# CONVEYOR BELT FIRE SAFETY – INNOVATIVE TECHNOLOGY FOR PROACTIVE SOLUTIONS

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## 1. INTRODUCTION

Conveyor belts do not spontaneously burst into flames, they require a significant amount of heat energy to burn; fire-retardant conveyor belts need considerably more.

It is the opinion of the author that most conveyor belt fires are preventable if the correct technology is utilised in measuring the environment around the conveyor installation.

This paper covers the following: flammability of conveyors, pyrolysis due to frictional heating, legislative requirements, preventative detection, detection along the conveyor belt, and cooling versus extinguishing.

## 2. FLAMMABILITY OF CONVEYOR BELTS

In a document published in 1956 entitled *Research to Develop a Schedule for Testing Conveyor Belts for Fire Resistance*[3], noteworthy testing was conducted to determine the ignition temperatures of various conveyor belt materials, as shown in Table 1.

| Sample No. | Type of Material | In Air | | | In Oxygen | | |
|---|---|---|---|---|---|---|---|
| | | Ignition Temp, °C | Time lag before Ignition, sec | Barometric Pressure, mm. Hg | Ignition Temp, °C | Time lag before Ignition, sec | Barometric Pressure, mm. Hg |
| 1 | 5-ply PVC | 463 | 14.4 | 745 | 381 | 18.8 | 742 |
| 2 | 4-ply Neopren e | 433 | 23.7 | 744 | 358 | 28.6 | 738 |
| 7 | 6-ply Rubber | 419 | 23.5 | -742 | 328 | 28.7 | 744 |
| 3 | 4-ply Rubber | 416 | 31.8 | 742 | 311 | 44.3 | 740 |
| 4 | do. | 406 | 24.5 | 742 | 315 | 32.3 | 746 |
| 6 | 7-ply Rubber | 405 | 22.1 | 742 | 300 | 34.7 | 744 |
| 5 | 4-ply Rubber | 403 | 33.7 | 743 | 303 | 17.4 | 745 |

Table 1. Summary of ignition temperature data in air and in oxygen on cross-sections of underground conveyor belting[3].

In South Africa, testing of fire-retardant properties on conveyor belts comply with the SANS 971:2013 standard: *Conveyor belting – methods of testing fire retardant properties of all conveyor belt constructions.*

In the SANS 971:2013 standard there are three tests done to determine the fire-retardant properties of a conveyor belt:

1. Flame resistance tests – SANS/ISO 340:2016
2. Drum friction test – SANS 971:2013/EN 1554
3. Flame propagation test – EN 12881-1 method C.

**CONVEYOR BELT FLAMMABILITY TESTS – SANS/ISO 340:2016**

SANS/ISO 340 test exposes individual samples of conveyor belt to a naked flame for 45 seconds causing them to burn. The source of the flame is then removed and the combustion time (duration of flame) of the test piece is recorded. Air is then applied to the test piece after the flame has died out to test if it will re-ignite[1].

Figure 1. SANS/ISO 340 test burner flame at 1 000 °C [2].

**Test result according to DIN EN ISO 340**

| Belt sample | Test according DIN EN ISO 340 | | |
|---|---|---|---|
| | Ignition Yes/No | Afterburning time | |
| | | With cover | Without cover |
| EPP 800/2 1.5/1.5, width 1000 mm (German) | Yes | 3 | 25 |
| EPP 800/2 1.5/1.5, width 1000 mm (German) | Yes | 4 | 39 |
| E/P-B-P/B 1000/1 PVC 2.5/2.5, width 1000 mm (UK) | Yes | 2 | 26 |
| EP 1000/3 2/2, width 1000 mm (Poland) | Yes | 1 | 3 |
| EP 1250/3 2/2, width 1000 mm (Poland) | Yes | 1 | 3 |

Table 2. Test results in a study by Edaffic [2].

**DRUM FRICTION TEST – SANS 971:2013/EN 1554**

This test simulates a belt slipping over a seized pulley or a pulley rotating under a stationary belt. On the surface, no flame or glow may be visible. A force of 343 N is maintained for one hour or until the test piece breaks[4].

