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- ◆ **Fire detection and suppression on underground conveyor belt installations**
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Marco Biffi
Honorary Editor



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Managing by fear

This editorial is written by candlelight - and thank goodness for resilient laptop batteries! Yes, it's power shedding time again in South Africa. A situation to which we are getting used and with which we will be forced to live for months, if not years, to come. The damage to the country's economy is significant and the response from authorities is totally inadequate. The irony of it is that no money in the world will buy the time, skills and experience required to bring things back onto an even keel. As taxes increase in an effort to find some respite from this absurd state of affairs (phraseology here is intended) the realisation is that adequate planning for expansion and timely execution of effective preventative management, amongst others, would have avoided this disastrous situation.

Along a similar vein, an engineer approached me recently concerned about the possibility of a catastrophic failure of an ammonia refrigeration plant. The opening question was "What can we do to prevent this from happening?" The thought of a couple of tons of ammonia being liberated in a few minutes is daunting and points to extensive damage and dispersion of a toxic plume. The million dollar question is: when does the hazard become a real risk? The simple answer is "when the hazard is not under control".

The designers of the Titanic felt that they would be able to manage the hazard posed by icebergs by providing water-tight bulk heads that could be isolated in case of an iceberg strike thus limiting the ingress of water. Note: the ship had a single skin hull and therefore rupture in the event of an iceberg strike was to be expected. The problem was that the designers had not anticipated an incident where the iceberg would open-up the hull like a sardine can, flooding more than the maximum of compartments required to ensure the ship would not sink. The fact that there were not enough life-boats, adds to the tragedy - by the way looking at the outcome of recent ship-wrecks it may be argued that some lessons have not been learned yet. Irrespective of these considerations, the Titanic would not have sunk if the collision with the iceberg had been avoided - and it would have been possible, even without radar, if the ship had been travelling at a more moderate speed.

The point of this discussion is that too often we allow situations to deteriorate to a point beyond which catastrophic outcomes occur or where only costly emergency repairs will resolve the problem. In the case of the Titanic there was a sense of invincibility: the dawn of the twentieth century with its numerous technical innovations lead the owners and operators of the ship to feel comfortable that even if an iceberg was struck, the ship would not sink. In the case of Eskom, the fact that the available power generation capacity had dwindled to well below acceptable reserve levels through inadequate planning and maintenance of ageing power stations, did not seem to be important to the powers that be until now.

Insofar as the ammonia refrigeration plant is concerned, here is a thought: we will never be certain that a catastrophic failure will never occur. However, modern refrigeration plants, designed to SANS 10147 specifications include numerous safety devices, working together to prevent catastrophic failure. If safety measures are not observed, instrumentation is not calibrated and tested as required, if safety systems are by-passed and if the plant condition is allowed to deteriorate, incidents, with significant consequences will definitely occur. Annual plant shut-downs are costly but necessary. Routine inspections by experienced personnel will highlight incipient problems that may be rectified in a timely fashion - the design code contains adequate factors of safety. The fact that will interest management is that a well maintained and properly operated plant will be optimally efficient.

As with so many other things in this modern world, too often, we are willing to skip plant maintenance, delay repairs ("the plant has two pumps after all") and ignore small glitches ("by-pass that interlock!") for the sake of saving a few "bucks" here and there - and ignoring the fact that we are exposing the company to much greater risk and potential for catastrophic failure.

Often, poorly operating equipment is kept going beyond certain acceptability levels thanks to good design codes and manufacture but at the peril of serious failure possibly leading to injury and production losses. If I were to say that the solution to the ammonia plant issue required X millions, my engineer colleague would have gone away and done some sums as to the

commercial feasibility of my solution against some risk that would not be easily quantifiable. That would not make sense since there is a good chance that the X million solution would also be allowed to become ineffective within two years from now, given the very same, demonstrated culture of poor maintenance. What is required is, again a change in behaviour: recognising that the solution is at hand so long as we do what is necessary to operate and maintain equipment in accordance with the design specifications. Only when we can achieve this new level of performance, consistently, we may say that we need not manage by fear but are doing it intelligently.

Paraphrasing some wisdom of old “it seems that there we never have the time (money, resources) to do (and keep doing) something properly but lots to do it again - or to have it fixed and suffer the damages!”

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Fire detection and suppression on underground conveyor belt installations

Brian P. O'Connor Pr. Eng. Head of Mechanical, Structural and Civil Engineering Anglo American Platinum

Background

On 20th 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 apparatuses 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 the 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 the 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% 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. Persons 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 are 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, jam or slip excessively.”

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.

The anti-slip device is configured such that should the belt speed reduce by more than 20%, the belt will trip immediately and an alarm is sounded. The device is programmed such 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



Figure 3: Anti-slip device

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 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 by which insured companies should comply to.

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 so that they can be approved by them. In addition to testing and certification, they are a major organisation in promoting safety awareness in relation to fires in general.

Standards

The two main 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% water and 1% 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 media and hence 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% of what is required from the water based systems.

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

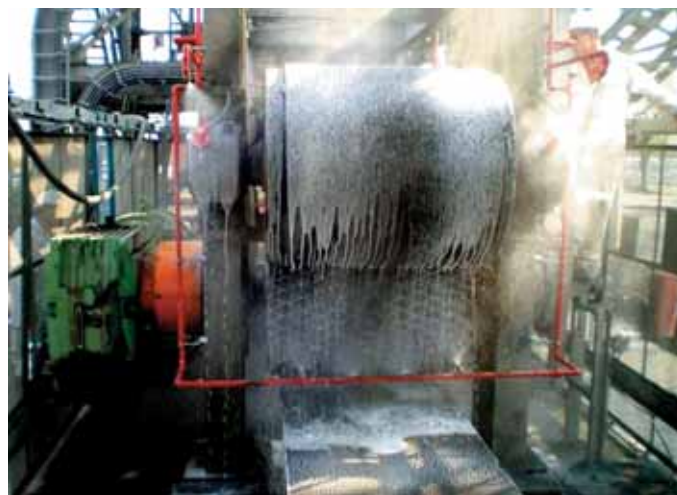


Figure 4: Drive pulley end after being sprayed with foam media

Methodology

As mentioned above, Anglo American Platinum made the decision to detect abnormal heat and prevent any condition where 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 and 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 below. 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 will seize. 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 will activate and initiate 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) below. 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 as they are rotating so fixing temperature probes was not an option. It was decided to use temperature scanners that can be 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.

These devices are calibrated such that it only senses 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 shows a typical schematic showing all three levels of heat and flame detection.



Figure 8: IR3 flame detecting sensor

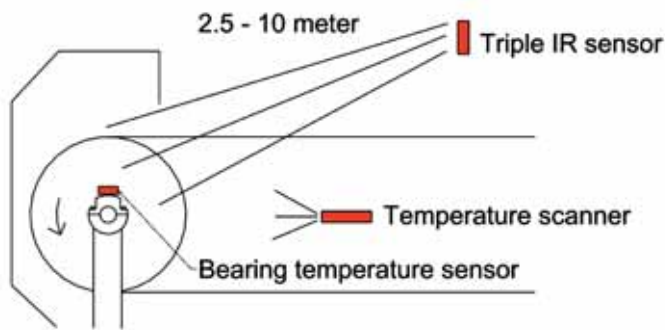


Figure 9: Typical installation schematic showing all three levels of detection

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 which

media to use, 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% 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 the 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 1800 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 below.



Figure 12: A three tank CAF system installed underground

Every mine has the choice as to which system to install depending on their operations circumstances as to water availability, pressure, storage volumes available, reliability of pipe networks etc. 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 media 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% 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 whole conveyor caught alight. Again no detection and suppression system was installed. The extent of the damage caused by the fire is shown in Figures 14 and 15.

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 after-



Figure 14: Surface view of conveyor fire



Figure 15: Damaged idler section

wards. 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.

Incident 3

At the same mine 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 including 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.



Figure 16: Damaged section of conveyor installation following fire

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 the first line of maintenance and fault finding. In addition to this, the supplier must conduct audits and over-inspections at least every three months if not monthly. The worst thing that can happen is the mine spends all the money 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 being water, foam or CAF. Any mine with a history of water shortages or pressure issues for example should be considering the CAF system to take the reliability away from water supply.

References

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

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Human Vibration, from theory to practice

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Abstract

The health and safety challenges that the mining industry faces are ever increasing. Humans interact on a daily basis with machinery in their everyday working environment.

Vibration exposure is associated with numerous health effects and injury. This paper discusses theoretical measurement- and exposure guidelines, associated with whole-body and hand-arm vibration experienced in the mining industry. A number of control measures are touched upon in an attempt to guide the mine occupational hygienist in the difficult task to reduce possible exposure to human vibration.

1. Introduction

The mining industry is confronted with numerous challenges, of which one is to produce in a safe and healthy environment. Every day humans interact with machinery and contact with vibration is sometimes unavoidable. Unfortunately, human vibration

is an emerging issue for the mining industry and it has been found that continuous exposure to mechanical vibration can lead to physical injury.

Vibration can be defined as regular, repeated movement of a physical object around a fixed point. Human vibration is then defined as the effect of mechanical vibration on the human body. Human vibration can be pleasant or unpleasant. Vibrations experienced when travelling in a vehicle on a bumpy road or when operating a power tool are more violent and classified as unpleasant and possibly harmful.

The harmfulness of vibrations depends on the intensity, the frequency and the time of exposure.

There are two types of human vibration:

- Whole-body vibration
- Hand-arm vibration

1.1 Whole-body vibration (WBV)

Whole-body vibration is caused by vibration transmitted through the seat or the feet. Exposure to high levels of whole-body vibration is known to cause or aggravate back injuries depending on the magnitude of exposure. Activities that are known to cause whole-body vibration are commonly related to off-road work and operating of mobile equipment as well as standing operations such as standing on crushing equipment.

Along with vibration, other ergonomic factors may contribute to back pain caused by WBV, and should be considered. The risk will be increased where a person is exposed to additional ergonomic factors while being exposed to WBV.

Possible reasons for back pain in drivers/machine operators in addition to vibration exposure may include:

- poor design of controls, making it difficult for the driver to operate the machine or vehicle easily;
- incorrect adjustment by the driver of the seat position and hand and foot controls which may result in awkward position of operator;
- sitting for long periods without being able to change position;
- poor driver posture; and
- repeated manual handling and lifting of loads by the driver (2).

The risk increases where the driver or operator is exposed to two or more of these factors together.

1.2 Hand-arm vibration (HAV)

Hand-arm vibration is vibration transmitted by the use of vibrating hand-held power tools such as pneumatic drills, hammers and grinders. Vibration is transmitted to the hands and arms of the person operating the tool. Regular exposure to hand-arm vibration can cause health effects commonly known as hand-arm vibration syndrome. Hand-arm vibration syndrome is a general term used to broadly describe the physical damage to the hands, fingers, and related structures resulting from chronic exposure to excessive vibration (vascular and neuropathic effects). Regular exposure to hand-arm vibration can cause reduced grip strength, pain in the arms and shoulders, white finger syndrome and carpal tunnel syndrome. If left untreated, white finger becomes progressively worse and irreversible damage can occur. Symptoms include tingling and/or numbness in the fingers followed by finger blanching that often occurring at night or while not at work.

