VENTILATION ENGINEERING – PROCESS DESIGN PLANNING AND LEGAL GOVERNANCE OF CONVEYOR BELTS

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ABSTRACT

This paper gives an understanding of the ventilation requirements, planning and design involved in preventing underground fires, taking into account the legal requirements. An overview of mining configurations and ventilation systems explains the potential high risk during an underground fire and the exposure of the working force to irrespirable atmospheres. In addition, the positioning of substations, underground stores, electrical cables and pipe networks can further increase the fire risks. The presentation highlights best practices and procedures which can be implemented to mitigate the risks.

1. INTRODUCTION

As the mining industry moves towards mechanisation, so the installation of conveyor belts will increase. As such, compliance with the conveyor belt regulations is mandatory. The Department of Mineral Resources stipulates the following requirements: The employer must take reasonable practical measures to prevent persons from being exposed to fires, fumes or smoke arising from a conveyor belt installation catching fire, including instituting measures to prevent, detect and combat such fires; the materials of which the conveyor belt is made in order to minimise the risk of igniting flammable gas or dust during installation or operation; and materials from which the conveyor belt is made in order to minimise the risk of any part of the conveyor belt catching fire. The mining industry must institute measures by means of procurement, planning and design to minimise the risk of conveyor fires in mining operations.

2. PHOTOS SHOWING EXTENT OF CONVEYOR BELT FIRES

Figure 1. Conveyor belt fire

Figure 2. Conveyor fire at Duva Power Station

This illustrates the conveyor system which supplies Duva Power Station with coal. During a routine inspection it was found that a pair of idler rollers had seized and were not rotating. The decision was made that these rollers were not critical and would be changed out during the planned maintenance scheduled in a week's time. The friction of the belt sliding over the seized rollers caused the coal dust to ignite. The efforts by Duva's fire/proto team were insufficient and the fire brigade from Ermelo arrived on the scene only three hours later.

Figure 3. Damage to conveyor belt structure after Duva Power Station fire

3. STATISTICS SUPPLIED BY THE MINE RESCUE SERVICES

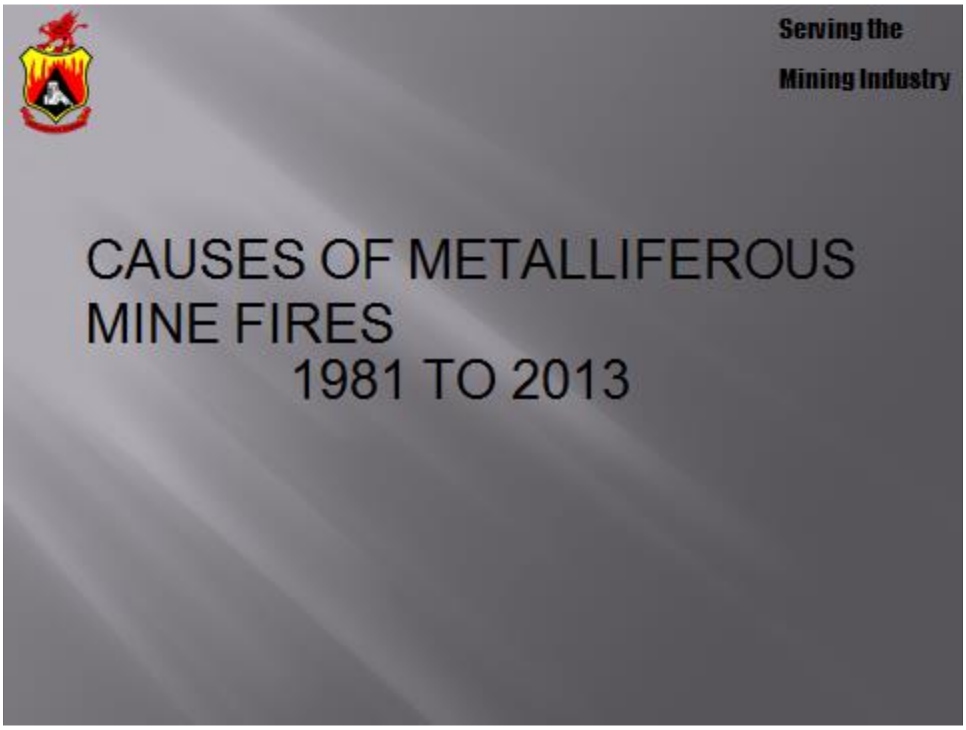

Figure 4. Causes of metalliferous mine fires, 1981–2013

Serving the Mining Industry

UNKNOWN	942
OTHER	43
CUTTING AND WELDING	215
ELECTRIC	644
FRICTION	80
SPON. COM.	18
SMOKING	78
EXPLOSIVES	301
SUSPECTED ARSON	211
VEHICLES/DIESEL	53
FLAMMABLE GAS	50

