AMP 222 FIBER OPTIC CABLES AND CONNECTIONS NOT SUBJECT TO ENVIRONMENTAL QUALIFICATION REQUIREMENTS (VERSION 2019)

Programme Description

The purpose of the AMP described herein is to provide reasonable assurance that the intended functions of fiber optic cables and connections that are not subject to environmental qualification requirements and are exposed to adverse localized environments caused by high temperature, radiation, moisture, wear, and chemicals (such as leakage of solvents, hydraulic fluid and borates) or surface contamination are adequately maintained.

A fiber optic cable may be defined as a cable containing one or more optical fibers, where the other cable elements provide protection to the optical fiber(s) from stress during installation and from the environment once installed [1]. Fiber optic cables and connections may degrade more rapidly than expected when exposed to an adverse localized environment. A fiber optic cable or connection subjected to an adverse localized environment may increase the rate of ageing of a component or have an adverse effect on operability. An adverse localized environment exists based on the most limiting actual operating conditions (e.g. temperature, radiation, moisture, wear, and chemical (such as leakage of solvents, hydraulic fluid and borates) or surface contamination) for the fiber optic cables or connections.

A fiber optic cable is composed of one of three basic types of material construction: fused silica (glass), polymer (plastic), or polymer-clad silica (PCS). A typical basic structure of fiber optic cable is shown in Figure 1. The cable core and cladding are enveloped by the coating, which is the primary protective layer. The buffer, also called “loose tube”, is the secondary protective layer whose basic role is to protect the core, cladding, and coating from physical impacts that might affect their optical or other physical properties. The buffer is typically based on stiff and tough polymer; it can be either dry or equipped with an inside jelly layer. The buffer also acts as a physical shock absorber, and it provides protection for the internal layers of the fiber optic cable from abrasions (wear), solvents, moisture, and other contaminants. The buffer does not have any optical properties that might affect the propagation of light within the fiber optic cable [2].

The jacket and buffer material for a fiber optic cable is usually a polymer so its ageing effects and degradation mechanisms would be similar to those experienced by polymer insulated and jacketed electric cables (e.g. flame retardant and ultra-violet protection). However, they serve only as a protective layer for the underlying coating, cladding, and core. The jacket and buffer serve to provide mechanical and environment protection. As a result of these significant differences, the failure modes, failure mechanisms, and condition monitoring inspection and testing techniques are unique to optic cables.

Jacket

Buffer

Coating

Cladding

Core

Figure 1. Simplified structure of a fiber optic cable

Environmental variables such as increase in temperature, radiation, moisture, wear, and chemical or surface contamination can result in ageing and increasing failure rates for fiber optic cables. In adverse localized environments (e.g. inside containment, certain areas outside containment), fiber coating material moisture degradation may occur. If coating is not designed to take this degradation into account, its properties may degrade severely and the coloured, thin outer lacquer layer on the coating may discolour or the coating may lose its adhesion to the glass [3].

The potential ageing effects in core and cladding of fiber optic cables are: (a) increasing signal attenuation or decrease in optic power transmission and (b) time dispersion of the signal. These ageing effects are produced by ageing related degradation mechanisms such as thermal degradation of organic materials used for coating, buffer, and jacket layers of fiber optic cable, their radiation induced oxidation, moisture intrusion and chemical contamination.

The ageing effects in fiber optic cable jacket are loss of structural integrity, discolouration and increasing intrusion of moisture, of chemical reaction products, or other contaminants into the cable interior. These effects are produced by ageing mechanisms such as embrittlement and cracking due to thermal and radiation (including ultraviolet (UV)) degradation of polymeric materials.

Decrease in optic power transmission and loss of signal may occur in fiber optic cable connection interface (splices and connectors) due to wear and loosening of connectors. Decrease in optic power transmission may also be due to discolouration and degradation of connection interface caused by chemical or surface contamination and wetting due to moisture intrusion.

