FIRE DETECTION AND SUPPRESSION ON UNDERGROUND CONVEYOR BELT INSTALLATIONS

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BACKGROUND

On 20 September 2004, a fire occurred on a conveyor belt installation underground at a platinum mine in the western limb of the Bushveld Complex. Nine people died during the fire despite wearing self-rescuer apparatus and the relative availability of nearby refuge chambers. The cause of the fire was a poorly fitted bearing on the tension pulley that eventually seized due to misalignment. The bearing collapsed as shown in Figure 1 and the friction generated between the pulley shaft shown in Figure 2 and the bearing started the fire. No detection or suppression systems were installed and the entire conveyor belt installation burnt out.

Figure 1. Collapsed bearing

Figure 2. Pulley shaft

This tragic incident caused all mining houses to review their fire precautions on conveyor belt installations with special emphasis on those underground. At Anglo American Platinum it was apparent that little was in place except hose reels and portable fire extinguishers. Neither of these could really be classified as being effective to fight a fire of this magnitude, especially after it has started and been burning for a while.

In light of this, a decision was made to install automatic detection and suppression systems. There was to be no dependency on human intervention to suppress a conveyor fire. It is human nature to run away from fires and in an underground situation this behaviour would be expected and should be anticipated. The overarching principle adopted was to monitor and detect all sources of heat and should any abnormal heat be detected, to take the appropriate action. The primary objective was to eliminate any potential for a flame condition to occur.

A brief survey conducted with fire professionals, environmental engineers and safety departments indicated that about 90 per cent of conveyor fires are caused by either the pulley bearings or the friction between the pulleys and the belt due either to stuck rocks, linings or misalignment. The third most likely cause is hot work. Personnel conduct hot work either on the conveyor installation or boxes and chutes feeding the belt. Sometimes hot slag lands on or near the belt and is not detected before the crew leave site.

LEGISLATION

The latest conveyor regulations for South African mines and works were published in August 2013. There are two regulations that relate to situations that could lead to fires on conveyor belts:

Regulation 8.9.2 (d) states:

> *The employer must take reasonably practicable measures to ensure that the driving machinery of the conveyor belt installation is stopped should the belt break.*

Most belt installations that are between elevations normally have anti-roll-back idlers or other means of arresting a broken belt. This situation is not likely to cause a fire even if the belt runs away. The big danger is a slipping or jammed belt for whatever reason. To monitor slip or jam conditions on conveyor belts, a simple anti-slip tacho-motor device is fitted under the belt along the idler section as shown in Figure 3.

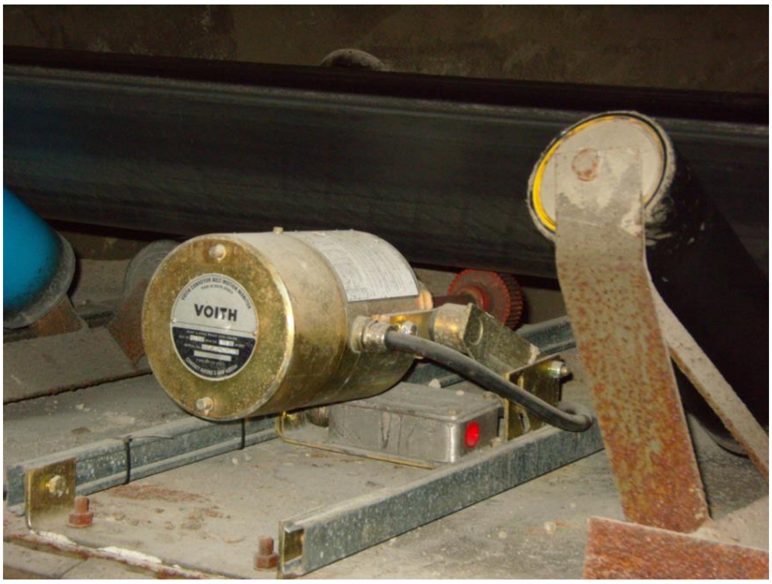

Figure 3. Anti-slip device

The anti-slip device is configured such that should the belt speed reduce by more than 20 per cent, the belt trips immediately and an alarm is sounded. The device is programmed in a way that it only takes effect after the belt runs up to full speed and stops functioning when the belt is stopped and runs down.

Regulation 8.9 (3) states:

> *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.*

This is not prescriptive and mining companies are able to decide on the level of prevention, detection and suppression depending on their appetite for risk.

