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Experience in the Application of Various Microduct Cable Designs

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Abstract

Depending on the field of use, the number of fibers required, the desired installation length, and the climatic and installation environment, a network designer needs to select the most suitable microduct cable design for a specific application. In this paper we will discuss various types of microduct cables, the designs, their performance test results and their main fields of application. There is no "all-purpose" microduct cable design. Recommendations are made for the different microduct cable constructions for an optimized product selection based on lab testing and field experience. Besides SZ-stranded micro-loose tube cables which have been developed in a wide variety of fiber counts and dimensions, central loose tube designs as well as tight designs will be discussed, with respect to the application and installation. Not only the cable design but also the preparation of the blowing process have a great impact on the success of a microduct cable installation.

Keywords: Microduct cable; cable blowing; blowing distance; optical cable; optical fiber; microduct; air blown; FTTH; flextube; access; midspan access; micro loose tube; stiffness; friction; low-temperature.

1. Introduction

Microduct cables in the recent past have conquered a significant part of the F.O. cable market. A wide range of microduct cables have been developed with respect to different installation environments and different operational requirements. We will discuss various types of microduct cables, the designs, their performance test results and their main fields of application. In this paper we only consider cables which can be blown in microducts not bigger than 16/13mm outer and inner diameter, respectively.

2. Basic Microduct Cable Designs

As the name indicates, microduct cables are made to be used in microducts, generally the installation is done by a combination of pushing and air blowing [1]. Especially for Fiber-to-the-Home it is often required that the cable can be installed over short distances by pushing only, without drag air. Although a wide variety of constructions have been developed, some basic structures can be distinguished which have their specific advantages in terms of fiber density, ease of handling and fiber access, low-temperature performance, and pushing/blowing performance. Low friction sheath material such as HDPE or PA hasve been identified as suitable [3] and are widely used for all kind of microduct cables.

For indoor/outdoor applications, also flame retardant designs are used, however the usual sheathing materials generally provide a higher friction and therefore installation distances may be shorter. In this paper we distinguish four main types of microduct cable designs for outdoor use:

a) Stranded loose tube microduct cables

This microduct cable design is very popular because of it's easy handling and installation. It is made with six (5 to 12) loose tubes which are SZ-stranded around a central strength element. The construction is very similar to normal size duct cables, it benefits from a proven technology and offers similar advantages, e.g. easy fiber identification and access.

b) Central loose tube microduct cables

Initially developed for low fiber counts, the central loose tube microduct cables today contain up to 96 fibers for blowing in a 10/8mm microduct. Most popular constructions are with plastic tube, with or without strength elements under the sheath.

c) Stranded tight buffer microduct cables

Similar to the loose tube SZ-stranded cable, but normally helically stranded. Unlike the loose tube constructions, the fibers are tightly embedded in the buffer material, thus have no freedom of movement inside the buffer tubes.

d) Central tight buffer microduct cables

The tight buffer central design allows for smallest cable dimensions, it is mostly used as drop cable, fiber counts between 1 and 6 are most popular.

3. Discussion of Microduct Designs

The first microduct cables being produced and installed were steel buffer central loose tube designs, see e.g. [11]. The designs compromised a thin walled stainless steel tube surrounded by a plastic sheath. Today these cable types are not being installed anymore and non-metallic microduct cables are used instead.

3.1 Stranded Loose Tube Microduct Cables

Easily spoken, these cables are miniaturized Loose Tube Duct cables. They have been derived from common loose tube duct cables making advantage of a long experience in design and manufacturing of Loose Tube Cables in combination with advanced production equipment and high performance materials. To achieve a small outer diameter, they not only have miniaturized buffer tubes but in general have a much thinner sheath (typically around 0.4 to 0.8mm) than standard duct cables.

Another important contribution however, is made by modern fiber design with tight coating diameter specifications and coloring-at-draw [8]. Such fibers can be as much as 6.4% smaller in diameter compared to fiber diameters specified in IEC 60793-2-50 when colored in a separate process with an extra color resin layer. This provides a significant advantage when designing optical fiber cables to the minimum possible dimensions. As an example, the decrease of a 6.6 mm cable to 6.2 mm results in a much better blowing distance [3].

