FIBER OPTIC CABLE DESIGNS ADVANTAGES AND DISADVANTAGES

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ABSTRACT

Although fiber optic cable is relatively new in the CATV industry it has been a commercial venture in the telephony industry for over ten years. This mature fiber optic cable industry offers a number of cable designs for different applications.

This paper presents an objective view of the different fiber optic cables being offered to the CATV market and the advantages and disadvantages of each. Different basic designs such as loose tube, central core tube, slotted core, and tight buffer are discussed. The advantages and disadvantages of dielectric vs. armored, and steel bearing cable are also examined. In addition a short discussion on future developments in fiber optic cable design is presented.

The methodology used in this paper is to examine, in detail, published specifications and papers and then attempt to present a one to one comparison of the different cable designs. Issues such as environmental, mechanical, and physical specifications are presented as well as field issues and how these pertain to the mostly aerial outside plant of this industry.

The results show that for different applications different optimum cable designs exist. Therefore, at this point in time, there seems to be no one optimum cable design for the CATV industry.

FIBER OPTIC CABLE

Design Objectives

The design objectives in fiber optic cable are fairly simple. The first concern of the cable designer is to protect the glass fiber from the outside environment. The fiber must be protected from the physical rigors of being installed and placed for up to 20 years in the outside plant. These include forces such as impact, tensile, twist, and compressive loads. In addition the fiber must be protected from any moisture. The fiber itself is degraded by moisture and if water were to get into a cable and freeze, it could physically crush the fiber. Probably the most critical design parameter is temperature performance.

The typical specified operating temperature range of fiber optic cable is from -40 to +70 degrees Celsius. The design problem is that the fiber has a coefficient of expansion on the order of 10^{-7}, while the majority of the plastics used in fiber optic cable design have coefficients of expansion on the order of 10^{-5}. Therefore, when the cable is subjected to temperature extremes the plastics expand and contract 100 times more than the glass fiber. If the fiber optic cable is not designed correctly this coefficient of expansion differential could impart forces onto the fiber which would manifest as drastic increases in attenuation or, in the extreme case, fiber breakage.

The cable designer offsets this differential in coefficient of expansions with high modulus, low coefficient of expansion materials such as fiberglass reinforced plastics and steel. The cable designer gives room for the fiber to collapse and expand like a spring by placing it in a loose tube.

In addition to the above technical design problems the fiber optic cable must be easy for the craftsman to work with. It should be easy to access and identify the fibers, as well as lightweight and small.

Fiber Optic Cable Designs

There have been a number different solutions to the design problems discussed above. For the purpose of this paper, tight buffer, slotted core, loose tube and central core cables are discussed. But because loose tube and central core cables are the products being offered to the CATV industry, the comparison sections of the paper will be limited to those two designs.

Tight buffer cables are called so because a layer of plastic is extruded directly onto the acrylate coated fiber, thereby creating a tight structure around the fiber. The advantages of such a design are in handling. Each fiber unit is larger, and less sensitive to handling mishaps because individual fibers have a relatively thick plastic protection covering them. Although these products have been used in outside plant environments, largely in the past by the Japanese, they are not well suited for those applications. The first problem is that whatever compressive or tensile forces are experienced by the cable are also experienced by the fiber. This means a large amount of high modulus, low coefficient of expansion materials, such as steel and aramid yarn, must be used in order that the fiber not see high strain levels. In addition, tight buffer cables become comparatively large and difficult to design when fiber counts exceed 24.

Slotted core cable is used great deal overseas and was used initially to some extent in North America. Slotted core cable consists of a cylindrical plastic core with longitudinal slots cut into it. The fibers are then placed into these slots. (See figure 1). After the fibers are placed into the core any number of a variety of armors and jacket layers can be applied. In some applications this design fell out of favor because of the difficulty in handling when the jacket was stripped off. Also the difficulty in filling and placing the fiber into the slots made for an expensive product. Slotted core cable combined with fiber ribbons are again gaining some popularity, especially in Japan, due to the high density of fiber that can be attained in such a configuration.

