

Table of Contents

1.0 General.....	3
2.0 Precautions.....	3
3.0 Pre-survey	4
4.0 Location and Depth	4
5.0 Plowing versus Trenching.....	5
6.0 Plowing.....	5
7.0 Trenching.....	9

List of Illustrations and Tables

Figure 1 Tractor and Plow	6
Figure 2 Splice Van	7
Figure 3 Figure-eighting Cable	7
Figure 4 Pulling the Cable	8
Figure 5 Using a Figure-eight Machine.....	8
Figure 6 Pulling Using a Figure-eight Machine.....	8
Figure 7 Cutaway View of a Buried Cable	9

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The practices contained herein are designed as a guide for use by persons having technical skill at their own discretion and risk. The recommended practices are based on average conditions. Panduit does not guarantee any favorable results or assume any liability in connection with this document.

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 installations.

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1.0 GENERAL

- 1.01** This best practices procedure provides general information for the installation of fiber optic cables in direct buried applications. The methods described are intended for guideline use only, as 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** Placement methods for direct buried fiber optic cable are essentially the same as those used for placing direct buried copper cable. However it must be kept in mind that fiber optic cable is a high capacity transmission medium which can have its transmission characteristics degraded when subjected to excessive pulling force, sharp bends, or crushing forces. These losses may not be revealed for up to two years after installation. For these reasons, extra care must be taken during the entire installation procedure.
- 1.03** 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 then adding the amount required to reach the splicing vehicle (truck or trailer) and some minimum of excess cable.
- 1.04** It is assumed in this document that the reader is familiar with the direct burial procedure used for copper cable. Direct buried fiber optic cable installation practices are essentially the same as those used for placing copper cable. The following methods of direct burial of fiber optic cables will be addressed: plowing and trenching.

2.0 PRECAUTIONS

- 2.01** The following are some suggested precautions that should be observed when working with fiber optic cables. Before starting any buried cable installation, all personnel must be thoroughly familiar with Occupational Safety and Hazard Act (OSHA) regulations. Also, company safety precautions for direct buried cable operations 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 which 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 when left unattended. The thermal protective covering provided with each reel of fiber optic cable should always remain in place when storing cable reels.
- 2.03** Whenever cable from the reel 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 preferred sized 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: An alternative to the manual figure-eight is the "figure-eight" machine. This equipment will "figure-eight" cable much faster than manual methods saving time and manpower. The machine winds any cable remaining on the reel on to the machine's drum. Once the inside cable end is accessible, the machine is reversed and the cable is pulled from the machine's drum through the duct. The machine's drum and rollers are designed to keep the cable at a bend radius greater than the minimum bend radius of the cable.

- 2.04** *Standard fiber optic cable has a maximum recommended pulling tension of 600 lbs. The maximum pulling tension is not to be exceeded. Please consult Panduit's Best Practices for the proper installation and use of pulling grips. 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.***

3.0 PRE-SURVEY

- 3.01** A pre-survey of the fiber cable route is very important in planning for a direct buried optical fiber cable project. Each section of the route from splice location to splice location must be prepared properly before cable installation begins. It is very important to identify all conflicts and obstructions along the route before installation is under way. Conflicts and obstructions will influence the preliminary selection of splice locations and will have a direct effect on the overall transmission design of the route. Splices cases should not be located where the splicing vehicle will have to be parked in a hazardous area. This would include: over a hill top, around a sharp curve, near an intersection, too close to the road, a hidden area in an unsafe neighborhood, or anywhere the splicing vehicle cannot get safely and completely off the highway.
- 3.02** One of the objectives of the pre-survey is to determine where each reel of fiber optic cable is to be placed. Slack locations and cable storage requirements must also be considered along with splice locations. The pre-survey will verify construction methods, special tools required, or possibly require a revision of preliminary splice locations.
- 3.03** The characteristic of the ground along the route needs to be investigated. If a subsurface investigation seems to be required, it should be conducted. This will clear up any concerns about underground conditions that may be encountered during plowing or trenching.
- 3.04** All road crossings, creek crossings, etc. need to be addressed so that preparatory work can begin before plowing or trenching. This will identify what casing is needed and what type of preparatory work will be required to negotiate these crossing points.
- 3.05** A good pre-survey and proper planning will preclude reel ends falling too close to roads, creeks, or any other undesirable locations.