GOVERNING BODIES

The most widely recognised body governing fire prevention in the world is the American National Fire Protection Association (NFPA). Their standards are used almost exclusively by most fire engineers and recognised by the majority of insurance companies as the standards to which insured companies should comply.

The other major body is Factory Mutual Global (FM). This body represents the interests of the insurance companies and their main role is to approve products used in fire detection and suppression installations such as valves, nozzles and other components. It is critical that any installation has all of its main components supplied with the stamp ’FM approved’ displayed. Should any non-approved components be used in an installation and a fire ensues, the insurance company could refuse to pay the claim.

The third body involved with fire safety, prevention, detection and suppression is Underwriters Laboratories (UL). This body tests and certifies all products related to fire engineering and submits their reports to FM for their approval. In addition to testing and certification, they are a major organisation in promoting safety awareness in relation to fires in general.

STANDARDS

The two most important standards relating to fire suppression on conveyor belts are NFPA 15 and 16. These two standards describe the requirements for water and foam based suppression respectively. Foam is defined as a mixture of 99 per cent water and 1 per cent foam concentrate. The concentrate is given the generic term Aqueous Film Forming Foam (AFFF). Although pure water is a good fire suppression medium, the foam media is much better as it forms a thin layer of foam skin on the surface of the conveyor belt. This is critical as belts often sprayed with water have been known to reignite after the water is switched off.

NFPA recognises the difference in the fire suppression capacities of both mediums and hence have two different criteria. NFPA 15 for water systems prescribes 10.2 litres per minute per square metre of belt coverage for thirty minutes. NFPA 16 for foam based systems prescribes only 6.5 litres per minute per square metre for ten minutes. From a volume perspective this equates to only 21 per cent of that which is required from the water based systems.

Figure 4 shows a conveyor drive pulley end after being sprayed with the foam medium. The thin film on the surface of the belt is clearly visible.

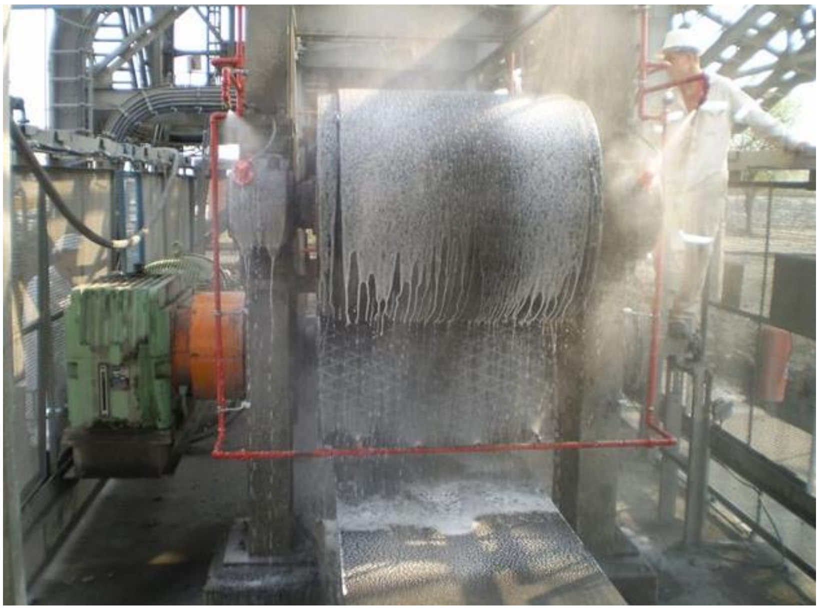

Figure 4. Drive pulley end after being sprayed with foam

METHODOLOGY

As mentioned above, Anglo American Platinum made the decision to detect abnormal heat and prevent any condition in which a flame could propagate. To achieve this objective, heat sensors were fitted to all pulley bearings and heat scanners located in close proximity to all pulleys. There were teething problems with some of the bearing heat sensors. One operation drilled holes into their bearing housings and fitted RTD100 temperature probes. These were unsuccessful because they were often stood on resulting in them breaking off. It was decided to stop using this method of measuring bearing temperature.

One of the fire detection and suppression companies established that the actual temperature of the bearing can be very closely estimated by measuring the surface temperature of the bearing housing. They developed their own temperature sensing device as shown in Figure 5. This was an analogue two-wire system.

