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Applicability of DTS as a Proactive detection system

C.A.P. Visagie
BBE Automation, South Africa

J.P Pearton
BBE Consulting, South Africa

ABSTRACT: There are numerous systems available for environment condition change detection. These systems vary in providing proactive or reactive detection, accuracy, coverage area, redundancy, maintenance and cost. When considering a system for conveyor installations, one would compare them based on reliability, survivability and availability. Proactive controls reduce the likelihood of the unwanted event while reactive controls reduce the consequence. Generally, the more proactive the control, the lower the total cost of ownership. If the likelihood can be reduced to the extent that one is certain that the event will not occur, it means that the unwanted event is entirely eliminated and that further capital for reactive controls is not required. If the objective of achieving zero harm is to be realised, the likelihood of a fire and the potential consequences must be appropriately addressed within the limitations of what is practical and feasibly possible. This paper will discuss the effectiveness and applicability of Distributed Temperature Sensing (DTS) as a proactive system for fire prevention in underground conveyor systems.

1 INTRODUCTION AND BACKGROUND

Underground conveyor belt fires are one of the leading risks found throughout the underground mining industry. The risk is present due to the presence and combustible nature of the materials used on and around the conveyor installation acting as a fuel, possible heat sources from friction and hot work activities and the availability of oxygen, all three components required to start and sustain a fire.

Underground conveyor belt systems form an integral part of ore transportation in many underground mines. They are typically installed in underground excavations (declines and tunnels) that serve as either (preferably) return or intake airways. When a belt burns, the composition of the belt produces high concentrations of toxic gases, heat and dense black smoke, that can rapidly spread into the ventilation system depending on the ventilation control status. The large amount of combustible material available increases the probable severity of causing harm during a fire.

Test work was carried out to prove the effectiveness of a DTS system to be used as a proactive fire prevention system on conveyer belts, using LIOS Technology equipment with the assistance of Advanced Automated Systems (AAS).

2 OBJECTIVE

The objective of these tests was to determine a DTS system's effectiveness using different methods of installation on conveyor belts in order to be used as a proactive method of control or detection.

DTS systems technology is designed to detect a change in temperature from either radiated or conducted heat. With conveyor belts structures mainly consisting of structural steel, the test mock-up conveyor allowed the opportunity to test for both types of heat transfer and detection.

3 PROACTIVE VS. REACTIVE CONTROL

3.1 *Proactive*

The Oxford Dictionary defines the word proactive as "(of a person or action) Creating or controlling a situation rather than just responding to it after it has happened". A proactive system is when controls are selected that are able to address all possible causes of a fire and include either redundancy or supportive controls so that the likelihood of a flame occurring is negligible. A proactive approach is usually both the safest and lowest total cost solution.

3.2 *Reactive*

The Oxford Dictionary defines the word reactive as "Acting in response to a situation rather than creating or controlling it". A reactive design is selected when a proactive control is unable to reduce the likelihood of the unwanted event from occurring or limit the area in which the unwanted event is likely to occur. The optimal solution then becomes a reactive one where the controls need to be able to extinguish a fire anywhere along the length of the conveyor before it can cause harm or serious damage.

4 DETECTION SYSTEMS

There are numerous fire detection systems available. These systems vary in whether they provide proactive or reactive detection, accuracy, coverage area, redundancy, maintenance and cost. Systems that could possibly be used on a conveyor installation were therefore listed and have been compared based on reliability, survivability and availability. The available detection controls are briefly described below:

4.1 *DTS*

Distributed Temperature Sensing (DTS) or Linear Heat Detection uses a fibre optic cable installed along the excavation. The controller at one end of the cable sends a pulsed signal down the fibre and the backscatter enables the temperature of the fibre to be accurately measured at 250 to 500 mm intervals for up to 10 km. When the heat source being measured is small, the position of the cable is crucial to ensure that the cable detects the radiation, convection or conductive heat.

4.2 *Thermal Imaging*

Thermal imaging cameras are able to detect the temperature of objects which can be used to trigger alarms. Cameras are limited in that they require line of site. The accuracy can also be affected by dust.

4.3 *Infrared Cameras*

Infrared cameras are able to measure the infrared spectrum and determine if there is a fire. The range is limited as the further the fire is from the camera, the larger the fire has to be before being detected.