Table 1. Principal causes of fires

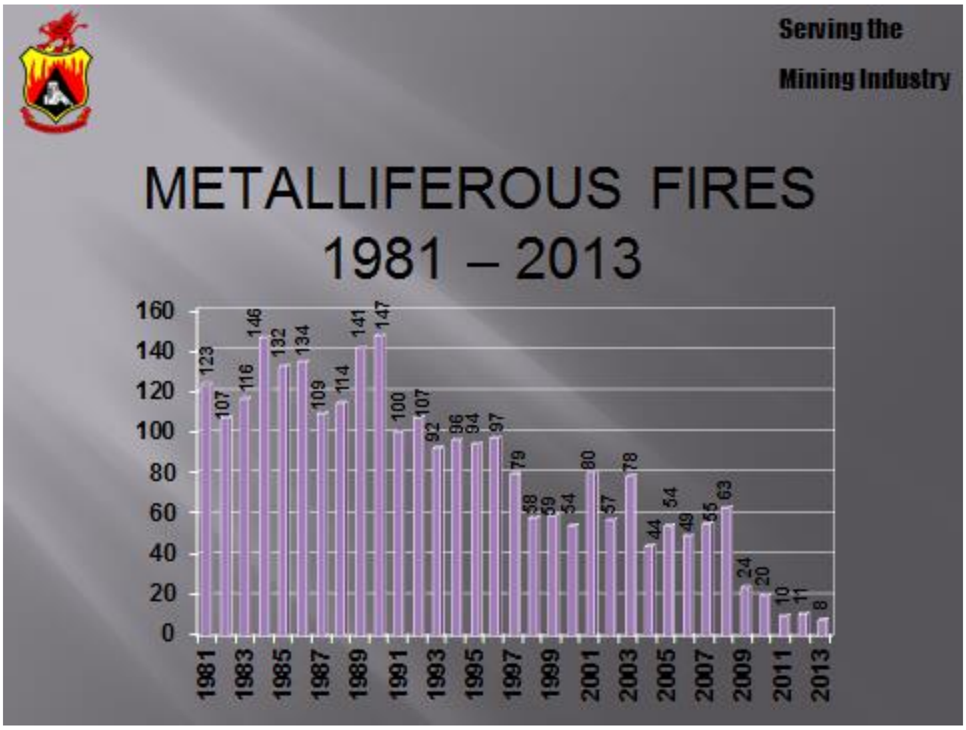

Table 2. Annual fire incidents

The above statistics indicate a gradual decrease in the number of fires which shows that the mining industry is on the right track regarding the institution of fire prevention tactics.

4. VENTILATION PLANNING PARAMETERS AND DESIGN METHODOLOGY

Basic requirements of emergency planning are as follows:

- Communicate the plan to all employees.
- Review company operations and identify probable emergency scenarios.
- Assign a probability of occurrence and a potential severity to the outcome.
- Assess the risk, (the product of the probability and severity mentioned above).
- Determine the legal requirements regarding planning for these incidents.
- Determine the legal requirements regarding response capabilities.
- Determine the local emergency organisations and their response time.
- Develop your plan.
- Select and train your response team.
- Conduct drills and exercise your plan and your teams.
- Implement recovery and re-start operations.
- Evaluate your effectiveness and improve your plan accordingly.
- Where practical, the conveyor belt excavations should be separate and not part of the intake airway system of a mine. Hence the conveyor belts must preferably be situated in the return airway system of a mine, if the prevailing environmental condition allow so.

- Develop the conveyor belt tunnels in a way that they can be isolated in the tunnels by means of steel ventilation doors and by opening of a fire door to the return airway system, or by starting a fan to redirect the smoke and gasses away from the working areas.

Another method is reversal of ventilation. The law of some countries, the United Kingdom for instance, requires that a means of reversing the mine ventilation shall be provided. This requirement is specially designed to reduce the exposure of persons to fire gases in the event of an intake fire for instance, on conveyor belts. In practice the use of reversal facilities can be complex and the decision to reverse the ventilation is not an easy one to make. A further factor of some relevance is the speed with which the reversal can be accomplished. If the ventilation is stopped for some time while the reversal arrangements are being put into operation, methane can accumulate and the accumulation will be drawn over the fire when ventilation is re-established. In the case of an axial flow fan, the ventilation is reversed simply by reversing the rotation, while in the case of a centrifugal fan reversal is achieved by opening or closing appropriate doors with the fan stopped. The operation of these doors can lead to problems, especially if they have not been in operation for a while. Frequent reversal practices should therefore be carried out. Underground airlocks must be designed to be effective with the ventilation in the normal or reverse direction. Airlocks should therefore have two doors opening in the normal direction and at least one opening in the opposite direction.

