Cable Installation Considerations for Fire Detection

Introduction

Distributed fiber optic sensing techniques such as Distributed Temperature Sensing (DTS) are powerful tools for monitoring long linear or other large assets. Consequently, these techniques fit perfectly with specific requirements of fire detection in tunnels, large buildings, industrial sites and large equipment. In fire detection applications fiber optic DTS systems are also referred to as a Fiber-Optic Linear Heat Detection (FO-LHD) systems; in contrast to conventional LHD systems that are based on electrical sensing. Some common fire detection applications are:

- Road and railway tunnels
- Railway and metro line stations
- Cable trays, shafts and ducts
- Parking lots
- Industrial sites such as refineries or steel plants
- Hazardous areas
- Floating roof tanks
- Mines
- Conveyor belts
- Nuclear power facilities (requiring special fiber)

In each of these applications, distributed fiber optic sensing offers the clear benefit in the ability to cover a wide area from a central monitoring point. There are numerous additional benefits: the passive fiber-optic cable is lightweight, small and easy to install. In addition, the insensitivity to electromagnetic interference, moisture and dust is a clear advantage in comparison to electrical heat and smoke detectors.

FO-LHD systems measure temperature profiles over location and time and use this information as the base for sophisticated alarming. FO-LHD systems use maximum temperature, several rate-of-rise and difference-to-ambient algorithms in order to maximize detection sensitivity and diminish false alarms. If required, all alarm parameters can be set individually for each alarm zone, which makes the system very adaptable to any environmental challenges.

In explosive environments, the absence of electrical energy is of clear benefit for explosion safety when a fiber-optic cable is routed through classified areas. Nevertheless, a potential release of optical energy in case of a cable break as well as potential dangers arising from fire propagation, electrostatic discharge or transmission of lightning energy by the cable itself have to be taken into account when evaluating explosion safety. Users are advised to compare the ATEX / IECEX certification of the FO-LHD system with the requirements of the project before deploying it in explosive environments.

Optimum performance for any particular application is dependent on the system configuration, cable type, installation method, cable position and the environmental conditions of the site.

This document provides guidance on best practice for the selection and installation of cables for distributed temperature sensing (DTS) in the fire detection domain.

Cable Selection

General

Fiber optic cables are essential parts of the FO-LHD fire detection system and must be certified together with the interrogator unit (DTS) by an approved body in accordance to national standards and regulations when required. This often limits the selection of cables to the offerings of the FO-LHD supplier. Cables should be selected according to the operational requirements of the asset to be monitored but also regarding the compliance with the interrogator unit. Depending on various factors, the design of the cable might affect the sensitivity and performance of the LHD system particularly when the design deviates from the fiber-optic cable that has been used for certifications. Cable selection details should be discussed with your fiber sensing supplier or industry specialists during the design phase.

Fiber Selection

Certified fiber-optic cables are offered by the FO-LHD supplier and contain appropriate fibers for the purpose. In most cases, fiber-optic cables offer two multi-mode fibers to enable redundancy and dual end/loop measurements also referred as a “Class A” setup. If the application doesn’t require a certified system or it requires a special cable, optical fibers should be selected based on the specification of the interrogator and the environmental conditions i.e. ambient temperatures, radiation, humidity, chemical load etc. For some applications like nuclear power plants or high temperature areas, pure-core silica fibers or phosphorous-free fibers - both optionally with polyimide coatings - may be used to improve the endurance of the fibers. For optimum performance and long reach, fibers shall have a low attenuation and sufficient “bandwidth x length” product for obtaining sufficient spatial resolution at longer distances. Conformity to telecom standards as ITU-T G651 is in general a good indicator for high-quality optical fibers.

Cable Design

Loose tube or tight buffered fibers are the most common configurations used for organizing and protecting optical fibers inside the cable core. This helps to keep fiber attenuation low and ensures fiber reliability post installation.