Loose tube cables are one of the two most popular designs offered in North America. One to 12 fibers are placed within a gel filled tube for protection. The tubes are then stranded around a dielectric or metallic strength member. The combination of the loose tube around the fibers and the stranding pitch of the tubes creates a tensile and contraction window. This window allows for the cable to contract and be elongated on the order of .3 % while imparting no stress on the fiber. The cable can therefore be designed such that at specified temperature extremes and tensile loads little or no strain is experienced by the fiber. This fiber optic cable core can then be protected by any number of different sheaths, depending on the application. This product has been very successful because of performance in the field and handling issues for fiber counts over 72.

The central tube fiber optic cable is the other popular design in North America. In this design the fibers are all encased in one large tube. The fibers are separated into groups either by ribbons or fibers bundled by colored ID threads. The ribbon design is applicable for high fiber count cables that are being put into systems that do not require low splice

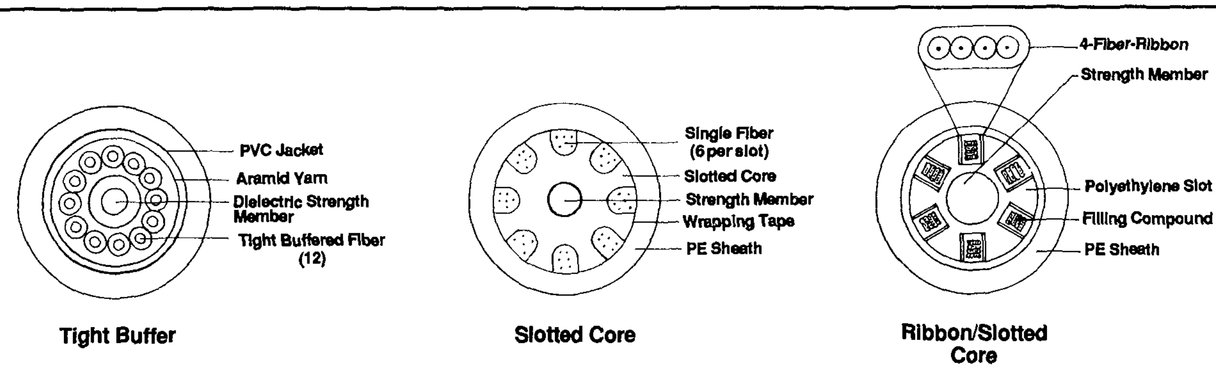


Figure 1

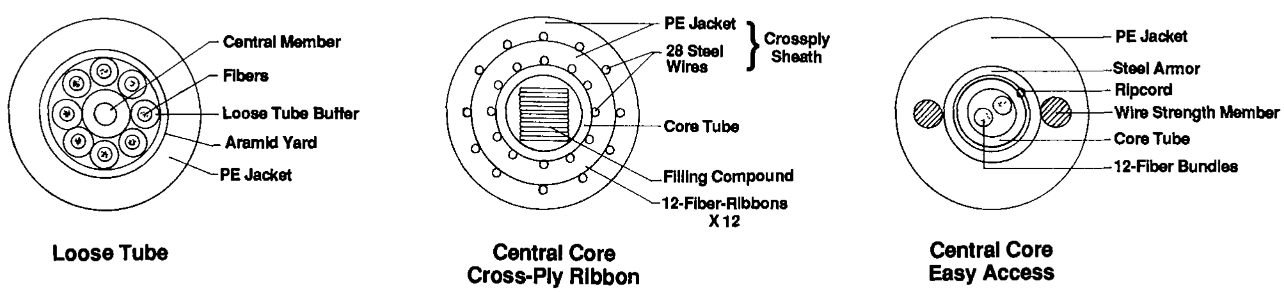


Figure 2

losses. These cables can be shipped pre-connecterized with easily used array splices, although the losses of the array splices can be sporadic and relatively high for single mode fiber. The fiber bundles have up to 12 fibers per bundle. Each individual fiber and binder thread is color coded. In fiber counts higher than 72 it can sometimes be difficult to manage all the fibers in one tube. In some sheath designs for this core a number of steel wires or small dielectric rods are used for strength and temperature compensation. These "crossply" sheaths are very environmentally stable but also very difficult to enter. A recent innovation to make these cable designs more user friendly is to armor the core and place either six dielectric or two steel strength members 180 degrees from one another longitudinally along the tube. After jacketing the cable, additional armoring and jacketing can be applied. This design, like the loose tube design, allows a contraction and tensile window for the fiber. Again, the cable can contract or elongate on the order of .3% with no effect on the fiber.

Because of field performance and ease of handling, the predominant cable designs being offered to the CATV industry are the loose tube and central tube type with bundled fibers. These two cable designs are themselves offered in a variety of different configurations. The remaining sections of this paper will compare and contrast these two cable designs and the different configurations of each.

