Minerals Council South Africa

MEMORANDUM

SUBJECT: CHAMBER OF MINES OF SOUTH AFRICA – CERTIFICATE IN MINE ENVIRONMENTAL CONTROL PAPER 3	**EXAMINER:** M. Coelho **MODERATOR:** A. Oosthuizen
SUBJECT CODE: COMMEC3– ECONOMICS, PLANNING AND TECHNICAL LITERATURE	**TOTAL MARKS:** 100
EXAMINATION DATE: 13 MAY 2021	**PASS MARK:** 60%
TIME: 14:30 – 17:30	

NUMBER OF PAGES:12

SPECIAL REQUIREMENTS:
THIS IS NOT AN **OPEN BOOK EXAMINATION**. **FORMULA HANDOUT IS AVAILABLE**
INSTRUCTIONS TO CANDIDATES:

1. Answer all questions **legibly** in English.
2. Write your **ID number** on the outside cover of each book used and on any graph paper or other loose sheets handed in.

NB: Your name **must not** appear on any answer book or loose sheets.

3. Show all calculations **and check calculations on which the answers are based.**
4. Hand-held electronic calculators may be used for calculations.
5. Write **legibly** in ink on the **right-hand page** only – **left hand pages will not be marked**.
6. Illustrate your answers by means of sketches or diagrams wherever possible.
7. Answers must be given to an accuracy which is typical of practical conditions.
   NB Ensure that the correct unit of measure (SI unit) are recorded, as marks will be deducted from answers if the incorrect unit is used (even if the calculated value is correct).
8. In answering the questions, full advantage should be taken of your practical experience as well as data given and clearly state any assumptions you make.
9. Please note that you are not allowed to contact your examiner or moderator regarding this examination.
10. Cell phones are **NOT** allowed in the examination room.

QUESTION 1

1.1 Name 5 hazards you will consider when conducting a health hazard identification for a workplace (5)

1.2 Name five criteria that you need to satisfy when planning ventilation requirements for a mechanised mine. (5)

1.3 List three advantages and two disadvantages of the full volume-reduced volume method of pressure surveys. (5)

1.4 Significant amounts of airborne pollutants such as (dust, fibre, etc) are generated during the shotcrete process. Taking all the airborne pollutants and factors into consideration discuss how the process can be manged? (10)

[25]

ANSWERS:

1.1

i. Noxious fumes from blasting.
ii. Dust created by blasting.
iii. Flammable gas
iv. Thermal environment.
v. Diesel emissions.
vi. Virgin Rock Temperature.

1.2 – ANY 5

i. Air quantity required to dilute and remove diesel exhaust gases, particulates and fumes
ii. Air quantity required to dilute and remove blasting fumes and dust.
iii. Air quantity required to dilute and remove the heat from rock, ground water and equipment.
iv. Air quantity required to dilute and remove flammable and other gases
v. Air quantity require to dilute and remove dust and other pollutants.
vi. Air quantity required to remove radiation (where required)
vii. Air quantity required to adequately ventilate excavations where men and machinery/ equipment operate.
viii. Air quantity required to comply with regulations or existing ventilation standards.

1.3

Advantages:

i. Few instruments used and easy to use.
ii. Measurements do not take long.
iii. Measuring is done at fixed positions.
iv. Corrections due to differences in elevation are not required.

Disadvantages:

i. Main fans must be stopped during measuring.
ii. Results are not always reliable.
iii. Calculations are a little difficult.

1.4 – ANY 10

i. A baseline risk assessment with all risk related to the shotcreting must be conducted before the work can commence.

ii. Employing wet mix shotcrete as significantly less airborne pollutants is produced, hence reducing the risk of exposure.
iii. The utilisation of the latest technology wet mix shotcrete equipment (wet mixing, feeding machine and spray gun).
iv. The correctly formulated addition of an accelerator to the wet mix to further reduce the airborne pollutants produced must be considered.
v. Air velocity to be maintained at a minimum of 0.3m/s and in problematic areas the velocity can be increased to 0.5m/s.
vi. A water mist spray system intervention will be introduced downstream of the shotcreting process to capture the airborne pollutants and reduce the risk of exposure.
vii. The establishment of a real-time airborne pollutant warning system with area monitoring within a 5-15m radius of the spray mixture machine and spray gun.
viii. All other activities excluded from the shotcreting must be executed more than 15 m away and will be zoned as non-operational shotcreting areas.
ix. These areas will enable personnel not associated with the shotcreting process to continue with normal working duties, but all precautions must be taken for exposure to airborne pollutants.
x. It is important do display awareness information at conspicuous areas portraying messages concerned with employee health, these must be updated on a regular basis to ensure that it remain effective.
xi. Shotcrete personnel must be equipped with the correct PPE for the task at hand with the related operations and activities of the shotcreting equipment.
xii. Wet mix should be l be prepared and batched from surface and transported to the required area .