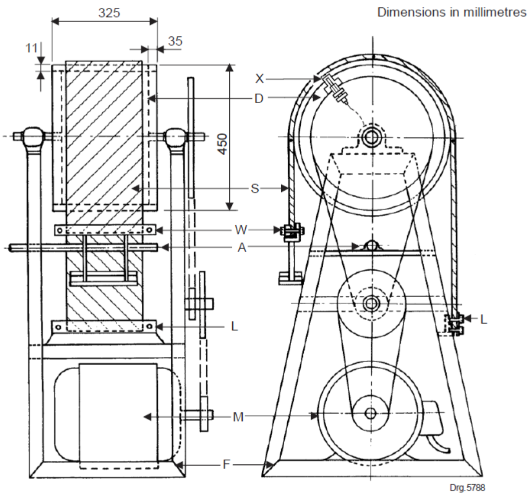



Figure 2. SANS 971 drum friction test apparatus.

Due to the lack of local test results, test results according to DIN EN 1554 representing the ignition behaviour resulting from frictional heat are shown in Table 3[2].

| Belt sample | Test according EN1554 Drum friction test | | |
|---|---|---|---|
| | Ignition Yes/No | Glowing Yes/No | Temperature Max [°C] |
| EPP 800/2 1.5/1.5, width 1000 mm (German) | No | Yes | 395 |
| EPP 800/2 1.5/1.5, width 1000 mm (German) | No | Yes | 407 |
| E/P-B-P/B 1000/1 PVC 2.5/2.5, width 1000 mm (UK) | **No** | **No** | **272** |
| EP 1000/3 2/2, width 1000 mm (Poland) | No | Yes | 363 |
| EP 1250/3 2/2, width 1000 mm (Poland) | No | Yes | 407 |

Table 3. Test results in a study by Edaffic[2].

Figure 3.  DIN EN 1554 drum friction test.

**FLAME PROPAGATION TEST – DIN EN 12881-1**

DIN EN 12881-1 describes four methods for measuring the propagation of a flame along a conveyor belt which has been exposed to a relatively high localised heat source such as a fire. The damage suffered by the conveyor belt, as well as its tendency to support combustion, is measured by observing the extent to which the fire spreads along the test piece.

In method C of the standard, a burner with six nozzles is applied for 50 minutes with a flow rate of 565 g/min of propane on a 1.5 m sample.

Figure 4.  EN 12881-1. Method C. Test gallery.

**Results of tests according to DIN EN 12881-1, Method C[4].**

| Belt sample | Propane rack test with the double burner DIN EN 12881-1, method. C | |
|---|---|---|
| | Average burned length (cm) | Test passed |
| EPP 800/2 1.5/1.5, width 1 000 mm (German) | 47.85 | Yes |
| EPP 800/2 1.5/1.5, width 1 000 mm (German) | 30.84 | Yes |
| E/P-B-P/B 1000/1 PVC 2.5/2.5, width 1 000 mm (UK) | 36.40 | Yes |
| EP 1000/3 2/2, width 1 000 mm (Poland) | 29.51 | Yes |
| EP 1250/3 2/2, width 1 000 mm (Poland) | 29.51 | Yes |

Table 4. Test results in a study by Edaffic[2].

In summary of conveyer belt flammability testing, conveyor belts require significant heat energy and time before they can burn freely. The heating of the conveyor belt is measurable and preventative action can be taken.

## 3. PYROLYSIS, THE INITIAL KILLER

Heating of a polymeric material induces thermal decomposition, releasing gases. The nature and flammability of these gases depend on the composition of the polymer. At high temperatures, sufficient gaseous products are produced to give a flammable mixture with oxygen, and ignition occurs[6].

Combustion continues if there is a sufficient supply of oxygen and a enough heat transfer from the flame to the solid material to give an adequate supply of flammable gas[6].

The main toxic risk from pyrolysis is hydrogen chloride (HCl) production. As little as 5 to 10 ppm can cause irritation to the mucous membranes[7].

For conveyor belting the HCl emissions are higher in the initial stage above 100°C than the steady-state stage. Most of the HCl is emitted as the polymeric material is being consumed in the initial stage. At the steady-state stage, the conveyor belt temperature averages 300°C[7].

