CELLCO

Laboratory Cellco Communications

Life Time Quality - OFS Optical cable

Kable OFS w ofercie Cellco Communnications.

OFS - część koncernu Furukawa Electric Company (obecnego na rynku od 1884 roku), jako pierwsi na świecie w roku 1974, znaleźli praktyczne zastosowanie dla kabli światłowodowych. W efekcie prowadzonych prac badawczych stworzono bogatą linię produktów, a OFS stał się jednym z wiodących na świecie producentów włókien optycznych.

Obecnie OFS ma niemalże 40-letnie doświadczenie w produkcji kabli światłowodowych.

Najwyższa jakość produktów OFS

OFS projektuje kable oraz dobiera materiały do ich produkcji uwzględniając wpływ środowiska zewnętrznego na włókno optyczne. Efekt prac zmierzających do minimalizacji wpływu warunków zewnętrznych wzmocniony jest działaniami R&D, skupiającymi się m.in. na unikatowych rozwiązaniach tub ochronnych. Innowacyjna konstrukcja tub minimalizuje naprężenia i siły działające na włókno podczas instalacji kabla oraz w późniejszej jego eksploatacji.

OFS nieprzerwanie prowadzi badania oraz testy w zakresie żywotności kabli optycznych. Ich użyteczność OFS determinuje w trzech obszarach:

1. Użyteczność mechaniczna (np. mikro pęknięcia włókna)
2. Użyteczność optyczna („ciemnienie” włókna)
3. Użyteczność parametryczna (przepustowość sieci)

Badania spełniają wymagania norm TelecordiaGR-NWT-000020, RDUP PE-90, ANSI/ICEA S-87-640-2006

Analiza wyników opiera się na porównaniu wyników uzyskanych w warunkach laboratoryjnych z pomiarami zainstalowanych kabli światłowodowych w funkcjonujących sieciach teletechnicznych, dające obraz fizycznego efektu starzenia się kabli.
Wynikową przeprowadzanych badań jest określenie czasu życia kabla światłowodowego. Inżynierowie OFS, na podstawie wyników testów laboratoryjnych i polowych, są w stanie z dużym prawdopodobieństwem oszacować czas życia produkowanych kabli światłowodowych. Okres ten określa się na 50-60 lat. W tym czasie parametry mechaniczne, optyczne oraz fizyczne nie powinny ulec zmianie w stopniu zmieniającym funkcjonalność produktu.

.pdf ← 50 year reliability

.pdf ← OFS Cable Lifetime

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Cable Lifetime
Application Note AN-006

OFS designs and selects raw materials for outside plant cables for a lifetime up to forty years under typical operating conditions and environments. Our designs provide for minimal degradation of the cable components and reliable performance over this period of time.

All cables are designed such that the optical fibers experience minimal tensile strain during installation and operation at the long term, residual cable load.

In addition, all completed cables are subjected to rigorous cable aging tests. The cable aging test is performed as an extension of TIA-FOTP-3, (Procedure to Measure Temperature Cycling Effects on Optical Fiber, Optical Cable, and Other Passive Fiber Optic Components). This test capitalizes on the intrinsic property of plastic materials to change dimensionally with age. As these dimensional changes are time and temperature dependant, the aging process can be accelerated to predict long-term affects from a short-term test. Specifically, the cable is exposed to an extremely high temperature (+85°C) for a prolonged length of time. At the completion of the test, the cable components shall show no signs of degradation and the optical fibers shall demonstrate very low attenuation.

As a result of these strenuous requirements, our optical fiber cables meet or exceed accepted industry standards (Telecordia GR-NWT-000020, RDUP PE-90 and ANSI/ICEA S-87-640-2006) for cable aging.

In addition, our lifetime estimation is based on longevity of current installed products. OFS has optical fiber cables that have been in continuous operation for over 30 years.

Exposure to atypical outside plant environment, adverse environmental conditions or corrosive materials/solutions may limit the cables useful life.

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50-60 year optical cable reliability[1]
David Mazzarese OFS

Optical cables were first deployed commercially in 1977. Thus, our knowledge of their performance in the field is only 34 years and much information provided in this document is speculative. Nevertheless, with this background how can we use our accumulated field knowledge combined with accelerated aging to estimate the 50-60 year reliability of optical cables? Reliability falls into three major categories:

- Mechanical reliability (will the fiber break over the cable lifetime)
- Optical reliability (will the fiber go dark over the cable lifetime)
- Bandwidth reliability (will a fiber have the attributes necessary to work in tomorrow's network)

It is hard to separate optical fiber reliability from optical cable reliability as the two are intimately related, but in this document we will focus primarily on the fiber attributes.

