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Application Note

Optical Fiber Cable Installation Guideline

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1. Recommendations for Fiber Optic Cable Installation

1.1 General recommendations for all installation and storage areas of cable (indoor/outdoor)

Where reels are supplied with protective material fitted over the cable, the protection should remain in place until the cable will be installed.

During installation, all curvatures should be smooth. The cable should be bent as little as possible. Turn-backs and all sharp changes of direction should be avoided. Avoid pulling cables over edges.

1.2 Recommendations for outdoor installation and storage areas of cable

If the cable remains outside for more than 24h during installation protective material should be used to prevent cable damage.

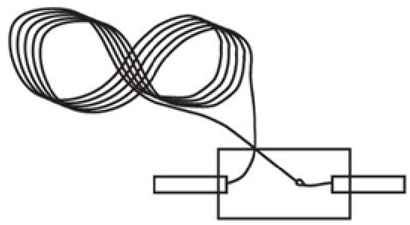
The maximum installation and storage temperatures specified for each cable in the data sheet must be respected. The specified values apply to the cable temperature and not to the ambient temperature. During the installation process LSZH sheathed cables are more sensitive to cracks and other damage caused by mechanical stress. The risk of damage occurring during the installation process rises with the temperature.

Ensure that the installation area has no objects that could damage the cable such as sharp rocks.

Minimize mechanical pressure on the outer sheath at crossing points: (armoured) cables crossing each other generate points of high pressure, so it is important when laying in figure 8 loops it is done in a correct way.

When laying loops of fiber on a surface during a pull, use “figure-8” loops to prevent twisting the cable. The figure 8 puts a half twist in on one side of the 8 and takes it out on the other, preventing twists.

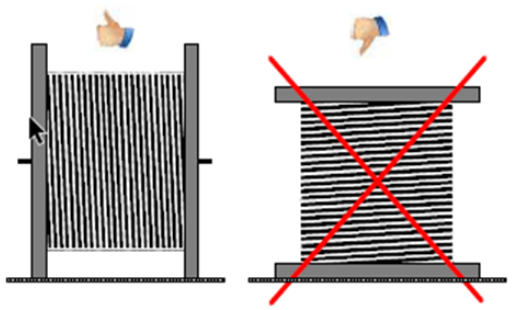
The size of the „8“ will be determined by the size and stiffness of the cable, but 2 to 4m is a common size. The end of the cable will be against the ground, use a plastic sheet to keep the cable clean. Pull slowly and carefully lay the cable in the figure 8 pattern to prevent kinking. Each “8” should be slightly offset from the previous one to minimize mechanical pressure. Finally pick up the cable and flip it over so the end to be pulled to the next location is on top.



2. Recommendations for Fiber Optic Cable Storage

The following recommendations for outdoor storage areas of Fiber Optic Cable apply:

- Where reels are supplied with protective material fitted over the cable, the protection should remain in place until the cable has been installed. If the protection is removed prior to installation (for inspection purposes for example) then it must be re-fitted as originally supplied before the reel is placed back in storage or onward shipped.
- The maximum storage temperature is specified for each cable in the datasheet and must be respected.
- Reels should be stored in areas with flat firm surfaces to prevent damage.
- Appropriate devices must be used to secure reels to prevent reel movement during storage.
- Avoid storage areas that are susceptible to flooding, or that could damage the cable, such as sharp, uneven terrain (rocks).
- Before de-reeling the cable, the reel should be visually inspected for possible damage caused during storage.
- Ends of the cables shall be sealed during storage (Heat shrink cable end caps are recommended) to prevent intrusion of moisture.
- All Fiber Optic Cable reels should be stored upright

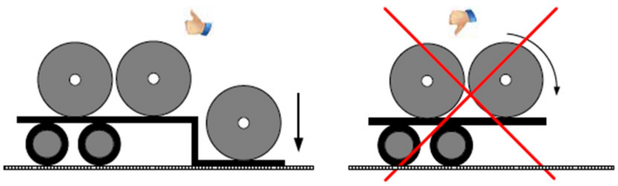


Laying the reel on its side may cause damage to the reel flange and/or cause the cable layers to shift – This may cause cable to snag during de-reeling.

