. Also, consult the innerduct manufacturer about lubricant compatibility. Some specially lined innerduct may have special requirements.

4.10 Before placement of the cable begins it is strongly recommended that the conduit or duct that the cable is being pulled into first be "proven". The duct can be "proven" by passing a fiberglass duct rod through the duct or by passage of a standard pneumatic projectile. Such testing will identify any potential problems before the fiber optic cable comes off the security of the reel.

5.0 CABLE PLACEMENT

5.01 First, identify the innerduct in which the fiber optic cable is to be placed. After the correct innerduct has been identified, it should be tied off to keep it from "creeping" as the cable is being pulled into it. Any spare ducts should be capped off so that they do not interfere with the cable pulling operation.

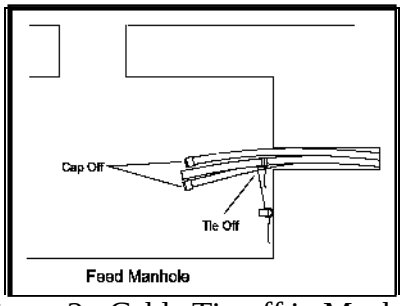

Figure 2 - Cable Tie-off in Manhole

5.02 Prepare the pull-through manholes. This includes un-racking the innerduct and removing slack caused by the racking, placing lubricant where appropriate, preparing the pulling line and usually re-coupling the innerduct to provide a continuous path for the cable to follow. The amount of lubricant used in intermediate manholes will depend on the length between manholes, type of innerduct, etc.

A general rule of thumb is to supply a minimum of one gallon of lubricant for every 1000 feet of the pull.

5.03 Position the pulling equipment (winch or capstan) at the pulling manhole. The pulling equipment should be fitted with a tension monitor and is to be operated at the manufacturer's recommendations. Never exceed the 600 pounds pulling limit of the cable.

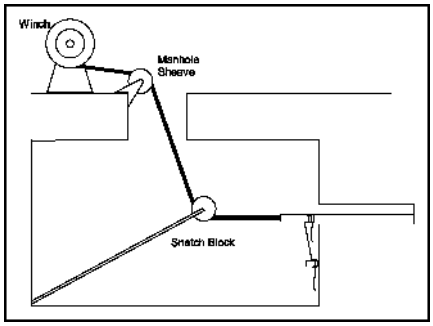

Figure 3 - Pull Manhole Setup

5.04 At the pull end manhole, install the proper guides specified by your company's practices. These guides are to ensure that the pull line and fiber optic cable enter and exit the innerduct in a straight path.

5.05 The intermediate manholes should be prepared for the cable pull by having any problems that were observed during the pre-pull survey already sorted out. The following is a list of some but not all possible issues that should be addressed:

a) If the innerduct is continuous, and has been racked, work the excess slack towards adjacent manholes. If necessary, slack can be removed using an innerduct slitter and cutter. Temporarily tie the innerduct to keep it from creeping into the main duct and to keep the innerduct ends in alignment during the cable pulling operation.

b) If the innerduct is not continuous, and the exit and entry ducts are aligned, the inner duct ends may be joined with a coupler. If the innerducts are not long enough to join, a short section may be added.

c) If the entry and exit ducts are offset by more than a 3:10 ratio (3 foot offset in a 10-foot manhole), innerduct can be used to form a gradual sweep. Properly sized sheaves may also be used instead of the innerduct.

5.06 Position the cable reel adjacent to the feed manhole so that the cable can be hand-fed in the manhole. The cable should be pulled off the reel by hand and manually fed into the manhole to reduce pulling tensions.