The effects of exposure to HAV are influenced by factors such as:

- acceleration and frequency of the vibration;
- duration of exposure during each work shift and number of years of exposure;
- state of tool maintenance;
- level of insulation on the tools;
- duration and frequency of work-rest periods;
- grip forces applied i.e. the tighter the grip, the more vibration is absorbed;
- surface area of the hand in contact with the source of vibration;

- hardness of material being contacted;
- posture of arm and hand during tool operation;
- type of handle on the tool;
- temperature of work environment, cold temperatures affects circulation;
- use of personnel protective equipment (gloves); and
- personal habits (smoking and use of drugs affects circulation) ⁽⁵⁾.

1.3 Units of measure

Vibration is defined by its magnitude and frequency. The magnitude of vibration could be expressed as the vibration displacement (in metres), the vibration velocity (in metres per second) or the vibration acceleration (in metres per second squared or m/s^2).

The amplitude and frequency of the vibration motion are measured in the three orthogonal directions (x, y and z) in terms of velocity. If you could watch a vibrating object in slow motion, you can see movements in different directions. The following terms are used to describe this movement:

Frequency

A vibrating object moves back and forth from its normal stationary position. A complete cycle of vibration occurs when the object moves from one extreme position to the other and back again. The number of cycles that a vibrating object completes in one second is called frequency. The unit of frequency is hertz (Hz). One hertz equals one cycle per second.

Amplitude

A vibrating object moves to a certain maximum distance on either side of its stationary position. Amplitude is the distance from the stationary position to the extreme position on either side and is measured in meters (m).

Acceleration

The speed of a vibrating object varies from zero to a maximum during each cycle of vibration. Speed is expressed in units of meters per second (m/s). Acceleration is a measure of how quickly speed changes with time and therefore, acceleration is expressed in meters per second squared (m/s^2). The magnitude of acceleration changes from zero to a maximum during each cycle of vibration. It increases as the vibrating object moves further from its normal stationary position.

1.4 Exposure limits

Numerous research studies have evaluated the effect of over-exposure to human vibration in the working environment and results have been applied in establishing international standards. The International Standards Organisation (ISO) consequently compiled the following standards relevant for the evaluation of human vibration:

- ISO 2631-1 (1997) Mechanical vibration and shock - Evaluation of human exposure to whole body vibration - Part 1: General requirements;

- ISO 5349-1 (2001) Mechanical vibration - Measurement and evaluation of human exposure to hand-transmitted vibration - Part 1: General requirements; and
- ISO 5349-2 (2001) Mechanical vibration - Measurement and evaluation of human exposure to hand-transmitted vibration - Part 2: Practical guidance for measurement at the workplace.

The primary purpose of these international standards is to define methods for the measurement of human vibration. These standards together with additional literature form the basis of this paper in order to formulate a measurement approach for human vibration⁽¹⁾.

The mentioned ISO standards define daily vibration exposures in terms of an exposure action value (EAV) and an exposure limit value (ELV). The EAV is the amount of daily exposure to whole-body vibration above which action is required to reduce risk. The ELV is the maximum amount of vibration an employee may be exposed to on any single day⁽³⁾.

The following exposure guidance is given by the ISO standards for vibration:

Vibration	EAV	ELV
HAV	2.5 m/s^2	5 m/s^2
WBV	3 m/s^2	6 m/s^2
VDV	8.5 $m/s^{1.75}$	17 $m/s^{1.75}$

Daily exposures to vibration may be assessed in terms of “Daily vibration exposure, $A(8)$ ” or “Vibration dose value, VDV”.

The $A(8)$ requires an exposure time and is the continuous equivalent acceleration, normalised to 8 hours, based on the root-mean-square averaging of the acceleration signal and is measured in m/s^2 .

VDV is a cumulative dose on the 4th root-mean-quad of the acceleration signal and is measured in $m/s^{1.75}$

The vibration dose value (VDV) provides an alternative measure of vibration exposure. The VDV was developed as a measure that gives a better indication of the risks from vibrations that include shocks (VDV is more sensitive to high peak vibrations). The units for VDV are metres per second to the power 1.75 ($m/s^{1.75}$), and unlike rms vibration magnitude, the measured VDV is a cumulative value (it increases with measurement time)⁽⁶⁾.

2. Measurement approach

In order to assess the daily vibration of workers a proper risk assessment should be conducted. The purpose of the vibration risk assessment is to enable a valid decision to be made about the measures necessary to prevent or adequately control the exposure of workers.

The risk assessment should:

- identify where there may be health or safety risks for which vibration is the cause or a contributory factor;

- estimate workers' exposures and compare with exposure action and exposure limit values; and
- identify the available risk controls.

Along with vibration, other ergonomic factors may contribute to the risk and will increase where a person is exposed to additional ergonomic factors while being exposed to vibration.

The daily vibration exposure of workers needs to be estimated and in order to do that the total daily duration of exposure to the vibration source must be known. In most instances vibration exposures will be interrupted by periods without vibration exposure, e.g. truck loading and waiting times. Usually, the vibration that occurs when the vehicle is travelling will dominate vibration exposures. Work patterns, therefore need to be carefully considered.

Vibration magnitude is the frequency weighted acceleration value in the highest of three orthogonal axes (x, y or z). This can be obtained by using manufacturer's data, if available. Vibration exposure, however, is very dependent on factors such as the quality of road surfaces, the speed the vehicle is driving, the manner in which the vehicle / equipment is operated etc. Initial exposure assessment data should, therefore, rather be confirmed by measuring the actual vibration magnitudes.

As mentioned before, the parameter used to assess vibration is the peak particle velocity expressed in millimetres per second (mm/s). The root-mean-square (rms) vibration magnitude is expressed in terms of the frequency-weighted acceleration at the seat of a seated person or the feet of a standing person, it is expressed in units of metres per second squared (m/s^2). The rms vibration magnitude represents the average acceleration over a measurement period.

2.1 Whole-body vibration

Vibration should be measured according to the coordinate system originating at a point from which vibration is considered to enter the human body, i.e. the seat or the feet (Figure 1).

If it is not feasible to obtain precise alignment of the vibration transducers with the preferred basicentric axes, the sensitive axes of transducers may deviate from the preferred axes by up to 15° where necessary. For a person seated on an inclined seat, the relevant orientation should be determined by the axes of the body, and the z-axis will not necessarily be vertical.

Transducers shall be located so as to indicate the vibration at the interface between the human body and the source of its vibration. Vibration which is transmitted to the body shall be measured on the surface between the body and that surface. Three principal areas for seated persons are described:

- the supporting seat surface
- the seat-back; and
- the feet

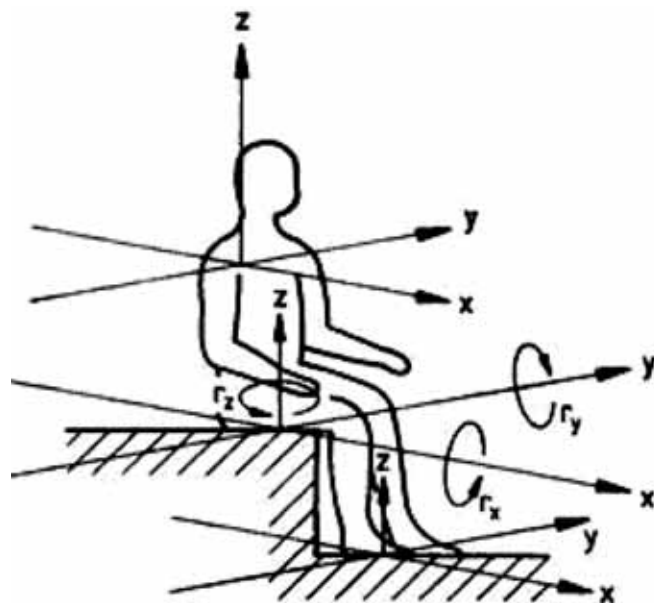


Figure 1: Basicentric axes of human body

As an extension, the steering wheel vibrations can also be measured in the same run.

Vibration measurements should be made to represent the vibration throughout the operator's working period. If achievable, measurements should be made over periods of at least 20 minutes, where shorter measurements are unavoidable they should normally be at least three minutes long and, if possible, they should be repeated to give a total measurement time of more than 20 minutes⁽¹⁾.

On completion of the assessment of the vibration risk to employees, one needs to decide if they are likely to be exposed above the daily EAV or if they are likely to be exposed above the daily ELV.

2.2 Hand-arm vibration

Measuring exposure levels of HAV is complicated. An accelerometer is used to measure the vibration

from a power tool that is converted to an electrical output. This output is modified to account for the range of frequencies that can cause harm to the hand and arm, which is a frequency weighted value that is measured in m/s^2 .

Vibration measurements should be taken at a point close to where Vibration enters the hand. Measurements should be taken in three axes (x, y and z) and the alignment of these axes of the accelerometer should be precise. Figure 2 shows the basicentric axes in which HAV exposure should be conducted.

Hand-transmitted vibration is measured at the contact point between the hand and the tool and sine cannot assume that the tool has a dominant axes, the measurement will take place in all three of the mentioned axes⁽⁴⁾.

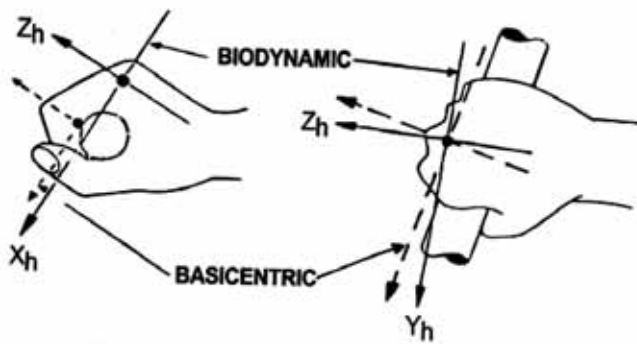


Figure 2 - Basicentric axes for HAV

3. Controlling vibration

3.1 Whole body vibration

The decision on the actions required should be in proportion to the risk identified. It is necessary to consider whether it is the WBV exposures that are contributing most or the additional factors such as manual handling or postural strain that may be significant. A higher priority needs to be given to control the specific stressor.

Actions for controlling risks could include the following:

Train and instruct operators and drivers on:

- Adjustment of suspension seats, to minimise vibration;
- Adjust the seat position and controls correctly, where adjustable, to provide good lines of sight, adequate support and ease of reach for foot and hand controls;
- Adjust the vehicle speed to suit the ground conditions to avoid excessive bumping and jolting;
- Steer, brake, accelerate smoothly; and
- Follow worksite routes to avoid travelling over rough, uneven or poor surfaces.

Choose machinery suitable for the job:

- Select vehicles and machines with the appropriate size, power and capacity for the work and the ground conditions; and
- Consult suppliers for advice.

Maintain machinery and roadways:

- Make sure that paved surfaces or site roadways are well maintained, i.e. potholes filled, ridges levelled, rubble removed etc.;
- Maintain vehicle suspension systems correctly i.e. cab, tyre pressures, seat suspension; and
- Replace solid tyres on machines before they reach their wear limits.