Because of their ideal stiffness and flexibility, Stranded Loose Tube Microduct Cables provide outstanding push/blow performance for an extremely fast installation. Together with typical SZ-stranded duct cable advantages, such as midspan accessibility, easy stripping and fiber identification, as well as their considerably high fiber content at light weight and small dimensions they are the ideal cables for metro distribution and access networks and are widely used by numerous operators around the globe.

Table 1 shows usual dimensions for stranded loose tube microduct cables.

Table 1. Typical SZ-stranded Microduct Cables

Fiber #	Cable O.D. [mm]	Fibers/tube	Microduct [mm]
24	4.0 ± 0.1	4	7/5.5
72	5.8 ± 0.2	12	10/8
96	7.0 ± 0.2	12	12/9.6 (10/8)

Blowing distances in in all tests exceeded 1km by far, with different blowing machines [2], [3], [5], [13] at a blowing speed of >50m/min.

In a recent test, the above 5.8mm cable was pushed without air support over a distance of 300m at a speed of 60-50m/min in a 10/8mm duct, the 4mm cable reached 200m without air drag in the 7/5.5mm duct. The test installation comprised a nearly rectangular underground route with 90° bends every 60m.

While the installed microduct network is growing in many regions, operators sometimes require more fibers to be blown into a given duct than initially planned. In a recent field installation, a 96 fiber cable of 7mm O.D. (Figure 1) had to be blown in a microduct of only 8mm inner diameter. To reach a maximum non-cascaded blowing distance, a newly developed cable lubricator [7] had been used.

In Table 2 the blowing distances reached for some SZ-stranded microduct cables are given. The indication "reference" is referring to a blowing reference test. Here a length of about 1500m is laid in loops with lengths of 100 m connected by bends of 180° with radius of 40 times the OD of the microduct. Here a cable is blown in with a pressure of 10 bar and the distance is recorded where the speed has dropped to 20 m/min. When the speed does not drop this is indicated. Sometimes also the end is reached with lower pressure. In Table 2 also a field result (New Zealand) is given.

Table 2. Blowing distances for SZ-stranded Microduct Cables

Fiber #	Cable O.D. [mm]	Microduct [mm]	Blowing distance [m]	Installation
72	6.0	10/8	1500	Reference
96	7.1	10/8	1250	Reference
96	7.1	12/9.6	1550[1]	Reference
96	7.1	12/9.6	1700[2]	New Zealand

[1] Speed 27 m/min at only 6 bar.

[2] End reached with almost no change in speed.

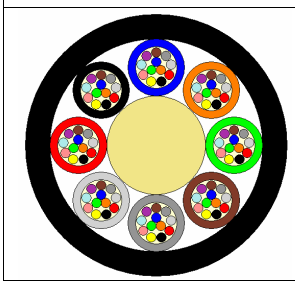
Cross Section	Main Parameters	
	Design	8x12
	Diameter	7.0 ± 0.2
	Weight	40 kg/km
	Operation Temp.	-40°Cto+70°C
	Tensile Strength	1000N

Figure 1. 96 Fiber Microduct Cable

Major customers in the United States often require microduct cables which meet the performance requirements of all standard fiber optic cables as outlined in Telcordia (BellCore) GR20 Issue 2. For Microduct cables, the key performance requirements are a tensile rating of either 300 lbs or 600 lbs, thermal operating requirements of –40C to +70C, and mechanical performance such as 125 lb/in crush strength. Listed below in Table 3 are the dimensions and characteristics of Microduct cables qualified to Telcordia GR20 performance requirements [12].

Table 3. Stranded Loose Tube Microduct Cables compliant with Telcordia GR20

Fiber #	Cable O.D. [mm]	Fibers/tube	Microduct [mm]
72	7.0	12	12/10
96	8.4	12	12/10 or 14/11
144	11.0	12	16/13

3.2 Central Loose Tube Microduct Cables

Unlike the stranded Loose Tube designs, the Central Loose Tube Cables for microduct installation in most cases have a different construction compared to standard central tube duct cables which often have radial strength elements embedded in the sheath. Central Loose Tube Microduct Cables allow for very small diameters which are required for customer drop connections. However, they are often used also for high fiber counts in metro backbones or even long distance applications. In those situations the extremely high fiber packing density is of main importance.

