ENHANCING FIRE DETECTION RESPONSE IN COMPLEX INDUSTRIAL FACILITIES

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1. INTRODUCTION

Oil and Gas refineries are large industrial facilities, representing investments in Billions of US$. In this paper, the word "refinery" is used interchangeably with "terminal" and "Storage Tank farm". Oil Refineries are complex facilities to process raw and refined hydrocarbon materials over its life of 30 years to 40 years. These facilities operate on a 24/7 basis with managed maintenance downtime. It is a priority to eliminate accidents at all stage at the refinery throughout its lifecycle.

Classical instrumentation has a one to one relationship between the sensor and the user; this is no longer applicable for large industrial facilities requiring measurements automatically. A distributed architecture effectively addresses the issue of complex instrumentation requiring several thousands of process measurements.

With elevated ambient temperature of the equatorial regions, together with oxygen in the dry air are environments enough to sustain a burning fire. In additional to classical Fire Detection, temperature monitoring for early sign of fire is required – hidden or smothering fire are difficult to detect using traditional methods

Linear Heat Detection had contributed to solving the above problems, such technologies are mature, a sensor is 'distributed' along the route requiring temperature monitoring. Traditional method uses an electric cable or metal tube presents limitation and inflexibility for today's challenges to industrial fire detection at large facilities.

For any commercial or Industrial fire detection application, knowing the location of the fire detected is the prime requirement to firefighting/suppression, this is achieved by dividing the monitored asset into Zones.

A state of the art Fiber Optic Linear Heat Detection (FO LHD) system using Fiber Optic cable as the temperature sensor demonstrates the features to achieve enhanced monitoring for fire, FO LHD is a Distributed Temperature Sensor (DTS), it reconstructs the temperature informational for the entire route of the Fiber Optic cable.

This paper outlines Belt Conveyor and Storage Tank installations of FO LHD system, and temperature data captured from a storage tank farm is discussed.

2. FIRE SAFETY ENHANCEMENT IN REFINERIES

Fire is a catastrophic class of accident at any industrial facility including refineries, Fire detection devices are used at complex facilities, the demand for reliability and accuracy increases together with the information needs towards effective decision making. The key functionalities of two basic devices are outlined:

1: Combustible Gas Detector
- Principle: Flammable gas concentration level
- Alarm Signalling: 4-20ma and Relay
- Alarm information: Analogue level

2: Flame detector
- Principle: Wavelength of flame
- Alarm signalling: Relay
- Alarm Information: Fire-alarm, Fault alarm and Auxiliary

Fire is a chemical reaction, the “Fire triangle” [1] explains three elements to be present to initiate and sustain this reaction. These elements are: Heat, or an ignition source, Fuel and Oxygen. The market had seen several reliable devices for detecting this chemical reaction. For such devices, a statutory compliance of the device and optionally with local authorities are requirements for market acceptance.

A refinery presents unique challenges for Fire Detection – this paper outline Belt Conveyor and Storage Tank to illustrate the problem of reaching to the physical location for placement of a fire detector device. A complete belt conveyor system or storage tank farms presents thousands of locations where fire detection are required, it quickly becomes impractical to use several thousand discrete detection devices. A hidden cost in addition to initial installation is its on-going maintenance cost.

Described below represent two architectures of Fire Detection systems. Detector devices at different locations are wired to the central controller, classic point-to-point wiring of detection devices and its equivalent as a Distributed architecture.

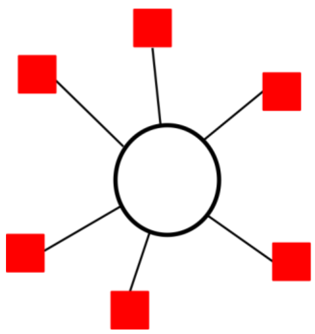


Figure-1: Point-to-point architecture

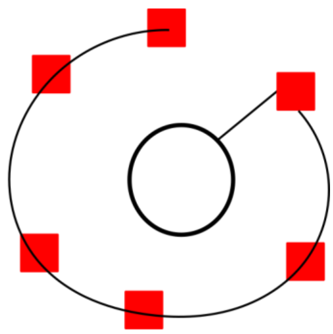


Figure-2: Distributed architecture

Environmental pressures limited the number of refineries coming on-line, expansion of existing refineries is an option, this means a need to extend fire detection to larger or denser industrial facilities at a justifiable level of capital investment. The increased volume and density of monitoring devices presents further constrain of additional Capex (Capital) and on-going Opex (Operational Expenditure) investment.