In addition, work schedules to avoid long periods of exposure in a single day and allow for breaks where possible can be introduced. Health monitoring in terms of back problems can be conducted⁽²⁾.

3.2 Hand-arm vibration

Risk controls for HAV can include:

- Alternative work methods which eliminate or reduce

exposure;

- Select the lowest vibration tool that is suitable and can do the work efficiently;
- Mechanise or automate the work;
- Equipment that is unsuitable, too small or not powerful enough is likely to take much longer to complete the task and expose employees to vibration for longer than is necessary;
- Work equipment is likely to be replaced over time as it becomes worn out, and it is important that you choose replacements, so far as is reasonably practicable, which are suitable for the work, efficient and of lower vibration;
- Get your employees to try the different models and brands of equipment;
- Find out about the equipment's vibration reduction features (consider maintenance);
- Train purchasing staff on the issues relating to vibration;
- Improve the design of workstations to minimise unnatural position of hands, wrists and arms;
- Use devices such as jigs and suspension systems to reduce the need to grip heavy tools tightly;
- Do not use blunt or damaged concrete breakers etc.;
- Limit the time that your employees are exposed to vibration, several shorter periods are preferable;
- Provide your employees with protective clothing when necessary to keep them warm and dry; and
- Gloves are available to protect hands from excessive vibration exposure⁽⁷⁾.

4. Conclusion

Despite the complexity of the assessment and evaluation of human vibration exposures, it is true that exposures can be managed without compromising production, health or safety. Together with continual improvements to manual handling, posture, prolonged operation, maintenance, training etc. the risks can be reduced.

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The effect of automated mining on the occupational environment

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Abstract

Underground mining has changed dramatically over the last century reaching depths in excess of four kilometres. Mining operations are continuously looking for new ways in terms of technology to remove people from risk while going even deeper. But, with new technology comes new risks. This paper gives an outline of a project by AngloGold Ashanti (AGA) to mine gold without people through technology and innovation, highlighting the challenges and solutions on the effect of automated mining on the occupational environment.

1. Introduction

AngloGold Ashanti South African operations are facing significant challenges and a breakthrough in the operating paradigm is required.

The challenges are:

- Undesirable safety performance
- Declining gold production
- Rising unit costs
- Leaving up to 40% gold behind in pillars
- Diluting the ore by more than 200%
- Mining only 75% of available shifts.

Longer term sustainability will require new technology that will reduce human risk, migrate to a technology intensive business and open up a competitive advantage.

2. Creating a new mining paradigm

The first steps towards a new mining paradigm will focus on:

- Stop blasting
- Remove people from high risk tasks
- Build a continuous operation
- Maximise the resource.

Technology will be used to drive this change in order to safely mine all the gold, just the gold, all the time. The focus will be on three dominant projects namely, speed of development, stop blasting and remove people from the face and efficient logistics.

Optimising the foundations will lead to safe operations, real time communication (everyone knows everything all the time), one source of information, reduce energy intensity and automation. All this will enable the operations to mine everything, 365 days a year, 24 hours a day and only the reef (no dilution).

3. Consortium

3.1 Approach

It was realised that most sustainable advances in business performance have usually been delivered through technology change. A consortium could be defined as “an association of two or more individuals, companies, organizations or governments (or any combination of these entities) with the objective of participating in a common activity or pooling their resources for achieving a common goal”.

By following the consortium approach the following benefits will be clear:

- It brings speed and diversity of team members and a proven track record;
- Reduce risk through sharing, and practical experience of team;
- Leverage entrepreneurial incentive of team; and
- Cover the complete range of attributes required to make a breakthrough.

3.2 Open innovation

“Open innovation is a paradigm that assumes that firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as the firms look to advance their technology”.

The characteristics of this type of open innovation approach in a consortium could be listed as:

- Define the problems with a wide group of suppliers and potential suppliers.
- Create teams to develop projects and technologies.

The open innovation approach certainly has its strengths and weaknesses.

Strengths:

- Greater potential for unimagined technologies.
- No immediate funding.
- Not based on our understanding of the world.

Weaknesses:

- Messy process.
- Difficult to ensure that the right companies are participating on the right teams.
- Ambiguity frustrates expectations.

3.3 ATIC

The AngloGold Ashanti Technology and Innovation Consortium, called ATIC, was formed during 2011. It involved more than thirty companies and eighty participants including universities, manufacturers, suppliers, engineering design companies, research and development institutes, technology platform providers and many others.



Figure 1: Consortium layout

Initially fifteen teams were set up covering the different aspects of mining:

IT Backbone (3) +ABB +Curtin +CSC +CSIR +WITS	Power +SNC +GE +FNBI +ABB	Cool Suits +Duys +BM +Delta V +FBI +Aucore	Underground Met Plant +MMD +SGS +Siemag +Atlas +Stroam
PhysRF (3) +ABB +Shaftsinkers +Robbins +Sandvik	Ore Grade +Curtin +CSC +SGS +Wits +CSIR +TheromFisher	Local/E/Control +Delta V +Stroam +Duys +CSC +ABB +Siemag +Dupont	High Strength Backfill +Durrast +Herrmann +CSM +WITS +CSIR
Remote Machines Auto Machines (3) +ABB +Curtin +Atlas +Sandvik +CSIR +WITS +Pylon Gears	Dir/Drill +Herrmann +TRG +CSC +Wits +Robbins +Atlas	Water +BM +Robbins +GE +Wier +Energy Recovery	2-Train (Continuous) +ABB +CSC +FL Schmidt +Robbins
	Env/Air/Water +Barriers +BM +GE +Dupont	Selamics +Ground Probe +GE +CSIR	In-situ Leach +SGS +BM +Backer +Hughes

Figure 2: Consortium teams

4. Roadmap

The roadmap follows three stages:

Stage 1- No people in stope:

- No drill & blast

- Remote stoping
- Continuous processes
- On-reef exploration and development
- Mechanical mining
- Tunnel boring machine development
- Reef-height stoping
- Consistent rock size at face
- Ore hoisted, backfill sent down
- Immediate high strength backfill
- Containers for material & people
- Reduced water use
- Energy savings
- Accurate information and data management.

Stage 2 - Intelligent mining:

- People only for control & maintenance
- Closed loop real time process optimization
- Low force fracturing
- Exploration & development in same step
- Underground concentration
- Backfill stays underground
- Hydro hoisting ore
- Hot mine (ventilation on demand)
- UG water recirculation
- No fresh water going down
- Mine knowledge management, weather map.

Stage 3 - Gold on tap:

- No people underground
- ISL: in-situ leaching
- Ore fractured but not moved
- Autonomous drilling: exploration & production transport in single step
- Real time accurate ore grade measurement at face
- Continuous backfill or support
- Solution pumped or container transported
- Beneficiated water for economic use on surface
- Geothermal surplus power produced
- Coordination by mine knowledge system.

Thirteen groups were formed and allocated into two project groups, namely critical success projects and second order projects as set out below:

Critical success projects

1. *Mine Design and Analysis*

- Mponeng
- Prototype block
- PZ2

2. *Exploration*

- RC Drilling incl. Coring vs. Chipping

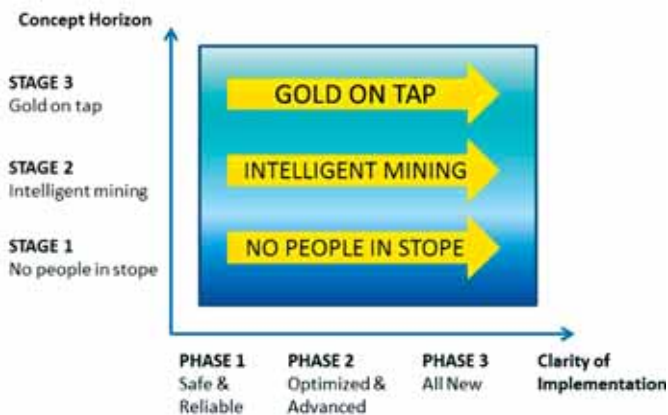


Figure 3: Roadmap matrix

3. Machines for Development

- TBM (Declines)
- HBM (Haulages and Drives)

4. Machines for Stopping

- Conventional Raise Borer (Robbins)
- Clara Rig Box hole Borer (Herrenkn.)
- Reef Borer (Wassara/Cubex/Sandvik)
- Slot Borer (Atlas Copco)

5. Material Handling iV Continuous Processing

- Railveyor
- Conveyor

6. Backfill

- Backfill Design & Sys. Architecture

Second order projects

1. Site Preparation

- Site Development

2. Information Technology

- IT Backbone

3. Micro-Plant

- Hydro Hoisting Study
- Vortex Commination

4. Water

- Clean and Dirty Water Study incl. Closed Loop Water Filtration

5. Environment

- Ventilation on Demand incl. Filters and Air Locks

6. Seismic

- Seismometer Implementation

7. ISL

- ISL Rock Mechanics Software
- ISL Rock Fracturing Study

A matrix was developed incorporating the phases into stages with specific emphasis on each group.

The example below depicts the identified projects within the Environmental group.

Stage 3 Gold on tap		• Geothermal power plus	
	• Area Env monitoring • Personalised noise monitoring • Env model / VUMA	• Air filter development • Closed loop environments • Vent on demand	
Stage 2 Intelligent mining	• Climate segmentation • Personal body cooling • Clean / dirty water study • Water monitoring, planning, reliability	• Cool suit development • Water recirculation filters, quality	
Stage 1 No people in stope	• Simple vent door • Absorption chiller • Water pressure energy	• Geothermal power generation	
	Phase 1 Safe & Reliable	Phase 2 Optimized & Advanced	Phase 3 All New

Figure 4: Roadmap matrix - ventilation

5 CRITICAL SUCCESS PROJECTS

5.1 Mine design

An initial “Blueprint” was developed based on a mined out section of Mponeng mine. The mine design for the “new” block of ground underwent eighteen iterations for full optimisation.

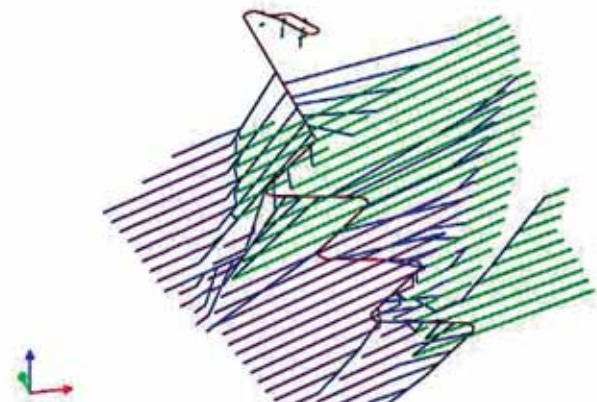


Figure 5: Mponeng blueprint

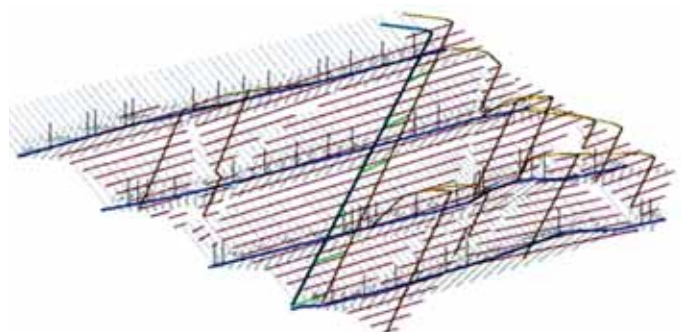


Figure 6: Final “new” mine design

The new mine design will cater for Tunnel Boring machines (TBM) to develop the main inclines and Haulage Boring Machines (HBM) for developing the reef drives. Smaller Reef Boring Machines (RBM) will be utilized to extract the ore.