Figure 5. Original bearing temperature sensor

It was estimated that when the surface temperature of a bearing housing is 68˚C then the actual bearing temperature is about 100˚C[1]. At this temperature the bearing grease liquefies and shortly afterwards the bearing seizes. To prevent this, the temperature sensor is calibrated to give an alarm and stop the belt should the surface temperature reach 68˚C. If the temperature reaches the 90˚C level, the system activates and initiates the full suppression sprays.

Although the first generation of bearing temperature sensors were reasonably robust, a later model was developed which is fitted between one of the housing bolts and the actual housing as shown in Figure 6 (a) and Figure 6 (b). This is a digital 4 – 20 mA system.

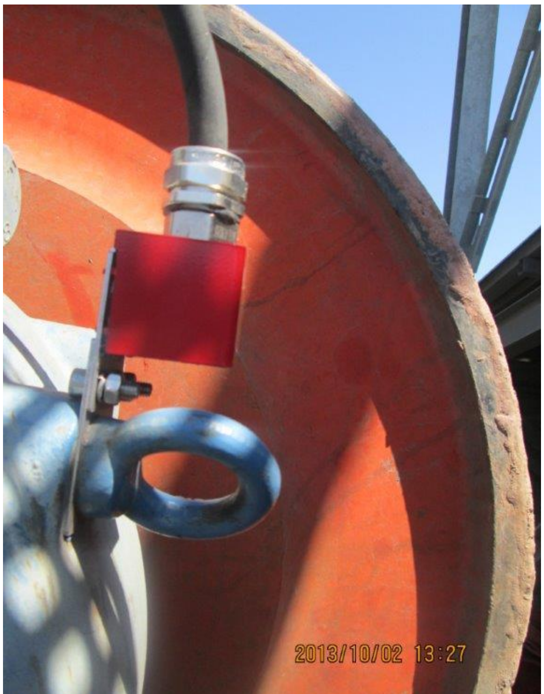

Figure 6 (a). Bearing housing temperature sensor

Figure 6 (b). Full view of sensor

Having dealt with the bearings, the next focus area was the pulleys. This represented a challenge since they rotate, so fixing temperature probes was not an option. It was decided to use temperature scanners fixed to a nearby structure and directed at the pulley surface. Similar to the bearing sensors, these general scanners are calibrated depending on the distance the sensor is from the pulley.

These temperature scanners are available in two different calibrated models – a 2:1 or 10:1 ratio. This means that a 2:1 ratio scanner can monitor a one metre wide surface from a distance of two metres. Similarly the 10:1 ratio scanner can monitor a one metre wide surface from ten metres. These would more than likely be used to monitor furnaces and other similar hot bodies. The conveyor belt fire models used are the 2:1 ratio due to the ability to fit them close to the pulleys. A typical installation is shown in Figure 7.

Figure 7. Temperature scanner mounted on conveyor structure

As for the bearing temperature monitoring, if a temperature of 68˚C is measured on the surface of a pulley, the belt is tripped and an alarm sounded. If it measures 90˚C, the full suppression system is activated.

The third and final level of detection is for a flame condition. To detect a flame from a distance requires a special sensing device called a triple infra-red (IR3) sensor as shown in Figure 8.

Figure 8. IR3 flame detecting sensor

These devices are calibrated in that they only sense a flame between certain spectrums. It is configured such that background lighting and passing trackless vehicles will not set it off. Any flame detected by the IR3 immediately activates the suppression system. The sensors have an AUTO/MANUAL switch to enable maintenance personnel to bypass it whilst working in the area especially with cutting torches.

Figure 9 is a typical schematic showing all three levels of heat and flame detection.