Mechanical damage to the fiber optic cable core and its cladding, coating, buffer (as the loose tube), jacket, and connection interface may occur due to mishandling and physical contact or abuse during installation, maintenance, operation or functional testing activities. This may lead to potential ageing effects such as:

1) increasing signal attenuation, decrease in optic power transmission, increasing time dispersion of the signal, and loss of signal for fiber optic cable core and cladding;

2) loss of structural integrity of cable coating, buffer and jacket;

3) decrease in optic power transmission and loss of signal in fiber optic cable connection interface.

The potential degradation mechanisms for fiber optic cable connection hardware (metal connection assembly components and plastic connection assembly components) are mechanical damage and misalignment of connection interface caused by mishandling and physical contact or abuse during installation, maintenance, operation or functional testing activities. These may lead to potential ageing effects such as decrease in optic power transmission and loss of signal. Moreover, loss of structural integrity, loosening of connection and loss of signal may occur due to mechanical damage to interface surfaces and fatigue damage to connection hardware caused by wear.

Evaluation and Technical Basis

1. ***Scope of the ageing management programme based on understanding ageing:***

This AMP applies to accessible fiber optic cables and connections subjected to adverse localized environments caused by temperature, radiation, moisture, wear, chemical or surface contamination and subject to ageing management according to national regulatory requirements.

1. ***Preventive actions to minimize and control ageing degradation:***

This is a condition monitoring programme and no actions are taken as part of this programme to prevent or mitigate ageing degradation.

1. ***Detection of ageing effects:***

Signal transmission performance decreases when cable degrades. It is assessed by measuring attenuation in signal, as increase in attenuation shows transmission performance has decreased. Chemical impurities added into fiber constitute a major source to change in optical and physical properties and cause increase in signal attenuation[12]. Visual inspection can detect mechanical damage and signal transmission performance can detect thermal and radiation damage. Discussion of transmission performance and test requirements are descripted in [8]. Other standards for test procedures to measure attenuation in cables are [5] for single mode attenuation measurement and [6] for multi-mode attenuation measurement.

Visual inspection can detect direct mechanical damage, such as physical impacts, bending, abrasion, cutting, contact, deformation, and perforation resulting from installation and maintenance activities in and around the location of a cable and connectors. Mechanical damage is a potential stressor that can affect fiber optic cable systems by direct damage to the optical fibers or, indirectly, by damaging the protective polymer jacket and opening a potential pathway for intrusion of moisture or other contaminants that could degrade the optical properties of the fiber optic core and cladding material (typically seen as increasing signal attenuation) [2]. The visual inspection of cable jacket and connection surfaces is periodically used to infer the adequacy of the fiber optic cable and connection. All abnormal conditions are evaluated, assessed, and corrective action taken as appropriate.

The condition of the cable for thermal and radiation damage is also assessed by evaluating signal transmission performance. The method to evaluate signal transmission performance is via attenuation measurement. An additional method for longer circuits is optical time domain reflectometry (OTDR) [4]. The detailed description of methods for OTDR measurement of the quality and functionality of fiber optic cables are given in [5] for multimode attenuation and in [6] for single‐mode attenuation, respectively. Spare optical fibers in operated cables, or deposit cables could be used for condition monitoring for low optic powers.

Cable system in nuclear power plant service are subject to a variety of ageing and degradation stressors that can produce immediate degradation or ageing-related mechanisms and effects causing degradation of the cable components over time. Stressors can generally be categorized as one of two types based upon their origin:

1) environmental stressors originate from conditions in the environment where a cable system is located;

2) operational stressors that are the result of operational factors such as inspections, or operating and maintenance activities in the vicinity of the cable system; or

3) internal stressors such as the optic power at its extremely high levels.

Optical fibers can degrade much faster at higher power levels [7].

(a) Starting from optic powers greater than about 100 mW, a significant deterioration of the transferred optic signal may occur from distances of the order of ten kilometers. In telecommunication, this undesirable change of a signal is denoted (called) as degradation. This case is not concerned to degradation of any of the fiber optic cable component or accessory.

(b) For optic powers over about 500 mW, a significant heating may originate at the inner surface of the coating layer in the strongly (tightly) bent optical fiber (bending radius lower than provided in manufacturer technical specifications). This leads to the thermal degradation of the coating which can be delaminated from the cladding or even broken, despite the glass core and cladding layers beneath (the coating) stay to be wholly compact.