- When rolling / moving reels do not “kick” the cables. Ensure that the route has no objects or uneven terrain that could damage the cable when the reel is being rolled.

- Where it is necessary to lift reels and the cable reel is too heavy to move manually, the reel must be moved upright by lifting the cable with a fork lift or reel mover. The forks must be placed under the reel with the forks always perpendicular to the reel flange.

- Never drop a cable reel from any height during transportation or use. Dropping a reel could affect its structural integrity and cause de-reeling issues – it may also damage the product.
- When unloading from a vehicle, use either the tail-lift / elevator (if fitted) or a suitable mechanical aid such as a forklift truck. Never let reels drop from the vehicle to the ground.



- It is recommended to record the data provided on the labeling tags of all the reels in case of any subsequent issues.
- Belden recommends that cable reels should be stored in a safe, locked location.

3 Fiber Optic Cable Installation

Generally speaking, fiber optic cable can be installed using many of the same techniques as conventional copper cables.

3.1 General Guidelines

The following contains information on the placement of fiber optic cables in various indoor and outdoor environments. In general, fiber optic cable can be installed with many of the same techniques used with conventional copper cables. Basic guidelines that can be applied to any type of cable installation are as follows:

- Conduct a thorough site survey prior to cable placement.
- Develop a cable pulling plan.
- Follow proper procedures.
- Do not exceed cable minimum bend radius.
- Do not exceed cable maximum recommended load.
- Document the installation.

3.1.1 Conduct a Site Survey

The purpose of a site survey is to recognize circumstances or locations in need of special attention. For example, physical hazards such as high temperatures or operating machinery should be noted and the cable route planned accordingly. If the fiber optic cable has metallic components, it should be kept clear of power cables. Additionally, building code regulations must be considered. If there are questions regarding local building codes or regulations, they should be addressed to the authority having jurisdiction, such as the fire marshal or city building inspector.

3.1.2 Develop a Cable Pulling Plan

A cable pulling plan should communicate the considerations noted during the site survey to the installation team. This includes the logistics of cable let-off/pulling equipment, the location of intermediate access points, splice locations and the specific responsibilities of each member of the installation team.

3.1.3 Follow Proper Procedures

Because fibers are sensitive to moisture, the cable end should be covered with an end cap, heavy tape or equivalent at all times. The let-off reel must never be left unattended during a pull because excess or difficult pulls, center-pull or backfeeding techniques may be employed.

3.1.4 Do Not Exceed Cable Minimum Bend Radius

Every Belden cable has an installation minimum bend radius value. During cable placement it is important that the cable not be bent to a smaller radius. After the cable has been installed, and the pulling tension removed, the cable may be bent to a radius no smaller than the long term application bend radius specification.

The minimum bend radii values still apply if the cable is bent more than 90 degrees. It is permissible for fiber optic cable to be wrapped or coiled as long as the minimum bend radius constraints are not violated.

3.1.5 Do Not Exceed Cable Maximum Recommended Load

While fiber optic cables are typically stronger than copper cables, it is still important that the cable maximum pulling tension not be exceeded during any phase of cable installation. In general, most cables designed for outdoor use have a strength rating of at least 2700 N. Belden fiber optic cables also have a maximum recommended load value for long term application. After cable placement is complete the residual tension on the cable should be less than this value. For vertical installations, it is recommended that the cable be clamped at frequent intervals to prevent the cable weight from exceeding the maximum recommended long term load. The clamping intervals should be sufficient to prevent cable movement as well as to provide weight support.

3.1.6 Leave Extra Cable

A common practice is to leave extra cable at the beginning and at the end of the cable run. Also, extra cable should be placed at strategic points such as junction boxes, splice cases and cable vaults. Extra cable is useful should cable repair or mid-span entry be required.