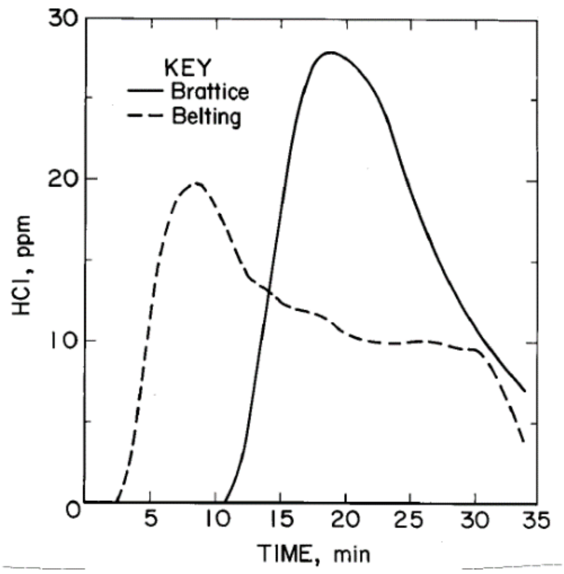



Figure 5. Results of typical HCl concentrations for conveyor belting.

Significant amounts of toxic fumes and smoke are emitted from a conveyor belt heating up to its ignition temperature, thus leading to an atmosphere that is not safe.

Subsequently, the sustained friction heat generated by the conveyor belt slipping over a stationary pulley or idler results in a large conveyor belt surface area releasing combustible gases and smoke.

When ignition point is reached, the conveyor will inevitably burst into flames.

## 4. LEGISLATION AND BEST PRACTICES

### MINE HEALTH AND SAFETY ACT, 1996 (ACT NO 29 OF 1996)[8]

**Chapter 5: Fires and Explosions** [8]

5.1(1) The employer must ensure that a competent person reports to the employer, at appropriate intervals determined in accordance with the mine's risk assessment, on

(b) The **adequacy** of measures in place to **prevent**, detect and combat the start and spread of mine fires.

**Chapter 8: Machinery and Equipment** [8]**.**

8.9.(3) The employer must take reasonably practicable measures to **prevent** persons from being exposed to flames, fumes or smoke arising from a conveyor belt installation catching fire, including instituting measures to **prevent**, detect and combat such fires.

**Chapter 9: Mine Environmental Engineering and Occupational Hygiene [8].**

9.1(2) Where the risk assessment at the mine indicates a significant risk of a fire and/or explosion and/or toxic release, that could lead to an **irrespirable** atmosphere or an atmosphere immediately dangerous to life or health, the employer **must** provide an **early warning** system or systems at all working places.

**Mandatory COP Conveyor Belt Installations; Annexure B; Fire Detection [9]:**

'There is a requirement for fire detection along the conveyor belt installation as the belt material can however also burn and give off noxious gasses'.

**Guideline for the Compilation of a Code of Practice on Emergency Preparedness and Response[10].**

**Reference 16/3/2/1-A5: 8.1.1 Detection and Early Warning Systems.**

- In order to ensure that emergencies are detected **as early as practicably possible** and persons are **warned timeously** of such emergency, the COP must cover at least the following:
  - Types and position of fixed detectors/early warning systems for the timeous detection and early warning of all identified possible emergencies.

It is understood from the legislation that the government's intent is to prevent employees from being exposed to any atmosphere that can be dangerous or which could negatively affect the wellbeing of an employee. Is the buzzword not 'Zero Harm'?

It is the opinion of the author that reactive conveyor fire protection systems only acting on a conveyance already engulfed by flames is irresponsible and not compliant with the objective set out by the Mine Health and Safety Act.

## 5. PREVENTATIVE DETECTION

Current fire detection equipment deployed in conveyor fire protection systems lack the ability to act preventatively upon the rapid heating of conveyance components due to friction.

**UV and or IR flame** detection equipment measures the radiation intensity of multiple frequency ranges in the electromagnetic spectrum, namely the ultra-violet (UV) and the infra-red (IR), both of which are present in fires.