The blueprint values for the new mine designs were listed as:

- Simple footwall development 70m under reef
- Most development will be on reef
- Declines will be 4.2m diameter
- Exploration drives will be 4.2m diameter
- Reef drives will be 2.8m diameter
- Drive spacing will be similar to conventional
- Reef boring will be 1.0m diameter.

The optimisation exercise was to determine the full potential of extracting gold with minimum dilution and leaving the least amount of gold behind.

Parameter	Value
Maximum gradient (degrees)	8
HBM maximum turning radius (m)	150
Reef drive spacing (m) (measured on dip skinto-skin)	30
Reef drive gradient (percent) (measured above strike)	2
Average working days per month	23
Geological loss (%)	75
Reef boring extraction (%)	78.6
Mine Call Factor (%)	70

Figure 7: Salient design parameters

5.2 Exploration and ore body analysis

Knowledge of the geological settings and associated ore-body characteristics ahead of the face, particularly ore-body geometry, represent crucial input parameters for optimal tunnels placement and confident ore-body extraction. The objective of the project was aimed at proving the concept of utilizing enhanced reverse circulation [RC] drilling technology (Megamatic 6 200N) to achieve a dense orebody intersection pattern (intersections being 30m apart) at significantly higher drill advance rates, when compared to conventional, underground diamond drilling. The second part was to test an in-hole camera.

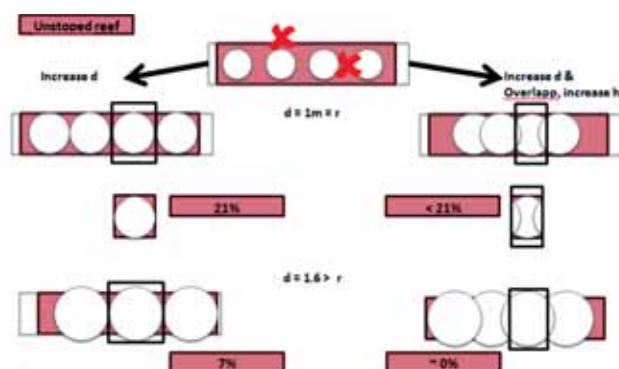


Figure 8: Reef extraction optimisation

A Megamatic 6 200N machine was imported from the USA and testing commenced at Tau Tona mine.

The in-hole camera was tested in a down-hole at Mponeng and despite grease being present along the sidewalls of the hole, hampering camera performance, the images depicted volcanic rock characteristics in great detail and at high resolution.

Fully assembled RC machine

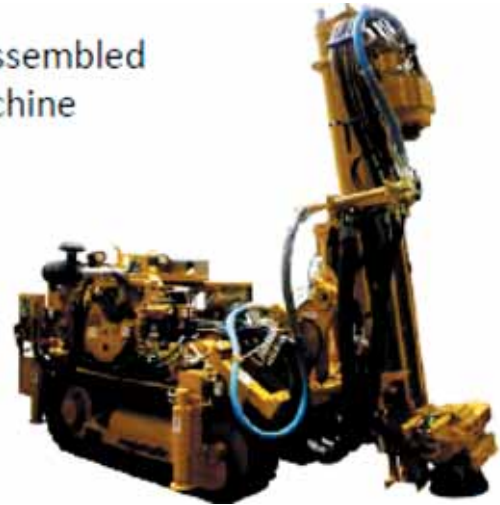


Figure 9: RC drilling machine

5.3. Machines for development

The approach the group took in identifying machines for development was to look at the available technology on the market, within and outside the mining industry (with some focus given to the civil engineering industry), that could possibly meet the underground development requirements.

The focus was on technology that was currently employed, i.e. proven technologies and therefore not in a development stage, even if in other industries. Among all the cutting technologies evaluated, full face tunnel boring was the only existing and proven technology on the market.

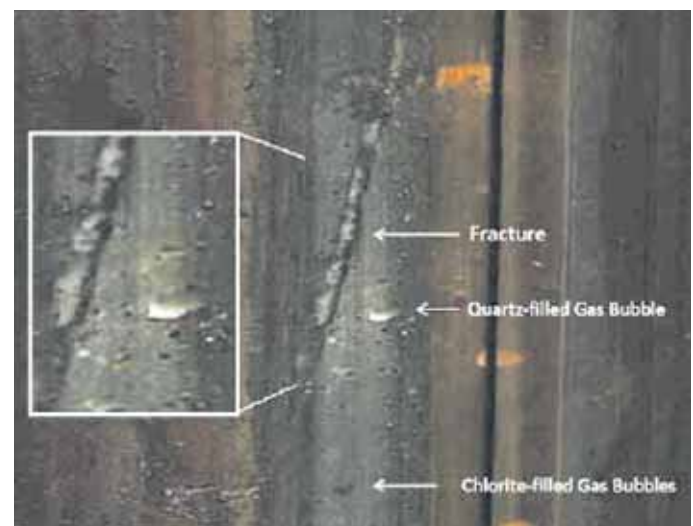


Figure 10: In-hole camera picture

A set of agreed requirements was developed after much interaction with other groups and prospective suppliers / manufacturers (particularly Herrenknecht) for both the HBM (Haulage Boring Machine) and TBM (Tunnel Boring Machine).

These requirements are to be surveyed in the market to determine whether there are machines readily available that can fulfil the requirements with minimum or no design development and testing required.

Such machines from different suppliers / manufacturers will then be evaluated by performing a Technology Readiness Assessment to ascertain the readiness and maturity of each for near term deployment.

The above approach will ensure that requirements are controlled and possible supply risks are identified and mitigated in time with the rest of the mining system design.

A context diagram was drawn up and used to determine all the requirements, their interdependencies and interfaces with other systems such as required by vertical integration and mine design.

A comprehensive set of approximately 244 requirements was compiled for the TBM and HBM which will be used to compile the final Design Criteria for the TBM and HBM.

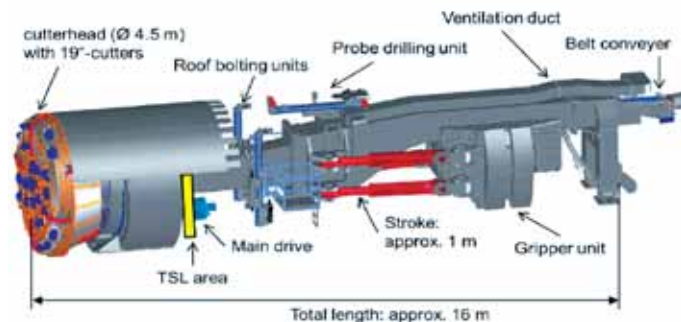


Figure 11: Schematic layout of TBM

5.4 Machines for stoping

As with the TBM and HBM, the group undertook to identify existing technology for the extraction of reef. The concept is similar to the TBM but on a much smaller scale. The optimum hole diameter was identified to be between 800mm and 1000mm.

The trial would include the boring of six holes extracting the reef. The trials at TauTona were completed for four out of the six trial reef bore holes. The approximate total volume bored is 70m³. Gold recovered from the four holes was 14 966 grams.

One of the biggest challenges was the control of Silica dust during boring operations. A vacuum sucking unit was identified and trials on the efficiency of dust control will be commenced.



Figure 12: Reef boring machine

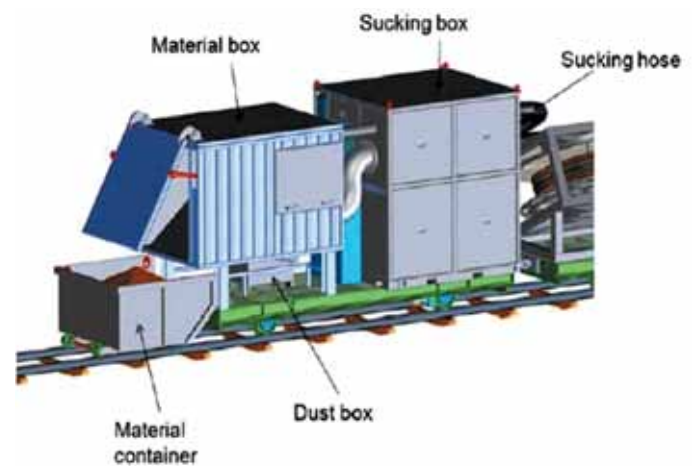


Figure 13. RBM sucking unit

5.5 Material handling

The group's objectives were to investigate the transport of ore and material. Criteria were laid down and comparisons made between the current available technologies. The ore transport system had to comply with the following design criteria:

- Volume flows up to 500 m³/h
- Inclinations up to 35°
- Flexible in routing
- Different loading and discharge points
- Mobile System

The final decision was to investigate the railveyor system further due to small size and flexibility.

A similar exercise was performed to identify material handling options. The following criteria were identified:

- 18 – 50 tons payloads
- Inclinations up to 25%
- 8 m turning radius
- Ability to crab
- Drivable from both ends
- Can operate in tunnels from Ø3m and larger

Criteria	Conveyors	Railveyors	Railway	Trucks	Hydro-transport
No drill & blast	✓✓✓	✓	✓✓	X	✓✓✓
Continuous process	✓✓✓	X	X	X	✓✓✓
Compact	✓✓	XX	X	XX	✓
Can keep off footwall	✓	X	X	X	✓✓✓
Can handle sharp curves	✓✓	✓✓✓	X	✓✓	✓✓✓
No large excavations required for drives, turning or passing bays	✓✓✓	X	X	XX	✓
Can negotiate gradients up to 8°	✓✓✓	✓✓✓	XX	✓✓✓	✓✓✓
Rock can be transported 'dry'	✓✓✓	✓✓✓	✓✓✓	✓✓✓	XXX
Relative power requirements	Low	Medium	Medium	Medium	High
Relative water requirements	Low	Low	Low	Low	Very High
Summary	+2.3	+0.8	+0.1	+0.4	+1.0

Figure 14: Comparison of ore transport methods



Figure 15: Railveyor

Criteria	Utility Vehicles	Rail Transport	Monorail
Versatility	✓✓✓	XX	X
Compact (can fit in Incline)	✓✓✓	✓✓	✓
Compact (can fit in Reef Drive)	✓✓	✓	✓
Can keep off footwall	X	X	✓✓✓
Can handle sharp curves	✓✓	✓	✓✓
Ability to transition from incline to reef drive	✓✓✓	✓	✓
No large excavations required for turning or passing bays	✓✓	X	✓
Can negotiate gradients up to 8°	✓✓✓	XX	✓✓✓
Doesn't need extensive structural supports or connections to rock	✓✓✓	✓✓	XX
Maintainability	✓✓✓	✓	✓
Electric or battery powered	X	✓✓	✓✓
Summary	+2.0	+0.4	+0.9

Figure 16: Comparison of utility vehicles



Figure 17: Diesel powered utility vehicle

5.6 Backfill

The scope included the development of a cost effective, ultra-fill backfill "recipe", which on curing will attain a 200MPa strength, in order to prove the idea that stress changes in the in-situ rock mass at depth of over 5 000 m can be minimised.