Existing Fiber Optic Cable Specifications

There are a number of existing fiber optic cable specifications for telephone industry that are used for the CATV and other industries. The most common specifications are written by GTE, Sprint, REA, and Bellcore. Bellcore's TR-20 is in most cases the more comprehensive and difficult specification to meet. TR-20 covers cable qualification tests, material qualification, mechanical and environmental tests with allowable decreases in performance for each test. It is important to note that all measurement methods in Bellcore TR-20 are referenced to an ASTM or EIA-455 test procedure standard. Some tests that to date have no standards such as lightning and rodent tests are spelled out in detail in the document. A summary of the mechanical and environmental tests with their corresponding allowances are listed in the following tables.

Two of the more important tests mentioned above have no standard testing procedure per se: the lightning and rodent tests. Although specifications do not require that certain test levels be met, they do require that the tests be performed and the level of resistance reported. Each cable construction of the two designs being discussed must be sted in every one of these tests because the result depends upon the core and sheath construction. Typical classifications of the results of these two test are listed below.

It is important to note is that all suppliers of fiber optic cable to the telephone industry must meet these specifications in order to be a supplier. Consequently, the performance of any cable that meets Bellcore TR-20 will be about the same as any other

Mechanical & Environmental Tests			
Test	**EIA -455 Specifications**	**Mechanical Requirement**	**Optical Requirement**
Tensile Strength	FOTP-33	600 $lb._f$ Bend Radius = 20x Cable O.D.	≤.1 dB increase @ 1550 nm
Compressive Strength	FOTP-41	1000 $lb._f$ Total Load	≤.1 dB increase @ 1550 nm
Cable Twist	FOTP-85	± 180° Twist, 10 Cycle	≤.1 dB increase @ 1550 nm
Low and High Temperature Bend	FOTP-37	Bend Radius = 15x Cable O.D. 4 Wraps ea. at -20° F, 140°F	≤.1 dB increase @ 1550 nm
Cyclic Flex	FOTP-104	Bend Radius = 15x Cable O.D.	≤.1 dB increase @ 1550 nm
Impact Resistance	FOTP-125	52 ft.- $lb._f$ Impact, 25 Cycles	≤.1 dB increase @ 1550 nm
External Freezing	FOTP-98	1 hr. min. freeze at -2° C	≤.1 dB increase @ 1550 nm
Temperature Cycling	TR-20	-40 to +70° C 4 Cycles	100% ≤.2 dB/km increase 80% ≤.1 dB/km increase
Temperature Aging	TR-20	+85° C, 5 Days	100% ≤.2 dB/km increase 80% ≤.1 dB/km increase