The issue of scalability addresses the limited capacity of existing detection system, where cabling technology is the bottleneck. A distributed method is one method to easily and economically introducing scalability to achieve reachability of sensor devices.

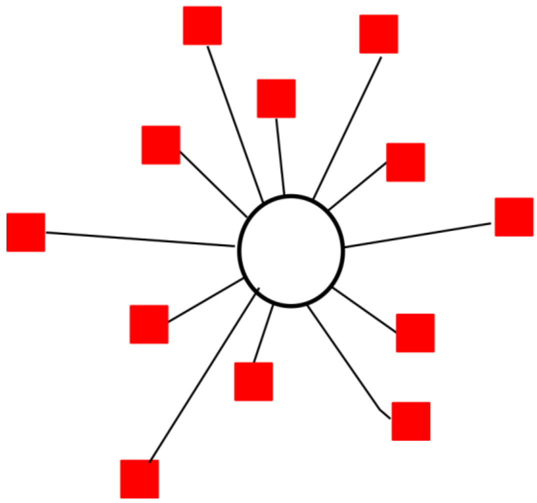


Figure-3: Point-to-Point architecture expanded

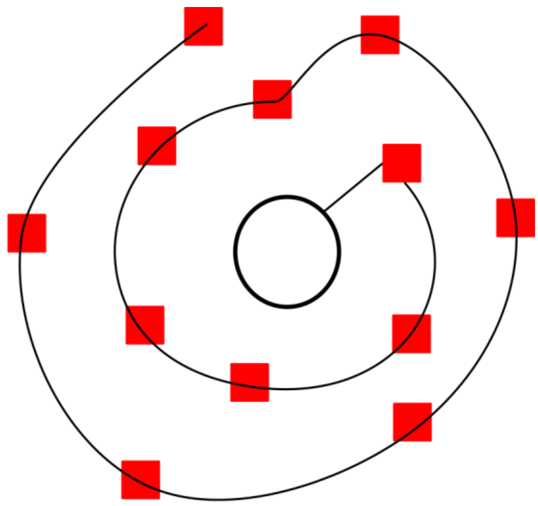


Figure-4: Distributed architecture expanded

Linear Heat Detection (LHD) is the broad term covering similar commercial methods to achieve the detection of heat using different principles: mechanical, electrical, pneumatic, electronic and optical

Where temperature is the principle method for Fire detection, the timeline of these commercial fire detector is perceived as:

- Since mìd 40's, Short circuited wires due to insulation breakdown - Digital LHD
- Since 80's, Resistance change of electrical wire - Analogue LHD
- Since 80's, Gas pressure changes inside sealed tube - Pneumatic LHD
- Since late 80's, miniature sensors embedded into electrical cable – Analogue LHD
- Since late 80's, Raman back scatter analysis - Fiber Optic LHD

Decision maker require accurate and reliable information upon discovery of a fire event, very often two options remain for catastrophic fire – either suppress fire or let fire burn. An enhanced fire detector requires a third option of Early Fire Detection, and a fourth option to capture Fire Dynamic Data for off-line analysis that contributes to improvement to fire rescue strategies.

3. MECHANISTIC APPROACH

For a system offering true flexibility to industrial Fire Detection, a mechanistic approach to re-construct a temperature profile and mapping the firefighting zone is described.

In contrast to traditional LHD sensor, electrical resistance of the copper wire is a constraint of the commercial LHD sensor device. Resistivity is expressed as below.

$$R = \frac{\rho l}{a}$$

This highlight the impractical approach to use larger diameter wire or use silver instead of copper material. To function as a LHD sensor, either limiting the length and keeping the wire diameter small represents the limitation of electrical LHD sensor devices. Since 1980; research of fiber optic (FO) as a sensor quickened, the intrinsic property of FO as it reacts to physical properties were well analysed and documented. Commercial FO LHD emerges that further overcoming issues and technical challenges of reaching longer lengths and performance enhancements using only telecom grade FO cable as the intrinsic sensor.

