FIBEROPTIC CABLES
INSTALLATION AND MAINTENANCE

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INTRODUCTION

As we all know, fiberoptic technology is beginning to find appropriate applications in CATV. As this technology comes out of the laboratories and into use over the next decade, the local system technical people will learn to deal with it on a daily basis. One aspect of this technology is the installation and maintenance of the fiber cable plant itself. During the next few minutes, we will discuss the fundamental physical characteristics of glass fiber and the resultant cable designs, installation practices and maintenance practices that will yield success.

CABLE DESIGNS

Your casual observations of most fiberoptic cables will discover that they differ in construction from traditional coaxial and twisted pair metal cables. The nature of glass has presented the cable manufacturer several challenges. First is the size of the fiber which is several orders of magnitude smaller than typical metallic conductors. Mechanically, glass exhibits very high tensile strength but very low elongation which means particular attention must be paid to bending of the fiber to prevent breakage; whereas, copper and aluminum have relatively good bending characteristics. However, perhaps the most challenging characteristic is fiber's performance sensitivity to mechanical strain. Under even very small sustained strain loads, the transmission characteristics will be altered and the life of the fiber may be shortened.

The first requirement of good cable design is to furnish finished product which has the intended life and performance under the installed conditions. Communications fiberoptic cables have followed the design life objectives of our traditional coaxial and twisted pair products. Thus, materials and environmental protections applied should under most conditions exceed 20-30 years excepting physical damage. Careful attention must be applied to construction techniques and to unusual environmental conditions so as not to compromise the design life.

Cable designers have been successful in developing cables which can be installed by conventional means with very few exceptions or changes. In fact, the areas of concern in construction practice for fiber cables mirror those of our traditional CATV coaxial lines. Materials and geometric design elements are chosen to combat severe bending, tensile elongation and impact loads. All construction techniques can be utilized including aerial lashed, aerial messengered, plowing, trenching and duct.

As with metallic cables, the most destructive environmental element is water in its several forms. Fiber cables intended for outdoor use, whether aerial or underground, must be protected from water ingress. For this reason, you will find flooding materials and bonding between cable elements commonly used in all cables. Glass is attacked by water in a process called hydrogenation. This results in microcracks which will propagate over time ultimately resulting in fiber failure.

Three basic cable designs have evolved, all of which are successful in obtaining the objectives set out. These are known as loose tube, slotted core, and ribbon cables.

Several implementations of basic loose tube design are available. One generally representative sample is shown in Figure 1.

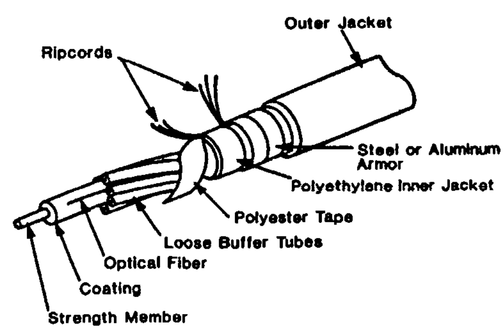

Figure 1

All of these designs utilize the concept of buffering and incorporate a strength member. Buffering simply means that the cable design attempts to mechanically isolate the fiber from all adverse conditions including impact, crushing, bending, tensile and thermal stress.

Figure 2 shows one of several variations in slotted core (open channel) construction.

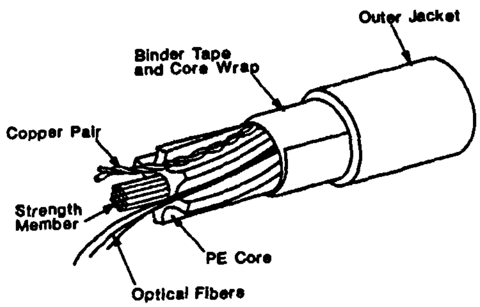

Figure 2

Strength members are available as either steel or a dielectric such as Kevlar or FRP. Both materials produce cables which meet all the mechanical, physical and optical requirements set forth. In cable designs which place the strength member in the center surrounded by fibers, the use of a dielectric is advantageous to prevent the possibility of an electrical potential between the strength member and outer steel armor or aerial strand. Also use of all dielectric designs for duct and buried plants may be particularly advantageous in higher lightning areas of the country. The marginal increased cost of dielectric materials are worthy of consideration particularly with higher fiber count cables which carry proportionately higher revenue traffic.

A very high density fiber design available from AT&T is the ribbon cable, shown in Figure 3. In many respects, this design is similar in concept to a loose tube construction.