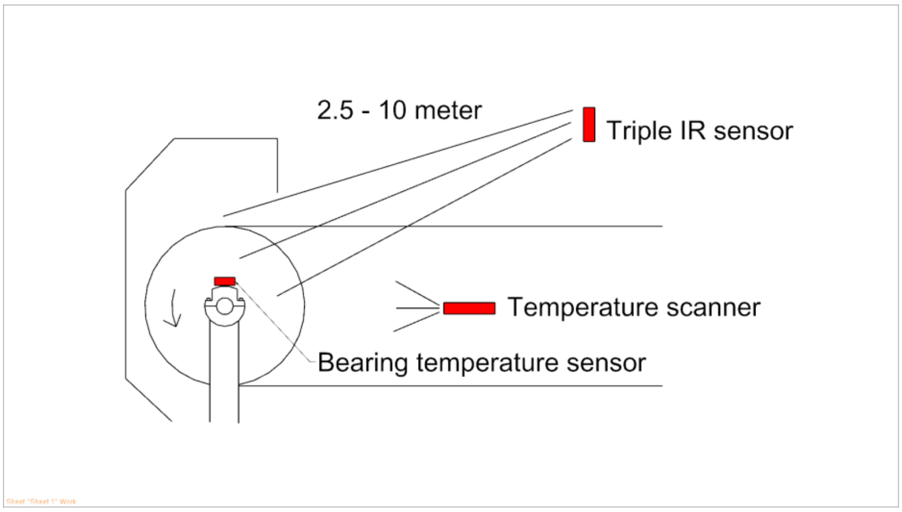

Figure 9. Typical installation schematic showing all three levels of detection

COVERAGE

Sophisticated software design packages have been developed to model the spray patterns and coverage. Such an example is shown in the model below in Figure 10.

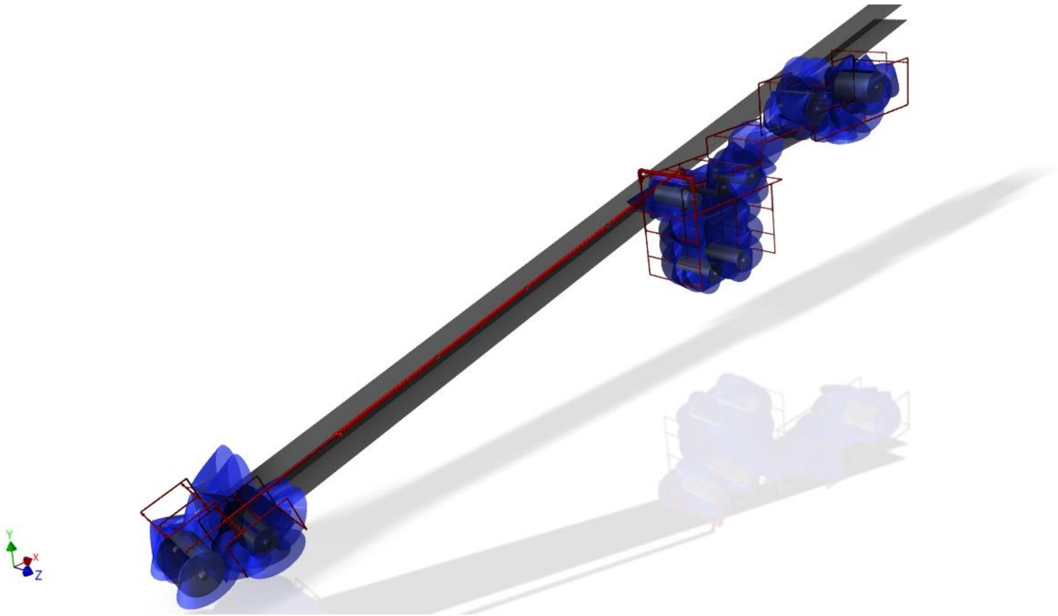

Figure 10. Model of spray patterns for a typical conveyor belt installation

INSTALLATIONS

As mentioned previously, there are two options as to the mediums used, either water or foam. In both cases normal mine water supply is used to feed the suppression systems. For the foam systems, a special arrangement is made to dose the mine water with the 1 per cent AFFF as it flows through to the suppression installation. Such an installation is shown in Figure 11 with a special non-electric dosing pump mounted on top to feed the AFFF into the pipeline.

Figure 11. In-line AFFF dosing system in accordance with NFPA 16

With the foam system, and mainly due to the low volumes required, a special stand-alone containerised system was developed especially for underground mining conveyor belt installations. It consists of a pressurised tank of pre-mixed foam feeding the suppression system. The tank volume is calculated according to the NFPA 16 formula and often more than one tank is required for an installation. The tank is pressurised using a nitrogen cylinder under 1 800 kPa pressure (18 bar). These systems are referred to as Compressed Air Foam systems (CAF). A typical installation underground showing the tanks and cylinders is shown in Figure 12.

Figure 12. A three tank CAF system installed underground

Every mine has the choice as to which system to install depending on their operational circumstances: water availability; pressure; storage volumes available; reliability of pipe networks and the like. The CAF system appears to be the preferred option due to its independence from the mine water supply and its stand-alone nature.