When using a loose tube configuration, fiber with appropriate excess fiber length (EFL) should be used to minimize micro-bending or fiber strain when the cable is under tension or when the temperature varies.

Typically, FO-LHD suppliers offer at least two types of cables: a dielectric one and an armored one consisting of a FIMT (Fiber in Metal Tube) as a central core. To improve handling and robustness, cables are designed with an aramid yarn or stranded with stainless steel wires and finished with a flame-retardant non-corrosive (FRNC) or low-smoke zero-halogen (LSZH) jacket material to prevent hazards for people or fire from spreading. Armored cables should be used in applications with high mechanical or chemical load. Stone chipping and rodents are examples of mechanical threats. Acid or solvent vapors may be chemical challenges for cables. Dielectric or metal-free cables may be used as a cost-efficient solution, provided they are compliant with the expected mechanical and chemical loads. Dielectric cables are lighter and usually easier to install.

Slow thermal response of a fiber-optic cable shall be avoided as much as possible. Cable diameter is an important-factor that affects the response time significantly. Depending on the overall design, cable diameters between 2 mm and 5 mm show, in general, sufficiently short response times compliant with alarm response requirements of standards for linear heat detection.

(a)

(b)

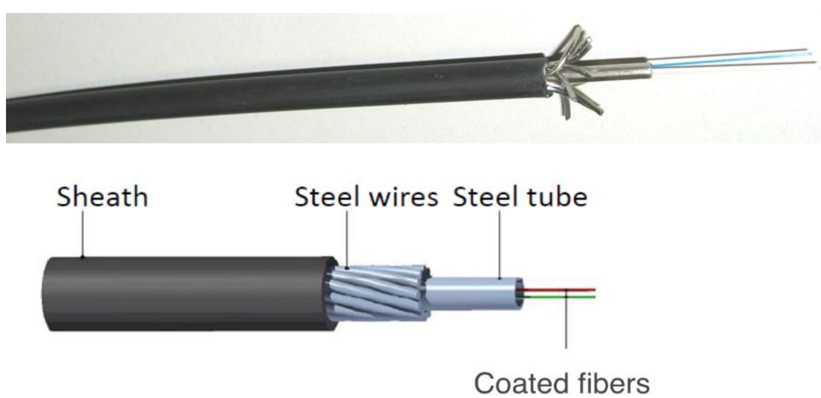

Figure 1: Example of fiber-optic cable - FIMT with stranded wires and plastics sheath (a) picture of real cable and (b) cable schematic

(a)

(b)

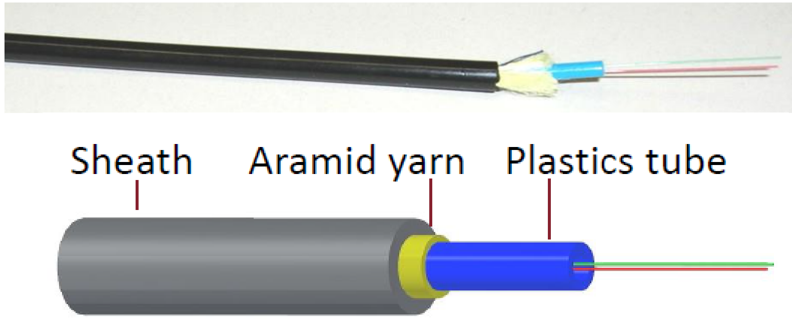

Figure 2: Example of fiber-optic cable – loose tube plastic cable (a) picture of real cable and (b) cable schematic

(a)

(b)