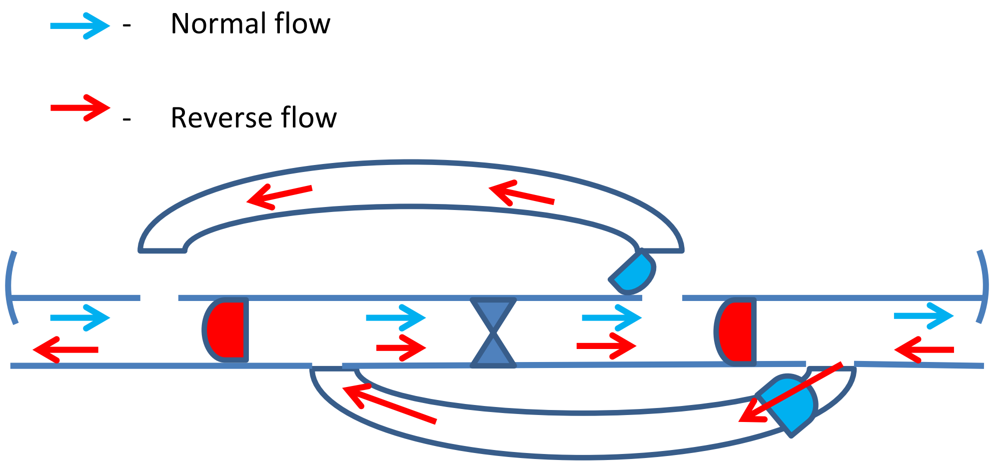

Figure 5. Reversal of ventilation method

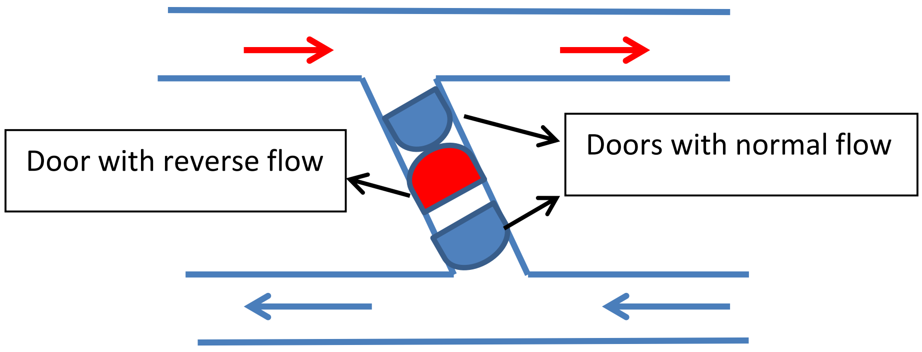

Figure 6. Air locks should have two doors opening in the normal direction and at least one opening in the opposite direction

It must be mentioned that this method will only be effective in a conventional mine and not in a board and pillar mine.

The planned air velocity along conveyor belts should be <5.0 m/s. The primary reason for this is to prevent the liberation of dust into the atmosphere. If the plan is to take 50 m^3/s along the belt, a minimum of 10.0 m^2 is needed to ensure not going over the 5.0 m/s.

Another method to control a fire is short circuiting. In some circumstances there may be merit in opening airlock doors outbye of a fire to reduce the current of air feeding the fire. It should however be remembered that the concentration of fire gases in the return airway inbye of the short circuit will increase and that depending on the rate and direction of dip the convection currents set up by the fire could reverse the airflow weakened by the short circuit. Conversely the convection currents could nullify the effects of the short circuit.

Illumination along the belts must be minimum of 50 lux. This is to allow safe travel along a belt and reduce the risk of an incident at the belt.

Refuge chambers must be installed as close as possible to, but not along the conveyor belt. If they are installed too close to the conveyor belt, during a fire the refuge chamber can become a death trap due to the liberation of heat that can destroy all the equipment in the refuge chamber and as such make it non-life sustainable.

All belt installations should be provided with a communication system to the control room. This is essential to tell the people where to go in a case of emergency, because the control people by means of the fire detection sensors can see where the most gas and smoke is and send them to the safest area or tell them to go to their refuge chamber and wait there until help arrives.

- No explosive boxes allowed within the belt excavation. Explosives can burn and explode and are therefore not allowed near the belt.
- No storage of combustible material within the belt excavation. Combustible material which is not stored correctly can ignite and cause the belt to burn. The store must be at least 20 m away from the belt.
- No plastic pipes, only steel pipes and they must be installed away from the belt and not within the belt excavation. During a belt fire the heat of the fire can destroy the gaskets in the pipe and cause excessive leakage which has the

effect that refuge chambers downstream can be rendered ineffective and become death traps. In some instances the heat can even melt the steel pipes.