4.0 LOCATION AND DEPTH

- 4.01** Buried fiber optic cable route locations are selected by the Outside Plant Engineering group. The cable route location should be one that is the least likely to be disturbed and that will have the least number of obstructions.
- 4.02** When burying fiber optic cables that must cross ditches, avoid crossing locations that might interfere with natural drainage. Also, avoid areas subject to surface drainage that may result in subsequent washing away of soil and exposing of the fiber optic cable.
- 4.03** Pipe or conduits are used at highway and railroad crossing.

- 4.04** The depth at which fiber optic cable can be buried will vary with local conditions according to freeze lines (depth to which the ground freezes in the winter). Under all conditions, the cable should be buried at a depth that will provide adequate protection. The depth may vary as conditions vary. In croplands and pastures, a cable depth of 36" is the minimum depth. The cable needs to be buried 12" deeper than the maximum depth reached by agricultural equipment.

5.0 PLOWING VERSUS TRENCHING

- 5.01** In general, the most desirable and economical method of cable placement in open or rural areas is plowing. Here there will be fewer obstacles to impede the progress of the plowing equipment.

Advantages of Plowing:

- ⇒ Speed of installation in open areas
- ⇒ Less ground disturbance than may be caused by trenching

Disadvantages of Plowing:

- ⇒ Large size and high cost of equipment
- ⇒ Requires skilled equipment operators, quality supervision, and equipment in good condition
- ⇒ Can not be used for all soil and terrain conditions
- ⇒ Possibility of damaging cables or underground utilities

- 5.02** In urban or suburban areas where there can be many obstacles such as underground utilities, sidewalk and paved road crossings, trenching has advantages.

Advantages of Trenching:

- ⇒ Lower cost of equipment
- ⇒ Digging operation is separate from cable placement
- ⇒ Better depth control
- ⇒ Less risk of damaging underground utilities
- ⇒ Provides the opportunity to place conduit at the same time

Disadvantages of Trenching:

- ⇒ Slower rate of cable placement than with plow
- ⇒ Not suitable for all soil and terrain conditions

6.0 PLOWING

- 6.01** It is important to notify all other utilities that may occupy the same right-of-way (ROW) that a fiber optic cable will be placed. If there is a "1-call-center" or a local utility location and coordination committee active in the area, they should be notified 72 hours before plowing operations begin. This will provide them with enough advance notice to locate and mark their route along the ROW prior to construction.

- 6.02** The ROW should be staked in advance of plowing. The locations of all underground structures such as culverts, water lines, and other utilities should clearly be marked for the plowing crew. If necessary, obstructions should be uncovered prior to plowing.
- 6.03** Cable plows are generally of two types: static and vibratory. Either type may be used to install fiber optic cable. Steerable plows, which can be offset to place the cable away from the centerline of the cable plow prime mover, are available in both types.