Depending on the required tensile strength and the temperature range, the cables are equipped with adequate strength elements which in most cases are embedded circumferentially between central tube and outer sheath. With the selection of the best suitable material combinations also for the central loose tube cables a temperature range of -40 °C to +70 °C can be realized.

However, even cables without additional strength members have been developed using sheath materials with low CTE [9].

Figure 2 below shows a 2.6 mm Microduct drop cable for installation in a 3.5 mm ID Microduct. A special jacket material was formulated using impregnated chips of a hardened material in a polymer resulting in a material with a low coefficient of friction as well as a reduced coefficient of thermal expansion. The special material allowed for this 12f cable to be blown 1200m (Figure 3), while still maintaining thermal stability at an operating temperature range of –15C to +70C.

Figure 2. 12 Fiber CLT Microduct Cable

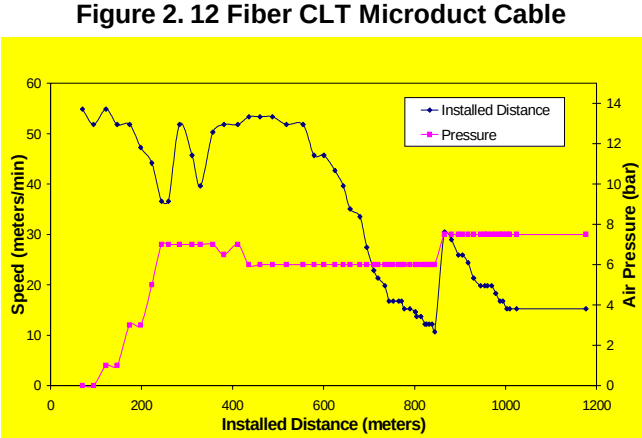


Figure 3. Blowing Diagram 2.6mm CLT Cable

Table 4. Typical Central Tube Microduct Cables

Fiber #	Cable O.D. [mm]	Strength Yarns	Microduct [mm]
12	2.6	No	3.5/5
8	3.2	Yes	7/5.5
24	3.9	Yes	7/5.5
36	4.1	Yes	7/5.5
48	5.0	Yes	10/8
60	5.6	Yes	10/8
72	5.9	Yes	10/8
96	6.5	Yes	12/9.6 (10/8)

In Tables 4 and 5 typical central tube microduct cable designs and the blowing distances reached for some of the cables are given. The indication "reference" is referring to the same blowing reference test as in Table 2. Also some field result (CERN) are given.

Table 5. Blowing distances for central tube Microduct Cables

Fiber #	Cable O.D. [mm]	Microduct [mm]	Blowing distance [m]	Installation
8	3.2	7/5.5	2650[2]	CERN
24	3.9	7/5.5	3474	CERN
36	4.1	7/5.5	1150	Reference
48	5.0	10/8	1500[1]	Reference
96	6.5	10/8	800	Reference
96	6.5	12/10	1500	Reference

[1] Speed 20 m/min at only 7.5 bar.

[2] End reached with almost no change in speed.

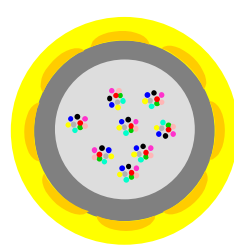
Cross Section	Main Parameters	
	Design	8x12
	Diameter	6.4 ± 0.2
	Weight	36 kg/km
	Operation Temp	-40 °C to +70° C
	Tensile Strength	200 N

Figure 4. 96 Fiber CLT Microduct Cable

Figure 4 shows the central loose tube 96 fiber cable with only 6.4 mm diameter.

