MAINTENANCE AND EMERGENCY RESTORATION OF FIBER OPTIC CABLE SYSTEMS

by Mike Genovese and Becky S. Frye
SIECOR Corporation

Abstract

As the deployment of fiber optics grows in the CATV industry, the need for a comprehensive and effective fiber optic cable system maintenance and restoration plan will become critical. A basic maintenance and restoration plan should include recordkeeping, personnel, training, equipment/materials and emergency restoration procedures. A well-defined plan will improve the operator's ability to swiftly identify faults and act on them, thus restoring service to the customer quickly.

Introduction

The CATV industry has quickly embraced the technology of fiber optics. With this new technology there are new requirements to maintain and ensure the reliability of the CATV operating system. Although the concept of having a maintenance and restoration plan for one's system is not new to the industry, there are unique issues/needs that must be addressed when dealing with a fiber optic cable system.

Fiber optic systems are becoming more economical and practical for CATV applications, but how does the use of fiber optics affect system maintenance and reliability? Fortunately, the CATV industry does not have to wait for their cable systems to age 10 years to get this information. Fiber optic cables have been used in the telecommunications industry for over 12 years and several studies have been made on installed fiber optic cable showing them to have excellent reliability.{3}-{5} Almost all of the cable system failures were due to extrinsic influences like digups, breaking poles, collapsing ducts, etc. One study concluded "that the existing data on the frequency of copper cable cuts in a given service area can be applied to fiber optic cable cuts".{3} This type of logic should be transferable to the CATV industry and can give the operator an indication of the minimum level of reliability for the cable system. In fact, fiber optic cables generally are more rugged than their coaxial cable counterparts and will in all likelihood provide better reliability.

But what about the electronics? We do know that in recent years DFB lasers have been used extensively in telephony digital applications and have shown outstanding reliability. But there is little experience with using lasers in the current CATV AM applications. Recently one lab study focused on the effects of accelerated aging on DFB lasers. The study indicated that the DFB lasers currently used in AM fiber systems can provide the performance and reliability needed by the CATV industry for a median life of 25 years.{1} If this is indeed true, then the biggest reliability issues for the company's fiber optic system are uncontrollable extrinsic failures like pole breaks, digups, etc. Given this assumption, having a well defined system maintenance/restoration plan could significantly improve a system's reliability.

First, the operating company must decide what level of maintenance and restoration capability to have. The company may want to maintain and restore their fiber optic system themselves, or may wish to contract out certain portions to contractors who specialize in fiber optics. This decision is a philosophical one as well as economic. For the rest of this paper we will assume that the CATV company will have a complete in-house capability.

There are two phases to consider with regards to maintenance and reliability of a fiber optic cable system: Pre-installation and Post-installation.

PRE-INSTALLATION

Although the system's equipment and materials are not always considered a part of the maintenance plan, the selection of system products can have a long-term effect. The operator should choose products that meet industry standards to ensure that the installed system will perform consistently over its expected life and provide the needed reliability. Standards for optical fiber, cables, and associated products have been developed and used in the telecommunications industry for over 10 years. Most of these standards are available and should be considered by the CATV industry.

While performance and cost are usually considered the key parameters of planning a fiber optic system, the system design can have a major impact on the system reliability. With today's watchwords being "customer service"," reliability and quality", it is imperative to design CATV systems that enhance reliability. Such features could include advanced monitoring and control systems, backup coaxial systems/AML systems (usually already installed), redundant optical cable routes and 1 x N protection with optical switches and electronics. Once the system is designed and installed there are other factors that need be addressed by the operator and come under the guise of "The System's Maintenance/ Restoration Plan".

POST-INSTALLATION

A CATV system's "Maintenance/Restoration Plan" should address five key elements: records, personnel, equipment/materials, training and restoration procedures. {2} We will examine each individually.

RECORDS

Complete and accurate records are invaluable for the troubleshooting and restoration of an operating system. It is important that the records be functionally organized and located in a designated place for easy access. Duplicate records should be kept in an alternate place to prevent accidental loss of this valuable data. Typical fiber optic system records should include:

1) Route/cable plan with cable feet or meter marks. Be sure to record any places where excess cable slack is stored. This will be a factor when using an OTDR to determine the geographical location of a cable fault.