Multiple cameras are therefore necessary to monitor the required area and the cameras are easily affected by dust.

4.4 *EMS and AMS*

The Environmental Monitoring System (EMS) and Air Monitoring System (AMS) comprise of CO, smoke and temperature sensors that are installed at key locations throughout the mine as a means to detect fire and ensure a safe work environment. Air velocity, direction and dilution as well as external influences such as dust and fumes from diesel equipment, all reduce the sensitivity of the system.

4.5 *RTD and Thermocouples*

Bearing temperature monitoring uses Resistance Temperature Detector (RTD) or thermocouples installed in the bearing to measure the temperature. The system if cheap and effective but is limited to measuring bearing, motor and gearbox temperatures.

4.6 *Reactive Detection Systems*

Firewire makes use of a pressurized tube that ruptures or an electrical cable which melts allowing the electrical wires inside to short and activate an alarm or suppression system.

Thermal linkage systems are typically alcohol bulbs where the temperature rating of the bulb can be selected. Once this temperature is reached, the bulb breaks and the suppression system is activated. Thermal linkage provides a practical solution which does not rely on electrical power and generally activates the required area only.

Table 1 provides a comparison of the systems as proactive controls with the questions adjusted based on the control requirements

Table 1. Proactive control systems

CONTROL QUALITY CALCULATION:		Thermal Imaging	Linear Heat (DTS)	EMS	Bearing Temperature
Reliability	Will the control detect heat/gas prior to a flame?	2	2	0	1
	Is the technology proven?	2	2	2	2
	Is the technology proven for early detection on underground conveyors?	1	0	0	2
	Is the system failsafe/ have redundancy?	1	2	1	0
	Is the design practical for full length of belt?	0	2	2	0
Survivability	Can it be damaged, impaired?	1	1	1	1
	Can the control be maintained during normal operating hours?	2	1	2	1
	Is failure automatically detected?	1	2	1	2
Availability	Can the system operate without mains power?	1	1	1	1
	Is the system easy to maintain?	1	2	1	2
	Can the control be tested to confirm correct operation?	2	2	2	1
Weighted Score		**14**	**17**	**13**	**13**
Control Quality Score		**64%**	**77%**	**59%**	**59%**
** Scoring: Good = 2; Average = 1; Poor = 0*					

5 DTS

DTS systems have been successfully used in installations such as metro and train tunnels, manufacturing and warehouses, cable installation monitoring and conveyor belt systems.

DTS fibre optic systems monitor the entire length of the cable and display the real-time temperature and heat transfer of the entire area at once. Based on the quantum mechanical RAMAN-effect and a patented code-correlation measurement technique AP Sensing's "Linear Heat Series" measures an accurate temperature profile along the optical fibre over several thousand meters with measurements every 5 to 10 seconds.