Disadvantages

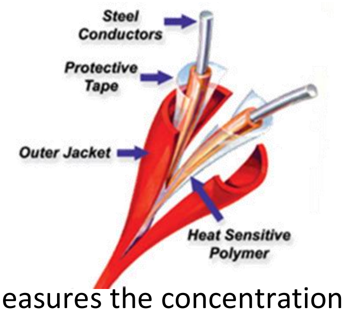
- *Requires a burning conveyor belt to react*
- Designed for static flammable fuel fires, not moving fires on a conveyor
- Slow response needs stationary fire
- High maintenance

- False alarms due to arc welding and grinding.

**Linear heat detection cable** consists of two cores separated by a polymer plastic that is designed to melt at a specific temperature making a contact that is monitored.

Disadvantages

- *Requires extreme ambient temperature to react, as generated by a burning conveyor belt*
- Very slow response time
- Prone to mechanical damage
- High false alarm rate
- Requires special care with installation.




**Carbon monoxide** monitoring, detects the presence and measures the concentration of carbon monoxide in the immediate vicinity of the detector in parts per million.

Disadvantages

- *Requires a burning conveyor belt to react*
- Accuracy easily affected by high air flow
- High maintenance and periodic calibration required
- Slow fire discrimination.


Background CO levels could easily mask early stages of fire CO levels.

**Fire sprinkler head (FM 7-11).** Sprinkler heads have a glass container filled with a glycerine-based liquid that expands at the pre-set ambient temperature; the glass then breaks and activates the sprinkler head.

Disadvantages

- *Requires extreme ambient temperature to react, as generated by a burning conveyor belt*
- Very slow response time
- 107 seconds to activate a 68°C bulb at an ambient temperature of 100°C with an air speed of 1 m/s

Conveyer belts do not spontaneously burst into flames, there is a significant measurable temperature build-up phase leading to pyrolysis and ultimately to ignition, then fire.

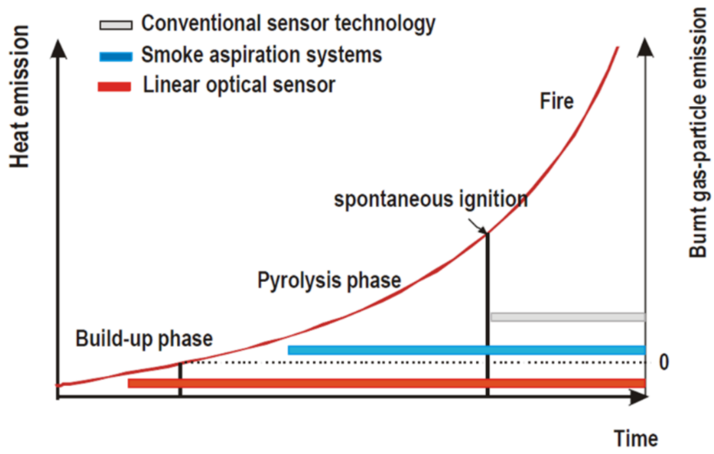



Figure 6. Graphic representation of the escalation from frictional heat to fire.

## 5.1 Preventative Detection – Designated Areas

### 5.1.1 Pulley Bearing Temperature Monitoring

Monitoring is done by installing a temperature sensor on the plummer block of all major pulleys to accurately measure the temperature of their operation.

If a temperature sensor measures temperatures exceeding the maximum rating of either the bearing or the lubricant, the conveyor belt can be tripped and further damage to the bearing can be avoided as well as the potential for frictional heat build-up due to a seized bearing.

### 5.1.2 Pulley and Conveyor Belt Surface Temperature Rise Monitoring

There is a measurable rate of temperature increase in belt surface temperature and the surface temperature of the pulley when the belt is slipping over a stationary pulley.

There is also a measurable rate of temperature increase in the surface temperature of the pulley when the pulley is slipping on a stationary conveyor belt.

A pneumatic-electronic linear fire detector using a capillary tube can detect the increase in temperature proximate to the conveyor belt as a function of the rate of change over time (Δt) irrespective of the starting temperature.

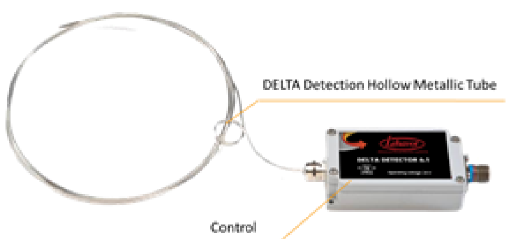



Figure 7. Pneumatic-electronic linear fire detector.