Table 1

Lightning & Rodent Testing			
Design	**Construction**	**Lightning Resistance**	**Rodent Resistance**
Loose Tube	Steel Core No Armor	80KA	Poor
	All Dielectric	N/A	Poor
	Dielectric Core Armored	150KA	Excellent
Central Tube	All Dielectric	N/A	Poor
	Dielectric Core Steel Armored	105KA	Excellent
	Dielectric Core Copperclad Steel Armored	150KA	Excellent

Table 2

Cable Construction Comparisons				
Design	**Construction**	**Lightning Resistance**	**Rodent**	**Cost**
	Steel Core, No Armor	Poor	Poor	1
Loose Tube	All Dielectric	Best	Poor	2
	Dielectric Core, Armored	Excellent	Good	3
Central Core	All Dielectric	Best	Poor	2
	Dielectric Core, Armored	Excellent	Good	1

Design	Fiber Count	O.D. In.	Weight (lbs/kft)	Fiber ID
Dielectric Core, Armored	48	.49	105	Excellent
Loose Tube	96	.59	150	Excellent
Dielectric Core, Armored	48	.63	170	Excellent
Central Tube	96	.74	230	Good

Table 3

cable that meets that performance standard. Characteristics of handling, weight, lightning, and rodent resistance that are dependent on the construction of the cable should be considered, but each supplier has an option available to satisfy these requirements.

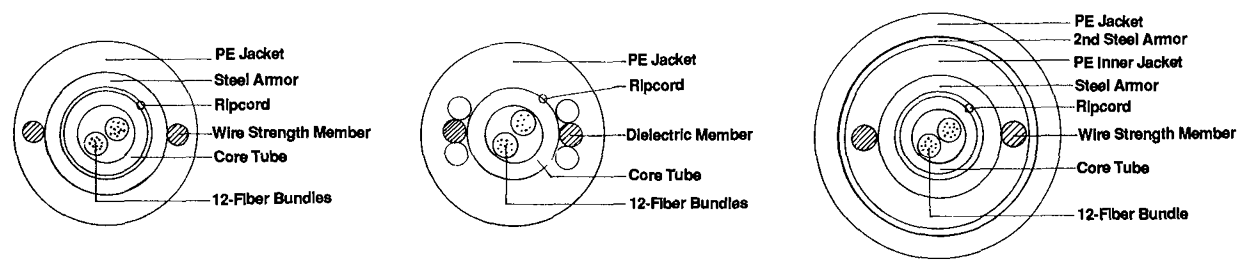
Comparison of loose tube and single tube constructions vs. specifications.

For each of the two designs being discussed there are a number of sheath designs. Each sheath design has cost/benefit trade offs.

For the central tube cable there are basically two different cable constructions. Both constructions, by the definition of this design, have a dielectric core. This is important in the case of lightning protection. If the purchaser of the cable is concerned about lightning protection it is important that no metallic member be within the fibers such that a high current surge could short to that member and destroy the fiber in its path. The cable can have no metal in it at all if lightning is a serious concern or if grounding of any metallic members could be a problem. In this case the strength members in the cable would be some combination of aramid yarn, fiberglass roving and fiberglass reinforced plastic. (GRP or FRP)(See figure 3) On the other hand, an all dielectric cable has almost no protection against rodents.