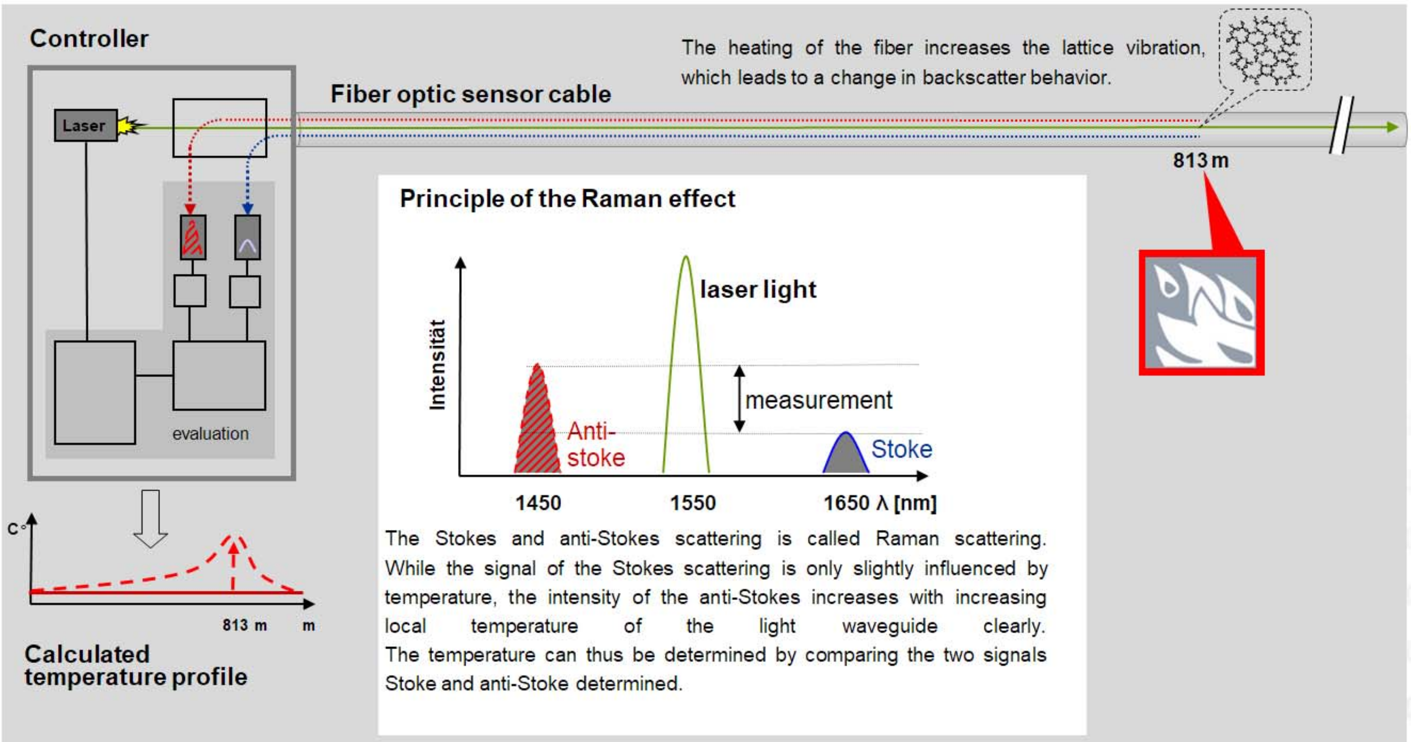

Figure 1. Principle of the Raman effect

6 DTS REDUNDANCY

The systems available typically have two types of redundancy, controller redundancy and fibre redundancy.

Controller redundancy refers to the use of a second controller and is in addition to the built-in redundancy that the controller has in order to comply with the standards for fire detection equipment.

It should be noted that any redundant system requires permanent power in the form of an uninterrupted power supply (UPS) powering the DTS controllers and any form of network communications between the controllers and the managing software.

6.1 *Non-redundant system*

A system with no redundancy is when a single fibre optic cable is installed to a single channel on a DTS controller and terminated in the field. Should there be a break on the fibre optic cable run, monitoring will be maintained up to the position of the break only and the remainder of the cable run will be unmonitored. The monitored values will also be compromised due to calibration issues in the fibre systems.

Figure 2. Non-redundant system

6.2 *Fibre redundant or looped system*

A fibre redundant or looped system is where the fibre optic cable starts and terminates at the same DTS controller using two independent channels as illustrated in Figure 3. This requires a controller with double the number of channels and twice the length of fibre optic cable. It enables the fibre to be monitored from both sides so that the system's ability to monitor the network is not affected outside of the actual broken section. If the cable is damaged in two places, the middle section will be unmonitored. Although the controller has built-in redundancy, if it does fail the system will be unmonitored.

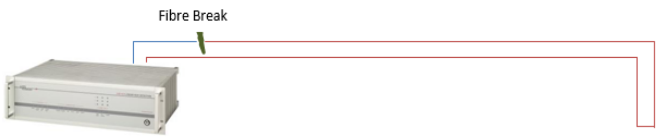

Figure 3. Fibre redundant or looped system

6.3 *Controller redundant system*

A controller redundant system is where the fibre optic cable starts at one controller and is terminated at a second controller at the end of the installation. This requires two controllers and only a single length of fibre optic cable. It enables the fibre to be monitored from both sides so that the system's ability to monitor the network is not affected outside of the actual broken section. If the cable is damaged in two places, the middle section will be unmonitored. If one controller fails, the second controller will continue to monitor the fibre.

6.4 *Full redundant system*

A full redundant system is where there are two fibre optic cables that start at one DTS controller and are terminated at a second controller as illustrated in Figure 4. This requires two controllers and two lengths of fibre optic cable but provides the highest level of protection. Both fibre optic cables would have to be broken in multiple locations in order for a section to be unmonitored.