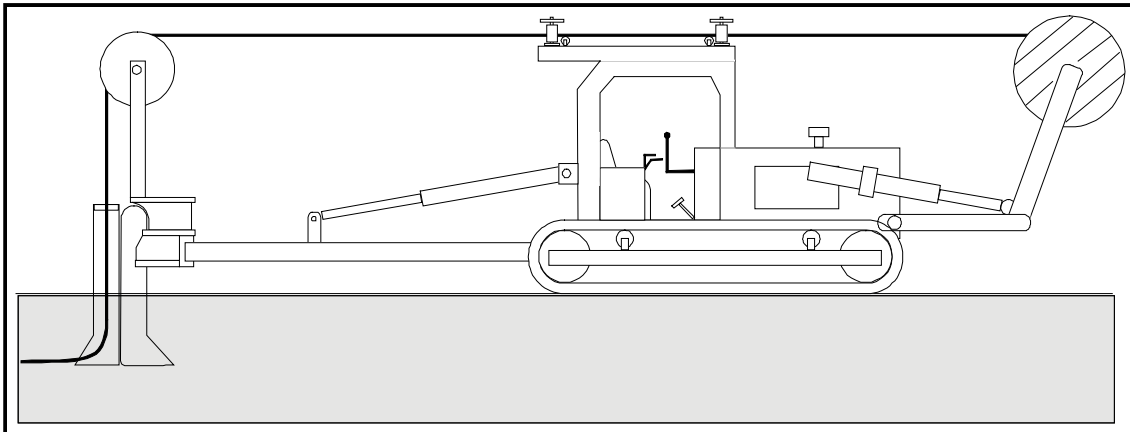


Figure 1 – Tractor and Plow

- 6.04** Successful and economical plowing of cable depends primarily on having equipment powerful enough for terrain conditions. Local soil conditions and cable depth are the two primary determining factors in the correct size of tractor necessary for plowing. Too much horsepower is better than too little horsepower.
- 6.05** A crawler tractor is most suitable for static buried cable plowing. A tractor equipped with a torque converter drive should be used whenever it is available. This will permit smoother plowing performance by absorbing the shock loads encountered in the plowing operations.
- 6.06** The drawbar force for soil penetration by a static plow may reach a magnitude of tens of thousands of pounds. Heavy and large equipment is needed to generate a drawbar force of this magnitude. A plow that vibrates substantially reduces the drawbar force required to plow-in cable when compared with the force necessary to move a static plow of the same size. With drawbar force reduced, the equipment size required for the plow is also reduced.
- 6.07** The reel carrier should allow for easy installation of the reel using such features as hydraulic lift assistance and should accommodate a reel or reels of adequate size for the intended installation. The cable feed system includes all the components mounted on the tractor which supports and guides the cable as it is fed into the plow chute. Typically, it includes a reel carrier, rollers and/or guide tubes. Use of capstan drive units is recommended. Capstan drive units, which provide pulling force of up to 250 pounds can help prevent excessive pulling, tension at the cable feed tube entry and exits.
- 6.08** All rollers or guides in the cable feed system which cause a change in the direction of the cable path must conform to the minimum bend radius of the cable being placed. Small diameter rollers (fairleads) can be used to guide the cable over the tractor cab, if the feed chute guide and cable reel are positioned so that the cable cannot be tensioned over the smaller rollers. Fairleads should be designed to prevent the cable from becoming wedged between the vertical and horizontal rollers.

- 6.09** The cable path inside the feed chute must be clean and free of burrs, sharp edges, stiffeners, or roughness. Welds must be smooth. Gussets on the divider gate in multiple chute designs must not interfere with the smooth passage of the cable. The cable must feed smoothly through the chute and must not exceed the minimum bending radius of the cable.
- 6.10** Before plowing begins, a means of communications must be established between the equipment operator and the supervisor monitoring the cable placement and route. The communications link must be able to override the equipment noise.
- 6.11** The starting point for the reel being plowed should be a splice pit or hole excavated to the proper depth. Sufficient slack should be reeled off at this point to reach a splice vehicle or splice location. The plow should start at the required depth from the splice pit.

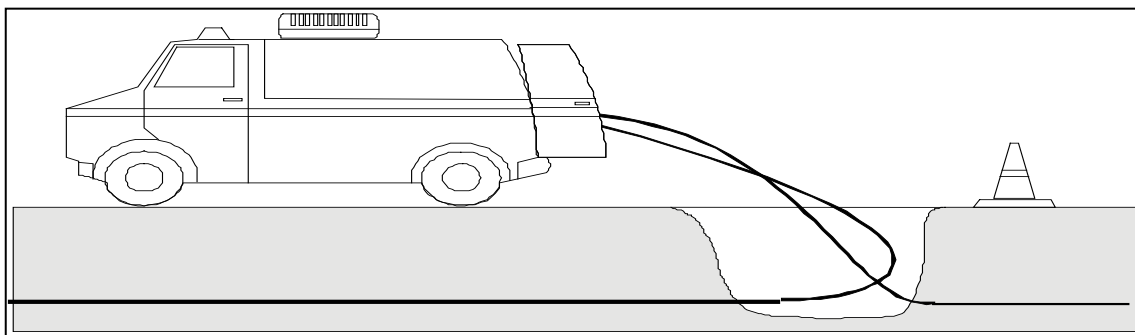


Figure 2 – Splice Van

- 6.12** A figure-eight operation is necessary whenever the cable must be pulled through a pipe or conduit. This often occurs at road, river, bridge, or railroad crossings. A figure-eight operation requires that the cable be removed from the reel.
- 6.13** With the plow stopped, remove the cable from the plow's chute. Do not raise the plow to the surface when the plow is not moving. **Never** back up the plow with a cable still in the chute. The cable to the rear of the feed chute must be excavated and slack pulled to prevent kinking the cable over the exit chute before raising the plow.
- 6.14** The cable remaining on the reel must be laid out in a large figure-eight configuration close to the pull-thru location. 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 can 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.