3.1.7 Document the Installation

Good record keeping is essential. This will help to ensure that the cable plant is installed correctly and that future trouble shooting and upgrading will be simplified. All Belden fiber optic cables have a unique lot number shown on the shipping spool. It is important that this number be recorded. Cable pre- and post- installation test data should be recorded in an orderly and logical fashion.

3.2 Pulled Installations

In order to effectively pull cable without damaging the fiber, it is necessary to identify the strength material and fiber location within the cable. Then, use the method of attachment that pulls most directly on the strength material—without stressing the fiber.

As a general rule, it is best to install cable prior to connector attachment. After connectors have been attached, it becomes more difficult to protect the fiber from inadvertent stress. If a pull is to be made entirely in one direction, connectors may be pre-installed on one end, leaving the other end for pulling.

If the cable **must** be installed with connectors attached, every practical means must be taken to protect the terminated end from damage or stress. Cushioned enclosures should be used to protect connectors during pulling.

The leading end of the cable should be sealed to prevent intrusion of water or other foreign material while pulling.

Bi-directional pulls are possible by laying the cable into large „figure-8"-shaped loops on the ground, from where it can feed from both ends.

For ease of cable installation, the area of the cable divided by the area of the duct or conduit should be less than 53% per a single cable. Permissible area to be occupied for 2 cables is 31%, for 3 or more cables it is 40%.

3.2.1 Direct Attachment

With direct attachment, cable strength material is tied directly to the pulling fixture. Conventional cable tools may be used. Loose fiberglass threads are not suitable for direct attachment because they may break if knotted. Fiberglass epoxy rods are too rigid to tie, but may be secured to the pulling fixture by using tight clamping plates or screws.

Direct Attachment: Strength member is tied directly to the pulling fixture. The cable end must be sealed to prevent intrusion of moisture while pulling.

3.2.2 Indirect Attachment

With indirect attachment, pulling forces are distributed over the outer portion of the cable structure. If cable strength materials are located directly beneath the jacket, this method will produce the least amount of stress on the fiber.

Indirect Attachment: Pulling forces are distributed over the outer cable structure.

A popular type of pulling fixture for indirect attachment is the "Chinese Basket" or "Kellems Grip".* The Kellems Grip is usually reliable for cables of 1/4" diameter or more. Large pulling forces are possible with a Kellems Grip if the grip's diameter and length are properly matched to cable characteristics.

A Kellem Grip should spread pulling forces over a 1m length of cable. For small cables, pre-stretching and taping the Kellems Grip to the cable helps to assure even pulling.

3.3 Cable Lubricants

Many lubricants are available for lowering friction forces. These include greases, waxes, clay slurries and water-basedgels. Fiber optic jacket materials are compatible with most of these. For new conduit, lubrication of the conduit before pulling is suggested—particularly if there are several bends.

3.4 Air Plenums, Trays, Raceways

Installation procedures for open placement of fiber optic cables are the same as for electrical cables. Care should be taken to avoid sudden, excessive force so as not to violate tensile load and radius limits. Sharp bending and scraping at entrances and covers should be avoided.

3.5 Direct Burial

Belden outdoor cables may be buried directly in the ground. Environmental hazards include freezing water, crushing forces from rocky soil, ground disruption from construction, and rodents. Burying the cable 90 to 120 cm deep may help prevent most of these hazards.

Direct plow-in installation requires a cable capable of withstanding uneven pulling forces. Loose tube cables are best suited for these types of installations.

Double jacketing, gel filling, metal sheathing and (CST) armoring are used as water barriers.

Use of double jacketed armored cables can sometimes be avoided by burying polyethylene pipe to form a simple conduit. The pipe makes a smooth passageway and may be curved to allow easy access at manholes and other pull points. Cables may be subsequently replaced without digging.

Polyethylene pipe can be used as a simple conduit. This allows use of less expensive cables in direct burial applications.

3.6 Cable Preparation

The following is a general description of cable preparation and termination procedures.