- No acetylene appliances must be stored within the belt excavation. If any welding or cutting must be done, a hot work permit must be issued to such a person. This hot work permit must be signed by the respective responsible people. The hot work permit comprises of the following: Gas detection instrument, fire extinguisher, hose with water, check ventilation flow, cutting and welding blanket and check the area before and after hot work was performed.
- All work and material used on the mines are subjected to some sort of a risk assessment. This is a legal requirement before any project or new material is used on the mines. To do a normal issue based risk assessment can take days to complete. The mini risk assessment below can be used as a tool to quickly determine if the belt is a high risk and thus allow measures to be put into place before employees are exposed to high risks.

Conveyor Belt Risk Assessment Tool

General Information

Site (e.g.; "Waterval Smelter")	
Assessment made by (name)	
Conveyor's name or reference	

Loss Type - Hazard Effects/Consequences

I. Harm to People (Safety & Health Hazards - SH):

Would a fire affecting this conveyor belt be the origin of any of the following ?

5 - Multiple fatalities / Impact on health ultimately fatal

II. Environmental Impact (EI):

Would a fire affecting this conveyor belt be the origin of any of the following ?

3 - Serious environmental harm - L2 incident (remediable within LOM)

III. Business Interruption/Material Damage (BI/MD) & Other Conseq. Losses:

Would a fire affecting this conveyor belt be the origin of any of the following ?

4 - Partial loss of operation - Cost of USD 10 to 75 millions

IV. Legal & Regulatory (L&R):

Would a fire affecting this conveyor belt be the origin of any of the following ?

4 - Major breech of the law; Considerable prosecution & Penalties

V. Impact on Reputation/Social/Community (R/S/C):

Would a fire affecting this conveyor belt be the origin of any of the following ?

4 - National impact - National public concern

Overall Expected/Estimated Frequency

Likelihood of this event: 3 - Possible (has happened once & could happen in the next 10 years)

Please refer to the MATRIX tab for reference and guidance in selecting the appropriate frequency for the event

OVERALL RISK RATING OF CONVEYOR

This conveyor has a risk rating of 22 (Ex).

It is considered a Class III - HIGH conveyor belt.

Table 3. Example of a conveyor belt risk assessment tool

Fire detection and suppression requirements for conveyor installations.
To be read in conjunction with CTR-ENG-050-0003-LS

	Requirement	Class 1	Class 2	Class 3
		Low risk	**Med risk**	**High risk**
		< 12	**13 - 20**	**21 - 25**
12.1	2 x 9 kg DCP fire extinguishers placed between 5 and 15 m from all pulley clusters.	Yes	Yes	Yes
12.2	25 mm x 30 m hose reels to be positioned every 30 m along the full length of the belt. The minimum dedicated pipe diameter feeding the reels is to be 50 mm and minimum nozzle pressure to be 300 kPa.	HR	HR	HR
12.3	65 mm fire hydrants within 85 m from all points of the conveyor structure. Hose boxes with 2 x 65 mm x 30 m hoses plus one 45 mm x 30 m hose with nozzles to be placed at each hydrant.	Yes	Yes	Yes
12.4	Anti-slip detection to stop the belt if the speed reduces by 20%.	HR	Yes	Yes
12.5	Automatic suppression system compliant to the requirements of NFPA 16. The suppression system is to cover the drive pulley; the head and tail pulleys; the take-up tension pulley and the last low tension bend pulley; the top and bottom belt surfaces around these pulleys to the minimum of NFPA 15 – 7.2.3 + 1 m outside these areas. Any machine or tank containing hydrocarbons in the vacinity of the belt must be included in the area of coverage. A pressure switch must be installed to trip the belt in the event of any suppression head activating	No	HR	Yes
12.6	Direct contact temperature probes must be fitted to all pulley bearings. If a temperature of 68 degrees is detected, an alarm shall sound and the belt must be stopped.	No	HR	Yes
12.7	Heat detection on all pulley clusters. It must sound an alarm at 68 degrees and must stop the belt. If a temperature of 90 degrees Celcius is detected it must activate the suppression system.	No	HR	Yes
12.8	Optical IR$_3$ flame detection on the main drive pulley clusters	No	HR	Yes

Yes = Mandatory requirement
No = Not required
HR = Highly recommended

Table 4. The above risk assessment tool is a quick and efficient way to determine the risk ranking of the conveyor belt and what systems must be installed

- No substation or mini substation should be installed along the belt. If a substation is ignited, it can ignite the conveyor belt and worsen the condition.
- Cables should be installed away from the belt, preferably not in the same excavation. The hot slack of burning cables can fall on to a belt which then can ignite.
- All belts should be covered with a fire detection system which is linked to a 24 hour manned control room. All belt tail and driving ends are covered with a smoke and carbon monoxide fire detection sensor. This enables the ventilation officer to determine the seat of the fire and therefore can speed up the escape of the exposed employees to their respective refuge chambers. Some fires on belts start after the belt had stopped and the people have left the mine. This

is caused by hot bearings. As the belt stopped, it could be ignited. This type of fire can be picked up by the fire detection sensors and the necessary alarm is raised by the 24 hour manned control room. Rescue teams are sent underground to extinguish such fires or limit the damage to the belts.