This will require the manufacture, in-the-hole placement and curing of the backfill to replace the ore removed by drilling, in the quickest possible time.

A curing time of seven days was set as a target and thus far this seems to be achievable with the latest backfill recipes in laboratory tests.



Figure 18: High strength backfill

6. Second order projects

6.1 Water

The scope of the group was to achieve the design criteria with integration of the new mining concept into the current infrastructure. The water reticulation system was designed and the objective achieved. A need was identified for an interface shell-and-tube heat exchanger between the mine chilled water (Primary Circuit) and the HBM & RBMs water cooling (Secondary Circuit). The required duty would be 1 193 kW.

The boring machines require a high quality of water for the cooling systems and a filter system has to be designed to obtain the specifications.

6.2 Environment

As with the water group, the objective was to confirm whether the new mining method can be ventilated within the current infrastructure of the mine.

The conclusion was that it is possible based on the Mponeng blueprint but a huge amount of air would be required due to the large excavations and heat load from the tunnel boring machines. The VUMA software was utilised for simulating all different iterations of the mine design.

In order to achieve the design parameters with one TBM, two HBMs and four RBMs a minimum of 150m³/s of air would be required.

The 5m diameter haulages would require as a minimum a 75kW fan with a 1200mm ventilation column. For size optimisation it was decided to settle on the twin-duct plastic ventilation column.

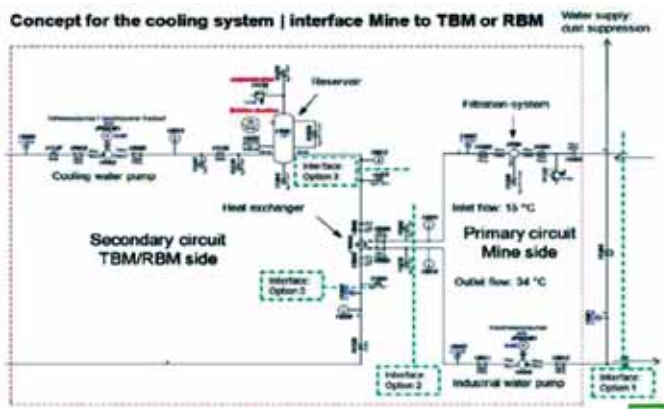


Figure 19: Water reticulation system

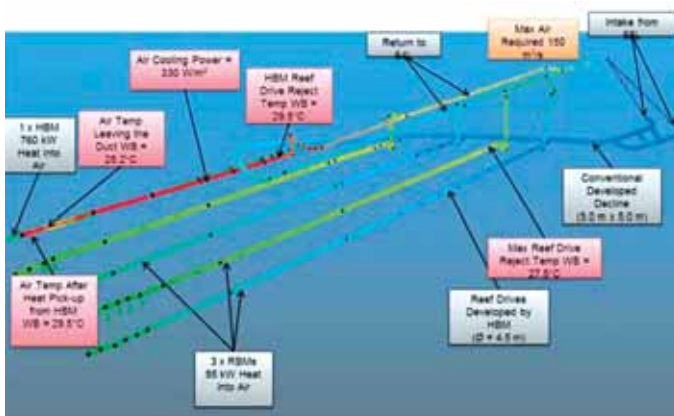


Figure 20: VUMA simulation

A cassette system was designed and built locally that would be fitted on the TBM containing 100m of ventilation ducting extending the column as the TBM moves forward. The cassette was designed for a single duct at the time.

Trade off studies were done between different refrigeration systems including absorption and adsorption chillers. The absorption and adsorption chillers were found to be inadequate for underground use and the decision was taken to utilise the current conventional refrigeration systems.

During the planning of the emergency preparedness it was decided that mobile refuge bays will be part of the TBM.



Figure 21: Twin-duct plastic ventilation column



Figure 22: Ventilation column cassette



Figure 23: Absorption and Adsorption chillers



Figure 24: Mobile refuge bay for TBM

7. Conclusion

The Consortium approach proved to be effective by bringing speed and diversity by team members. The thirteen identified groups performed well in identifying and testing new and current technology that can be applied in this new paradigm of mining. From an environmental point of view many challenges faced the team including but not limited to risks such as heat, Silica dust, flammable gas, fires, etc. The team proved that this new mine design can be ventilated in accordance with the company's design criteria and within the current infrastructure.

8. Acknowledgements

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- 6) Herrenknecht
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Tunnel boring machines in hard rock mining

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Abstract

Historically, mine planners have recognised the benefits of using Tunnel Boring Machine [TBM] technology to facilitate rapid access to ore reserves in hard rock mines. Recently methods that utilise TBM technology to extract ore from narrow reef ore bodies have been researched. Operating TBMs in a deep hard rock environment presents many new complications, not least the greater heat loads and ventilation and refrigeration systems required to mitigate them. Heat is added by the drive motor, exposed rock, rock handling and by ancillary equipment required by the TBM including conveyors and Load Haul Dumpers [LHDs] and it is important that the ventilation and cooling system are compatible with other service requirements [power, water and compressed air]. This paper discusses the heat load and energy balance estimates and practical integration of the TBM systems with environmental considerations including air temperatures and quantities, distance of the advancing face from the through ventilation position, high face advance rates and suppression of dust, noise and other pollutants.

1. Introduction

Tunnel Boring Machines [TBMs] are used for large bore, rapid tunnel excavation. TBMs typically have a circular cross section between 1 m and 8 m and can bore through a variety of soil and rock strata.

The cutter head typically rotates at between 1 and 15 rpm, depending on the TBM diameter and the rock type. The advance rate of TBMs can vary between 10 m/day and 60 m/day, depending on the ground conditions.

Mine planners have recognised the benefits of using TBM technology to facilitate rapid access to ore reserves in hard rock mines and the earliest application of TBMs in mining dates back as early as the late 1950s. Although the penetration rates achieved at the time exceeded those of drill and blast operations, the capital and operational costs could not be justified.

More recently methods that utilise TBM technology to extract ore from narrow reef ore bodies have been researched. Meaningful work has been conducted to investigate the application of TBMs in hard rock mines by AngloGold Ashanti. The intent is to utilise TBMs for development as well as ore extraction, Beukes &

Labuschagne (2013). References to similar work include papers by Cigla et al. (2001), Allum & Van Der Pas (1995), etc.

Operating TBMs in a deep hard rock environment presents many new challenges with regards to heat loads and the ventilation and refrigeration systems required to mitigate them. There are multiple heat sources in a TBM drive and it is important that the ventilation and cooling system are compatible with other mine service requirements.

Note: The paper refers to TBM drives, which can either be a development end or a production zone.

2 Background

The first TBM ever reported was built by the Belgian Engineer Henri-Joseph Maus. In 1845 he obtained approval to construct the first railroad connection between France and Italy and started designing the 'Mountain Slicer' that was to dig the Fréjus Rail Tunnel through the Alps. Maus completed building the 'Mountain Slicer' by 1846 in an arms factory near Turin. It consisted of a locomotive-sized machine, with 100 percussion drills mounted in the front, mechanically power-driven from the entrance of the tunnel. However, it was never used and the tunnel was finally built using conventional drill and blast methods.

The first "successful" TBM manufactured and operated was in the United States in 1853, during the construction of the Hoosac Tunnel. Unfortunately, it drilled only 3 m into the rock before breaking down. One hundred years later, James S. Robbins manufactured a machine that was able to cut through a very difficult shale rock formation, at an advance rate of 49 m/day, which at the time was ten times faster than any other advance rate.

The breakthrough that made TBMs more efficient was the invention of the rotating head and the use of cutting discs/wheels instead of rotating spikes. The consequence was that the frequency of replacement of the wearing parts could be reduced. TBMs typically consist of one or two shields to protect the TBM and personnel (depending on the integrity of the rock) and trailing support mechanisms.

At the front of the shield is a rotating cutter head and behind the cutter head is a chamber. Behind the chamber is a set of hydraulic jacks, which is used to push the TBM forward. The cutter head cuts the rock face into chips or excavating soil (called muck). Depending on the type of TBM, the muck will fall onto a conveyor belt system or into skips and be carried out of the tunnel. Figure 1 shows a typical TBM. Surface boring machines with total lengths of

up to 150 m (machine and train) are not uncommon. The train contains the operator's cabin, hydraulic equipment, cooling equipment, ventilation equipment, hose reels, spares, consumables, etc.



Figure 1: Tunnel boring machine

TBM's are generally very expensive due to special engineering and non-mass production and can be difficult to transport. However, it is becoming more feasible to make use of the TBM method than conventional drill and blast methods, due to the high advance rates of these machines.

A TBM with a diameter of 14.4 m was used for the Niagara Tunnel Project to bore a hydroelectric tunnel beneath the Niagara Falls. The TBM was manufactured by the Robbins Company and is to date the largest hard rock TBM. The largest TBM ever built (to bore through soft ground) for the Orlovski Tunnel, was built by Herrenknecht AG and had a diameter of 19.25 m.

The Gotthard Base Tunnel (railway tunnel) beneath the Swiss Alps is expected to open in 2016. The tunnel is bored with a TBM and will have a total route length of 57 km, which gives it the title of the world longest rail tunnel.

3. Conventional hard rock mining

The primary method of production and rock breaking in the South African hard rock mining industry is conventional drilling and blasting. The critical path for the drill and blast cycle includes (Stewart et al. 2006):

- Drilling
- Charging and blasting
- Ventilation (clearing blasting fumes)
- Mucking
- Preliminary ground control

Because of this time consuming process, tunnelling advance rates in fully mechanised drill and blast hard rock mines are limited to approximately 5 m/day per single end, applying multi-blasting. Due to the high advance rates of TBM's, the mining industry has been investigating the utilisation of TBM's for rapid access to ore reserves in hard rock mines. Although the earliest application of TBM's in mining dates back as early as the late 1950s, methods that utilize TBM technology to extract ore from narrow reef ore

bodies have recently been researched.

Drill and blast is a well-developed technology in the hard rock mining industry and the choice of the method of excavation becomes a matter of economics.

One of the key issues when considering the two methods is the haulage (tunnel or development) length. TBM's have high capital costs, but due to higher advance rates, unit cost per meter of tunnel is lower (beyond a certain tunnel length). One of the downfalls when considering the use of a TBM in mining is the turning radius of the machines and the length of the train behind the cutting head. A fit-for-purpose underground TBM with a diameter of 5 m can be designed with a machine length of about 15 m, a train length of approximately 30 m and a turning radius in the order of 75 m.

A rule-of-thumb factor, as documented in Nord (2006), indicates when a TBM application might be financially suitable. It takes into account the tunnel length, tunnel diameter and the rock strength. Typically, if the factor is higher than three, it might be economical to use a TBM but if less than one, drill and blast is the preferred option. The rule, however, does not take into account ground conditions and the rock abrasiveness.