3.6.1 Jacket Removal

The procedure for stripping fiber optic cables is very similar to electronic cables. However, care should be taken not to cut into the layer of aramid directly beneath the jacket. This would either reduce the pull strength of the cable, or weaken the connection. For this reason, if a blade must be used, a cut which does not

completely penetrate the jacket can be made. This will weaken it sufficiently and allow the jacket to be peeled. Most Belden cables utilize a ripcord capable of tearing the outer sheath.

3.6.2 Cutting and Trimming Aramid

Aramid can be easily cut with sharp scissors if the threads are confined in movement so that cutting pressure can be applied. Ceramic scissors may also be used.

3.6.3 Steel and Fiberglass Epoxy Rod Members

Temperature stabilized cables of both loose and tight buffer constructions often have steel or fiberglass epoxy rods. Use of heavy-duty cutters is recommended for these hard materials.

3.6.4 Buffer Tube Trimming

Buffer tubes are made of plastic materials with various characteristics of hardness and flexibility. Belden buffer tubes are both flexible and strong, but may be trimmed easily. The simplest way is to score one side of the buffer tube firmly with a razor blade, then bend the tube sharply away from the score mark. The broken-off piece is then pulled straight off, leaving the fiber intact.A stripping tool which barely cuts through the tube is also satisfactory. If it is intended to cut through both the buffer tube and the fiber, use diagonal cutters and cut through cleanly.

3.6.5 Breakout Element Trimming

Breakout subunit element jackets are most easily removed by a stripping tool which cuts circumferencially. The jacket may then be pulled straight off, exposing the aramid.

3.7 Fiber Preparation: Stripping

Optical fibers must be stripped of buffer coatings to allow a close fit within precision connectors.

(Note: always wear safety glasses or goggles when working directly with fibers.)

Buffer coatings are usually removed mechanically with sharp blades or calibrated stripping tools. In any type of mechanical stripping, the key is to avoid nicking the fiber.

(Note: Dispose of broken pieces of fiber by placing them on a piece of tape. Glass fibers are difficult to see and may not be felt until through the skin. Eyes should not be rubbed while working with fibers.)

3.8 Splicing Optical Fibers

Preparation of fibers for splicing is very similar to the process described under connectorization. After jacket materials, strength members and buffer tubes have been cut to the appropriate lengths, the fiber buffer coatings must be removed.

3.8.1 Cleaving

After the buffer coatings have been removed, fibers must be cleaved in preparation for splicing. Cleaving is a method of breaking a fiber in such a way as to create a smooth, square end on the fiber.

Principles of Cleaving

Glass is typically strong until a flaw occurs and creates aregion of high stress under pressure. The first step in the cleaving process is to create a slight flaw or“ scribe“ in the outer surface of the fiber.

Optical fibers can be scribed with a sharp blade of hard material such as a diamond, ruby, sapphire or tungsten carbide. The scribe is made by lightly touching the cleaned fiber, at a right angle, on the desired cleave point with a scribing tool. Only the lightest pressure is required to produce a scribe if the blade is sharp. NOTE: DO NOT USE A SAWING MOTION. A crude or slanted scribe will produce shattered or scalloped end surfaces.

After the scribe is made, a straight pull will produce the cleanest break. If bending accompanies pulling, a square break is less likely, especially with large fibers. Dispose of broken fiber pieces by placing them on a piece of tape. ALWAYS WEAR SAFETY GLASSES WHEN WORKING WITH OPTICAL FIBERS.

The level of quality required for a given cleave depends on the application. For fusion splicing, mechanical splicing and some connectors systems, cleaves must be nearly perfect. Some connector and splicing systems use cleaving to produce the final end surface on the fiber (no subsequent grinding or polishing). However, for quick continuity checks with a flashlight, less than perfect cleaves may be acceptable.

A 30x to 50x hand microscope is useful for quick checks of cleave quality.

Cleaving tools are available in inexpensive hand models or more sophisticated mechanized tools.

3.8.2 Splicing Methods

There are two basic types of splices: Fusion and Mechanical.

Fusion Splicing

Fusion splices are made by positioning cleaned, cleaved fiber ends between two electrodes and applying an electric arc to fuse the ends together. A perfusion arc is applied to the fiber while the ends are still separated to vaporize volatile materials which could cause bubbles.