2) Splice plan detailing fiber assignments, splice locations and restoration priorities.

3) Splice loss data

4) Transmitter output levels

5) End-to-End system attenuation

6) OTDR signature traces

For AM fiber systems that are to be hard-wired (without optical connectors) into the electronics the OTDR signature trace can also provide system attenuation.

7) Checks and calibration of test and troubleshooting equipment.

PERSONNEL

The operator must designate which personnel are responsible for maintaining and more importantly, troubleshooting and restoring the fiber optic system. As with any new technology there will be gaps of knowledge and experience within the company. Properly trained personnel should be given specific task responsibility for testing, troubleshooting and restoration of the fiber optic system. In addition to these responsibilities, the designated personnel should have responsibility for maintaining the emergency restoration materials and equipment, as the primary users of it. Also, the maintenance plan should have provisions for how designated personnel will be notified when an emergency occurs.

It is important to note that it is very easy to end up with an elite "fiber team" in the company. Although this may be a functional necessity at first, in the long run, it will be to the operator's advantage to cross-train as many personnel as possible in fiber optics to give flexibility to scheduling and emergency restoration task assignment. Thus, training of the personnel is the next critical link in the maintenance/restoration plan.

TRAINING

The initial training required by a restoration team begins with ensuring each team member practices proper safety procedures. During a time when speed and accuracy are critical, it is also very important that team members remain injury-free. System repair begins with the identification and location of the system failure. To do this, team members must learn the skills necessary to operate equipment such as OTDRs and power meters.

Once located, the fault must be repaired. This may involve replacing a damaged connector, replacing a link of cable or anything in between. So the team must be well versed in all possible solutions. Proper cable handling procedures, hardware preparation, mechanical splicing and fusion splicing are vital and necessary skills in the event a system repair is needed. A maintenance/restoration plan isn't worth the paper its written on, without well trained personnel to implement it. It is recommended that the initial classroom training include some basic theory as well as extensive hands-on training.

Cross training of personnel is also important. The ability to perform more than one task will prove beneficial in the event that one team member is not available when an emergency occurs.

Refresher training is equally important and should not be overlooked. As personnel changes occur, the replacement personnel will require the same sequence of training to ensure a smooth transition of responsibilities as well as stability of the system. Refresher training ensures that old skills remain sharp and new skills also are implemented. Refresher training for emergency restoration is best done with a combination of classroom training and mock restoration drills once every six months.

EQUIPMENT/MATERIALS

Everyone knows how difficult it is to perform a job without the proper tools —— with an emergency restoration this difficulty increases ten-fold. But having the proper tools is just part of it, having the tools readily accessible is just as important. One method for accomplishing both of these objectives is to have an Emergency Restoration Kit (ERK)™ contain all the needed tools and materials for repairing an optical cable system at the restoration site. A typical kit should include:

1) Optical Cable: The restoration cable should have the same fiber count as the highest fiber count cable in the optical cable system. It should also be of sufficient length to span the longest pole span distance in the system, plus slack for splicing, (typically add 100 feet). If the system contains ducts or manholes, the restoration cable should be of sufficient length to span the largest distance between manholes, plus slack for splicing, (typically 75 feet). With buried cable you have more flexibility in locating the new splice points. The cable needs to be of sufficient length to span the damaged area, plus slack for splicing.

Note: Keep in mind that, certain types of depressed clad single-mode optical fiber are susceptible to modal noise if the two adjacent splice points are less than 20 meters apart.{6} Consult your optical cable manufacturer to determine if this is a concern for your system.

Typically, there is a restoration cable reel that is used to supply the cable for the kit. The restoration cable reel, should contain about 1000 - 2000 feet of optical cable. The restoration cable reel should be centrally located and clearly marked so that it is not installed into another portion of the operator's system by mistake.

2) Splice Closures: Two closures should be included. The operator should choose splice closures that have sufficient capacity for the restoration cable, are easy to splice in, seal and reenter.

3) Splice Trays: There should be a sufficient number of single-mode splice trays placed in each splice closure to route the buffer tubes of the restoration cable. The operator may wish to consider using splice trays that are designed for both mechanical and fusion splices. This way the transition from the temporary mechani-

cal splice to the permanent fusion splice will be much easier.