4. TBM operation

Due to the size of TBM's, most machines would have to be dismantled for transport underground and then re-assembled. It is therefore necessary to prepare surface and underground assembly sites.

An area large enough to host the TBM must be constructed with a framework and hoists that can support the maximum weight of the components that need to be lifted. Additional services required to do tests runs of the machine must also be installed.

A launching chamber must be prepared at the start of the tunnel to initiate TBM mining. All haulages along the route to the launching chamber must be large enough to ensure a clear passage of the TBM. The launching chamber is developed by conventional methods. Other preparation work includes provision of services such as power, water and compressed air. Figure 2 shows a typical layout of a TBM.

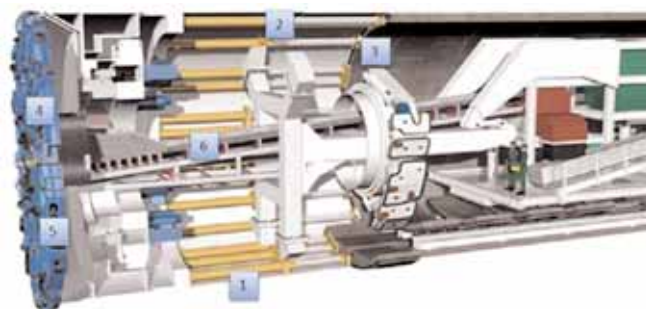


Figure 2: Typical Layout of a TBM

The TBM consists of a tapered steel structure, which is protected by a shield (1). The machine extends and drives forward in the tunnel and in order to do this, it is supported by hydraulic thrust cylinders (2), installed on the last segment ring (3). The cutter head wheel (4) is fitted with hard rock cutting disks, which roll across the tunnel face, cutting the rock face into chips or excavating soil (muck).

Muck bucket lips (5), which are positioned behind the disks, carry the extracted rock behind the cutting wheel. The muck then falls onto a conveyor belt (6) and is carried out of the tunnel.

TBM use spray water to allay dust and cool heat generated in the cutting discs by friction during face cutting. This may either be delivered in a separate water pipe or alternatively spray water can be tapped off from the chilled water pipes, which provide chilled water to the TBM for removal of motor heat, etc.

5. TBM drive heat loads

It is important to control the temperature and air conditions at all points in the tunnel, air duct and the face zone (referred to as the TBM zone) to protect operators and equipment. It is therefore necessary to take into account all possible sources of heat in the TBM drive. From previous work (von Glehn & Bluhm 1995) that included monitoring and simulation of TBM drives; it was evident that the heat loads could be divided into two groups; heat loads from the tunnel zone and heat loads from the TBM zone.

The following have to be taken into account when calculating the heat load in the tunnel zone:

- Heat flow from the surrounding rock (including moisture effects)
- Effect of chilled water and spray water pipes in the tunnel (including condensation)
- Effect of diesel vehicles operating in the tunnel (including moisture)
- Effect of ground water and drain water
- Heat transfer between air in the tunnel and air in the duct
- Thermal effect of the fans in the tunnel
- Thermal effect of lights, cables, transformers, electric motors, etc.
- Heat transfer from the muck (broken rock and water mixture)

The following have to be taken into account when calculating the heat load in the TBM zone:

- Heat generated by the TBM (electric motors, hydraulic oil pumps, fans, etc.)
- Effect of machine cooling water
- Effect of spray water
- Effect of airflow through the TBM cutter head zone
- Effect of airflow through the dust scrubber
- Heat transfer from the muck to the air

- Heat flow from the surrounding rock in the TBM zone (including moisture effects)
- Thermal effect of additional fans in the TBM zone
- Thermal effect of diesel vehicles operating in the TBM zone (including moisture)

The heat generated by the TBM motors is the most substantial heat load in a TBM zone. All the electrical power used by the TBM (not the motor rated power), will essentially manifest itself as heat; either into the broken rock (muck), cooling water or directly into the air. The TBM rated motor power may include the cutter head drive motors, hydraulic pump motor, lube pump motor, conveyor drive motor, auxiliary fans in the TBM zone, scrubber fans, probe drill and backup hydraulics.

From previous work carried out (von Glehn & Bluhm 1995, 1997), it has been found that thermal storage takes place in the muck, surrounding rock and in the cutter head parts in the TBM face zone.

Due to the thermal capacity of the components, a damping effect results with a time-constant of approximately two hours. Measurements indicated that the maximum average heat from the TBM is between 40% and 55% of the rated power (hereunder referred to as the TBM Factor). This, however, will vary from case to case.

The heat generated by the TBM that is not removed by the cooling water is split up, with approximately 70% being transferred to the muck and 30% transferred directly into the air. Consequently, heat is transferred from the warm muck into the air in both the TBM zone and the tunnel zone.

Another significant thermal input into the air is the heat from the surrounding rock, especially in the TBM zone where the hot rock is newly exposed.

Due to the high-speed development of TBM drives, this heat flow must be taken into account in both the Tunnel zone and the TBM zone.

6. Thermal energy balance and cooling requirements

A typical energy balance for a TBM drive is shown in Figure 3. The TBM drive is divided into the Tunnel zone and the TBM zone.

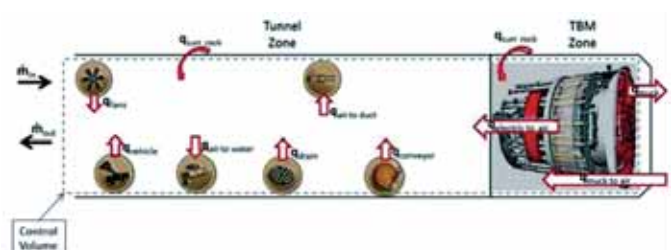


Figure 3. Energy Balance in the TBM Drive

In the Tunnel zone, cool air enters the ventilation duct and is forced to the TBM zone. As the air flows through the duct, the air temperature will increase due to heat transfer from the warmer return air to the cooler intake air. The mechanism of heat transfer from the return air to the intake air is a combination of both convection and conduction and is a function of the duct material properties and the temperature difference.

Similarly, the return air will gain heat from sources such as surrounding rock, vehicles, broken rock on the conveyor, lights, open drains and chilled water pipes. All these heat sources and sinks influence the heat transfer between the return air and the intake air in the duct and thus the temperature of the air being delivered to the TBM zone. Calculating the temperature of the air delivered to the TBM zone is therefore an iterative process.

The most significant heat load in a hard rock Tunnel zone is typically from surrounding rock. The estimation of the heat transfer from the surrounding rock, for rock surfaces that have been exposed for long times, is well documented (Goch & Patterson 1940, Jaeger & Chamalaun 1966, Hemp 1985). Due to the complexity of the fundamental equations, calculation methods rely on interpolated approximations.

For TBM drives with newly exposed rock, approximations to the Jaeger and Chamalaun tables (Jaeger & Chamalaun 1966) were used as they are valid for newly exposed excavations.

In the TBM zone, the heat generated in the TBM cutter head is the most significant heat load and is electrical energy converted to friction heat. Factors that affect heat flow in the TBM zone are spray water flow, spray water temperature, TBM advance rate and Virgin Rock Temperature (VRT).

The enthalpy of the air in the TBM zone and Tunnel zone is then used in conjunction with psychrometric properties to calculate the air condition. By taking into account all heat sources, an energy balance is carried out to calculate required air cooling.

7. Ventilation system and integration

Figure 4 shows the typical secondary ventilation of a TBM drive.

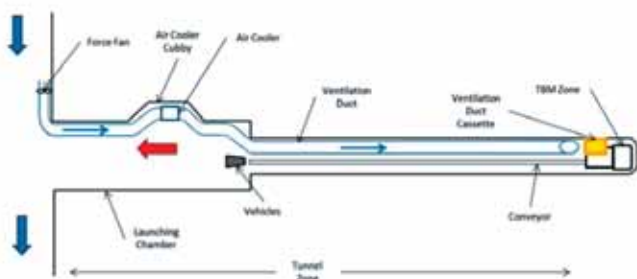


Figure 4: Typical Ventilation of a TBM Drive

The secondary ventilation design for a TBM drive must first consider the type of ventilation system to be implemented (force or exhaust). Typically a forced ventilation system would be the option of choice; as this allows for more flexibility when considering the type of ventilation duct and duct installation.

Some of the advantages of a forcing system that are applicable to conventional mining as well as TBM mining are:

- Good quality air is delivered to the face at a high velocity
- The fan and motor are always in fresh air
- Leakage is from the column and is thus easily detected

The only disadvantage of the forced system in TBM mining is:

- People travelling and working in the TBM drive do so in return air

Two types of duct can be considered: steel ducting and flexible ducting. In general, flexible ducting has a lower friction factor (k-factor) than steel ducting and because of long tunnel lengths achieved with TBMs and significant air-flow requirements this becomes one of the major considerations. The k-factor for a steel duct is typically in the order of 0.004 Ns²/m⁴ and for flexible ducting it is typically less than 0.002 Ns²/m⁴. Flexible ducting is light and is typically supplied in 100 m lengths, utilizing a cassette fitted to the TBM feeding the ducting and a suspension wire as the TBM moves forward. The 100 m lengths are then coupled together with methods such as zippers, Velcro or interlocking rings and clamps, which in turn reduce labour intensity. Although flexible ducts are not as strong as steel ducts, a typical 1 000 mm diameter flexible duct, with a safety factor of 10 can withstand a positive pressure of in excess of 10 kPa.

The leakage factor is specified as a function of the pressure, with most flexible duct suppliers specifying a leakage factor lower than 0.055 m³/s per 100 m at 1 kPa. However, the most important issue with leakage in actual mining situations is the maintenance of the duct material and proper installation of couplings. Taking this into account, it would be safe to assume a maximum leakage factor of 0.05 m³/s per 100 m per 1 kPa.

Long tunnel lengths also have a major effect on the fan selection and heat loads. Firstly, the longer the tunnel (or ventilation duct) the more pressure is required from the fan to deliver air to the face (friction).

The higher the pressure and the longer the duct; the more leakage there is from the duct. In order to deliver the required quantity to the face, a high pressure fan station is required, which could consist of a number of axial flow fans in series or the utilisation of a single centrifugal fan.

To reduce the pressure load on the ventilation fans, larger ducts sizes can be installed. Flexible ducting is also available in flat "oval" shapes, which yields larger cross-sectional areas with better utilisation of the available space as shown in Figure 5.

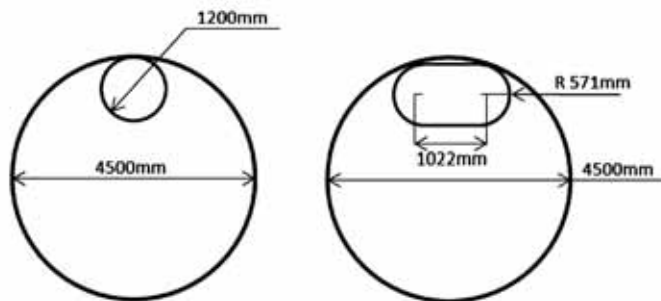


Figure 5: Flexible Ducting with an Oval Shape

Air cooling might be required in the tunnel zone as well as in the TBM zone if sufficient cooling cannot be provided by the ventilation air alone. If air coolers are to be installed in-line with the ventilation ducting, provision must be made for cooling coil/car cubbies

When air coolers are considered, the pressure drop over these coolers has to be taken into account when the fan selection is carried out. The air pressure drop across these coolers can vary between 1 000 Pa and 2 000 Pa.