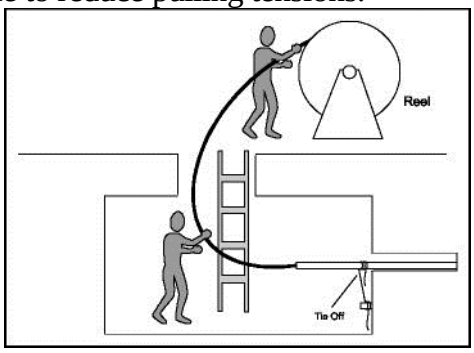

Figure 4 - Reel End Setup

5.07 Connect the pulling line to the pulling eye/grip installed on the fiber optic cable with a swivel connector.

5.08 An approved cable lubricant should be used to lubricate the entire duct run being used in order to reduce pulling tension. Apply the lubricant to the cable before it is fed into the innerduct according to standard company practices. The method of lubricant application will vary according to company practice. Some methods include: pulling a swab throughout the innerduct as part of the pulling line placement, pouring the lubricant directly onto the cable in the cable trough, or using pumps and gravity feed devices as lubricant applicators. (As noted in paragraph 4.09, consult the innerduct manufacturer regarding lubricant compatibility).

5.09 Before pulling operations begin a communications link must be established between the feed and pull manholes (and any intermediate manholes the cable may pass through).

5.10 Start the pull by engaging the winch/capstan at a slow speed. Hand turn the reel as the pull begins to decrease start-up tension. After the pulling eye/grip has entered the duct at the feed manhole, the speed of pull may be increased. The speed should be slowly built up to a maximum speed of approximately 100 feet per minute (30 meters per minute).

5.11 The cable must be kept thoroughly lubricated however low the pulling tension may be. Surges and stops during the pull should be kept to a minimum and, if possible, they should be avoided altogether. The maximum pulling tension is 600 pounds. If the pulling tension approaches the limit, the pulling operation must be stopped so that the pulling tension can be reduced by intermediate assists, or by changing the pulling operation to a back-feed method.

5.12 The winch/capstan operator at the pull manhole controls the speed of the cable pull. He must be kept informed of the cable's progress as it passes through each intermediate manhole. A constant pull rate is the desired method of placing cable in innerduct. Variations in pulling speeds, starts and stops are to be avoided. If it is necessary to stop the pull at any point, the winch/capstan operator should stop the pull but not release the tension on the cable. Pulls are more easily resumed if tension is maintained on the pull-line and cable.

5.13 Once the cable appears in the pull manhole it may be pulled over a sheave or quadrant block as long as the diameter of the sheave or block meets the cable's minimum bend radius under tension. No attempt should be made to inch the cable to its final manhole length. This may cause undesirable surges to the end portion of the cable.

6.0 BACK-FEEDING

6.01 When pulling problems are expected due to long duct lengths, excessive curvatures in the duct or for other reasons, the cable can be pulled in from two directions.

6.02 Locate the fiber optic cable reel at the mid-feed manhole. Attach the pulling line to the fiber optic cable and position the reel in the same manner as for an end pull. The pull manhole setup and the feed manhole setup are the same as they were for an end pull. Communication, lubrication and cable pulling are all conducted as for an end pull.

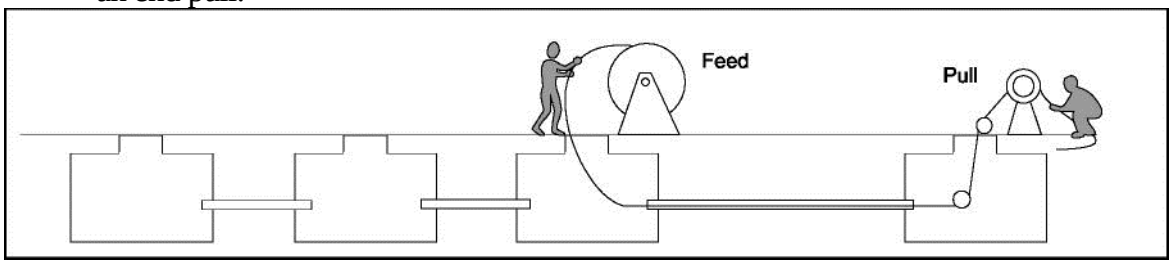

Figure 5 - Bi-directional Pull Start

6.03 When the cable reaches the pulling manhole and sufficient slack has been acquired, stop the pull and move the pulling equipment to the opposite end of the run.