QUESTION 2

2.1 It is required to cool 50 m^3/s of air, which enters a single stage spray chamber, to 14ºC. The temperature of the air entering the spray chamber is 26/27ºC at a barometric pressure of 110kPa. Chilled water at 10ºC is available. From the 110 kPa psychrometric charts the following information is available

Apparent specific volume of the air (υ)	0,908 m^3/kg
Sigma heat of the air into chamber (26ºC)	74,9 kJ/kg
Sigma heat of the air out of chamber (14ºC)	35,7 kJ/kg
Sigma heat of the water into chamber (10ºC)	28,3 kJ/kg

2.1.1 What is the theoretical (ideal) Water/Air ratio required? (5)
2.2.2 How much water must be circulated? (2)
2.2.3 The water efficiency. (3)
[10]

Answer 2.1.1

m = Q/ υ
=50/ 0.908
=55.1 kg/s

The optimum or theoretically ideal conditions exist when the temperature of the water leaving the spray chamber is equal to the wet-bulb temperature of the air entering the spray chamber and the temperature of the air leaving the spray chamber is equal to the temperature of the water entering the spray chamber. The ideal water/air ratio can now be determined as follows:

M_{water} x c x Δt_{ideal} = mair x ΔSideal

$(m_{water}/m_{air})_{ideal}$ = (74.9-28.3)/((26-10) x 4.187)
=0.70 kg/kg

Answer 2.2.2

The amount of water needs to be circulated in ideal conditions as follows:

(m_{water}/m_{air}) = 0.70
= m_{air} x 0.70
= 55.1 x 0.70
= 38.3 kg/s

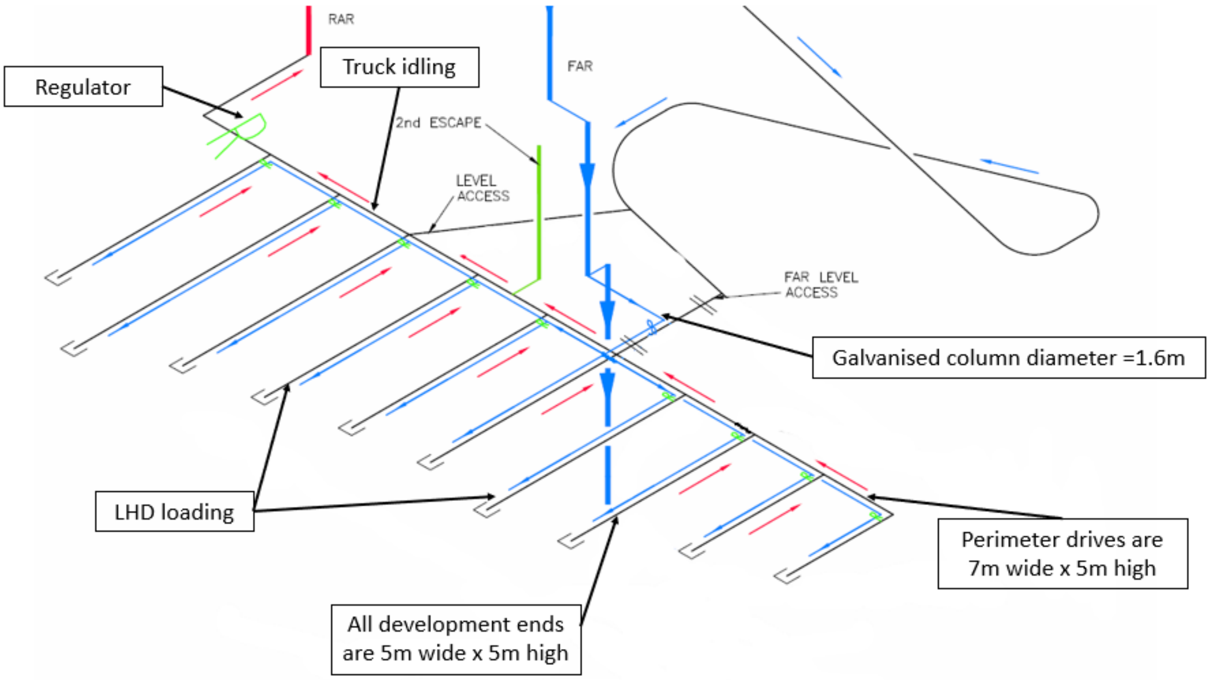
Answer 2.2.3

The temperature of the water leaving the spray chamber is not given and a realistic figure must be determined/assumed. Under ideal conditions the water temperature out would have been 26ºC. Assume that the water will be heated to a temperature ($t_{w\ out}$), which is the average of the $t_{wb\ in}$ and the t_{wbout} In other words (26 + 14)/2 = 20ºC. The water efficiency can now be determined as follows:

Water efficiency = $((t_{w\ out} - t_{w\ in})_{actual} / (t_{w\ out} - t_{w\ in})_{ideal})$ x 100%
= ((20-10)/(26-10)) x 100%
= 63%

Question 3

You are the consulting ventilation engineer for the extension of an existing mine to access a new 2000m deep copper deposit that will be exploited using the Sub-level open stoping method accessed from a single decline. The figure below indicates a typical level with a single fan and column supplying 10 development ends with air. Air is regulated to each development end using dampers/regulators. Air intakes from the Fresh Air Raise (FAR) and returns via the Return Air Raise (RAR) (Density is = 1.2 kg/m^3 and assumed consistent throughout the mine)



A level will have a 2 x 275 kW LHD operating in the development ends and 1 x 567 kW truck which will operate as far as the perimeter drive. I It is required that a development end should have a minimum velocity of 0.1 m/s.

3.1 Calculate the volume requirements at point of application for diesel dilution for the LHD and truck operating assuming a dilution factor of 0.06 m^3/s per rated kW. (2)
3.2 Calculate the volume requirement per level that will need to be supplied by a fan in tight circuit positioned on each level, assume 10% column leakage (5)
3.3 If the total airway lengths for a level is 350 m. Determine the fan duty? (4)
3.4 Calculate the total volume requirements if there are 4 production levels, 20% commitments and 20% leakage in the mine (4)
3.5 Calculate the diesel heat load component factoring in 25% additional heat added from the secondary fleet, using a diesel heat factor of 1.5 x rated kW and a machine utilisation of 80% (5)

[20]

Answer 3.1

Q_{LHD} = 275 x 0.06 = 16.5 m^3/s
Q_{truck} = 567 x 0.06 = 34 m^3/s

Answer 3.2
Minimum Q_{dev} = 0.1 x 5 x 5 =2.5m^3/s
Quantity for 2 x LHDs required = 2 x 16.5 = 33 m^3/s
Q_{total} no leakage= 2.5m^3/s x 10 + 33m^3/s = 58m^3/s
Quantity with 10% column leakage included = 64 m^3/s

Answer 3.3
k-factor = 0.0037 Ns^2/m^8 typical for a galvanised steel column

$P = kCLQ^2/A^3 = (0.0037 \times 1.6 x\prod \times 350 \times (64)^2) / ([\prod(1.6)^2/4])^3 = 3280$ Pa

Fan duty = 64 m^3/s @ 3280 Pa

Answer 3.4

Total Q = 64 x 4 =256 /.80 = 320/.80 = 400 m^3/s

Answer 3.5
For LHDs per level = 2 x 275 x 1.5 x 0.8 = 660 kW
For Trucks = 1 x 567 x 1.5 x 0.8 = 680.4 kW
Total per level = 1340 kW
Total heat including secondary fleet = 1340/ 0.8= 1675 kW
Total diesel heat load for mine = 4 levels x 1675 = 6700 kW

QUESTION 4
4.1 A machine is bought for R 50 000 and costs R 30 000 per year in operating costs. The estimated life span is 15 years and interest is reckoned at 10% compound. Another machine can be bought R 70 000 and the operating costs will be reduced to R 25 000 per year. Briefly discuss the significance of the numbers mentioned in the context of depreciation and taxation. (4)

4.1 Answer
The problem can be restated by asking the following question:
Does the saving in operating cost of R 5000 per year (R 30 000 – R 25 000) for 15 years justify the additional capital outlay to the amount of R 20 000 (R70000 – R 50000)? The significance of these numbers are, that if the R70000 machine was bought the mine would have made a greater profit. This profit is taxable and the actual saving would be less than the actual R5000 indicated.