Bathopele mine in Rustenburg has gone one step further by installing a large storage tank on surface which is dosed with AFFF feeding the entire mine. In other words, all red fire piping underground contains foam. In the event of any fire, a medium with five times the fire suppression capabilities of water is immediately available. With Bathopele being a trackless mine, this is highly advantageous. Figure 13 shows the surface reservoir and dosing system.

Figure 13. Surface reservoir with AFFF dosing pumps at Bathopele

CONVEYOR FIRE INCIDENTS

Since the multiple fatal incident in 2004, several conveyor fire incidents have been reported. Some were surface mine conveyor fires and some were underground.

INCIDENT 1

As stated earlier, bearings, pulleys and hot work account for probably 98 per cent of conveyor fires. In this incident on surface, a trackless vehicle was clearing material in close proximity to the drive pulley of a conveyor feeding from the main shaft to the plant silo. The trackless vehicle reversed up against the drive end and was left there, idling for a short period. The heat from the engine was sufficient to burn some dry grass close to the drive and the entire conveyor caught alight. Again, no detection and suppression system had been installed. The extent of the damage caused by the fire is shown in Figures 14 and 15.

Figure 14. Surface view of conveyor fire`

Figure 15. Damaged idler section

INCIDENT 2

In March 2012, a fire broke out on an underground conveyor at the head pulley at an underground mine in the Rustenburg region. Five people tried with fire extinguishers and hoses to fight the fire but were beaten back. They were sent for medical observation and released shortly afterwards. This highlights the cosmetic nature of fire extinguishers and 25 mm hoses at underground conveyor installations. Figure 16 shows the extent of the damage. The mine personnel had to wait five days before they could re-enter the area due to the heat.

Figure 16. Damaged section of conveyor installation following fire

INCIDENT 3

At the same mine in 2013, a year later, another conveyor caught fire underground. Hot work was conducted on a Sunday and the crew were keen to get to surface to watch a national football game. They left hot metal next to or on the belt as well as the oxygen and acetylene cylinders nearby. In this instance, a water based fire suppression system was installed. However, on the same Sunday another crew were conducting maintenance on the surface water supply reservoir so it was empty. The system detected the fire and activated the suppression system. Unfortunately there was no water and the belt burnt down setting an acetylene cylinder explosion. In this instance, four conveyors burnt in sequence and there were considerable production losses as well as the consequential costs involved with rebuilding four new conveyor installations.

MAINTENANCE

It is critical that these systems be maintained in accordance with the supplier's recommendations. Mine personnel need to be trained and found competent by the supplier to perform first line maintenance and fault finding. In addition to this, the supplier must conduct audits and over-inspections at least every three months, if not monthly. It is far worst for the mine to spend all the budget on fire prevention equipment and when there is a fire, the system does not activate because it was not maintained.

CONCLUSION

Since the fire detection and suppression systems were installed at Anglo American Platinum eight years ago, not one single conveyor fire event has occurred. The suppliers have reported that they have received several alarms through the years as a result of hot bearings. In every case the belt was tripped and bearings were replaced. No instances of suppression systems being initiated were recorded. This is an indication that the philosophy of abnormal heat detection is the correct methodology and everything should be done to prevent a flame incident.

Mines with underground conveyor belts should consider installing these systems as the cost is minor in comparison with the risk of multiple deaths of persons and the consequential losses due to production delays and replacing the belts.

It is important that mines do a complete risk assessment before they decide on which option they choose: water, foam or CAF. Any mine with a history of water shortages or pressure issues for example, should consider the CAF system and not rely completely on water supply.

REFERENCES

1 Sperosens report "Plumber block cap temperature report V2" dated 21 August 2014

ABOUT THE AUTHOR

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Brian is head of mechanical, structural and civil engineering at Anglo American Platinum. He graduated from Trinity College, Dublin, and joined Anglo American as a junior engineer in 1982 at Vaal Reefs Gold Mine. He was appointed as a section engineer in various positions before being promoted, in 1997, to engineering manager at President Steyn in Welkom. He returned to Vaal River in 1998 as engineering manager, metallurgy. In 2003 he was transferred on promotion to consulting engineer at Anglo American Platinum. In October 2013 Brian was appointed as the head of mechanical, structural and civil engineering, a position he still holds today. He is a registered Pr. Eng.

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