4) Mechanical Splices: The splice should be fast and easy to use. Typically mechanical splices that accept cleaved fibers and require no epoxy or polishing are the fastest and easiest to install. The goal is to get optical continuity as quickly as possible while achieving a reasonably low splice loss. The advantage of the mechanical splice is that the restoration cable can be stripped, loaded into the splice trays and have the splice installed on each fiber prior to an emergency ever occurring.

5) Optical Power Meters: At least one optical power meter should be included in the kit so that the output power of the damaged cable can be measured to ensure that all the damaged cable has been cutout. Inexpensive, handheld power meters are readily available that can measure both 1300 and 1550 nm. To measure the output power of a bare fiber the power meter should be equipped with a bare fiber adaptor.

6) Optical Fiber Cleavers: The kit should contain two fiber cleavers, one for each restoration crew member. The cleavers should be handheld, rugged and require no external power supplies.

7) Miscellaneous Tools/Materials: This would include items such as: sheath knifes, isopropyl alcohol, tissues, electrical tape, tywraps, silicone RTV, etc.

The restoration cable should be fully prepped and installed into the two splice closures. The buffer tubes should be routed to the splice trays and the optical fibers should be prepared and installed into one side of the mechanical splice parts. This preparatory work will save about 1.5 man-hours of on-site restoration work and will enable the operator to bring up the fiber optic system that much faster. Restoration kits are available from several optical cable manufacturers including Siecor.

There are other tools/equipment needed for troubleshooting the fiber optic system from the headend or hub:

* Optical Time Domain Reflectometer (OTDR): This is a very versatile piece of equipment that operates on the same principle as an electrical TDR, but is used only on optical fiber. The OTDR can measure splice loss, detect system faults, measure system length and estimate the system's link loss. This is an essential piece of equipment for any operator having a fiber optic system.

* Optical Power Meter: As described before, this piece of equipment measures optical power and is used to measure the output power of the Laser Transmitters.

RESTORATION PROCEDURES

This is where the fun starts. Its 1:30 PM on Super Bowl Sunday. The headend technician has just discovered that the status monitor system indicates a loss of optical and backup coaxial transmission to the hub that just happens to be the largest one in the system and provides service to the city mayor. What should happen?

Step 1: Commence Troubleshooting: The headend technician should inspect the appropriate system electronics to see if the failure has occurred there. If the RF electronics/laser indicates it is operating properly, the next step is to inspect the optical cable system.

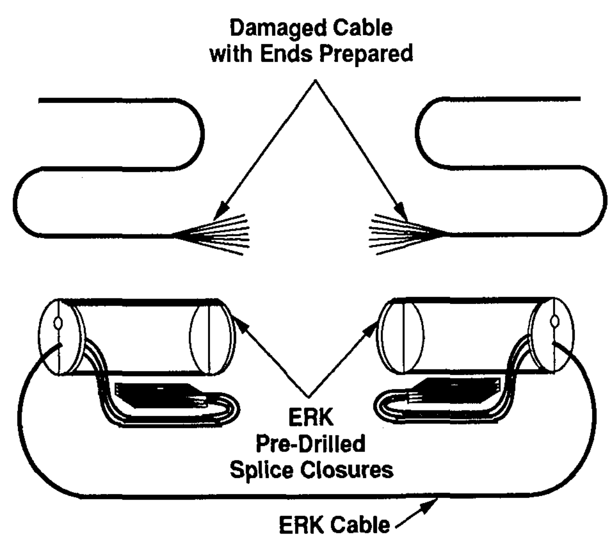
Step 2: Test Cable System: The technician should take the OTDR located in the headend and obtain an OTDR trace of the optical fiber. The trace should be compared to the original signature trace to see if any abnormalities exist. Let us assume that the OTDR indicates a fiber fault. The OTDR will give an approximate distance from the headend to the fault. By comparing the distance given by the OTDR to the cable route diagrams, the technician can estimate the geographic location of the fault. At this point, the headend technician should notify the designated emergency restoration team of the cable system fault and its approximate location.

Step 3: Site Evaluation: The emergency restoration team arrives on site with its restoration kit, safety equipment, access ladders, etc. They find that a little old lady, from Pasenda, with a 1969 Cadillac has knocked down a large tree and although the lady and the Cadillac are fine the aerial coaxial and fiber optic cable have been severed. Its now 3:30 and the Super Bowl starts in less than 3 hours.