3.3 Stranded Tight Buffer Microduct Cables

In the tight buffer designs the fibers are either embedded in one or more layers of UV-curable resin, or are buffered with a thin layer of soft plastic material (semi-tight flexible tube) [14]. With this technology, even smaller stranded cables are possible compared to loose tube constructions. Because the fibers are tightly surrounded by the buffer material they have no freedom of movement inside the buffer like this is the case with loose buffer tubes. For that reason special care must be taken in design and manufacturing to de-couple the fibers from external forces. These cables are normally helically stranded to avoid radial pressure from the necessary binders when SZ-stranded.

3.4 Central Tight Buffer Microduct Cables

Single fiber tight and semi-tight buffer central designs are well-known since decades for indoor use, e.g. as patchcords. For the microduct cables with central tight design, preferably 2 to 6 fibers are tightly embedded in buffer, surrounded by strength yarns and a low friction sheath. They are the preferred choice for FTTH customer connections, blown into sub-bundles of 4mm microducts [4]. The blowing distance is about 1300 m, while many relatively sharp bends can be negotiated..

Table 6. Central Tight Buffer Microduct Cables

Fiber #	Cable O.D. [mm]	Buffer O.D. [mm]	Microduct [mm]
2-4	1.8	0.9	4/3
6	2.2	1.0	4/3

4. Experiences in the Application

To select the right microduct cable for a desired fiber connection not only the required fiber count and the cable transmission characteristics are important. It is essential to know the circumstances under which the cable is to be installed. Some of the most important factors to be considered are:

- Desired installation distance
- Microduct nominal diameter
- Microduct condition (dirt, leakage, damage)
- Microduct design (pre-lubricated, liner, ribbed or grooved)
- Microduct route (number and radii of curves)
- Accessibility of the microduct at both ends

4.1 Decision on Basic Cable Design

Although networks designers often have a preference for a general cable structure, such as loose tube, central tube, or tight buffer, for the right choice of a specific cable design some basic considerations have to be made. Besides the desired fiber count and the duct inner diameter also the targeted installation length must be taken into consideration. Generally, because of their higher stiffness due to the rigid central strength element, stranded cables allow a higher pushing force compared to central (plastic) tube cables. Ideally, stranded microduct cables normally have a textured surface by applying a thin sheath in a way that the core structure is reproduced on the sheath outer surface [10], [12] which can increase the air drag and decrease the friction. However, with each given cable design it is very important to have a smooth surface and a tightly limited tolerance of the cable's outer diameter.

For pushing without air support it is furthermore essential to have the cable O.D. at minimum of 50% of the duct inner diameter. If the duct is too large, the cable will buckle and cannot be pushed any further. This is somehow conflicting because pushing without air is mostly required in the drop area where microducts are often installed with tight bends, more difficult to pass for a tight fitting cable.

4.2 Preparation for Blowing

Before a cable can be blown into a duct, to reach the desired installation lengths in due time it is essential to spend some time on the evaluation of the microduct condition, especially when it was installed some time before the cable blowing. Sometimes there are sharp bends in the route, e.g. duct loop in a remote street cabinet which possibly can be widened temporarily. To clean and (sometimes) lubricate the microduct, a sponge soaked with lubricant can be blown first. Furthermore, a gauge with the same diameter as the cable may be blown through the duct. This helps to find out kinks or flattening in the duct before an unsuccessful blowing of the cable is started. However, both the sponge or the gauge will be difficult to locate when stopped by any irregularities in the duct. If the gauge does not transmit a signal it is difficult to find. Some installers prefer to just blow the cable and see how far it reaches, then they know where to dig.

Not only the duct must be clean but also the cable, especially when stored for a longer period the cable on the drum will collect some dirt. Therefore it is important to clean the cable before it is blown.

As the cable has to bear the force of paying itself off the cable reel, it is important that the reel is well balanced and the pay-off bearings provide easy rotation.

4.3 Influence of Lubrication

If the non-lubricated cable is blown into a microduct without low-friction liner or without pre-lubrication, the resulting blowing distance may reach only as low as 10% of the possible distance under optimum lubrication on the same trajectory. An indication of blowing performance in % for different lubrication of microduct and cable (Cable Lubricator [7]) is given in Table 7.