(c) From the optic powers of about 2–5 W — depending on the glass fiber diameter and doping system —, the fiber core is ignited, and the local fusion starts to periodically propagate towards the power accompanied by emitting a visible white light. After the locally fused zones cooled down, the fiber core shows a string of voids strongly limiting the signal propagation.

The failure modes for optical fibers include attenuation of signal to unacceptable optic power levels, distortion of the signal (time dispersion) causing an unacceptable bit error rate (BER), or complete loss of signal. Using the failure modes and effect analysis (FMEA) of fiber optic cable systems, the piece parts of a cable (e.g. silica fiber optic core, cladding, coating, buffer, jacket, the precision silica fiber connector interface, the fiber optic cable splice, and connector hardware) are each analyzed to identify the constituent materials. The stressors and associated potential ageing and degradation mechanisms have already been discussed in the programme description of this AMP.

Identification of local adverse stressors, such as high temperature, high radiation, high moisture or flooding is important since these stressors can lead to ageing effects caused by degradation mechanisms which could have an adverse effect on cable performance [2].

The coating material in fiber cable coating is important. High temperature and moisture degrades the fiber coating and it may discolor or lose its bond to the glass [11]. The fibers may be coated with suitable materials to withstand harsh environmental conditions [10].

1. ***Monitoring and trending of ageing effects:***

Trending actions are not included as part of this AMP, because the ability to trend visual inspection results is limited. However, condition monitoring inspection results if they are trendable may provide additional information on the rate of cable or connection degradation.

1. ***Mitigating ageing effects:***

This programme is a condition monitoring programme. This programme has no specific operation, maintenance, repair or replacement mitigation aspects.

1. ***Acceptance criteria:***

Any indication or relevant conditions of degradation may be evaluated for acceptance in accordance with the pertinent governing requirements or guidance documents. Examination results and flaws that exceed the acceptance criteria in the pertinent governing requirements or guidance documents may require repair or replacement activities, or further evaluation to demonstrate that the component will continue to perform its intended function through the period of long term operation.

Guidance on various types of fiber optic cable system testing techniques has been developed and incorporated into testing standards, known in the industry as fiber optic test procedures (FOTPs), sponsored by the Electronic Industries Alliance (EIA) and the Telecommunications Industry Association (TIA). A list of these EIA-TIA fiber optic test procedures can be found on the Fiber Optics Association (FOA) internet website [8].

When visual inspection is performed, accessible cables and connections are to be free from unacceptable visual indications of surface anomalies that suggest that cable or connection insulation degradation exists. An unacceptable indication is defined as a noted condition or situation that, if left unmanaged, could lead to a loss of the intended function.

Acceptance criteria for condition monitoring techniques will depend on the condition monitoring technique used (e.g. applicability of the condition monitoring technique to the fiber optic cable and connection). Acceptance criteria are based on degradation in relation to applicable manufacturer guidance or substantial changes from initial design specified values of attenuation.

1. ***Corrective actions:***

An engineering evaluation is performed, and corrective actions are taken when unacceptable conditions are found. The evaluation is to consider the age and operating environment of the component as well as the severity of the anomaly and whether such an anomaly has previously been correlated to degradation of optic cables or connections. Corrective actions may include, but are not limited to, testing, shielding, or otherwise changing the environment or relocation or replacement of the affected cables or connections.

1. ***Operating experience feedback and feedback of research and development results:***

This AMP addresses the industry-wide generic experience. Relevant plant-specific operating experience is considered in the development of the plant AMP to ensure the AMP is adequate for the plant. The plant implements a feedback process to periodically evaluate plant and industry-wide operating experience and research and development (R&D) results, and, as necessary, either modifies the plant AMP or takes additional actions (e.g., develop a new plant-specific AMP) to ensure the continued effectiveness of ageing management.

The ÚJV Řež is performing research on abnormal behaviour of fiber optic filaments stored in jelly loose tubes. The plant monitor R&D activities and assesses the applicability to this AMP.

1. ***Quality management:***

Site quality assurance procedures, review and approval processes, and administrative controls are implemented in accordance with the different national regulatory requirements, e.g. [9].

References

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