6.04 At the mid-feed manhole, remove the remaining fiber optic cable from the reel. The cable must be laid out in a large figure-eight configuration close to the manhole opening. Keep the cable as clean of debris as possible by not figure-eighting the cable onto sand or dirt which might adhere to the cable. Sand or dirt clinging to the cable will cause increased pulling tensions. Spreading out a sheet of polyethylene before beginning to figure-eight is one method that will help keep the cable reasonably clean. Figure-eighting onto clean pavement or grass will also help lower the possibility of a dirty cable.

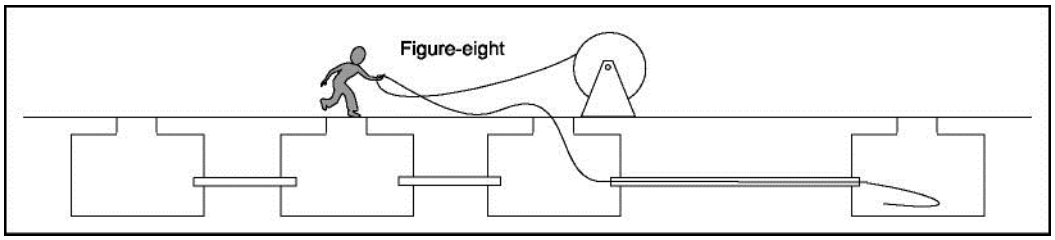

Figure 6 - Bi-directional Pull Figure-eight

6.05 With all the cable off the reel and laying on the ground in a figure-eight, attach the pulling line to the end of the cable. Begin the pull just as before by hand pulling the cable out of the figure-eight and into the manhole. Once the cable end has entered the duct, the cable should be carefully guided from the figure-eight by hand. Radio communications must be maintained to ensure the pull can be quickly stopped if trouble develops with feeding the cable from the figure-eight.

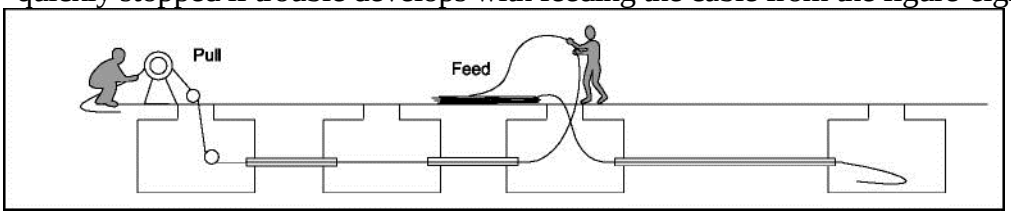

Figure 7 - Bi-directional Pull Completion

6.06 An alternative to manually figure-eighting the cable off the reel before continuing the pull, is to use a figure-eight machine shown in Figure 8 below. Instead of pulling the cable from the reel and laying it on the ground, the cable is looped over the barrel of the figure-eight machine. Guided by a revolving arm and a series of rollers, the cable can be rapidly removed from the reel as it is wound around the machine's drum.

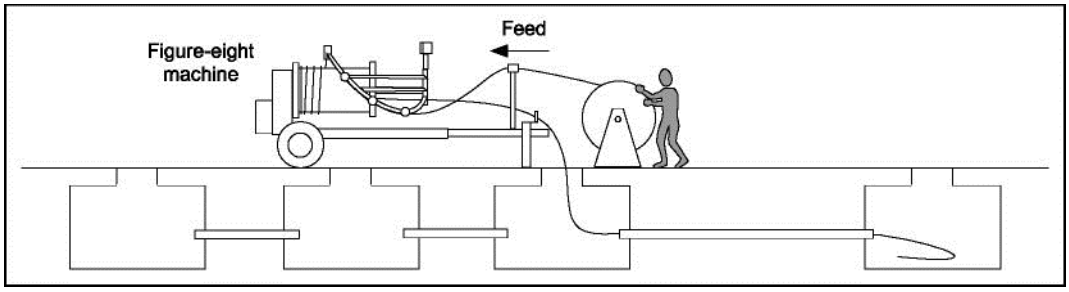

Figure 8 - Back-feeding Using A Figure-eight Machine

Once the inside end of the cable is freed, it is connected to the pull line and the figure-eight machine reversed. The cable is now removed from the figure-eight machine's drum as the end winch or capstan pulls the cable through the duct.