Business, however, can write off or depreciate capital expenditure against profits before tax. This means that tax is only payable on the profits in excess of the capital expenditure. Alternatively the machine may be a replacement and considered an operating cost rathe than a capital cost. Again this is written off against profits before tax. Taxation rates vary throughout the world and can be either a constant proportion of the profits or a variable rate dependent on the level of profits.

4.2 What is the present value of a profit of R 5 000 before tax if the expenditure was R 20 000? Assume a life of 15 years, interest at 10%, allowing depreciation according to profits and use 35% as the tax rate. (6)

4.2 Answer
The total expenditure (additional) = R 20 000
The total saving per annum = R 5 000
This means that the total allowance amount will be applicable for R20000/ R5000 = 4 years
This means that the for the first 4 years the profit subject to tax = R 0
Tax flow to the company will therefore be = R 5 000
During the last 11 years no depreciation allowance and therefore the profit subject to tax will be R 5 000.

The cash flow to company (R 5 000 x (1 – 0,35)) = R 3 250 per year.

The present value for R 1 per year for 4 years at 10% = R 3,1699

The present value of R 1 at 10% interest in 15 years = R 7,606
The present value of the profits after tax is as follows:

R 5000 x 3,1699 = R 15 850

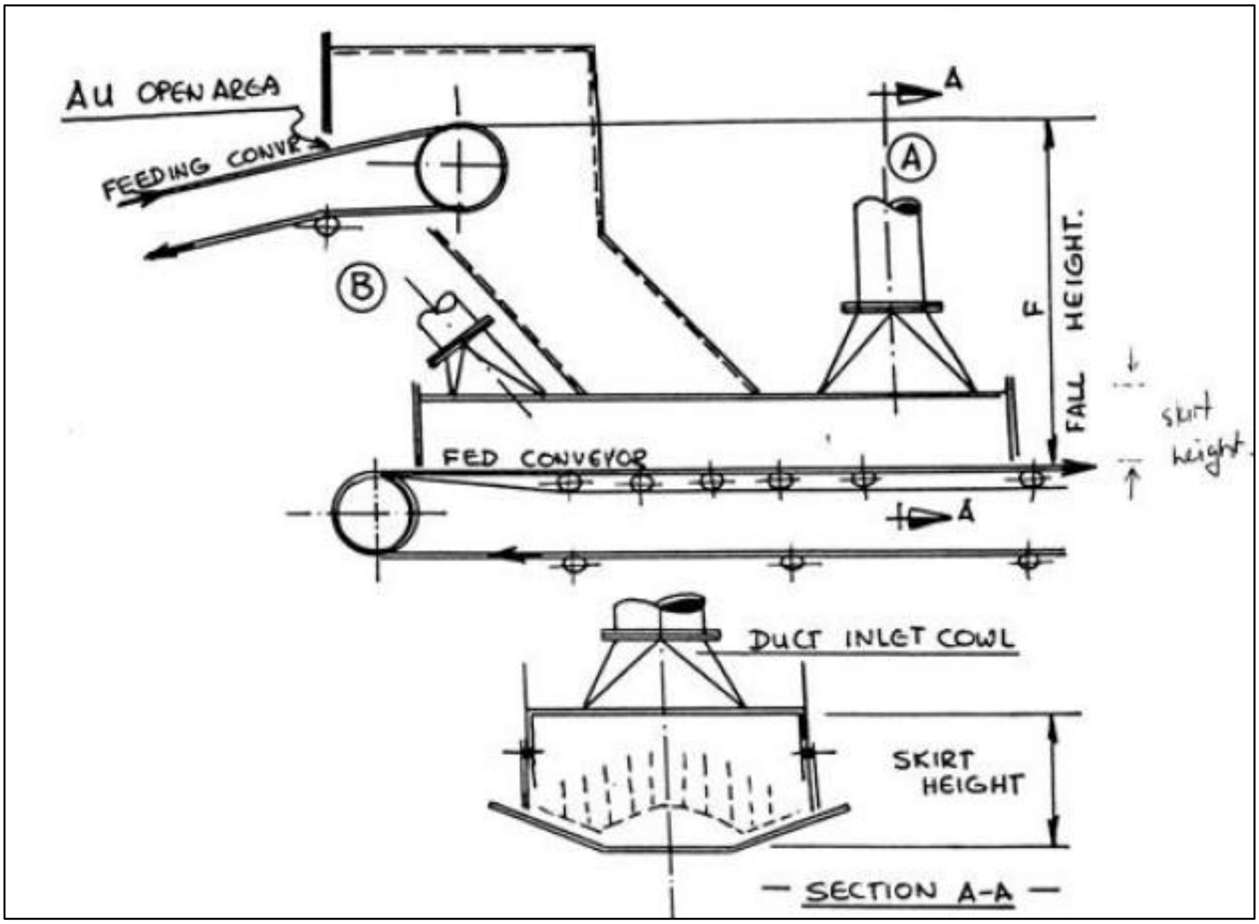
Plus R 3 250 x (7,606 - 3,1699) = R 14 417