Through-ventilation distance is another issue that has to be considered. At a certain face advance distance, it becomes impractical to ventilate the face with a forced system alone and connections between TBM drives must then be made to keep the throughventilation distances economically viable.

From previous studies conducted by AGA, (Beukes & Labuschagne 2013), it has been concluded that the amount of ventilating air required for TBM mining is higher than for conventional methods.

This is mainly due to more heat being generated in the face zone by the TBM thus the implementation of TBM mining requires non-conventional ventilation and cooling methods.

8. Occupational hygiene and health and safety

Where personnel have to operate the TBM and work in the Tunnel zone, wet-bulb temperatures have to be kept below a certain design limit, typically below 29°C.

The next major pollutant is dust. This is managed at the TBM zone via a scrubber system integrated into the TBM. Dust will also be liberated from the conveyor belt. This dust is managed by controlling the air velocity over the conveyor and by wetting the rock. It might be required in long drives to re-wet the air as the rock dries out. Dust masks can also be used where dust is a problem.

The next pollutant to deal with is noise and this is firstly managed by addressing it at source and this is done by TBM manufacturers to client specifications. In addition, hearing protection must be used by personnel. TBM drives in hard rock mines introduce a risk of fire due to the presence of electricity, oil, diesel and conveyor belts and personnel should be provided with self-contained self-

rescuers. In addition an early warning system should be installed and refuge bays need to be provided as per legal requirements.

9. Conclusions

Implementing TBM technology in hard rock mining is challenging from a ventilation and cooling perspective and requires non-conventional ventilation and cooling methods.

The amount of ventilating air required for TBM mining is higher than for conventional methods and requires high pressure fans and duct systems. Heat load calculation methods exist to predict TBM zone and Tunnel zone air conditions and allow design of appropriate ventilation and cooling systems.

Due to the typically high airflow and cooling requirements for TBM mining integration with existing mining systems needs to be carefully considered where TBM mining is implemented in an existing conventional mine.

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Cocktail function in appreciation

At a Cocktail function held on 20th March 2015, at the Johannesburg Country Club, President of MVSSA Vijay Nundlall presented certificates of appreciation to authors of the "Ventilation and Occupational Environment Engineering in Mines" book for their contribution to the 2014 edition.



M Bailey McEwan



Marco Biffi



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DO del Castillo



Jan du Plessis



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Schu Schutte



Frank von Glehn



Derek Walters

Northern Branch year end function

Francois Slabber, Chairman MVS Northern Branch

Abstracted with thanks from a letter sent to the sponsors of the Northern Branch's 2014 Year End Function

On behalf of the MVS Northern Branch I would like to express my gratitude for your contribution towards our year end function which was held on Saturday, 29 November 2014 at Waterkloof Resort, Kosterdam.

The function was attended by 229 people and was thoroughly enjoyed by young and old.

The MVS is about its people - to live our values, care and walk the talk.

This was an opportunity to give back to our members which was successful thanks to our sponsor's contributions to our function. The pictures below serve as testimony of the great day.



Obviously with a day like this a lot of planning and organising are done behind the scenes and for this I would like to thank Bill Erasmus of Waterkloof Resort for the excellent facilities and hospitality to make this day a success for us.

Everything was in place and clean and no work or help was too much. The friendly faces of the staff were infectious just to complete a joyful day.

Journal of the Mine Ventilation Society of South Africa

Published quarterly, the Journal is well-known for its papers, which have been used for reference and teaching purposes over the last 70 years. It has been very influential in establishing many procedures, which have now become standard practice throughout the profession.

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Refining ID and access management at mining sites

Jordan Cullis, Director of Sales Australia and New Zealand, HID Global

The mining industry has a long history of innovation in technology. From exploration to production, sales and logistics, mining companies have harnessed technology to bring greater accuracy and automate processes to introduce ever-greater efficiencies. More recently, the industry has begun to pioneer new approaches for use of smart card technology as a means of securing assets and operations.

In the past, mining organisations typically relied on multiple credentials and access control systems to fulfil different tasks, resulting in the proliferation of single-purpose systems running in parallel. In addition to being resource-intensive, disparate access control and security systems do not scale and can be costly to integrate.

A consolidated strategy is therefore crucial. Today, the focus has moved to converged systems capable of securing a wide range of sensitive sites and assets, including heavy equipment and transportation.

Meeting multiple challenges at scale

Aside from hazardous materials and harsh working environments, numerous factors expose mining organisations to significant risk. Remote sites, limited local infrastructure and geopolitical instability can all make installations susceptible to malicious attack. Any security breach has the potential to endanger staff, damage the local environment and disrupt production.

In addition, these factors are magnified by the scale of the operation involved. Mines may cover a large area and employ hundreds or thousands of staff. Companies must not only ensure the well-being of these communities, but also have the necessary infrastructure to quickly and positively identify each individual, issue each individual with the required credentials, and restrict movements on-site according to the access rights demanded by the individual role and corresponding credentials.

Besides taking into consideration all of the policies and processes of an organisation, there are two major aspects to consider when managing and controlling access to information and resources:

Physical access to sites – This is often delivered via hardware and software components including access control readers, which are autonomous devices performing the single purpose of interfacing with credentials;

Logical access to computer networks – Information technology access control procedures that restrict a user's ability to interface with computing and networked resources and data. These procedures include secure authentication, data encryption, single sign-on, and remote VPN (virtual private network) access.

Logical credentials are virtual or knowledge-based 'tokens', such as a password or PIN (personal identification number), and for enhanced security, a physical credential might also be employed for another layer of authentication. Physical credentials include security tokens such as key chains and USB devices, but smart cards have become the mining industry's de facto standard.

According to Global Industry Analysts (GIA) Inc., the global market for smart cards is forecast to reach US\$26.3 billion by 2015. This increase will be driven by security and infrastructure projects and the ongoing shift to replace traditional magnetic-stripe cards in banking/financial institutions with the latest chip-and-pin payment technology.

A pipeline of practical solutions

Still, there is no 'one size fits all approach' to a comprehensive smart card, and identity and access management, strategy for the mining industry. Accordingly, are there a host of factors introducing specific vulnerabilities, such as the level and type of threats faced, and the physical environment?

For example, some facilities will be particularly challenged by environmental factors such as heat, dust, and risk of explosions and these conditions may require rugged wireless access control solutions. In the office environment, the risk of a physical attack or accident may be lower, but the threat to information security is may be greater. In this case, a physical credential may be preferred to combine PC logon security (logical access) and physical access onto a single smart card. This combined solution increases logical security while also resulting in significant cost savings since the same credential can be used for multiple applications.

However, consolidated strategies entail more than simply the credential and the control reader. To ensure a balance between convenience and security, access rights should be centrally managed, and a holistic approach that integrates operational support systems, network infrastructure and facility management solutions should be taken.

Smart cards have become the solution of choice for mining applications because they guarantee higher levels of cryptography and security than that offered by legacy proximity card solutions. They drive efficiencies and cost savings by enabling the same credential to be used for many other applications, such as equipment vending machines that enable management to keep track of who has what safety equipment at a given site, or touch screen training systems that record essential health and safety data.

Additionally, large mining companies should consider requirements based on the national and or worldwide footprint of their facilities. For these organisations, an identification and access management system must be capable of being deployed across continents, integrated with a wide variety of host systems and adaptable to include additional country or site-specific security measures.

The importance of securing mining assets is unlikely to diminish in the years ahead. Indeed, as some resources grow scarce, the need to secure information and limit physical access to assets will become greater. The challenge is to achieve the required level of security without forgoing convenience and efficiency, and this is where the value of a converged smart card strategy will become increasingly apparent.

EXAMINATION PROGRAMME 2015

PAPERS	EXAMINATION DATES	
	May	October
MEC Paper 1	11 May 2015	12 October 2015
MEC Paper 2	13 May 2015	14 October 2015
MEC Paper 3	14 May 2015	15 October 2015
MEC Int Paper 1	15 May 2015	16 October 2015
MEC Paper 4	15 May 2015	16 October 2015
MEC Int Paper 2	18 May 2015	19 October 2015
MEC Paper 5	18 May 2015	19 October 2015
MEC Paper 6	19 May 2015	20 October 2015

ENROLMENT COST: R1000.00 PER PAPER

Time: 14:30 - 17:30 (All papers) except 08:30 - 10:00 (MEC Paper 6)


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NEW



ACTOM Mechanical Equipment successfully executes mine vent retrofit project at Black Rock manganese mine



The new shaft top being lowered into place over the mouth of Black Rock mine's 500 m deep main vent shaft.

Mining ventilation fans manufacturer and contractor ACTOM Mechanical Equipment successfully performed a major mine ventilation fan retrofit project recently, replacing an existing fan assembly with an extended version within a three-day shutdown period at Assmang's Black Rock underground manganese mine near Kathu in the Northern Cape.

Black Rock is operated by Assmang Ltd, which is jointly owned by Assore Ltd and African Rainbow Minerals Ltd.

As a result of expansion of its mining operations Black Rock required an upgrade of its main ventilation fan system with the addition of a fourth 2,9 m diameter centrifugal fan to the existing three-fan installation, which ACTOM Mechanical Equipment designed, manufactured and supplied eight years ago.

"Traditionally we have always produced mine vent fans for new installations, either for a new shaft for an existing operating mine or for a new mine that is about to start up, so what was new for us in this project was that it involved a retrofit on an already operating shaft where we were allowed

a very limited shutdown period in which to execute the changeover," said William Nichol, ACTOM Mechanical Equipment's Project Manager on the project.

"The shutdown period was exceptionally tight at only three days because the mine depends on this main ventilation system for all its ventilation and it therefore necessitated shutting down all mining operations while the changeover of the fan system was carried out."

The changeover involved having to remove the existing shaft top, replace it with a new one and make the entire system ready to go back into service on the morning of the fourth day. "This required careful preplanning that included coordinating the civils in preparation for the new installation and delivering the fan system comprising the replacement shaft top and quadfurcation to site to preassemble them on site ahead of the shutdown. We were also required to present method statements, safety procedures and an installation schedule to satisfy the mine's engineering consultants overseeing the project as to the soundness of our installation

procedures and to ensure that they met all the mine's requirements," Nichol explained.

The installation process, executed at the end of July 2014, went smoothly and was completed well within the shutdown period.

Said Craig Johnston, ACTOM Mechanical Equipment's General Manager: "We have been planning for some time to enter the retrofit market for mine ventilation fans. Having proven through the success of the Black Rock Project that we have the skills and project management expertise to carry out such projects efficiently we intend to go all out to obtain more work of this kind.