## 5.2 Operation of the Pneumatic-electronic Linear Fire Detector

**Gay-Lussac's Law**

Gay-Lussac's law, or the pressure law, was pronounced by Joseph Louis Gay-Lussac in 1809. It states that, for a given mass and constant volume of an ideal gas, the pressure exerted on the sides of its container is proportional to its temperature.

*Practical Application*

The volume of the capillary tubing is constant. However, as the environmental temperature changes, the air temperature within the capillary tubing also changes and thus the pressure increases proportionally to the temperature.

**ΔT or Delta-T**

Where the change in temperature is Delta-T and each temperature T1 and T0 are given in degrees Celsius:

Therefore

$$\Delta T\ (°C) = T1\ (°C) - T0\ (°C)$$

**Newton's Law of Cooling or Heating**

Newton's Law of Cooling states that the rate of change of the temperature of an object is proportional to the difference between its own temperature and the ambient temperature (i.e. the temperature of its surroundings).

*Practical Application*

The pressure transducer in the delta detector measures the pressure constantly to determine the rate of change in pressure over duration. Since the pressure is proportional to the temperature, the change is measured in °C/min.

When the rate of change exceeds the set point, the total gain in temperature over the period is calculated as Sigma T in °C.

The alarm condition is a function of both the rate of change in temperature and the total gain in temperature.

## 6. DETECTION ALONG THE CONVEYOR BELT AS PER THE MANDATORY COP

The current technology utilised for this application suffers from the same inherent flaws as does the technology used for designated area conveyor fire detection in that it requires a burning conveyor belt, and lacks the capability of determining the exact position and temperature of the fire, as well as the direction of fire spread and the propagation of the toxic fumes and smoke.

The Mandatory COP for Conveyor Belt Installations; Annexure B; Fire Detection refers to 'noxious gasses'. Referring to the study of the gases released at the pyrolysis phase due to frictional or other heating of the conveyor belt, it is essential to rather measure the temperature in real-time along the conveyance installation to detect overheating components before they pose a significant threat to the conveyor belt.

### 6.1 Distributed Temperature Sensing

Distributed temperature sensing systems are optoelectronic devices which measure temperatures by means of optical fibres functioning as linear sensors connected to an evaluation unit.

Unlike conventional temperature sensors, temperatures are recorded along the optical fibre sensor cable, thus not at points, but as a continuous profile.

The heating of the optical fibre sensor cable increases the lattice vibration, which leads to a change in backscatter behaviour called the Raman effect; measurement of the local temperature at any given point along the optic fibre sensor cable is derived from the relative intensities of the anti-Stokes and Stokes light.

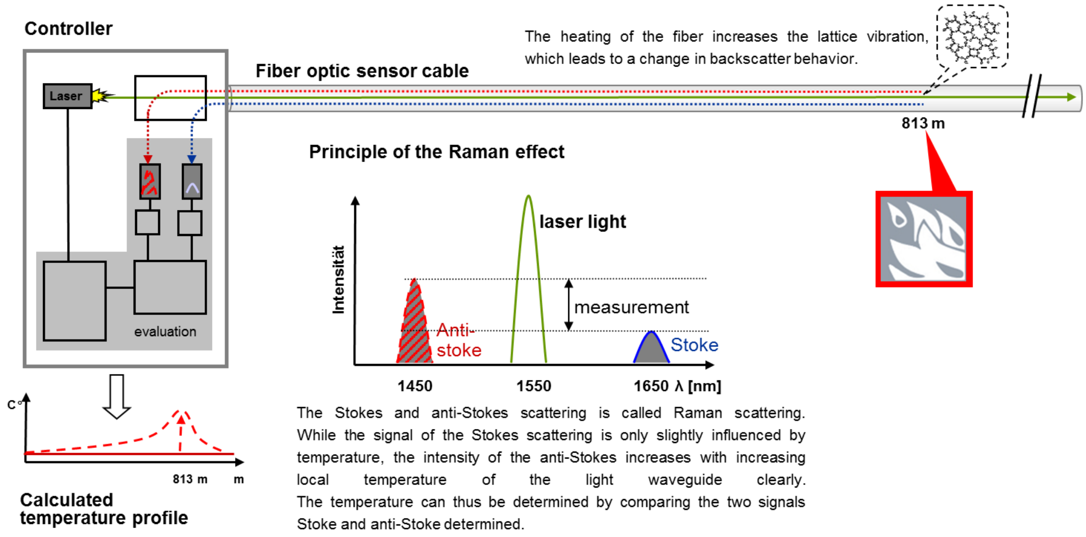



Figure 8. Graphic representation of the operation of a distributed temperature sensing system.