5. OCCUPATIONAL EXPOSURE LIMITS FOR AIRBORNE POLLUTANTS

Substance	OEL Stel	TWA
Carbon Monoxide	100ppm	30ppm
Nitrogen dioxide	5ppm	3ppm
Oxygen	Not less than 19%	
Carbon Dioxide	30000ppm	5000ppm
Methane	1.4% in general atmosphere	

Table 5. Airborne pollutant limits

The strict exposure limits that are promulgated in the Mine Health and Safety Act do not allow any leeway, therefore the fire prevention and fire suppression systems must be world class and be regularly maintained by the mine and OEM. Testing for the presence of noxious, asphyxiate or inflammable gases in air is often done for the purpose of determining whether or not the atmosphere complies with standards laid down for safety and health. If this is the objective then it is essential to obtain an immediate estimate of the concentration of any contaminant present so that the necessary corrective action can be taken as soon as possible. In these circumstances, great accuracy is often not required and gas detection is used rather than gas sampling and analysis i.e. detection provides an immediate indication of the concentration of the specific gas. Therefore, it is sensible to be pro-active and install fire detection sensors at strategic places underground to timeously warn the people of an emergency and to prevent any exposure to a low concentration of gas. Failure to do so will result in many people being sent to hospital for a 24 hour observation period with a consequent decrease in productivity.

6. FIRE PROTECTION SYSTEM

An automatic fire protection system should be designed with the objective of preventing a fire condition as well as the effective control of a fire. The debate is always whether to stop a belt during a substandard condition or let it run until the problem can be identified and fixed. Our standard is designed to stop the belt before the bearing or belt reach ignition temperatures. This system is monitored continually for 24 hours in a control room and when such an alarm is activated, the responsible artisan is notified and he attends to the problem. To keep the belt running during a fire can be disastrous as it can ignite the other belts as it runs.

Another problem is to test the water sprays as the system is under constant pressure with 3% foam and 97% water. To overcome this problem a by-pass test column was designed to test the water sprays weekly for operational effectiveness. (Figure 7).