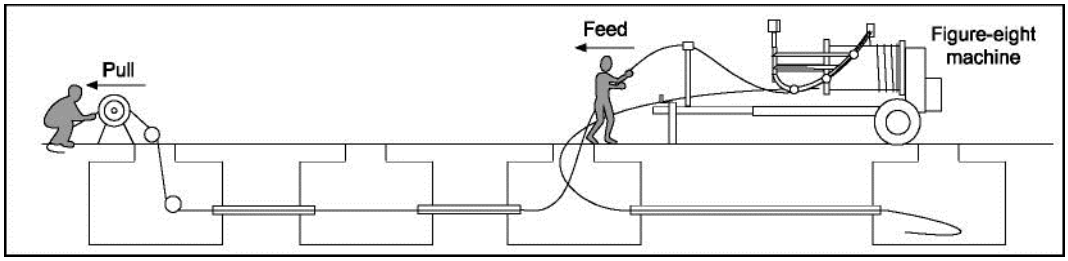

Figure 9 - Pulling Using A Figure-eight Machine

7.0 MID-PULL ASSIST

7.01 For pulling cable into a duct that may be very long, have an uphill slope, or have some severe curves in it, a middle manhole capstan pulling assist may be the solution. The figure below illustrates a middle manhole capstan setup.

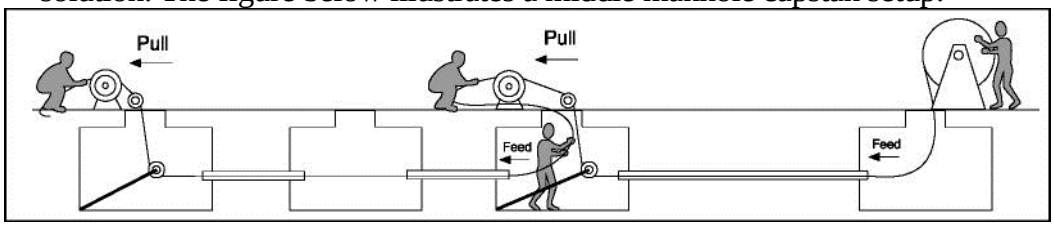

Figure 10 - Mid-pull Assist Setup

7.02 At a midpoint in the duct run, a second pull capstan is positioned near the manhole. The cable exits the manhole, wraps around the capstan, returning into the manhole to be pulled onward by the far-end winch or capstan. The radius of the mid-pull capstan and associated sheaves or quadrant blocks must not exceed the minimum bend radius of the cable under tension.

7.03 Using the setup illustrated above, it is important that good communications be established and maintained between all workers involved in the pull. The mid-pull capstan will first begin pulling followed by the far-end winch or capstan. To stop, the order should be reversed with the far-end winch or capstan stopping before the mid-pull capstan stops.

7.04 The mid-pull capstan must maintain a steady pulling rate that will enable it to feed cable that is not under tension back down into the manhole for the far-end winch or capstan to pull.

DISCLAIMER OF WARRANTIES AND LIMITATIONS OF LIABILITIES

The practices contained herein are designed as a guide. Since there are numerous practices which may be utilized, Prysmian has tested and determined that the practices described herein are effective and efficient. The recommended practices are based on average conditions.

In addition, the materials and hardware referenced herein appear as examples, but in no way reflect the only tools and materials available to perform these evaluations.

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