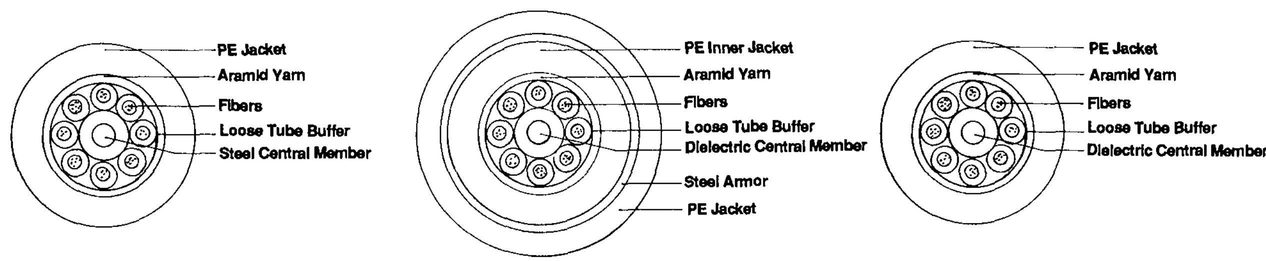
When rodent protection as well as some lightning protection is desired, an armored version is available. In this case the dielectric core is surrounded by an armor. Strength members inside the armor are generally dielectric and those outside the armor can be metallic. If additional rodent or lightning protection is needed different configurations of armors and jackets can be used to give the necessary protection.

In the case of loose tube cables solutions to the above listed problems also exist. The most inexpensive loose tube cable made has a steel central member and no armor. This is a dangrous design in that it yields both poor lightning and rodent protection. (See figure 4) In a loose tube cable a dielectric core should be specified when lightning



Dielectric Core/ Armored | All Dielectric | Dielectric Core Double Armor

Center Core Tube Constructions
Figure 3



Steel Central Member No Armor | Dielectric Core/ Armored | All Dielectric

Loose Tube Construction
Figure 4

is a concern. An all dielectric construction is completed with aramid yarn for strength and a PE jacket for protection. When rodents are a concern, an armor and additional jacket can be added. If both lightning and rodent resistance are desired, an armored cable with dielectric central strength member should be specified.

Since the performance of all cables meet the same specification, the only comparisons to be made between the two types of products are a comparison of what construction is best suited for each individual application. Table 3 shows a summary of the best options available and their relative costs based on material usage for the loose tube and single tube designs. Handling issues are essentially a matter of fiber identification, sizes, weights, and personal preference.

SUMMARY

All suppliers of fiber optic cable to the Bell system must meet TR-20 specifications. The product they sell to markets other than Bell companies do not necesarily meet all TR-20 specifications. Therefore, it is important that either a well written specification be submitted or an existing specification such as TR-20, or equivalent be referenced in a request for quotation. When another existing specification is referenced, any special considerations that may be required for CATV installation must be included, since all existing specifications have been written for the telephone industry with digital transmission in mind.

If the fiber optic cable meets the specification then the important issues are attenuation levels, lightning resistance, rodent resistance and personal preference. All of these issues are addressed equally well by different methods.

There is no one design best suited to the CATV market. Both central tube and stranded loose tube products meet the same specifications and each design has a construction that can meet the demands of almost any environment.

REFERENCES

Bellcore TR-TSY-000020 Issue 4

"Compact Lightguide Cable Design", P.D. Patel, C.H. Gartside, III, International Wire & Cable Proceedings 1985.

"Optical Stability of Single Mode Fiber in Loose tube cable designs", K.A. Emig, et al, IWCS Proceedings 1985.

"Qualitication Testing of Fiber Optic Cables", R. Ohlhaber, et al, IWCS Proceedings 1984.

"Multi-Hundred-Fiber Cable Compared of Optical Fiber Ribbons Inserted Tightly into Slots", S. Hatanoetd, IWCS Proceedings 1986.

"Lighting Considerations in Optical Cable Design", J.A. Olszewski, J.B. Masterson, IWCS Proceedings 1986.

"The effect of temperature dependent materials on Fiber Optic Cable Design", K.L. Coupe, et al, IWCS proceedings 1986.

"Qualification Procedure for Fiber Optic Cable Design", G. McKay, et al, IWCS proceedings 1986.

"A High Performance non metallic sheath for Lightguide Cables", C.J. Arrogo, A.C. Jenkins, P.D. Patel, IWCS proceedings 1987.

"LXE - A Fiber Optic Cable Sheath Family with Enhanced Fiber Access", P.D. Patel, M.R. Reynolds IWCS Proceedings 1988.