Total = R 30 267

4.3 The amount of air induced or pulsated into a conveyor belt transfer point governs the amount of air that must be extracted from such a transfer point to control the dust generated from the ground transfer action. The formula used to calculate the amount of air induced (extracted from the system) is expressed as follows:

$$Q = 0.116\ x\ AU\ x\ \sqrt[3]{\frac{R\ x\ F^2}{D}}$$

Where Q = The quantity of air induced (m^3/s)
AU = Head chute open area (m^2)
R = The rate of material flow (kg/s)
F = Fall height of material (m)
D = Average diameter of product (m)
0,116 = Inducement factor



Given the following operating conditions:
AU = 2.5 m^2 with rubber apron seal on
R = 300 tons per hour
F = 3 m
D = 150 mm
The highest volume of air is extracted at Point A at 75% of the total amount of air extracted and the rest at point B (25% of the total).

4.3.1 Calculate the quantity of air to be extracted at points A and B (4)

4.3.2 What would the extraction quantity be if the AU value was decreased to 1.875 m^2 (assume all other factors remain constant)? (3)

4.3.3 The fall height is reduced to 2m, what impact will this have on the air quantity required compared to the original amount determined? (3)

4.3.4 If the belt width is 1.5 m at the extraction point A, how high should one design the skirt height to prevent excessive dust pick up of small stones and very large dust particles? Assume an airflow design velocity in the skirt area of 6m/s. (5)

[25]

Answer 4.3.1

R = 300 t/h = (300 x 1000)/(60 x60) =83.3 kg/s

$$Q = 0.116\ x\ AU\ x\ \sqrt[3]{\frac{R\ x\ F^2}{D}}$$
$$= 0.116\ x\ 2.5\ x\ \sqrt[3]{\frac{83.3\ x\ 3^2}{0.15}}$$
= 4.96 m^3/s

The quantity of air that must be extracted from A and B must now be calculated:

At Point A = 0.75 x 4.96 = 3.72 m^3/s
At Point B = 0.25 x 4.96 = 1.24 m^3/s

4.3.2

With AU = 1.875m^2 (all other factors remain constant)

$$Q = 0.116\ x\ AU\ x\ \sqrt[3]{\frac{R\ x\ F^2}{D}}$$
$$= 0.116\ x\ 1.875\ x\ \sqrt[3]{\frac{83.3\ x\ 3^2}{0.15}}$$
= 3.72 m^3/s (25% reduction)

4.3.3

$$Q = 0.116\ x\ AU\ x\ \sqrt[3]{\frac{R\ x\ F^2}{D}}$$
$$= 0.116\ x\ 2.5\ x\ \sqrt[3]{\frac{83.3\ x\ 2^2}{0.15}}$$
= 3.78 m^3/s (approximately 25% reduction)

This also a reduction of ± 25% and is highly recommended. The design engineer should therefore consider fall height as critical and keep it as low as practically possible.

4.3.4

A velocity of ± 6 m/s in the skirt area is recommended to prevent excessive pick-up of small stones and large dust particles.