General trends in optical transmission must be considered in our evaluation of optical reliability. The general trend is towards more information traveling down optical fibers. Optical cables are trending toward higher fiber counts in smaller optical cables resulting in the potential for more residual strain on the individual optical fibers. A trend towards the use of more of the optical spectrum and thus a desire to preserve the attenuation near the water peak (1385 nm) and at higher wavelengths (1550 – 1625 nm) is desired to allow the most opportunities for bandwidth upgrades. Supporting higher transmission speeds have put greater consideration of polarization mode dispersion and how it will be mitigated in next generation networks. A commitment to green technologies has pushed transmission formats to lower powers to conserve energy and smaller optical cables to conserve materials, and going forward we need to carefully consider the materials used to help assure they will have a minimal effect on the environment.

Mechanical reliability

Most of the mechanical reliability work has been done thought the IEC Technical report "TR 62048 Optical fibres –Reliability – Power law theory" and COST 218 work prior to that. Much of this work predicts the reliability of fiber based on small flaws in the glass that grow when the glass is under tension. Essential to these predictions are understanding the initial distribution of flaws and then determining how they change with time.

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The estimates for fiber reliability are based on a flaw distribution that has two regions: a strong “intrinsic strength” and a weaker “extrinsic strength”. The intrinsic region is characteristic of short lengths of fibers as would be found in a tight bend and can be determined by testing small amounts of fiber. The intrinsic strength depends on the type of glass used and its median value is typically greater than 600 kpsi for OFS fiber. The extrinsic strength distribution characterizes larger flaws that occur at a lesser frequency and are a result of external “damage” to the fiber during processing. The maximum allowable flaw size is determined by proof testing optical fibers. Current optical fibers are proof tested to 100 kpsi which screens flaws that are ½ micron or larger.

Understanding the transition between the intrinsic and extrinsic region is essential in determining the lifetime for long lengths of fiber that are under tension. Modern optical fibers are manufactured with synthetic silica or ultra high purity natural quartz. These materials have very few flaws (with synthetic quartz virtually eliminating any impurities). The majority of large flaws are introduced during processing and their frequency is a measure of supplier manufacturing excellence. OFS break rates during prooftesting are at historical and industry leading lows. Thus fiber break occurs infrequently in the 1000’s of km tested. Prooftesting characterizes only a narrow part of the extrinsic curve. The tests for intrinsic strength on the other hand are done on short gage lengths and only look at 100 meters to a few kilometers at the most. This results in a large gap between the few meters to the 100’s of km lengths. And this length range is where most optical cables fall, so understanding it is essential. The approach that relates these two sets of data is the power law reliability equation given in IEC TR 62048. The equation of interest that relates these parameters is:

$$t_f = t_p \left(\frac{\sigma_p}{\sigma_a} \right)^n \left\{ \left[1 - \frac{\ln(1-F)}{N_p L} \right]^{\frac{n+1}{m_d}} - 1 \right\}$$

where

t_f, time to failure (lifetime)

t_p, prooftest time

σ_p, prooftest stress

σ_a, applied stress

F, failure probability

N_p, prooftest break rate

L, fiber length under tension ($L = 0.4 L_B \left(\frac{n m_d}{n+1} \right)^{-1/2}$ for bending)

m_d, Weibull m from dynamic fatigue

In this equation n and m_d are unknowns that are determined using dynamic strength testing. Unfortunately, even this is not simple as it has been shown that n values can increase over time and thus the initial value that is determined during qualification is likely conservative for cabled fiber. The dynamic m_d for the low strength tail is likely on the order of 2, but again to be conservative a value of 4 is used in the calculations. Overall the net result is a conservative estimate of the lifetime of the optical fibers.

What further complicates determining fiber mechanical lifetime is that the environment the optical fiber is in can impact n and m. This is where cable design becomes critical. Optical fiber coatings combined with cabling materials, gels and water blocking agents, are designed to keep corrosive materials such as water away from the glass optical fiber. Thus characterizing the unaged fiber for mechanical strength along with dry aged fiber should give a good estimate of what will be observed in the field. This has been validated as it is a rare event for a mechanical failure to occur in the cabled portion of the fiber without an external mechanism such as a tree fall. One exception to this is the relatively short length of optical fibers in splice enclosures. Here, the optical fiber can come directly in contact with moisture or water. This is why tests on temperature/humidity aged samples only need to consider the intrinsic properties. Note that because of the uncertainty of conditions encountered in splice enclosures it is essential that stress be minimized on the optical fibers.

Optical Reliability

In the 30 years of commercial optical cable deployment, a few mechanisms have resulted in deterioration of the optical performance of glass fibers. The first is a result of micro-bending, the second is a result of hydrogen aging, and the third is radiation sensitivity.

Microbending loss occurs in single-mode fiber when small transverse perturbations in the fiber axis result in the coupling of energy out of the fundamental mode and into lossy higher order modes. Significant microbending loss can occur even when the magnitude of the perturbations have nanometer scale size if they occur at the appropriate frequency along the fiber axis so that strong (sometimes resonant) mode coupling occurs. The spectral dependence of microbending loss varies with the axial distribution of the perturbations.

