American Polywater's

TeleTopics

A NEWSLETTER COVERING TECHNICAL SUBJECTS OF INTEREST IN TELECOMMUNICATIONS CONSTRUCTION

ROUTE TO:

Volume 2-2

EFFECT OF FLEXIBLE DUCT PLACEMENT ON FIBEROPTIC PULLING TENSION

Straight as a Snake

"Flexible duct" is the continuous, plastic-tube-type duct commonly used for fiber optic cable. It is often called "innerduct" or "sub-duct." For this discussion, it does not matter whether the flexible duct is thick wall, thin wall, ribbed, corrugated or smooth- - as long as it comes from continuous lengths on a feeder reel.

Long runs of flexible duct placed directly between two points are usually presumed to be "straight." However, since the duct is not rigid, it can conform or "snake" over distance. Factors such as reel memory and detours around or over obstacles produce this "snaking."

Cable pulling *theory indicates* that with a "typical" fiber cable and POLYWATER® F, we should be able to pull this cable *over 5,000 meters (16,400 feet) into straight duct* with less than 230 Kg (500 lbs) of tension. Yet, unassisted pulls of this length are rarely possible. What part does "duct snaking" play in this limitation?

Most crews pulling long runs of fiber cable have seen the effects of duct placement on pulling tension, although they may not realize it. What they know is that sometimes they can pull fiber optic cable more than 2,000 meters (6,500 feet) with no mid-assist, and with less than 230 Kg (500 lbs) tension!! At the other extreme, sometimes fiber cable can't be pulled 150 meters (500 feet)!!

A number of factors can be "blamed" for high tension and short pulls in "straight" duct. Aside from lubrication, the *major factor is duct placement*. Specifically, "conduit snaking" (residual winding) can cause apparently straight line pulls to have excessive tension.

A Reel Demonstration

A dramatic way to demonstrate the effect of snaking is to pull cable into a continuous duct while the duct is on a reel (or wrapped around a core or drum). Each time the cable goes around the reel, it has gone through 360° of duct bend. Results of such a test with a one-meter (3.3-foot) diameter drum and 2.3 Kg (5 lbs) back tension on the cable are given below:

	Lubricated with POLYWATER â F Kg (lbs)	**No Lubricant Kg (lbs)**
1 revolution (360°)	4 (9)	18 (40)
2 revolutions (720°)	7 (16)	145 (318)
3 revolutions (1,080°)	12 (27)	1,148 (2,530)
4 revolutions (1,440°)	22 (48)	Crunch!!
5 revolutions (1,800°)	39 (85)	
6 revolutions (2,160°)	68 (149)	
7 revolutions (2,520°)	120 (262)	
8 revolutions (2,880°)	210 (461)	

Even with pulling lubricant, we couldn't pull 30 meters (100 feet) with less than 230 Kg (500 lbs) of tension because the total bend was over 2,800°! Without the lubricant, we couldn't even go six meters (20 feet)!!

Coefficients of Friction (COF) for **POLYWATER®** F, calculated from this type of test are 0.10 to 0.13. These are lower COF's than such tests show for other lubricants, including silicone and other polymer types. In other words, regardless of the length of pull or lubricant used, we cannot expect to pull through 2,800° of cumulative bend with less than 230 Kg (500 lbs) of tension!

The Real Field

As a general rule of thumb, when there are more than *600° to 900° of evenly distributed bends* in a conduit, tensions on typical fiber cable will move above 230 Kg (500 lbs), even with the superior friction reduction of **POLYWATER®** F Lubricant.

How much "bend" actually comes from "duct snaking?" We find it depends on the "amount of snaking;" that is , the frequency and severity of the waves and wiggles.

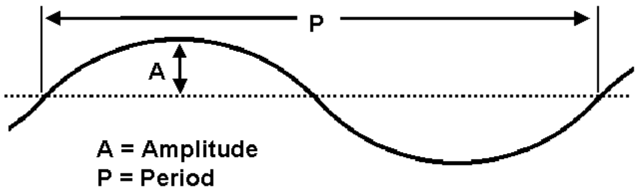

Figure 1 – Two-dimensional Snaking Duct

In Figure 1, if we treat each wave in the conduit as a large radius bend, we can calculate that bend (in degrees). With "P" as the distance of the wave, and "A" as its height (or amplitude), here are results of such calculations:

P (m)	**A (mm)**	**Total Bend Per 1000 meters**
30	150	305°
30	70	145°
30	25	50°
15	150	1220°
15	70	570°
15	25	205°
8	150	4270°
8	70	2000°
8	25	715°

These results show the true significance of conduit snaking (or other sources of micro-bending). It's all too easy to have over 1,000° of large radius bend in 300 meters (1,000 feet) of conduit. We can see why some long fiber optic pulls are not possible**,** *regardless of the quality of the pulling lubricant, pulling rope, conduit interior, etc.*

The calculations show that lower values for "A" (height) and higher values for "P" (distance) result in less bend from "snaking." Basically, this shows the obvious, that "straighter" conduit has fewer bends, and thus will show less tension on cable installation.

The Duct-Placement Factor

The importance of duct installation in maximizing pulling lengths now becomes obvious. The following are techniques and comments on placing "straight" duct.

Plowing: Technique and equipment are very important - - "Preripping" to prepare for smoother plowing helps - - Rocky terrain makes matters very difficult. You'll probably never be able to pull as far in duct plowed in rocky terrain, even with the best plowing technique.

Trenching: It's very difficult to lay straight, continuous duct in trench and then back fill - -Linear tension on duct and/or a "V" shaped trench can help straighten duct. Otherwise, hard sided duct is recommended.

In Conduit: Innerduct waves are limited by I.D. of conduit - - There's also some indication that pulling cable itself tends to straighten innerduct in conduit. Too many innerducts in a conduit may inhibit this self-adjustment and ultimately add to tension in pulls.

Regardless of the effectiveness of the placing technique, there will still be differences in pulling tensions caused by variance in duct placement. What, then, is the best way to pull cable into ducts that have some degree of "snaking?"

Lubricant Critical

We saw the effects of friction in the extreme, wound duct test. There, lubricant allowed us to pull four times farther with the same tension.

The table below shows tensions at different COF's from pulling through 1,000 meters (3,280 feet) of duct with 200° of bend per 333 meters (1,092 feet) (total of 600°of bend).

Friction Coefficient	**Tension** Kg (lbs)
0.13	390 (860)
0.16	747 (1,647)
0.19	1,405 (3,098)

While the friction coefficients of 0.13 to 0.19 are all "good," you can see that the superior friction reduction (from POLYWATER® Lubricants) is critical in multi-bend pulls. Even small compromises in product or application can make a big tension difference.

Past Guides the Future

It is not possible to measure "snaking" during duct placement, and to plan pulls based on these measurements. It is possible, with the PULL-PLANNER™ Software, to take *field pulling tensions and determine the "effective" friction coefficient from a field pull*. Such data can help plan additional pulls in similar duct, or even help evaluate and optimize duct placement method.

Web Calculator Available

American Polywater has a free calculator on the Internet that will estimate fiber optic pulling tensions based on the model above. You can go directly to the calculator at:

www.polywater.com/calculators/calculator.asp

If you would like to receive additional information or preview the PULL-PLANNER ™ 2000 Cable Tension Estimating Software, please contact our Customer Service Department at 1-651-430-2270 or via email at custserve@polywater.com or visit the product flyer online at www.polywater.com/pullplan.html

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