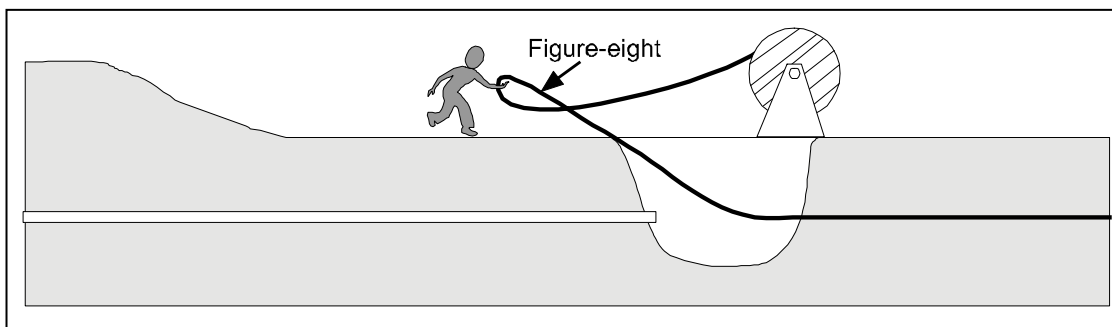


Figure 3 – "Figure-eighting" of the Cable

- 6.15** 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 feeding it into the pipe or conduit placed under the obstacle. Once the cable end has entered the pipe or conduit, 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.

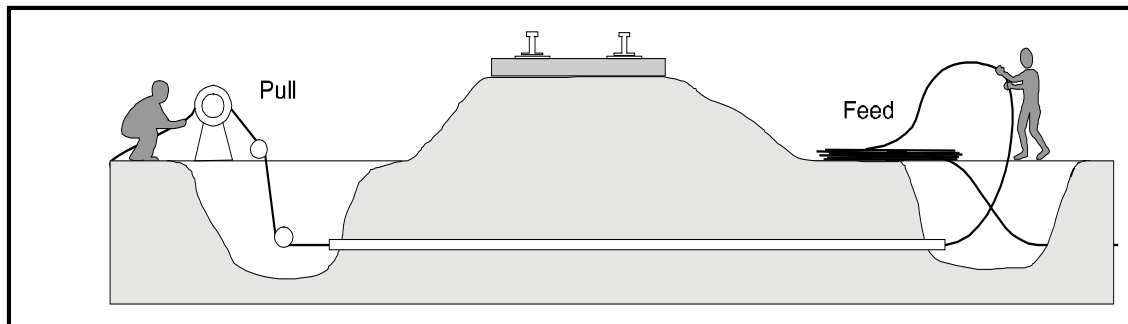


Figure 4 – Pulling the Cable

- 6.16** 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 5 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.

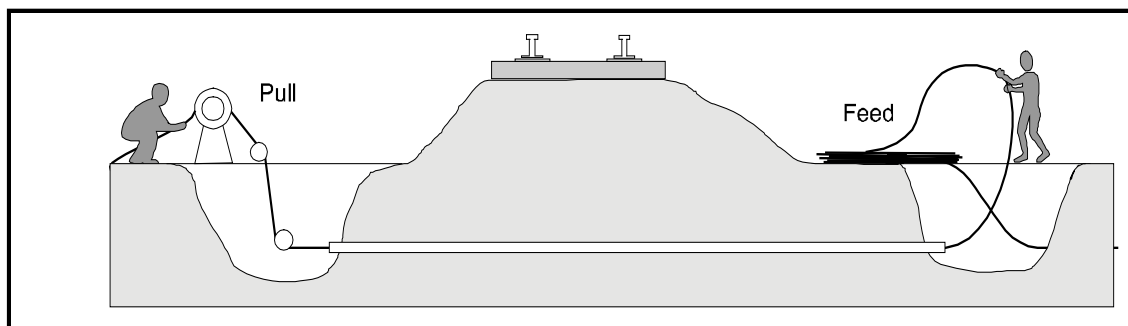


Figure 5 – Using a Figure-eight Machine

- 6.17** 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.