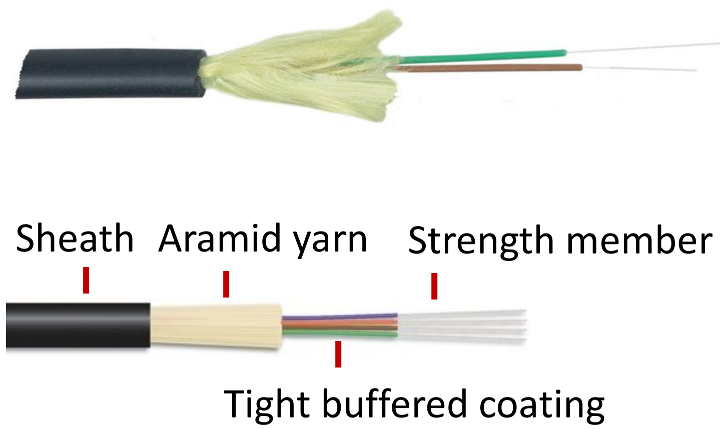

Figure 3: Example of fiber-optic cable – tight buffered plastic cable (a) picture of real cable and (b) cable schematic

Bare loose tubes are in general susceptible to kinking and other types of mechanical load. Fiber-optic cables are therefore equipped with additional protection layer(s). Such layers may consist of a second tube layer, stainless steels wires or aramid fibers for strain relief and/or plastics sheath for better handling and mechanical / chemical protection.

Cable Marking

Meter markings on the cable are recommended to enable the configuration of precise alarm zones. During cable installation meter markings at the zone boundaries are noted to prepare the zone plan. In addition, approval authorities demand a distinct approval cable marking. Please ensure that only cables with appropriate marking are installed in applications requiring compliance to such approvals.

Cable Installation

General

Installation methods shall be selected in accordance to local regulations and environmental conditions. They also shall protect the cable from weather, accidental or malicious damage, and shall accommodate sensing performance as well.

Cable Mounting

Cables for FO-LHD are sensitive to convection heat and radiation heat. For fast response times, it is therefore essential to have free flow of heated air around the cable and to minimize thermal coupling to massive heat sinks like walls. This normally means that the cable is mounted while providing a small distance to the ceiling or in a place where sufficient convection is allowed. A typical cable distance between 5 and 50 cm (2 to 20 inches) from the ceiling is recommended. The mounting clip should fix the cable tightly without causing strain or damage to the cable. Excessive cable sagging should be avoided. Therefore, a longitudinal clamp distance of between 1 and 1.5 m (3 to 5 feet) is recommended. Clamp materials shall be in accordance to the project requirements e.g. high-grade stainless steel is advisable for installation in a salt loaded/high corrosive environment.