Final precise alignment is done by moving fiber ends together until there is slight pressure between end surfaces.

An ideal fusion cycle is short and uses a ramped or gradually increasing arc current. A short, ramped cycle is considered least likely to produce excessive thermal stress in fibers. Cold temperatures require increased time and arc current.

Experienced operators consistently produce fusion splices with losses less than 0.2 dB per splice and averaging 0.3 dB on multimode fibers. Sophisticated fusion splicing systems for single-mode fibers produce typical splice losses of 0.05 to 0.1 dB.

Mechanical Splicing

Mechanical splicing systems position fiber ends closely in retaining and aligning assemblies. Focusing and collimating lenses may be used to control and concentrate light that would otherwise escape. Index matching gels, fluids and adhesives are used to form a continuous optical path between fibers and reduce reflection losses.

3.9 Testing

3.9.1 The Flashlight Test

A simple continuity test for short-to-medium length fiber optic links is to shine a flashlight into a cleaved or connectorized link and observe if light comes out of the other end. On short lengths, it may be necessary to cleave only the end where the flashlight injects light into the fiber.

This simple check can be made on cable lengths of up to a 1,5km and more. If cable ends are outdoors, sunlight may be used. NOTE: on longer lengths, the light observed at the opposite end may appear red in color. This is normal and is caused by the filtering of light within the fiber.

CAUTION: NEVER LOOK DIRECTLY INTO A FIBER CONNECTED TO LIGHT LAUNCHING EQUIPMENT. THIS CAN CAUSE PERMANENT EYE DAMAGE.

3.9.2 The Optical Time Domain Reflectometer (OTDR)

OTDRs are typically used to measure distance and attenuation over the entire fiber link. They are also used to identify specific points along the link where losses occur, such as splices.

An OTDR is an optical radar which measures time of travel and the return strength of a short pulse of light launched into an optical fiber. Small reflections occur throughout the fiber, becoming weaker as power levels drop with distance. At major breaks, large reflections occur and appear as strong peaks on an oscilloscope. Testing of short and medium distance fiber optic systems seldom requires an OTDR. In smaller systems, optical power meter tests are faster and more useful.

3.9.3 Magnifying Glasses and Microscopes

Because the naked eye cannot detect scratches or defects in optical fibers, use of magnification equipment is required. For most routine inspections, and ordinary battery-powered illuminated microscope of 30x to 100x can produce satisfactory results. Some microscopes are available with special adapters specifically designed for use with fiber optic connectors.

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4 Fibre Optic Cable Blowing

Some interesting installation methods are being used to put fiber optic cable in duct.

Sometimes called „cable blowing“, these methods use a high-volume air flow (7 bar back pressure) to „push“ the cable.

4.1 Blowing techniques

Most blowing machines also have mechanical „pushing“, where the cable is pushed by traction rollers as it enters the duct. First, let us review the two basic types of blowing installation.

4.1.1 Piston Type

In this type of blowing unit, an air-tight piston is attached to the front of the cable. The air pushes this piston, and the piston “pulls“ the cable. The pulling force is essentially the air pressure times the piston area. At 8 bar, the force can be 700N for 32mm high density polyethylene innerduct.

Field users should be aware that a pulling force exists in piston blowing, and cable tension maxi-mums should be respected.

4.1.2 Laminar Flow Type

The second type of blowing unit does not use a piston - and allows full air flow through the duct.

Calculations indicate that air speeds of 100 m/h are possible. This rushing air pushes on the cable jacket, providing a general force “all over“ the jacket.

4.1.3 Mechanical “Pushing“

Pushing has always been an effective way to make short runs of cable in conduct. However, you can only push a cable to the point that it buckles, which can be less than 50N for a flexible, indoor cable, and up to 300N for an armored, outdoor type cable.

Even in straight ducts, pushing of typical outdoor cables is limited to maximum 100m.

This means the air forces, piston or laminar, are key to making blowing units function for the 1000 - 2000m runs typical for outdoor cable application.