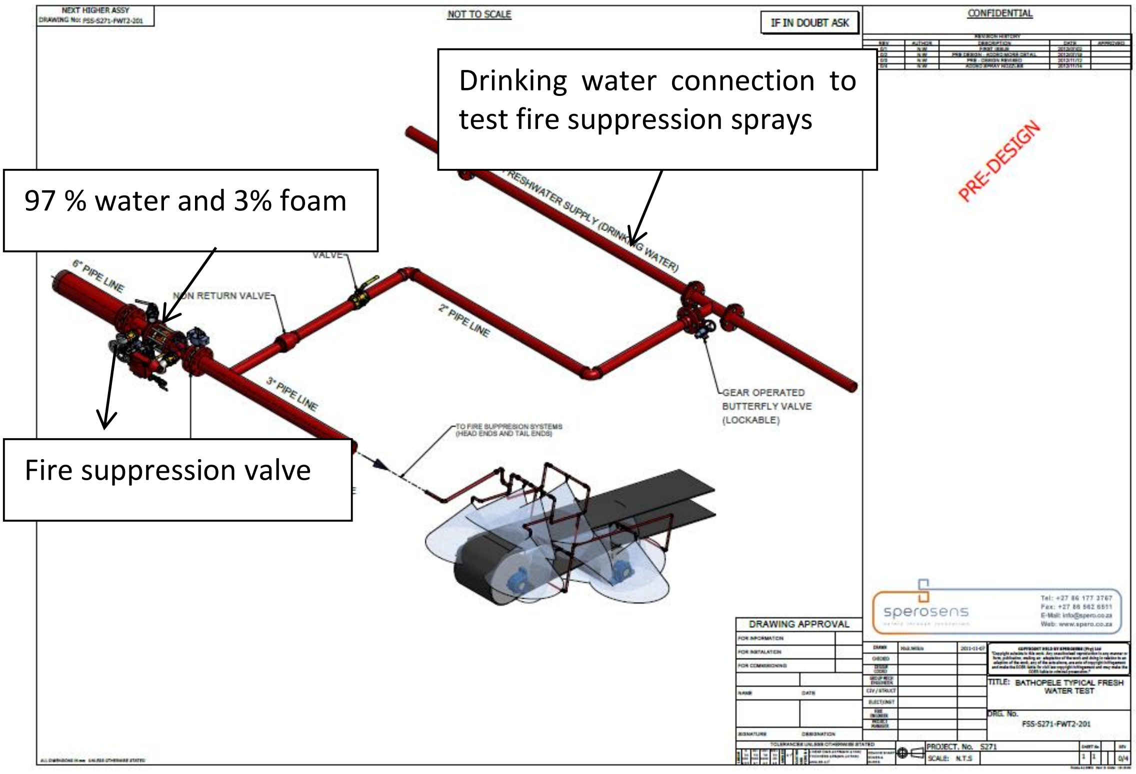

Figure 7. By-pass water connection to test fire suppression sprays

6.1 Monitor bearing temperature

All plummer blocks should have direct contact temperature monitoring devices fitted. An alarm should sound and stop the belt when an external temperature of 68°C is detected.

FireWire Cap

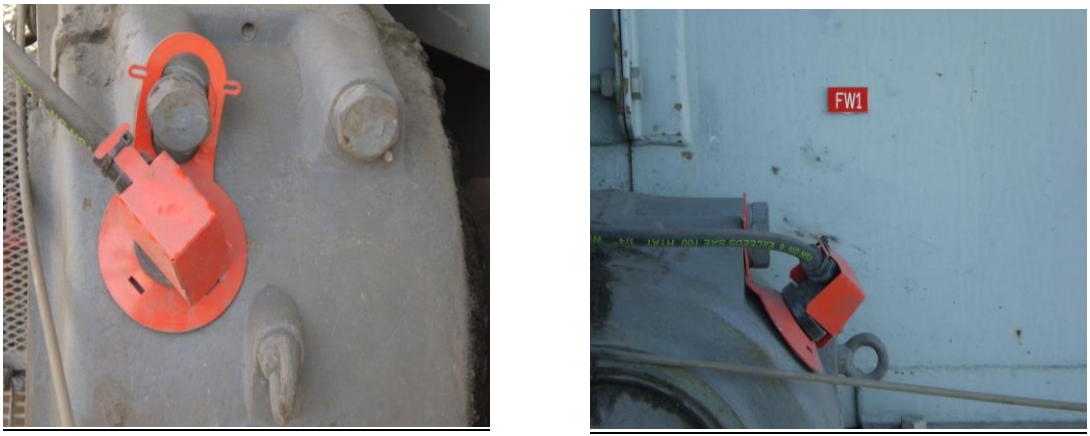

Figure 8. This sensor is used to monitor the bearing temperature

6. 2 Flame detector

Figure 9. Flame detector

Figure 10. Sounds an alarm and activates the suppression system upon any detection of a flame

6.3 Sprays

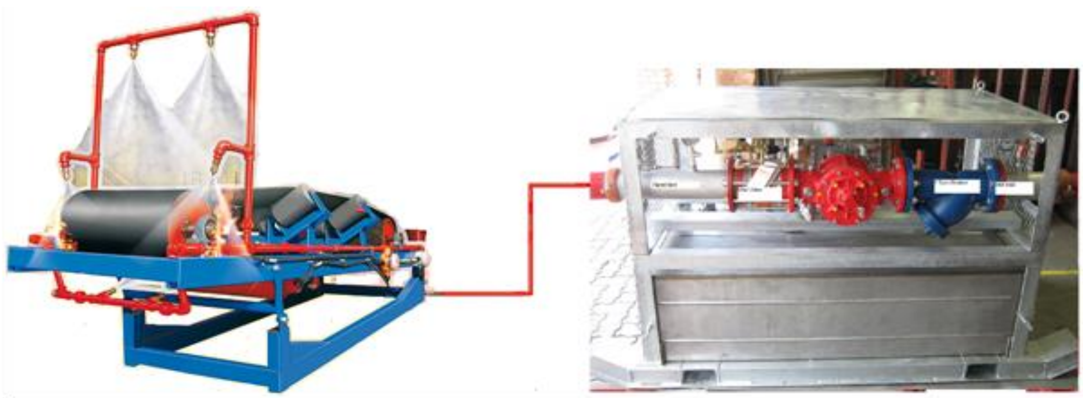

Figure 11. Fire supression spray system

6.4 Emergency activation

Figure 12. Emergency activation alarm

6.5 Fire hydrants

Figure 13. Fire hydrant

Fire hydrants should be located every 85 m with a hose box containing 3 x 65 mm x 30 m flat fire hoses.