Distributed temperature sensing systems deploy the method of optical frequency domain reflectometry (OFDR).

The fibre optic radar system can detect thermal overloading during the first phase of initial damage (build-up phase) prior to or during the early pyrolysis phase.

OFDR technology provides an unchanged spatial resolution along the entire sensor length, in contrast with OTDR technology, which is affected by a broadened spatial resolution.

OFDR distributed temperature sensing systems can continually measure the temperature with a very high accuracy of 0.01°C and resolution down to 0.25 m over distances up to 10 km.

The OFDR distributed temperature sensing systems have a temperature measurement range of -180°C to +1 000°C depending on the sensor cable. The optical fibre sensor cable responds faster to temperature changes than conventional thermal sensors due to its low mass.

The optical fibre sensor cable requires no maintenance and is absolutely immune to humidity, dirt, dust, smoke, corrosion, electromagnetic fields or radiation. It is also certified for explosive environments ATEX zone 0, for gas and dust.

The optical fibre sensor cable itself is strong, resilient, and flexible and can be mounted close to the conveyor belt and onto the plummer blocks.


Figure 9.  OFDR distributed temperature sensing evaluation unit.

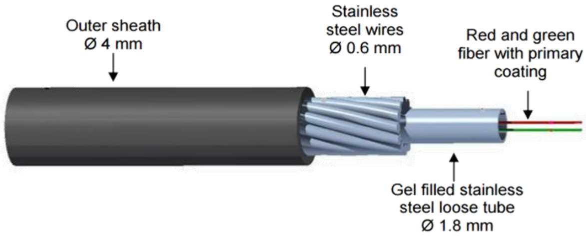
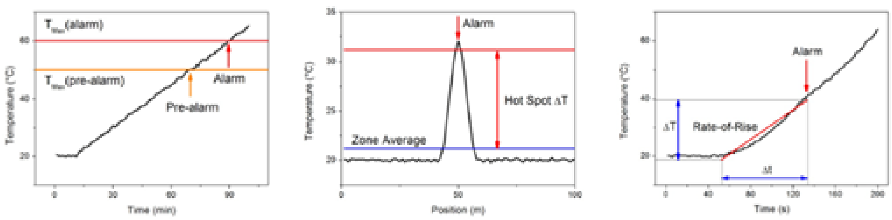



Figure 10. Optical fibre sensor cable.

OFDR distributed temperature sensing evaluation units can have up to four channels and each unit channel can accommodate up to 10 km of optical fibre sensor cable.




**Maximum temperature**

Smouldering fires
Alarm at e.g. 60°C

**Hot spot**

Small, localized heating
Alarm at e.g. ΔT = 10°C
e.g. bearing of conveyor belt

**Rate-of-Rise**

Fast starting fires
Alarm at e.g. 10°C/min

Figure 11.  Graphic representation of alarm triggering parameters.

Up to 1 000 zones can be freely configured for every optical fibre sensor cable channel. The zones can be configured as small as 0.5 m, and every zone can further be configured with five pre-alarm and five alarm parameter sets.

The distributed temperature sensing systems can monitor vast infrastructure starting from a single evaluation unit. The optical fibre sensor cable can be routed through all types of critical areas ultimately providing a constant overview of the entire infrastructure.