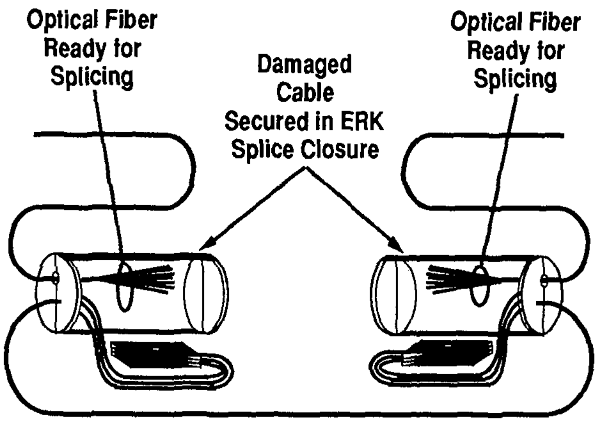
Step 4: Cable Restoration: The restoration team should inspect the damaged cable and cutout the damaged section plus an additional 10 feet on each side in case there are any offset breaks. In this case, the team decides to run their restoration cable along the ground next to the street until the broken steel messenger is replaced.

The following is a sequence of cable restoration using a restoration kit.

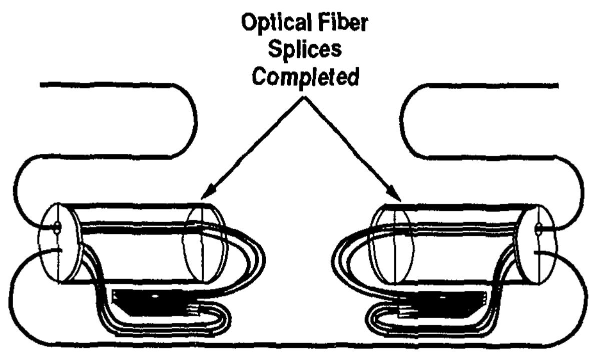
Prepare the damaged cable ends for installation into the splice closures.



Route the buffer tubes of the damaged cable into the splice trays. Measure the received optical power of the damaged cable end coming from the headend to ensure fiber continuity.



Consult the emergency restoration plan and mechanically splice the high priority fibers



first. Check with the headend technician to see if the status monitor alarm has cleared. Once cleared, continue splicing the remaining fibers. The splice closures can be temporarily sealed until the permanent fusion splicing can take place.

Its now 5:50 P.M. and the Super Bowl starts in ten minutes, and your customers are celebrating the quick return of their CATV service.

SUMMARY

As the use of fiber optics gathers wider acceptance and application in the CATV system, the importance of a maintenance/ restoration plan will also grow. The 12 plus years of fiber optic experience in the telecommunications industry indicates that fiber optic cable systems are very reliable and that most system failures can be traced to uncontrollable extrinsic failures. By having a well defined maintenance/restoration plan, the operator will have the ability to swiftly identify system faults and act on them, thus quickly restoring service to the customer.

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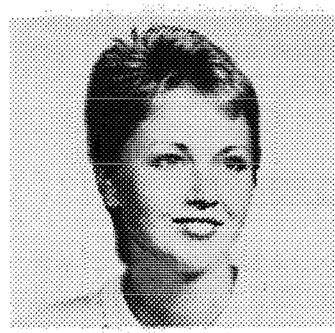
Mike Genovese

Mike received a B.Sc. degree in Mechanical Engineering from The Pennsylvania State Univ., State College, PA in 1978 and was commissioned as a Naval Officer in the Nuclear Submarine Service. In 1984, he joined Siecor where has held positions as Project Engineer, Field Engineering Manager and is currently Product Manager for the CATV and Utility market.



Rebecca S. Frye

Rebecca is Training Supervisor at Siecor Corporation, where she is currently responsible for the development, coordination and implementation of all Technical Training. She holds both B.S. and M.A. degrees in Mathematics with concentrations in Education, Physics and Psychology. A member of SCTE, Ms. Frye is actively involved in the development of courses to further education the CATV industry in use and applications of fiber optic technology.