Figure 4. Full redundant system

7 FIBRE OPTIC DETECTION

Fibre optic sensor cable is a passive element with little maintenance required and not influenced by Electromagnetic interference, dust and dirt (if spliced and installed correctly), extreme environment conditions or chemicals and other fluids. Fibre optic cable is also generally used for communication and process control systems on mines.

The fibre optic cable plays an important role in the DTS measuring system. It is generally designed for its application with a gel filled stainless steel tube and outer stainless-steel wire to protect the fibre cores from mechanical damage. A non-steel version is also available for use in electrical systems. The fibre cable has a limited bending radius that should be considered during installation to prevent the glass fibre cores from breaking or splintering. Figure 5 shows the typical fibre cables used by DTS suppliers.

Fibre optic sensor cable with the DTS technology adds to the continuous measurement over vast installation distances. The installed distance can be more than 10km, depending on the type of controller used and number of splices in the cable.

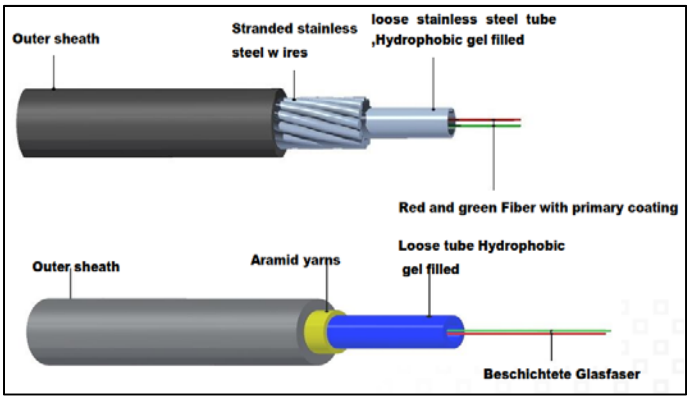

Figure 5. Fibre Optic Sensor Cable

8 EFFECTIVENESS OF DTS SYSTEMS

This application of the DTS system is to detect a rate-of-change of temperature, measuring heat from conduction and radiation from the idlers, conveyor belt, and surrounding steel as per installation. The DTS system is also able to determine hot spots pro-actively, activating an alarm or create control operator awareness.

The following tests were conducted based on the possible heat generating components along the length of a conveyor being mainly friction caused by seized idlers. An open butane flame was used to simulate the heat source by heating up the steel idler and the surrounding area.

- Conducted heat by means of strapping the fibre sensor cable directly in contact with the support frame steelwork of the conveyor, as close as possible to the idlers.
- Radiated heat by means of strapping the sensor cable parallel to a heated idler at 50 mm and 100 mm intervals.

Test readings indicated that conducted heat can be prioritised for the most effective early detection, whereas radiated heat will serve as an additional detection to augment the conducted heat sensing.

The test work was done outdoors with external conditions as follows:

- Spot test prior to heating was 19°C ambient on the conveyor steel structure
- DTS calibrated reading of the exposed conveyor steel structure prior to heating was 17°C
- Weather was reported at ~18°C (overcast and cold)
- Windage was minimal

8.1 *Conducted heat*

Two tests were carried out, one with ambient external conditions and the other with a fan applied to simulate the ventilation within the mine. Air speed at the conveyor was measured at approximately 2.5 m/s.

To simulate a real-life heating scenario, the system was heated from ambient and measurements, both on the DTS and actual surface, were taken at five-minute intervals. Note that the DTS readings were on the opposite side of a 100 mm wide steel channel, and not where the steel temperature was measured. Figure 6 shows a thermal image of the hot steel surface at the test section. Tables 2 and 3 show that the DTS measured temperature follows the trend in the temperature increase of the steelwork with enough agreement to enable accurate prediction.