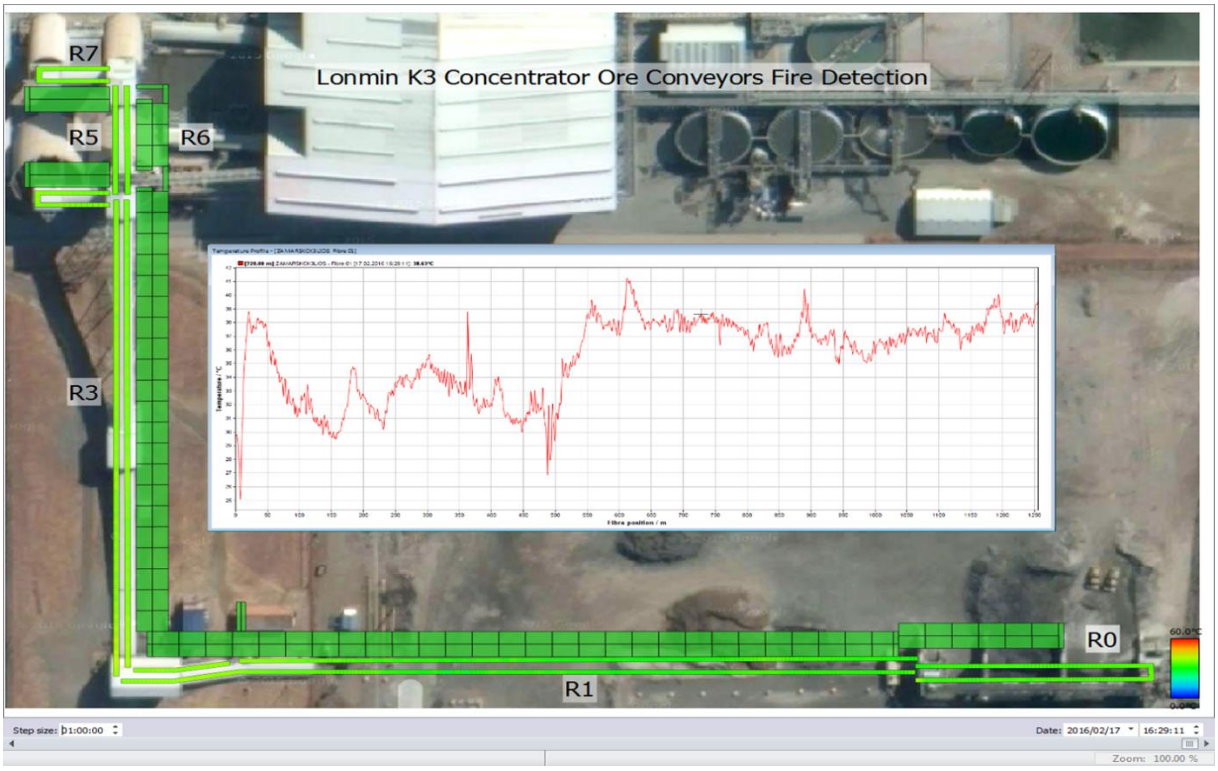



Figure 12. Graphic representation of the temperature gradient information along a conveyor installation.

## 7. COOLING VERSUS EXTINGUISHING

Current conveyor belt protection systems deploy water deluge spray systems to suppress a fire after its detection.

It is the opinion of the author that extinguishing is not an efficient way of dealing with a conveyor belt that is on fire, it is better to prevent than to combat.

There is significant temperature build-up that is measurable before the start of a fire, which can trip the conveyor belt when it is heating up. A wet chemical agent can cool the hot conveyor belt surfaces, pulley surfaces and plummer blocks.

The main composition component of the wet chemical agent is ethylene glycol with a specific heat capacity 3 140 J/kg°C, that acts like a heat sink to absorb heat energy away from the conveyor belt, inhibiting the forming of combustible gases.

The wet chemical agent's composition also contains phosphates which react chemically within the fire chemical chain reaction and create stable bindings which are not combustible.

The wet chemical agent's composition also contains foaming agents which create a film foam seal on the conveyor belt to prevent atmosphere penetrating, thus inhibiting the forming of combustible gases.

The wet chemical agent system is deployed on the frictional surface of the conveyor belt specifically at designated areas were the greatest risk of a frictional fire could occur.