Microbends occur when non-uniform forces are applied to the fiber. This can be a result of temperature changes causing the cables to expand and contract or swelling of the fiber coating or cabling materials as they react with the external environment. Fibers and cables are exposed to temperature cycling to observe the impact of the former and exposed to high humidity, liquid water, solvents, etc., to get at the latter condition. These tests are described in the IEC cable documents as well as Telcordia GR-20.

These accelerated aging tests give a good indication of how the cable will perform today but as the cabling materials age uneven forces develop on the optical fibers may see this property change over time. Current materials have been developed to minimize the impact of aging on attenuation, and temperature humidity tests are used to validate that the material system will protect the performance of the optical fiber. Accelerated aging done at higher temperatures and higher moisture levels may give insight into the long term performance of the cabling materials. When performing these tests one must be careful that high temperature degradation mechanisms are not activated resulting in an unrealistically short lifetime estimate.

Hydrogen aging is a challenge with all optical fibers manufactured before 2000. In this process hydrogen reacts with defects in the glass resulting in OH groups. If these form in the light carrying portion of the fiber the attenuation slowly increases and in some cases the optical fibers become unusable. Lucent's optical fiber solutions business unit (OFS' predecessor) was the first to develop a process to mitigate hydrogen aging in 2000; OFS has continued to have industry leading performance in this area. The ITU-T G.652D specification was developed to address this degradation process, and today most optical fibers meet this specification minimizing concerns over hydrogen aging effects.

With 30 years of deployed optical cables and an assumption that any degradation effect will double with twice the time we can assume that other than the hydrogen effect we are unlikely to see any new degradations to optical performance that will result in more than a few 100ths of a dB per km over the life of the optical cable

The exposure of germanium-doped optical fibers to low doses of ionizing radiation can cause defects to form in the atomic structure of the glass resulting in an increase in absorption losses. Radiation testing is currently performed at high does rates over short time intervals. The results of these accelerated tests are then used to estimate the increase in the fiber attenuation over the estimated useful lifetime when the radiation exposure at the typical background levels. This area is unknown as we have experience with optical cables deployed for the time frame where radiation would impact attenuation but with 30 year cables looking OK it is assumed that doubling that may still be reasonable but this is speculation. IEC TR 62283 Ed1, "GUIDANCE FOR NUCLEAR RADIATION TESTS ON OPTICAL FIBRES" still need refinement before accurate predictions can be made.

Bandwidth reliability

One constant in optical systems is that as time has progressed more bandwidth is being deployed over individual fibers. This is accomplished by deploying higher transmission speeds and more wavelengths. At higher transmission speeds polarization mode dispersion (PMD) is a critical parameter. Though several new transmission formats have been developed to minimize the impact of PMD they are more costly and in general the lower PMD in the optical fiber will improve system performance. The current ITU-T standard for optical cable is 0.20 ps/sqrt(km) LDV and some Large European Operators specifications are 0.1 ps/sqrt(km) LDV or less. This level of performance should be sufficient for most deployments, but in the future one may consider looking at lower values. Currently the practical minimum is in the range of 0.05-0.06 ps/sqrt(km) and achieving this level of performance will require increased measurement costs on the optical cable produced.

With the deployment of Raman pumping and DWDM more wavelengths are available for transmission than ever before and as a result more of the available optical spectrum is likely to be deployed as time progresses. Two areas of concern are near 1385 nm which can be mitigated by deploying low or zero water peak fiber and at wavelengths beyond

1550 nm where bending can impact performance and the fiber may not be characterized after installation. Checking all installed optical links at 1625 nm is strongly recommended to assure the installation is ready for future wavelength upgrades.

Summary

Optical cable materials are chosen to preserve the optical fibers they contain. They were developed to minimize the impacts of the external environment on the glass fibers. For the optical fibers we looked at three major reliability categories:

- Mechanical reliability
- Optical reliability
- Bandwidth reliability

Modern cables have been developed to minimize the impact of all of these categories over many years however, when one looks at the question of 50 year reliability, such categories are more difficult to address as we need to extrapolate our 30 years of data and hope for the best.

Bandwidth reliability is not an issue with current transmission systems; on the other hand, the concern is what will be deployed in 50 years. Most early failure mechanisms associated with optical reliability have been addressed with improved materials. Based on what we know today, it is unlikely any major degradations (over a few 100ths of a dB/km) will occur in the 50 year timeframe, but until we have observed long term deployments and fully understand the impact of other effects (such as long time period low level radiation) this is not certain.

With fibers deployed for 50 years mechanical reliability may be the greatest challenge. Random breaks of fibers in optical cables occurring after initial installation are a rare occurrence. Thus, the conservative estimates we have used to predict their occurrence is consistent with our observed knowledgebase of installed fibers. Unfortunately, the equations show us that once failures occur more are on the horizon. The largest challenge is the short lengths of fiber in the uncontrolled environment of splice enclosures. Here reliability is a direct result of intrinsic strength of aged fiber. Further understanding of this critical area may provide the most insight into how optical fibers can be preserved over a 50 year time frame.