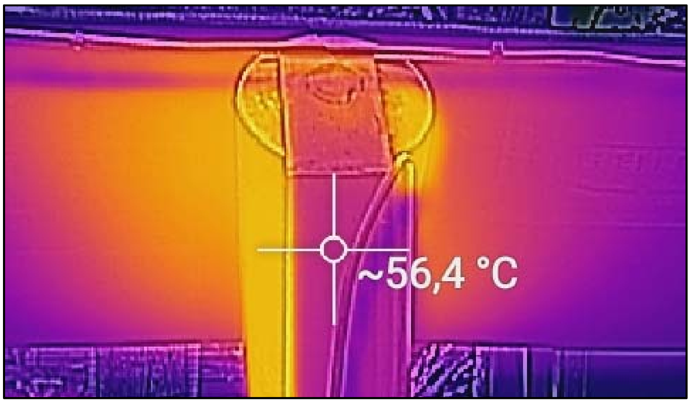

Figure 6. Temperature of idler frame steelwork due to conduction

Table 2. Conductive test without fan – Test No.1

Time	Laser Measurement	DTS Measurement
0 Minutes	20 °C	18 °C
5 Minutes	66 °C	21 °C
10 Minutes	64 °C	26 °C
15 Minutes	180 °C	54 °C

Table 3. Conductive test with fan – Test No.2

Time	Laser Measurement	DTS Measurement
0 Minutes	20 °C	18 °C
5 Minutes	87 °C	38 °C
10 Minutes	88 °C	40 °C
15 Minutes	139 °C	50 °C

8.2 *Radiated heat*

For the measurements to be as accurate as possible, the fiber optic sensor cable was kept away from the idler during the heating process. The idler was heated to approximately 300°C by means of an open flame. Once the idler had reached the desired temperature the heating process was stopped and the sensing fiber cable placed at 50 mm below and parallel to the heated idler for the first test as illustrated in Figure 7.

Figure 7. Fibre sensing cable installed for radiated heat test

As the idler cooled, spot readings were taken on the surface of the idler at the same time intervals as the DTS readings. As the results in Table 4 indicate, even as the idler cooled, the DTS reading increased from ambient temperature, thus giving a definitive reading for the desired purpose.

The second test was exactly the same with the exception of the distance from idler to fibre sensor cable. In this case the DTS readings can be seen starting to decrease after 3 minutes. This is due to the external factors having a more significant effect on the fibre cable at the 100 mm offset.

Table 4. Temperature readings based on distance from heat source – Test No.3

Distance	Time (min)	DTS Temp.	Idler Temp.
50mm	0	17 °C	~300 °C
	1	21 °C	243 °C
	2	23 °C	216 °C
	3	24 °C	175 °C
100mm	0	17 °C	~300 °C
	1	19 °C	242 °C
	2	23 °C	211 °C
	3	22 °C	193 °C

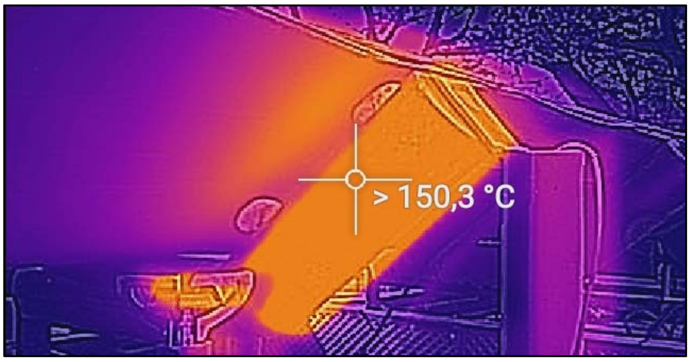

Figure 8. Temperature of idler just after heating sources have been removed

9 CONCLUSION

The test results on the effectiveness of the DTS indicated that the system is effective at determining an abnormal temperature rise along the conveyor, however the positioning of the cable is critical. The heat will be both radiated from the idler and conducted through the idler shaft to the idler frame and surrounding steelwork. This allows a sufficient length of cable to be exposed to both conduction and radiation, improving the sensitivity of the system.

The position of the cable should be as close as possible to the idler to detect radiated heat while being protected from being damaged due to material falling off the conveyor, cleaning or maintenance. The cable must be securely strapped to the steelwork using banded type strapping, which has a longer life than cable ties and will not break as easily if the cable is accidentally hooked. Being tightly strapped to the steelwork will allow the system to detect heat through conduction. This method of measuring the temperature will see a high temperature variation which will allow hotspots to be identified more rapidly and with more certainty.

The rate of change with conducted heat is significantly more than for radiated heat based on expected installation distances required between the cable and idler. Conducted heat does not require line of sight however it depends on the conductive properties of the structure and maintaining good contact between the cable and the structure. The impact of radiated heat is affected by both obstructions and distance. It is therefore recommended that the installation is based on conduction with the benefits of radiation being secondary.

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