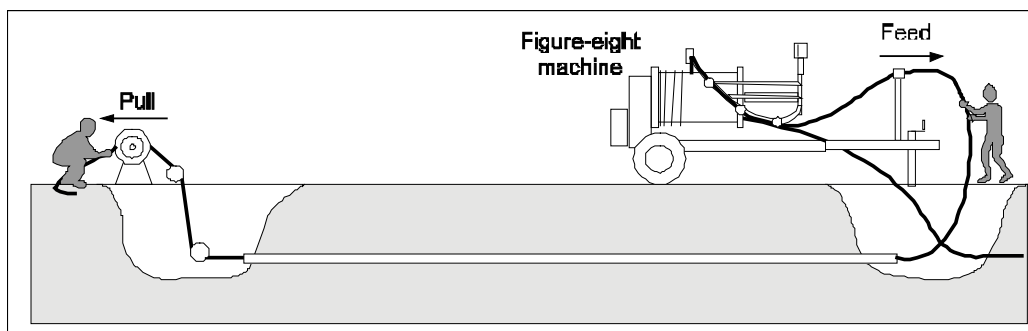


Figure 6 – Pulling Using a Figure-eight Machine

- 6.18** Company practices may prescribe a ripping pass to the depth of the cable burial along the entire route prior to plowing in operations to ensure the route is clear between start and stop locations. The ripping pass is made in the same direction as the cable plowing operation. The ripping pass ensures the route is clear before the fiber optic cable is loaded for plowing.
- 6.19** When plowing in fiber optic cable a warning tape is placed 12" below the surface of the ground directly above the cable. Both the cable and the warning tape are normally plowed in at the same time.

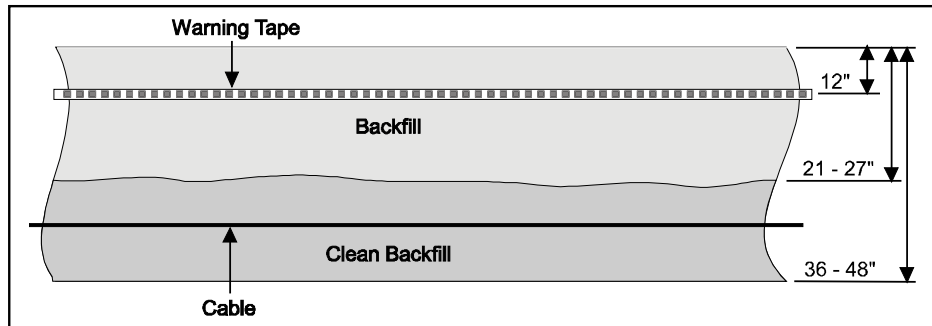


Figure 7 – Cutaway View of Buried Cable

- 6.20** The plow movement should be started slowly and its speed gradually increased after all cable slack has been taken up from the delivery system. Plow attitude and depth should be changed gradually. Changes should be made only with the plow underway. **Never** raise the plow to the surface if the plow is not moving. The cable to the rear of the feed chute must be excavated and slack pulled to prevent kinking the cable over the exit chute before raising the plow. **Never** back up the plow with a cable still in the chute.
- 6.21** Each section, after it is plowed in, should be checked with an OTDR for possible increases in attenuation due to pressure or breaks.
- 6.22** Any cable ends left for future splicing should have their protective caps reinstalled and sealed with tape prior to burial.
- ## 7.0 TRENCHING
- 7.01** Trenching may be chosen to bury fiber optic cable in urban and suburban areas where the high number of obstacles (sidewalk and street crossings) makes plowing impractical.
- 7.02** The choice of location for trenching in fiber optic cable follows the same set of rules as for plowing. Buried cable should be located where there is the least possibility of it being disturbed. Along roads, the cable should be located so that future surfacing and widening operations will not extend over it. Care should be taken that the route selected will not interfere with the natural drainage of the area and so that the natural drainage does not result in the depth of cable coverage being affected.
- 7.03** Trenching is normally conducted by using machinery. In some areas however, it may be necessary to hand-dig the trench. For maximum speed, hand digging should be held to a minimum. For maximum trenching speed, never dig a deeper or wider trench than required. However, it is recommended that a 4" wide trench be considered the minimum practical width.

- 7.04** The backfilling material must conform to local regulations. Clean backfill should be placed from 9" to 12" from the bottom of the trench to provide protection for the cable. On private right-of-way (ROW), the earth should be mounded over the trench to compensate for future settling. The backfilled trench may, in some cases, be satisfactorily packed down by running the tractor or wheel of a truck along the trench line on top of the backfill. When possible the top should be filled with top soil. Rocks and debris should never be left in the bottom of the trench. Surface compression could cause cable damage in the future.
- 7.05** All permanent pavement and sidewalks must be restored to the satisfaction of proper authorities. When shrubs or other local vegetation must be disturbed it should be set aside and replaced when possible. Where lawn has been removed, it should be replaced or re-seeded.
- 7.06** Following the installation of the cable, each section should be checked with an OTDR for possible increases in attenuation due to pressure or breaks.
- 7.07** Any cable ends left for future splicing should have their protective caps reinstalled and sealed with tape prior to burial

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