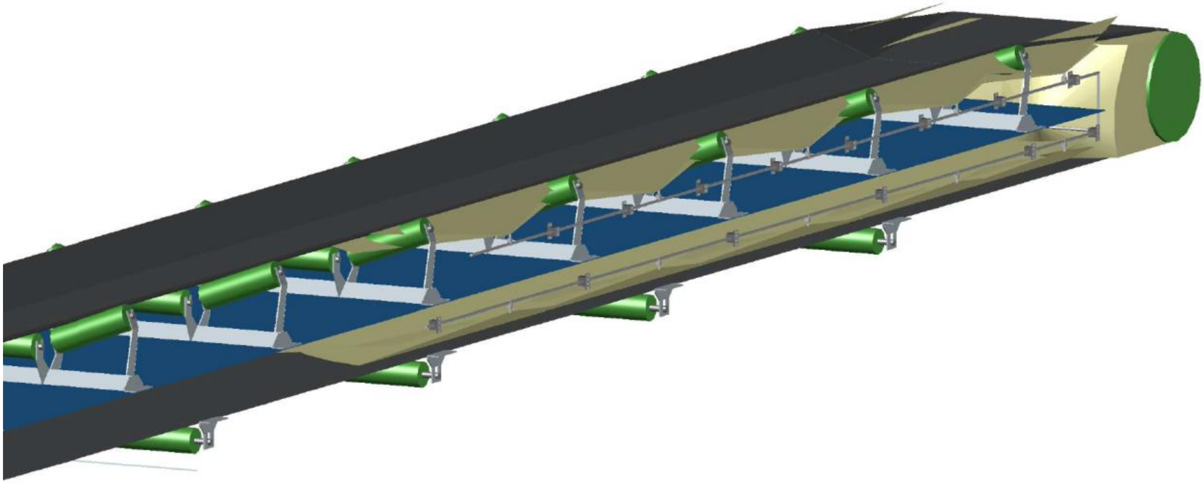


Figure 13. Graphic representation of a typical wet chemical installation on a designated area of a conveyor belt.

The wet chemical system is capable of effective fire extinguishing at high air flows up to 3 $m^3/s$ volumes, and has been tested to stringent SPCR 183 and the FM 5970 certification[11].

It has a piston agent tank providing a constant discharge pressure of 7 bar at the nozzles for the full discharge duration[11].

It also has automatic activation by a dedicated fire control panel and manual mechanical activation which is not reliant on power.

## 8. CONCLUSION

After investigating the testing involved concerning the flammability of conveyor belts, the conclusion is that conveyor belts require significant heat energy and time to burn freely.

This heat energy is measurable with the latest pneumatic-electronic linear fire detectors and distributed temperature sensing systems utilising optical fibres.

If these conveyor belts are left undetected, frictional heat can cause a significant mix of toxic, combustion cases and smoke.

The Mine Health and Safety Act aims to prevent people from being exposed to flames, fumes and smoke, thus it is necessary to monitor the conveyor belt environmental temperatures in order to detect as early as possible any significant temperature changes and to react preventatively.

Deploying a wet chemical agent on the designated area affected by frictional heat to cool down the conveyer belt and inhibit the generation of combustion gasses and prevent fire is one such preventative method.

It is the author's opinion that by applying proper risk assessment and the correct technology, most if not all, conveyor fires can be prevented, saving lives and ensuring business continuity.

## REFERENCES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11 Dafo Forrex Test of fire suppression system for buses and coaches according to SP Method 4912.

## ABOUT THE AUTHOR

HERBERT SCHMITZ

Herbert Schmitz is the co-founder of two companies namely Advanced Automated Systems which specializes in engineered risk solutions and AMIT Technologies which currently holds two international patents and several intellectual properties within mining safety.

By utilizing his experience in the mining sector and developing unique state of the art engineered solutions for fire and other operational risks Herbert together with his partners currently hold the distribution rights to some of the world's leading technologies namely Dafo, Lios-Tech, Telefire, Lehavot, Exxfire, Elotech, MSR, Thermarestor, Safex, Firefly and FirePro.

Herbert worked closely with a major platinum producer in the Rustenburg area for three years in developing the first proactive fire protection system which is fully compliant with the requirements of the Mines Health and Safety Act.

He is committed to continuous improvement of fire protection standards and serves as an industry expert on various fire related work groups within the South African Bureau of Standards.

Herbert constantly informs the industry on the latest technologies available by presenting some of his research at various forums such as the MineSafe conference.

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