4.1.4 Air Tight Duct

Cable blowing machines don‘t work unless the duct is air-tight. Reinforced duct splices are usually required. Most cable blowing to date has been done in continuous polyethylene innerduct, which minimizes opportunities for air loss. It‘s a mistake to try to blow cable into a duct that has not been prepared for the pressures and forces involved.

4.2 Key Application Parameters

Fiber Optic cable-blowing research indicates three major factors control how far a cable can be blown. These are:

- Duct **fill** (cable to duct size ratio)
- Cable **flexibility** or stiffness
- Coefficient of **friction** (lubrication)

Belden completed a series of experiments in 1996 on high speed air blowing with both piston- and laminar flow unit. Coefficient of friction was studied. The results are useful to those blowing or planning on blowing cable.

4.3 Unlubricated versus Lubricated

With paraffin oil coated on the duct wall as a lubricant the friction forces will be reduced. The effect of lubrication is most significant with stiff jacket materials (nylon, high density polyethylene). As a result the maximum blowing distance can be doubled.

Use only cable/duct lubricants recommended by its blowing equipment manufacturer for optical fiber cable. Do not use soap or equivalent substances that may induce stress cracking of the jacket material.

4.4 Lubricating: Duct vs Cable

Preferably the lubricant is applied to the interior of the duct (by blowing through a coating missile before blowing the cable). This gives better results compared to coating on both the duct and cable. This indicates the cable jacket should not be “slippery“ for optimal laminar-flow blowing.

Remember, the air “pushes“ on the jacket - through friction. A low friction jacket will not be as easy for air to push. Normally 0.25 liter lubricant is used to coat 2000m duct.

4.5 Jacket materials

In order to gain minimum friction forces during cable blowing it is important to know the effect of different cable jacket materials. Relatively stiff materials like polyamid (nylon) and high density polyethylene (HDPE) give better results compared to low density polyethylene (LDPE) and flame retarded compounds (LSZH).

4.6 Duct internal design

The maximum blowing distance can be influenced by the internal design of the duct (smooth, ribbed, corrugated, etc.). In general, the blowing distance in a S/Z ribbed duct will be 100% more compared to a longitudinally ribbed duct.

4.7 Bends in Duct run

Sharp bends will reduce the maximum blowing distance. We advise a minimum duct radius of 1m. A large distance between the individual bends has also a positive effect. With a piston flow unit it is better to have the bends in the first part of the duct run, with a laminar flow unit at the end.

The piston type of blowing leads to double blowing distances in comparison with laminar flow.

4.8 Recommendations for Blowing Fiber Cable

- Follow the recommendations of both the blowing equipment and cable supplier.
- A crash test should be performed to determine the **maximum push force**. Excessive pushing will cause the cable to cork screw in the duct or fold over which will damage the fiber.
- Cable with **smaller diameters** and **lower weight** will require a lower maximum push force and achieve larger blowing distances.
- The maximum cable push force will also decrease as the duct inside diameter increases.
- Do not exceed a 55 bar force for Loose Tube cables with a diameter < 15mm and 35 bar for cables < 12mm. Cable guides must be used for cables ≤ 25mm in diameter.
- Prepare the duct for blowing. This includes assuring the duct inside diameter has sufficient cable clearance for proper blowing. The duct entrance/exit must meet the cable bend radius specifi-cation.
- Use the **proper cable seals**/guides based on the cable diameter.
- Cable **end cap** or sealing is recommended to keep the air pressure out of the cable.
- Do not over tighten the top of the blowing unit. Use springs to control the maximum compression force.
- Consider the route to determine the maximum blowing distance. Follow the blowing equipment suppliers blowing distance recommendations; **1000 to 2000m is a typical blowing length**. A set up with multiple blowing machines may be required.
- Maintain proper air flow to “blow” the cable verses “pushing” the cable.
- Using an air compressor with a **minimum flow** of 420 m3/h (32mm duct) to 640 m3/h (40mm duct) is recommended. The minimum air pressure in the duct should be 7 bar with 8,5 bar recommended. Using a piston flow unit will reduce the flow to 240 m3/h.
- Air compressor cooler should be used as recommended by the blower equipment manufacturer. Typically this is when the ambient air temperature exceeds 27˚C.
- Do not attempt to overdrive the blowing machine. Higher speeds will not provide much of a time savings or increase the maximum blowing distance.
- Cable / Duct size ratio: To prevent buckling of the cable is it recommended not to use relatively small diameter cables in large ducts. As a guideline we recommend cable with an outer diameter approximately 50% of the duct inner diameter.
- The cable should be clean as it enters the blowing equipment to allow for proper gripping of the cable. Contamination of the cable will increase the friction and result in reduced blowing distance.