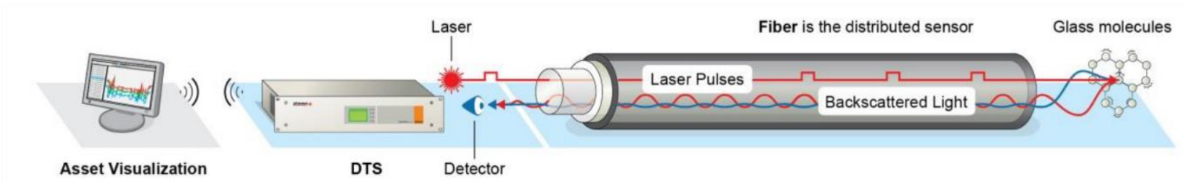


Figure-5: Fiber Optic LHD system components

The FO LHD technique is described:

- With laser light launched into one end of the FO, scattering by light bouncing off glass molecules in the FO is observed, back-scatter is analysed by the DTS because FO LHD only has access one side of the FO cable. The relationship [3] between back scatter and temperature is simply represented as a ratio and named after Dr Raman [2].

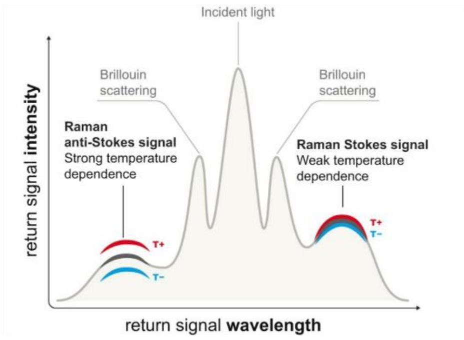


Figure-6: Raman spectrum of back scatter

$$\frac{Is}{Ias} = \left\{\frac{\mathrm{v} - \mathrm{vR}}{\mathrm{v} + \mathrm{vR}}\right\}^4 \exp\left[\frac{hcvR}{kT}\right]$$

Figure-7: Relationship of stokes signal and temperature

- Similar to the principle of Radar, pulsed laser light is launched into one end of the FO travels at known velocities. Establishing precise location along the FO cable [3] by correlating the Timing of back scatter to its launch time

- Modern Digital Signal Processing (DSP) techniques reconstructs the temperature profile of the entire FO cable length in real-time, simple logic then compares the temperature profile information against user programmed temperature threshold(s) for all zones and control the appropriate signalling towards the Fire Alarm Panel. [4]

To address the complex layout of industrial sites needing reliability, redundancy requirements, FO LHD present flexible arrangements to match:

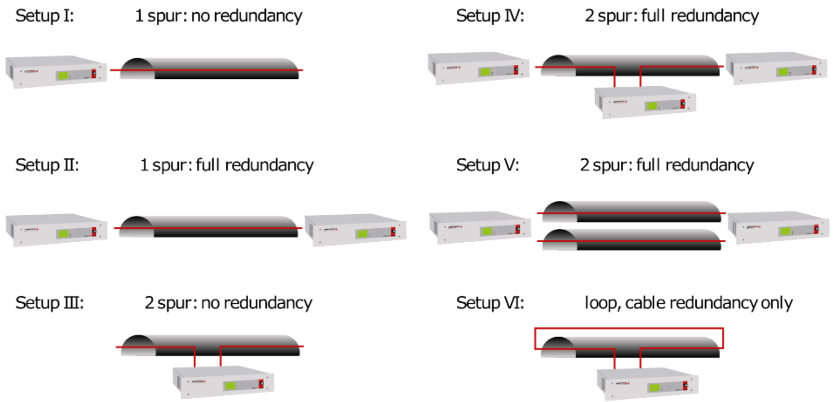


Figure-8: Flexible arrangement of FO LHD system

Another critical components of FO LHD is the laser light source, its wavelength being a critical consideration for FO LHD because of natural attenuation losses in commercial fiber optic cable. The main cause of attenuation is due to water absorption, for most installation environments, it is omnipresence.