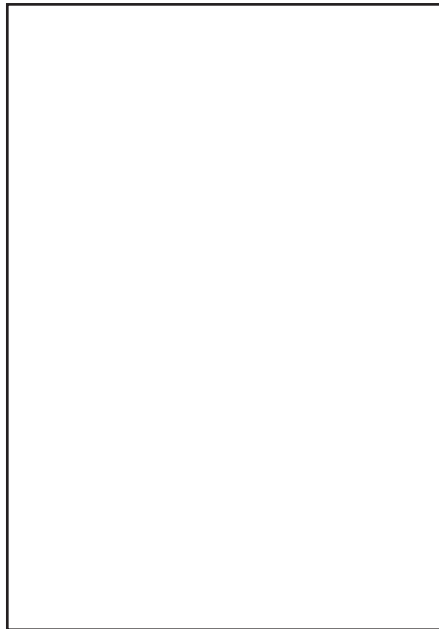
"We hope in this way to extend the scope of our ventilation fans business, especially in the high end of the industry where we already enjoy a longstanding good reputation as a supplier and contractor on new vent fan installations."

Contact Craig Johnston,
ACTOM Mechanical Equipment
Tel (011) 878-3029
E-mail craig.johnston@actom.co.za

SVANTEK 104is intrinsically safe noise dosimeter

Envirocon Instrumentation have recently launched the SV 104IS - SABS intrinsically safe version of the revolutionary personal noise dosimeter, the SV 104. Both instruments offer a new approach to occupational health and safety noise monitoring presenting features such as 1/1 octave band real-time analysis and audio events recording functions which are a new quality in an instrument of this size. All results are clearly displayed on the amazing OLED screen which offers excellent visibility even in full daylight or darkness.

This personal dosimeter has a robust 1/2" MEMS microphone enabling easy calibration using most commonly available acoustic calibrators. The new microphone has a large dynamic range of the 90dB which allows to measure noise from 60 dBA to 140



dBA. The long list of microphone advantages includes also the auto calibration feature and TEDS memory

that stores the calibration info in the microphone itself. The auto-calibration means performing the acoustic calibration automatically once the microphone is inserted into the calibrator.

The SV104IS is a cable-free dosimeter and is typically attached to the user's shoulder, close to the ear using the mounting clips supplied. The instrument works with Svanteks health and safety software package, "Supervisor", that provides various tools for data analysis and reporting. The docking station supports data transfer to the PC through the infrared interface as well as handles the battery charging. Rechargeable batteries of SV104IS are able to power the instrument for 50 hours.

Contact Envirocon Instrumentation
Tel: +27 11 476-7323
www.envirocon.co.za



environmental and occupational hygiene instruments





SV103 Personal Hand Arm Vibration Meter



SV104 Noise Dosimeter



SV971 Type 1 Sound Level Meter



SV106 Hand Arm/Whole Body Vibration Analyser



T: 011 4767323
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sales@envirocon.co.za
www.envirocon.co.za

Cost Reduction & Milestones Achievements



Dates:

20-22 May 2015

Venue:

Emperors Palace
Kempton Park
Johannesburg



Contact:
MVSSA
Tel: +27 11 482-7957
Email:
secretary@mvssa.co.za
www.mvssa.co.za

Call for Papers

Pertinent dates:

- 2nd March - Deadline for abstract submission
- 13th March - Notification if paper is accepted
- 8th May - Submission of paper/power point presentation for publishing in the conference handout

Practitioners of all experience levels are encouraged to submit papers on the wide variety of fields of engineering that are applied to solve mine ventilation challenges.

Particular emphasis should be given to topics relating to this year's theme "Cost Reduction & Milestones Achievements". Areas that are related should include:

- Heat and refrigeration
- Water reticulation systems
- Cost of energy and energy management
- Fires fighting strategy
- Prevention of methane and coal dust explosions
- Dust and other pollutant controls
- Diesel emission control and measurement
- Main and auxiliary fans
- Ventilation planning
- Ventilation in coal mines
- Instrumentation
- Achievement of new MHSC milestones on noise and dust

Presentations will be distributed at the conference in a bound format
Papers that are submitted for publication in the Journal will be peer-reviewed

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Cost Reduction & Milestones Achievements

Provisional Programme



Dates:
20-22 May 2015

Venue:
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1. Solving localised cooling problems: operational experience with Air Cooling Units at Beatrix Mine. *R Potgieter, B Nel, HJ van Antwerpen, M van Eldik*
2. Protocol for the evaluation of continuous miner heading ventilation systems using practical on-site measurements. *A Thomson, AP Cook, RM Fourie*
3. Using CFD analysis to optimise mine ventilation systems. *J Viljoen*
4. Ice thermal storage system on air cooling plant at Impala. *TS Pooe, AR Branch, A Pieters*
5. AAP School of mines, the energy saving initiative. *I Sibisi*
6. Risk assessment factors for frictional ignitions by continuous miner cutter picks. *TF Ngobeni*
7. Optimising ventilation systems in a coal mine heading for effective methane dilution and control using computational fluid dynamics. *CF Meyer*
8. Development of a risk management model to assist mine management and operators to prevent methane ignitions in continuous miner headings. *D Marais*
9. The Sibanye Gold noise and dust management strategy to achieve the revised MHSC Milestones issued to the mining industry on 19 November 2014. *DC van Greuning*
10. In-stope dust control at Beatrix Gold Mine. *JJL du Plessis, MH van der Bank*
11. Effectiveness of applying dust suppression palliatives on haul roads. *JJL du Plessis, L Janse van Rensburg, LP Janse van Rensburg*

Papers discussed, not received in time for review, but seem acceptable for inclusion

12. Use of alternative cooling fluids to reduce cooling costs. *R Wilson*
13. Performance contracting - Putting the Esco's money where its mouth is to save energy. *J Prange*
14. Effective commissioning plan for Northam Platinum underground refrigeration system. *A Andhee*
15. Evolution of ventilation software into real-time management tool. *H Botma*
16. Diesel engine emission deterioration - a preliminary study. *C Pretorius*
17. Intra-sampler performance variability of respirable dust samplers used in mining environments. *C Pretorius, E Cauda, C Wolfe*

First pass of allocating papers to sessions

Day 1 papers	Day 2 papers
Solving localised cooling problems at Beatrix	Effective commissioning plan for Northam Platinum underground refrigeration system
Protocol for the evaluation of continuous miner heading ventilation systems	Development of a risk management model to assist mine management and operators to prevent methane ignitions in continuous miner headings
Optimising ventilation systems in a coal mine heading for effective methane dilution	Using CFD analysis to optimise mine ventilation systems
The Sibanye Gold noise and dust management strategy to achieve the revised MHSC Milestones	In-stope dust control at Beatrix Gold Mine
Use of simulation to examine the effect of ventilation changes on a fire	Risk assessment factors for frictional ignitions by continuous miner cutter picks
Performance contracting to save energy	Effectiveness of applying dust suppression palliatives on haul roads
AAP School of mines, the energy saving initiative	Ice thermal storage system on air cooling plant at Impala
Use of alternative cooling fluids to reduce cooling costs	Diesel engine emission deterioration - a preliminary study
Intra-sampler performance variability of respirable dust samplers	Junior 3
Junior 1	Junior 4
Junior 2	Junior 5



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Cost Reduction & Milestones Achievements

Delegate Registration Form

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Full registration	20-22 May	R 4 500.00		R 4 000.00	
Single day registration	20 May	R 2 500.00		R 2 200.00	
	21 May	R 2 500.00		R 2 200.00	
Students per day				R 500.00	
Cocktail party only		R 1 000.00		R 1 000.00	



Dates:
20-22 May 2015

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The Mine Ventilation Practitioner's Data Book

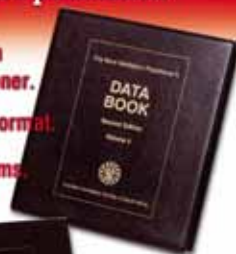
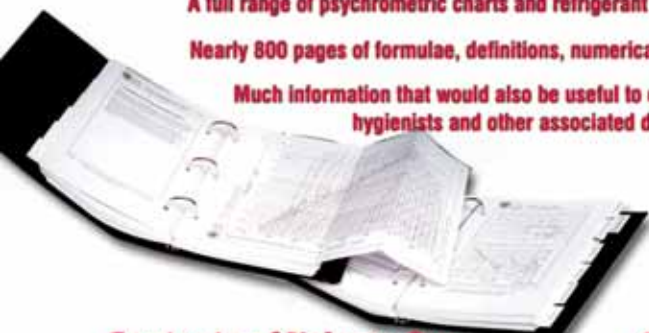
The new revised and enlarged second edition of this much-acclaimed publication

Now in two volumes, and retaining the loose-leaf format, the Data Book is an extensive compilation of reference information for the mine ventilation practitioner.

A full range of psychrometric charts and refrigerant property diagrams in A4 format.

Nearly 800 pages of formulae, definitions, numerical data, graphs and diagrams.

Much information that would also be useful to engineers, occupational hygienists and other associated disciplines.



Contents of Volume One

GENERAL REFERENCE: Miscellaneous data. SI units. Conversion tables. Conversion factors. Software. **MATHEMATICS AND STATISTICS:** Mensuration. Mathematics. Statistics. **FLUID MECHANICS:** Property definitions. Numerical data. Dimensional analysis. Statics. Energy equations. Momentum equations. Pumps. Turbines. Dimensionless groups. **FLOW OF AIR:** Basic equations. Flow in airways. Flow in fittings. Airflow measurement. Atkinson's equation. Ventilation columns. Miscellaneous. **FLOW OF WATER:** Flow measurement. Flow in pipes. Dynamic losses. Miscellaneous flow. **THERMODYNAMICS AND PROPERTIES:** Principles of thermodynamics. Thermal properties. Psychrometry. **HEAT TRANSFER:** Conduction. Convection. Thermal radiation. Latent heat. **WATER QUALITY:** General information. Quality standards. Properties and contaminants. Water treatment. **NOISE:** Hearing. Sound. Levels and criteria. Noise assessment. Hearing protection. Generation and attenuation. References. **ILLUMINATION:** Definitions. Lamps and luminaires. Illuminance levels.

Contents of Volume Two

FANS: Fan performance. Combined fans. Drifts and evasees. Auxiliary fans. **UNDERGROUND VENTILATION:** Ventilation doors. Seals and brattices. Crossings and regulators. Control in stopes. Development ends. Special locations. **INDUSTRIAL VENTILATION:** General ventilation. Air conditioning. Local exhaust. Cleaning equipment. **HEAT STRESS:** Stress indices. Underground work. Surface work. **HEAT EXCHANGERS:** Heat transfer Indirect contact. Air coolers. Direct contact. **REFRIGERATION EQUIPMENT:** Refrigeration cycles. Refrigerant properties. Refrigeration machines. Indirect coolers. Direct contact coolers. **PLANNING:** Ventilation refrigeration. **COMPRESSED AIR:** General. Planning. Consumption. Rockdrills. Pressure losses. Leakage. **PIPES AND FITTINGS:** Steel pipes. Plastic pipes. Ventilation ducting. Pipe insulation. **FIRES AND EXPLOSIONS:** Ratios and triangles. Ignitions and explosions. Combustion and products. Fire fighting. Explosion control. Explosion panels. **IONISING RADIATION:** Radioactive decay. Unit definitions. Dose limitation.



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Vuma-3D

VUMA is a comprehensive suite of computer programs with 3D interactive graphics which allows for the monitoring of mine pressure, velocities and the distribution of pollutants. A comprehensive simulation of mine ventilation and cooling networks