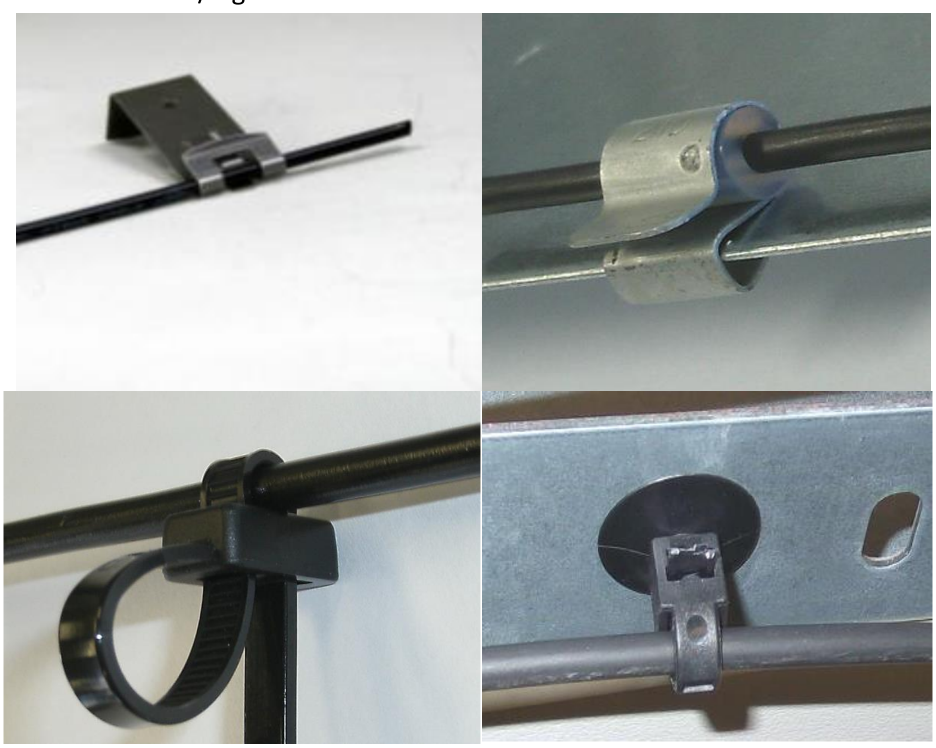

Figure 4: Different cable clips for mounting fiber-optic cable at a distance to a ceiling or wall

No barriers or obstacles shall be present between the cable and the location of the potential fire to maximize the responsiveness to convection and radiated heat. In addition, a dark color for the fiber-optic cable may make the cable more responsive to heat radiation. Figure 4 shows some common methods of ensuring correct installation of the cable.

Zone Plan

The layout of the fiber-optic cable should be outlined in a zone table. Meter markings of the cables at the asset beginning, splicing locations, zone boundaries, etc. shall be registered in the zone plan during installation. Test zones may be required for regular testing of interrogator function using cable heating equipment. It is beneficial to locate test zones outside the actively monitored area to perform testing without interrupting regular operation i.e. closing of a traffic tunnel. Intentional heating or cooling of the cable is useful to exactly locate zone boundaries. This may be necessary because the length of the optical fiber may differ slightly from meter markings on the sheathing of the fiber-optic cable.

Cable Handling

The fiber optic cable is supplied on a cable drum. The cable drum must always stand upright on its flanges to avoid damage (cascading) during handling and storing. The maximum pull force and the minimum bending radius must never be exceeded throughout the installation and commissioning.

Cable Positioning

For cable positioning, user shall always heed the nature of heat development and heat distribution of a fire as well as obey international or local standards and advices of planners and consultants. However, some “rules of thumb” can be derived from best practice of cable positioning.

Asset protection (conveyors, cable trays, machines etc.) requires cable positioning as close as possible to the assumed hazardous heat source. e.g. a coal conveyor’s highest risk is smoldering of accumulated coal below the conveyor. The optimum position of the cable is therefore along the lower frame of the conveyor.

Room protection (tunnels, production halls, parking garages etc.) requires a different approach. A good rule is to position the cable in such a way that the maximum distance between any point at the ceiling and the fiber-optic cable doesn’t exceed 3.5 m (11.5 feet). This automatically leads to a fiber-optic cable spacing of maximum 7 m (23 feet) and a maximum distance of 3.5 m (11.5 feet) to the side walls.

For fire detection in tunnels, a maximum horizontal distance of 5 to 6 m (16.5 to 20 feet) between any monitored location and the fiber-optic cable is acceptable if the fiber-optic cable is installed at the maximum height. The exact spacing depends on the ceiling slope – a flat ceiling allows a maximum distance of 5 m (10 m tunnel width), whereas a curved ceiling allows up to 6m to the side walls (12 m tunnel width) provided that the fiber-optic cable is installed at the center of the ceiling. Thus, a tunnel with two road lanes, a curved ceiling and a width of up to 12 m (40 feet) may be monitored using one single line of fiber-optic cable. Consequently, additional fiber-optic cables lines are required for wider tunnels to comply with national or international fire safety regulations.

Cable Positioning should consider possible sources of false alarms. Positioning shall keep a safe distance from heat sources such as lamps and shall avoid locations with sudden temperature changes. If allowed, less sensitive alarm parameter sets may be used to prevent false alarming at such locations.