Designers of FO LHD can choose to avoid the tails of water absorption peaks by shifting laser operating wavelength to 1064nm. Such design decision overcome the hidden problem from using telecom laser operating at 1550nm, a gradual reduction of system optical budget is expected after a few years due to Water Absorption peak attenuation and results in lower system reliability.

FO LHD uses modern digital signal processing further optimise the power requirement of the laser source [3], one challenge is to increasing transmission range, without using a higher power laser source. Another is to address the problem of needing to couple sufficient intensity of laser light into the length of fiber. FO LHD in Linear Heat Detection applications already employ DSP to further implement robust mathematical code that achieves 10km range on commercial FO cable using only Class 1M low power laser source.

4. Deployment

Early Fire Detection of trough belt conveyor system is described, its full length coverage includes head/drive end, transfer station and of important drive components; FO cable is mounted along the belt conveyor onto the idler stations. A location sufficiently close to detect heat from fire and overheating idlers is selected, and FO cable is attached using metal spring-loaded clips, the termination of FO cable is brought into an equipment room for DTS to access the FO cable, power supply, Fire Alarm panel and suppression controllers via SCADA.

Figure-9: FO cable mounted on idler station of a trough conveyor

At tank farm, Floating Roof Tank (FRT) storage tank store fuel oil, and Rim Seal Fire detection is achieved with FO cable fitted along the rim seal area located on the floating deck. Each tank holds fuel oil for the its power plant, Appareils destinés à être utilisés en **AT**mosphères **Ex**plosives (ATEX) directive compliance is compulsory for installation within an area that could cause an explosion. A single pass of FO cable is routed consecutively to each storage tank and covering the rim seal area, metal brackets are mounted to suitable points at about 1m intervals. The FO cable is terminated to the control room where power and relay interfacing the suppression controllers

Fig: FO Cable mounting on Rim seal area of a FRT.

4.1 Outline of test

At a tank farm installation located in the Middle East, 1450m length of FO cable was routed on the site reaching all storage tanks, the tank is about 14m in diameter and is of similar height. Each rim seal area is defined as a Fire Detection zone being 14π in length, at this location, the FO cable is exposed to the atmosphere.

FO LHD controller equipment

FO LHD controller manufacturer: AP Sensing
Model: Linear Heat Series N4387B, 2km, 2ch
Spatial resolution 3m
Sampling Interval 1m

FO sensing cable

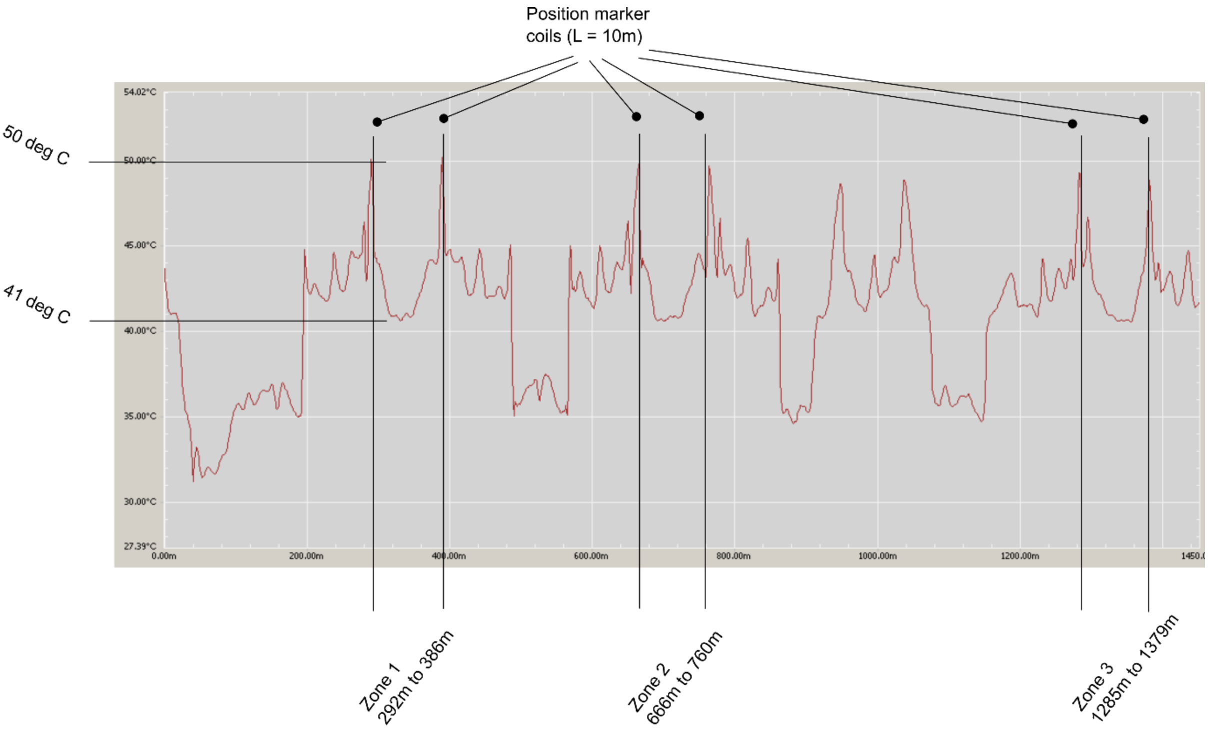
For each channel, a single length of 50/125μm multimode FO cable was used, the FO cable reached to the Rim Seal area of four Floating Roof Tanks. To assist visualisation, position marker coils of 10m each were additionally implemented at the physical start and end position of each zone.