Table 7.Blowing performance (%) for different ways of lubricating microduct and cable

Microduct \ Cable	No lubrication	Cable Lubricator
No lubrication	10-30%	50-70%
Liner or pre-lub	50-70%	70-90%
Field lubrication	60-80%	100%

Figure 5 shows the newly developed field lubrication machine which allows to reduce the preparation time for blowing to a minimum and ensures maximum blowing distance.

Figure 5. Cable blowing equipment (blue apparatus) and cable lubricator (red apparatus)

5. Conclusions

Microduct cables exist in a wide variety of designs which have been successfully used in many applications. Initially developed to extend the capacity of limited metropolitan duct space, it is now often chosen by operators and installers just because of the small size and low weight of both the ducts and the cables which allow for easy handling and small installation equipment. With the ever better installation techniques and a growing experience, microduct cables today can be safely installed in many environments without compromising the optical performance.

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Biographies

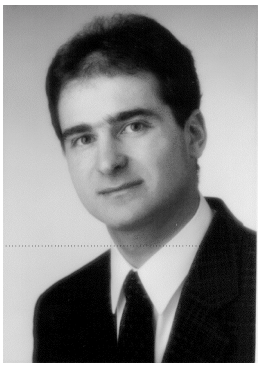
Klaus Nothofer (1956) received his Dipl.-Ing. degree in Telecommunications and joined AEG-Kabel (now Draka Comteq) in 1981. From 1984 he held various management positions in O.F. cable manufacturing, development, and marketing in Alcatel Europe. He is now director engineering and development for optical fiber cables at Draka Comteq Germany GmbH & Co.KG, Bonnenbroicherstr. 2-14, 41238 Mönchengladbach, Germany.

Willem Griffioen received a M.Sc. degree in Physics and Mathematics from Leiden University (Netherlands) in 1980 and worked there until 1984. He joined KPN Research, St. Paulusstraat 4, 2264 XZ Leidschendam, The Netherlands. Responsibilities R&D of Outside-Plant and Installation Techniques. He worked at Ericsson Cables, Hudiksvall (Sweden) and at Telia Research, Haninge (Sweden) in the scope of exchange/joint projects with KPN Research. He received his Ph.D. (Reliability of Optical Fibers) in 1995 from the Technical University of Eindhoven (Netherlands). Currently, since 1998, he is product manager at Draka Comteq Telecom, Zuidelijk Halfrond 11, 2801 DD Gouda, The Netherlands.

Arie van Wingerden received his B.Sc. degree in Electrical Engineering in 1971. In the same year he joined Draka Comteq - NKF Telecom, Zuidelijk Halfrond 11, 2801 DD Gouda, The Netherlands. He worked in the R&D department and was involved in various cable development projects and high frequency measuring methods. In 1984 he became Engineering Manager of the Project Department and responsible for engineering of Outside-Plant and Telecommunication Systems. Today he is responsible for Technology and active in advanced network concepts.

Olivier Tatat received his Engineering degree with a specialty in Materials in 1982, from the Institut des Sciences de l'Ingenieur in Montpellier (France). In 1985, he joined Alcatel Cable France, working as a Material Engineer. From 1993 to 1998 he was the Material Technology Group leader in the Alcatel Optical Fiber Cable Competence Center (OFCCC) in Claremont, NC (USA). Then, he joined the Optical Aerial Cables Engineering Group of Alcatel Cable in Monchengladbach (Germany). Since 2001, he is leading the Engineering and Development Group of Draka Comteq France in Calais.

Arnie Berkers received his M.Sc. degree in Electrical Engineering in 1987. In the same year he joined Draka Comteq Telecom, IJzerweg 2, 9936 BM Delfzijl, The Netherlands. Today he is responsible for the development of optical fiber cables.



Alexander Weiss (1961) obtained his degree of graduated chemist of the University of Tübingen in 1990. In the same year he joined AEG (now Draka Comteq). He held various management positions and is currently manager of the development for optical fibre cables at Draka Comteq Germany GmbH & Co.KG, Bonnenbroicherstrasse 2-14, 41238 Mönchengladbach, Germany.

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