6.6 Fire hydrants every 85 m

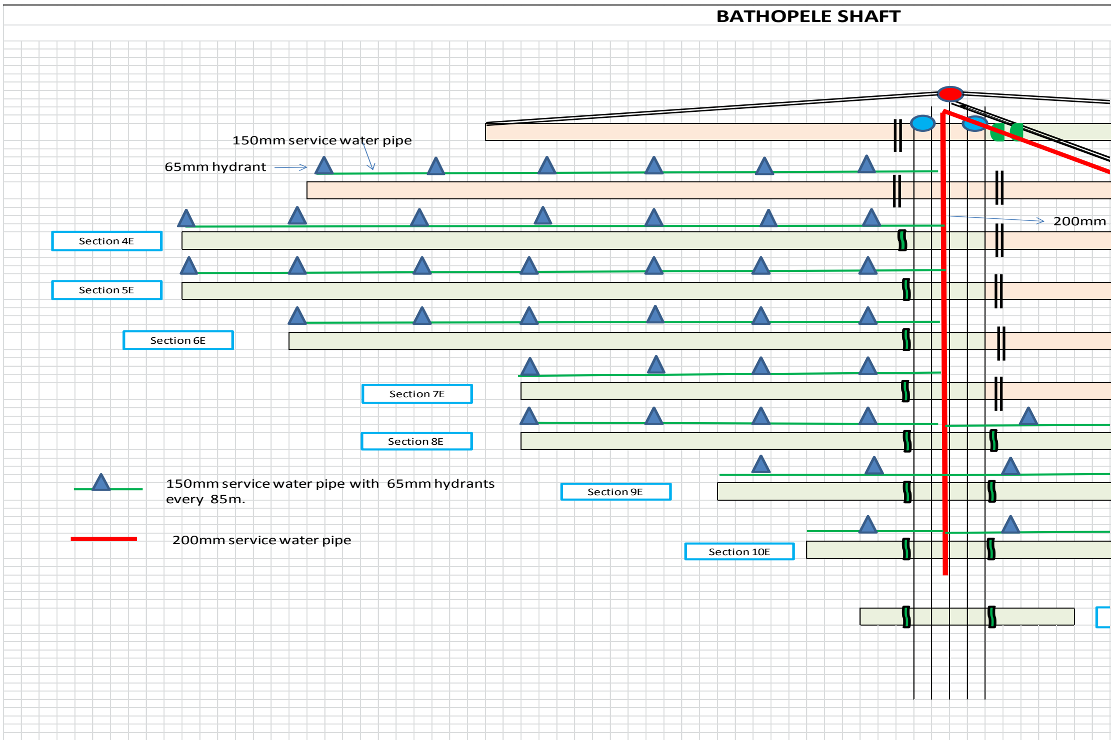

Figure 14. Schematic of fire hydrant placement

7. DUE DILIGENCE

There are many mines where the conveyor belts are installed in the intake air shaft, therefore placing all workplaces at risk in the event of a conveyor belt fire. From a due diligence point of view, the mining industry needs to re-look at the mine design and systems in place to ensure that these comply with the legal requirements. From a holistic view, systems should be in places which are effective and compliant. In such a scenario, fire suppression systems and emergency procedures must be effective to prevent exposure of employees to an irrespirable atmosphere.