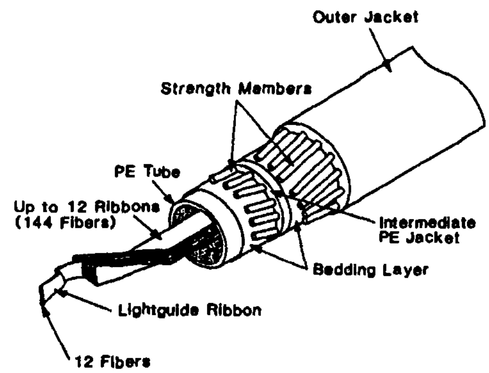

Figure 3

AERIAL INSTALLATIONS

All of the general techniques and methods of aerial installations which have been successfully used with coaxial cables can be applied to fiberoptic cables.

In order to have a successful install, the fiber must be protected from stress. If a fiber is subjected to a stress equal to 30% or more of its breaking strength, there will be a reduction in the life of the fiber. Such excessive stress produces microcracks in the glass which over time will propagate resulting in failure.

Cables have been designed and are specified for maximum tensile load strength such that the fibers are sufficiently protected. It is vital that the cable specifications are adhered to. Most cables carry a specification of at least 600 pounds maximum pulling strength. Observing this limit strictly during pulling will prevent fiber damage. It is recommended that a tensiometer, fusable link or other device be used during the pulling process so as to guarantee that the maximum pull strength specification is not exceeded.

All cable designs incorporate one or more strength members. Their purpose is to absorb the tensile load applied during installation and during the life of the cable. Attaching the pulling devices to the cable properly is essential to transferring the load to the strength member rather than to the fiber. Kellums® grips, pulling eyes, etc. should be effectively attached to the central strength member.

Back Pull (stationary reel)
Installation Method

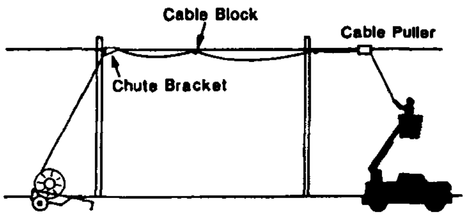

Figure 4

One characteristic of fiber cable is its light weight. In most cases the cable is lighter than coax. Even so, rollers and other support devices must be used along the spans to support the cable during a backpull. The size, number and spacing should be equivalent to good coaxial cable installation. Failure to use sufficient support may result in excessive drag or exceeding the minimum bend radius.

Drive Off Installation
Method

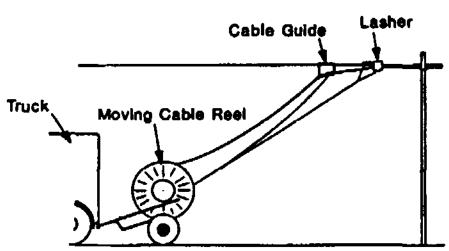

Figure 5

Cable designs have been chosen to give minimum bend radius essentially equivalent to other types of cables. This is usually specified at about ten (10) times the cable diameter. Thus, the standard practice with regard to corner blocks should be followed. Obviously every additional corner encountered during the pull will increase the pulling tension.

The splice case will contribute substantially to the overall life of the installation. First of all, it must be environmentally qualified for the installation. Water entry into the case will create a significant problem. The internal structure of the case must be designed with the bending characteristics of the fiber, the type splice to be used, the type cable and convenience of the splicer in mind. The case must be designed to contain excess fiber lengths up to several meters. This allows the fiber ends to be brought out to the splicer for easy effective work. The excess length also allows the fiber to be coiled back into the case with large enough radiuses to avoid damage to the fibers or excess attenuation. Specific coil frames are usually provided to hold the fibers. The case should also contain some mechanical means of holding the splice after the job is finished. The splice cannot be allowed to hang free. All of these requirements are usually fabricated into what is generally called a fiber organizer inside the splice case.

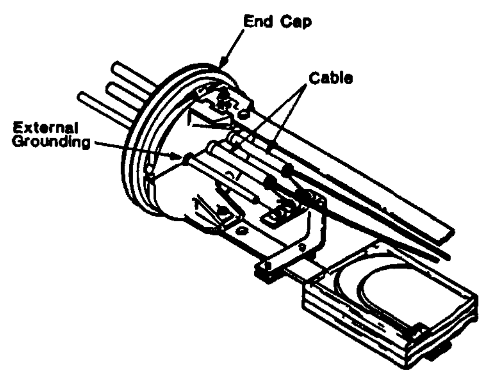

Figure 6

All splicing techniques are relatively sensitive requiring some equipment and a convenient work space for the splicer. As a result, common practice is to do the splicing at ground level as shown in Figure 7.