The FO LHD controller has four zones programmed (three zones on Ch1 and one zone on Ch2), the pre-programmed temperature alarm criteria being a static temperature of 65 deg C.

4.2 Test condition and discussion

With system installation completion in September 2011 and during a recent routine service visit in August 2016, an updated temperature profile was captured.

Inspection of the temperature profile below revealed the temperature profile along the entire length of the FO cable of Ch1. In this paper, we focus on the temperature at Zone 1, 2 and 3.



With the FO LHD in measurement mode, any fire detected at the aforementioned zones will be represented as heat exceeding the 65 deg C threshold. From examination of several temperature profile of Ch1, it was confirmed the maximum temperature measured does not exceed 45 deg C throughout a 24-hour period. Position Marker coils of 10m length are easily seen on the temperature profile as peaks at the selected spatial resolution.

To simulate fire condition, a heat-gun was used to locally heat a section of the FO cable to increase the temperature. The FO LHD compares the temperature information with the pre-programmed alarm threshold. With the alarm criteria defined and having sufficient heat detected, the FO LHD controller energise a zone-mapped relay signalling an alarm from that zone. The section of FO cable was allowed to cool down and the relay became de-energized to signal the absence of temperature exceeding alarm threshold value.

5. CONCLUSION

An overview of Belt Conveyor and Storage tank installations are described, enabling the FO cable to reach difficult and remote locations. The main installation challenges were to minimise down-time by using field proven quick-and-simple installation methods. Installation take place during the short maintenance time [5], after FO cable is installed, mapping of physical zones along the FO cable is accomplished.

To demonstrate the importance of identifying and precisely locating the fire at industrial facilities, Fiber Optic Sensing cable is installed close to potential heat source of Belt Conveyor and Floating Roof Tank. Effective and efficient control of fire suppression equipment is achieved by accurately knowing the position of the heat source. [4] Oil refineries presents a hazardous environment from airborne dust and combustible material, demanding fire detection devices compliance to ATEX directive.

Internationally certified fire detection must be proven to be reliable, any false alarm represents potential discharge of suppression and unwanted cost to the end user to replenish the suppression and its clean-up, which translate to expensive down-time of the industrial facility such as an oil refinery.

Smothering fire or early fire detection is achieved with the same installation, further enhancement such as Fire Dynamic analysis is already reality with FO LHD continue to capture fire burn progress up to 750 Deg C for off-line analysis to further enhance the Fire Suppression and Rescue strategies.

A holistic view would see the combination of FO LHD with point form detectors deployed at strategic location of any industrial facility to benefit from coverage and speed of detection.

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