5 Guidelines for the Vertical Installation of jelly-filled Loose Tube Optical Fibre Cables

5.1 Installation Procedures

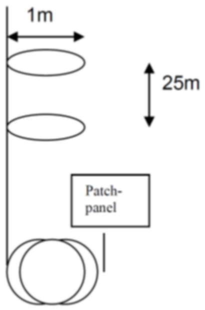
The following section contains information on the placement of jelly-filled loose tube optical fibre cables in vertical installations. Both indoor and outdoor environments are described. In general, optical fibre cables can be installed using many of the same techniques as for conventional copper cables. Basic guidelines regarding min. bend radius and max. pulling tension are quite similar and it is important to ensure that any load is applied to all the cable components to avoid slippage.

5.2 Vertical Installation

Most optical fibre cables can be installed in vertical situations without any issues arising. In tall buildings like TV towers with a height of max. 650 m, our experience shows that no filling compound will drip from the cable when the installation guidelines shown below are followed:

- The cable must be looped with a minimum radius of 50 cm. every 25 m. These so-called friction loops decouple the vertical drop from the lower termination.
- The cable should be looped 3 times, with a min. bending radius of 50 cm, below the lowest patch panel. The cable should enter the panel from its underside.

These guidelines are illustrated in the below figure:



This installation set-up will prevent jelly dripping from the cable. An appropriate termination of the cable is especially required for cables installed in outdoor situations, e.g. down the side of a building and in direct exposure to sunlight. The daily temperature cycle that causes expansion and contraction of the cable produces an efficient pumping mechanism.

5.3 Filling Compound

In particular, there are two properties which the filling compound in the loose tube(s) in vertically installed optical fibre cables should meet:

- Low slump

Filling compounds with low slump must meet the IEC 60794-1-E14 "Compound flow (drip) test". In this test cable samples are heated 24 hrs at 70 C; no dripping should occur.

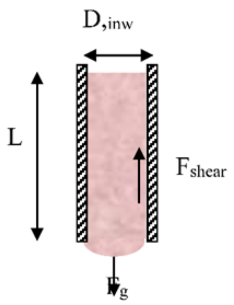
- Oil separation

Filling compounds with 0% oil separation must be used to guarantee that the compound material has a homogeneous composition during the lifetime of the cable.

The filling compounds in Belden optical fibre cables are carefully selected and meet these qualifications.

5.3.1 Theory:

According to the rheological theory the maximum inner diameter of vertically installed loose tubes can be calculated:



No dripping occurs if:

$F_g < F_{shear}$

$F_g = 9.8 \times M$ (M= mass)

$F_{shear} = \eta D \times A$

(η = viscosity; D= shear rate ; A= shear surface = $\pi \times D_{,inw} \times L$)

5.4 Cable Features

The guidelines for vertical installations described above are recommended for both multi- and central tube cable:

5.4.1 Outdoor/Indoor use:

- Universal Multi-tube OF cables (metal-free) with UV-resistant halogen-free jacket
- Universal Central-tube OF cables (metal-free) with UV-resistant halogen-free jacket

5.4.2 Outdoor use:

- Outdoor Multi-tube OF cables (metal-free) with UV-resistant PE outer jacket
- Outdoor Central-tube OF cables (metal-free) with UV-resistant PE outer jacket

5.5 Applications

- In tall buildings such as office blocks or TV towers