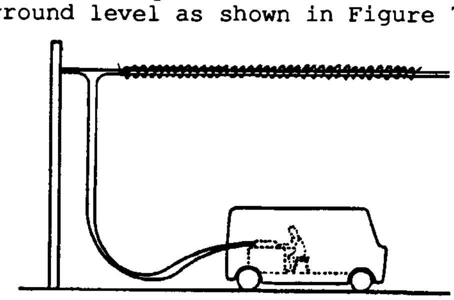

Figure 7

After splicing is complete, the splice case and excess cable is lashed up to the strand as shown in Figure 8. Care should be taken to place the case and cable away from the pole to prevent damage by other pole occupants.

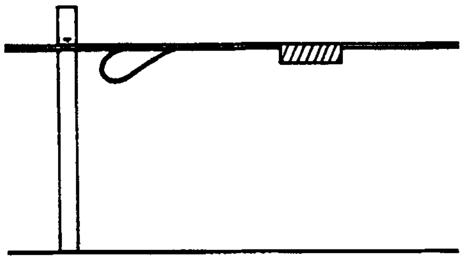

Figure 8

Fiber cables have a need to be as longitudinally dimensionally stable as can be reasonably accommodated. Thus, unlike coaxial cable sag and tension practices, a tight span is preferrable to a loose span. The objective of the cable design and installation is to minimize the chance of stressing the fiber. A very loosely sagged strand will exhibit more differential length movement due to temperature, ice, wind and snow which in turn increases the chance of applying stress to the fiber. In practice, sag conditions will usually be restricted by other cables installed on the poles. Whenever possible, place the fiber cable in the uppermost available space on the pole.

Overlashing of a fiber cable to existing cables is acceptable with a single precaution. The strand must be of sufficient size and installed correctly so that the finished installation of fiber cable and other cables will meet the sag and tension needs of all the cables.

Standard practice in CATV coaxial cable construction requires expansion loops periodically to accommodate the difference in thermal coefficients of expansion of steel and aluminum. In fact, specific care must be given to the geometric configuration of the loop to prevent premature failure of the cable. The materials used and the configuration of fiber cables present a different situation and in fact, the requirements may differ between cable types and even between implementations of the same cable type. For example, loose tube cables can be designed such that expansion loops are <u>not</u> required. This is achieved by carefully constructing the cable in such a way as to accommodate the expansion and contraction of the strand. It is best to consult your cable supplier for a specific recommendation. Conservative practice may be to install a minimum number of loops. Because of the flexibility of fiber cables, and their lack of susceptibility to stress concentrations, the natural shape of an expansion loop is quite adequate.

DIRECT BURIAL

Fiber cables are suitable for direct burial using either the trenching method or plowing. All of the precautions considered in aerial installations apply here with a few additions. For plowing operations, special attention is needed for the plow design and for the entry of the plow into the ground. In both cases, precautions must be taken so that severe bend stress is not put on the cable. For added strength, bend protection, and environmental protection, an armored cable design is recommended for underground.

DUCT INSTALLATIONS

These are quite common with fiber cables and should present no problems. Some precautions should be observed to prevent over tensioning of the cable. The duct should be cleared before pulling the cable. An inner duct may have to be pulled in to assure sufficient clearance. Never attempt to fill a duct over 60% of its cross sectional area. Excessive filling will create excessive tension. Use of lubricants is recommended to reduce tension.

IN GENERAL

The success of a fiber cable installation is planning and careful attention to stress. The cable runs should be well planned for clearances, avoidance of obstructions, location of splice points and the ability to place long lengths of cable. All conditions which will create difficulties should be eliminated or accounted for in the planning stage.

One of the advantages of fiber optics is to utilize long lengths of cables and in fact, splicing should be minimized. For particularly long runs, whether aerial or duct, there is potential for generating excessive stress or in the case of aerial construction, having to go above other facilities perpendicular to the run. A technique which can help in these situations is to start the cable placement in the middle of the run and work in both directions reducing the run by half. To accomplish this, it will be necessary to take the last half of the cable length off the reel in order to access the bottom end. The cable can be laid on the ground in a figure eight configuration. By using the figure eight, the cable will pull out into the last half of the cable run without kinking. This avoids the natural twist which would be induced if a simple coil were used.

To clear obstacles along the route of an aerial placement, one can use the figure eight technique. After figure eighting the cable on the ground, the cable end is pulled over the obstacle and the cable can then be rewound on to the cable reel by hand.

RESTORATION

Repairing a fiber cable which has been damaged will be a necessary part of the system maintenance. Unlike the initial installation which will usually have been done by specially equipped contractors, restorations may be done locally due to time and to cost.