8. TYPICAL VENTILATION LAYOUT FOR A MECHANISED MINE

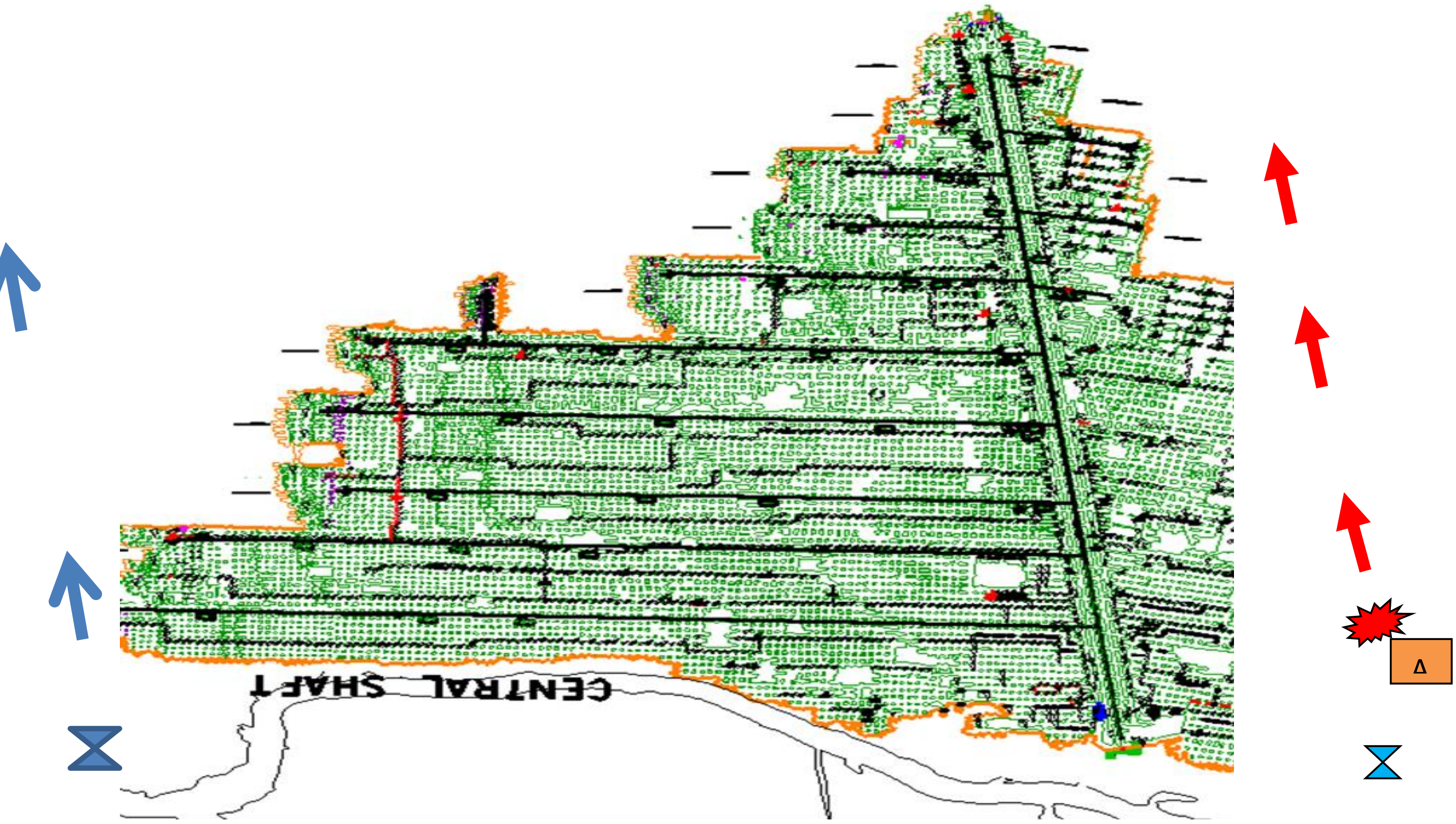

Figure 15. Typical ventilation layout for a mechanised mine

The total length of belts in this mine is 38 km. A fire on conveyor belts at point A will contaminate the whole mine as indicated above. The working places are all ventilated in series. To isolate the belts is not possible in such a mining layout which indicates the huge risk to which the mine is exposed. As the working places are all in series it is critical to have the necessary refuge chambers 500 m from working places and that the refuge chambers are checked by a responsible person every day for life sustainability. Fire detection sensors at the intake and return of every working place are important to determine where the seat of the fire is and to send the people to the safest places. The supervisors are issued with continues gas detection instruments to give then an early warning of gases. People paging and tracking can be done by means of his cap lamp where important information can be communicated to him. From the mine's side, it does everything reasonable to protect its employees from gases and dangers, but the risk of a conveyor belt fire remains a high risk.

9. CONCLUSION

Conveyor belts will and are an integral part of a mechanised mine, therefore the collaboration and input of all role players such as the manufactures, planning and design, ventilation and safety personnel are of cardinal importance to ensure that mines are safe and productive to work in.

An important safety strategy is working together as one team, and in this instance it is literally the case, because without adhering to this principle, there are no winners.

> 'Going far beyond the call of duty, doing more than others expect… This is what excellence is all about. And it comes from striving, maintaining the highest standards, looking after the smallest detail, and going the extra mile. Excellence means doing your very best, in everything in every way'.

ABOUT THE AUTHOR

FRANCOIS SLABBER

Francois Slabber started at Lorraine Gold Mines in January 1980 as a learner ventilation observer, as they were known at that stage. In July 1980 he obtained his practical certificate and in October 1980 his Elementary Certificate in Ventilation Engineering. In July 1987 he obtained his Certificate in Environmental Control. In January 1988 he moved to Freddies Mine as a section ventilation officer where he worked until 1992. During this time he also qualified as a Brigades man and was a member for ten years. He was involved with as many as three to four fires a year during this time. In January 1992 he was appointed as an environmental and safety manager at President Steyn Mine, following the amalgamation of the ventilation and safety departments, a post that he held until 1994.

Having obtained all the necessary safety qualifications, he joined Anglo Platinum after the Anglo mines were sold to Harmony Gold. In January 2006 he was appointed as chief ventilation engineer at Anglo Platinum in Rustenburg where he is today.

Francois has been a fellow of the Mine Ventilation Society for 21 years and is presently the branch chairman of the Northern Branch.

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