Cable routing and extra lengths

At the beginning of each installed cable, a surplus length of approx. 3 to 5 m (10 to 16 feet) should remain in the cabinet so that a pigtail extending from the interrogator can be spliced to the sensor cable.

A surplus cable length of at least 20 m (66 feet) must be left behind the last fire compartment as a non-active section. This extra length of optical fiber prevents any negative effects of a fiber end reflection on the fire alarming. In addition, the end of fiber should be properly terminated for minimizing end reflection.

If an unambiguous mapping of events between separate fire compartments is required, an extra length of sensor cable shall be laid at the crossing of the fire compartments. The extra length should cover about three sampling intervals on each side of the crossings and can be up to 20 m (66 feet) long depending on the system configuration.

Redundancy

Cable installations enabling redundancy are required by most fire detection standards. The easiest way to achieve full redundancy is to measure two fibers of a fiber-optic cable from the opposite ends of the cable using two interrogators. (see figure 5) This setup covers any single failure in the system (interrogator fault or cable break). A partial redundancy with respect to the fiber-optic cable only is achieved by measuring two fibers of a cable loop from the opposite ends using a single 2 channel interrogator unit. This is usually called in the safety industry a “Class A” configuration.

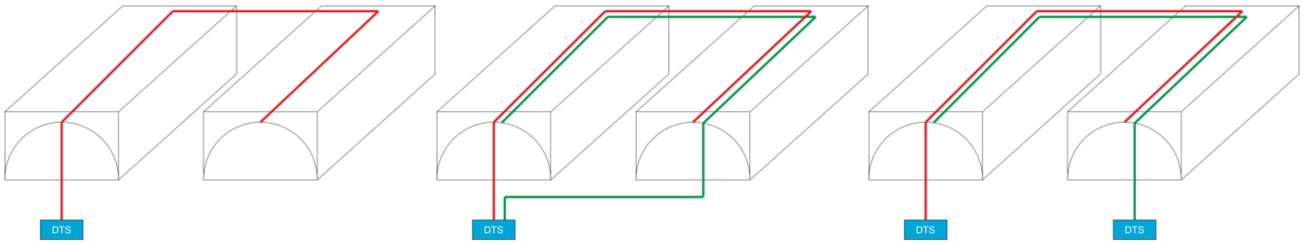

Figure 5: Non-redundant (left), cable-redundant or "Class A" (middle) and fully redundant (right) FO-LHD configurations using the example of a two-tube tunnel

International Guidelines

Fire protection is a highly regulated application. Designers, planners, manufacturers and users are well advised to obey national and /or international standards that apply for planning, installation, services and the equipment used. Fire-detection approvals may be limited to specific system settings (range, number of measurement channels, alarm parameters etc.). Therefore, it is advised to check the entire approval document - including enclosures - if the considered FO-LHD system is compliant with the requirements and specification of the respective project.

Specifics for Europe

In Europe, FO-LHD systems shall comply with the EN 54-22 standard. Planning, design, installation, commissioning, use and maintenance of the system are covered by EN54-14 and VdS 2095 or other guidelines related to the national requirements like the German DIN VDE 0833-2.

Specifics for the US

In the United States, FO-LHD systems shall comply with UL 521 and/or FM3210 / FM3010 standards.
Fiber-optic cables for fire detection are to be installed in accordance with:
- NFPA No. 70 "National Electric Code"
- NFPA No. 72 "National Fire Alarm and Signaling Code".

Specifics for Canada

In Canada, FO-LHD systems shall comply with the ULC-S530 standard.
Fiber-optic cables for fire detection are to be installed in accordance with:
- ULC-S524 "Standard for the Installation of Fire Alarm Systems", and CSA 22.2
- The National Building Code of Canada
- The Canadian Electrical Code, Part 1
- The National Fire Code of Canada

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Please visit www.fiberopticsensing.org for further information on the application of fiber optic sensing.