The first step is to have extra cable on hand. Usually some extra length is added to the initial order to have on hand for repair purposes. Since fiber cables at this time are generally made to order, obtaining a repair length from the factory may require several weeks. If necessary, long jumper cables can be used as a temporary repair. If a length of the original cable is not available but a length of a different cable containing sufficient fibers is available, then it can certainly be used. Under emergency conditions, even splicing together fibers from a different manufacturer is acceptable temporarily (for multimode fibers they must be equal core sizes).

For the permanent repair, two splice kits and a length of appropriate cable will be needed. The type of splices chosen and the splice cases chosen should be consistent with the objectives originally set out for the entire cable run. Some factors to be considered are splice loss, cost, reliability and local expertise.

How much cable should be removed to be assured that all damaged fiber is eliminated? One concern is that all fiber which has been overstressed and would as a result have a reduced life be removed. It is probably impossible to know with any certainty the answer due to the variability of installations and type of damage incurred. One rule of thumb which is commonly proposed is to cut back ten (10) meters each side of the damage. A second factor to consider is the introduction of modal noise due to locating two splices close together. The importance of this factor is dependent on the particular manufacturers' fiber used. Avoidance of this situation requires separating the splice by twenty (20) meters. From a practical point of view then it seems that whenever practical, a repair section should be about twenty (20) meters long. If the particular situation makes this difficult, you should consult your cable supplier.

Another approach is to install an accumulated excess of cable at points along the cable run. These points could be chosen for their proximity to likely damage locations such as an area which is expected to see significant construction and development in the near future. The accumulation of excess cable can be done as in Figure 9, always keeping in mind minimum bend radius and tension.

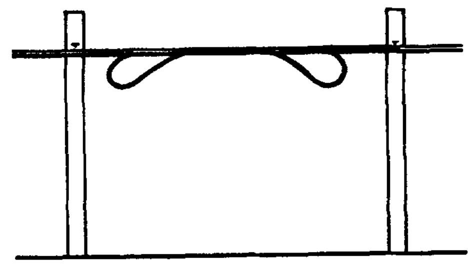

Figure 9

This excess cable can then be pulled out and relashed so that the restoration can be done with a single splice.

FIBER SPECIFICATIONS

Single mode fibers being provided for telecommunications today have parameters which in most cases are standards.

Attenuation
0.40 to 0.70 dB/km @ 1300 nm
0.30 to 0.70 dB/km @ 1500 nm

Fiber Mode Diameter (μm) ≈ 9.0

Fiber Outer Diameter (μm) 125 ± 3

Coated Fiber Diameter (μm) 250 ± 15

Other physical characteristic differences between fibers are generally artifacts of the manufacturing process employed. While these do produce some operational differences, they are of secondary importance and with accepted cable design, installation practice and splicing practice, should not significantly impact the installed system operation.

CABLE SPECIFICATIONS

The objectives of designing a cable fall broadly into the categories of protecting the fibers and providing ease of use by the user. Protection specifications are relatively standardized because they are quantitative and the requirements are well understood due to the long history of building and installing metallic cables. On the other hand, ease of use, convenience, adaptability, etc. are more qualitative attributes and vary depending on the needs of the specific installation.

Typical physical specifications for single mode telecommunications cables include:

Operating Temperature Range
- 50°C to + 70°C

Crush Resistance	
Armored	460 lbf/in.
Non-armored	400 lbf/in.

Impact Resistance	
Armored	20 times @ 3.7 lbf/ft.
Non-armored	20 times @ 2.2 lbf/ft.

Minimum Bend Radius
depends on fiber count
≈ 10 times cable outer diameter

Maximum pulling tension 600 lbf

The specific geometric configuration and materials used in the cable may bear on the convenience to the user. Single tube, multi-tube, open channel or ribbon cable designs each have their own strengths and weaknesses from a user perspective. The choices may depend on individual preferences, installation, etc.

CONCLUSION

Fiberoptic cables are finding use in CATV systems today and many are predicting much wider use in years to come. The CATV operator can be assured that the cable manufacturers have the ability to provide products and accessories that can be installed and maintained in a practical sense. Some understanding of the characteristics of fibers and the design philosophy of cables by the user will help make the deployment of fiber cables successful. The objective of the cable manufacturers is to provide product which will minimize the need for special treatment.

REFERENCES

1. "Training Manual, DTS-1100", January 1988, Ditel.

2. "Fiberoptic Splice Training Course", March 1988, Ditel.

3. "Alcatel Cable Systems Group; Celwave/Valtec Cable Products Catalog and Specifications", August 1987.