With velocity of 6 m/s and an extraction quantity of 3,72 m^3/s at A:

Q = A x v
= 3.72/6
=0.62 m2

The belt width is 1.5m and the height should therefore be:

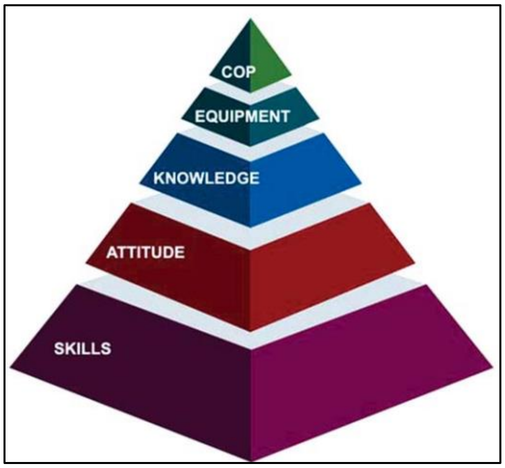
h =A/width
=0.62/1.5
=0.413 m

QUESTION 5

Elaborate on the relevant section in the article related to mine environmental control and occupational hygiene, which appeared in the following publication

"The shortcomings of emergency evacuation training in underground mines" by D van der Walt – Rescue One Equipment (Pty) Ltd., October/December Volume 73 No 4

The author discusses the various components that form the foundation of effective self-rescue as shown in the image below.



Elaborate and discuss the knowledge and skills components (20)

[20]

NB! Elaborate on this section of the journal only

TOTAL MARKS: [100]

Question 5 Answer

5. KNOWELDGE AND SKILLS

5.1 Lifesaving information

Knowledge of how to escape in an emergency is lifesaving information. Miners should now their emergency preparedness code of practice, their escape routes, their safety and emergency signage and alarms and how to use their emergency evacuation systems such as the SCSR and Lifeline®. Most

COP documents are lengthy. Do mining personnel read through the COPs? Are the COPs explained to them? The COP should be condensed into a document that can be easily consumed by all mining personnel.

Traditional classroom training or even emergency response training in a mock mine can only accommodate some of these requirements namely transferring knowledge on the emergency preparedness and response COP, safety and emergency signage and alarms. Escape routes in each section will have its own peculiarities. And SCSR and Lifeline® use cannot be sufficiently addressed with classroom training. It requires repetitive skills training to ensure mining personnel can use these systems with confidence and without hesitation. Especially during an emergency when every second is of the essence.

5.2 SCSR

Biffi and Sehlabana (2018) quotes research done at the University of Kentucky on SCSR use. It was clear from the research that miners were not confident in the use of SCSRs. Amongst others, they did not follow the procedural steps correctly, about 25% forgot to don their nose clips, over 12% did not use their goggles, around 12% could not activate their oxygen supply, and several tangled the SCSR neck strap with the cap-lamp cord.

From this study it was recommended that:

1. Only one donning procedure should be taught;
2. Training should be more hands on with direct evaluation and feedback;
3. Training should be conducted on-mine to avoid interruption to production; and,
4. Hands-on follow-up sessions should be held throughout the year and combined with fire drills.

Biffi and Sehlabana (2018) quotes research done by Brnich et al (1999). Forty six miners were interviewed after escape experiences. Significant observations included:

- None of the miners had worn a SCSR prior to the emergency;
- Most miners indicated that they were not proficient in donning an SCSR;
- Some miners delayed donning their SCSR because they were aware of the limited duration of the unit;
- About 67% indicated they donned the SCSR in smoke; and,
- About 59% admitted to removing the mouthpiece or to breathing around it in smoke once the felt the resistance to breathing had become excessive.

Some of the practical issues that Biffi and Sehlabana (2018) have identified around the use of the SCSR include:

- The ability to proficiently start a SCSR in poor visibility;
- The awareness that when using the SCSR the unit provides both resistance and heat through the air that is breathed;
- The unit will heat up and create a feeling of warm on the user's chest;
- The SCSR could cause irritation of the mouth and upper respiratory tract;
- The chemical reactions may cause an unfamiliar taste in the mouth;
- The nose clip may cause discomfort and may prompt the user to remove it;
- Goggles can be very uncomfortable in an incident and the tendency may be to remove it;
- The breathing bag will fill up with air and could overflow through the relief valve; and,
- It could be uncomfortable to crawl through tight spaces with the airbag overflowing.

Underground personnel should be made aware of all the above through practical, realistic training. As mentioned before, the aim would be to get to a point of unconscious competence. In an emergency, time is of the essence. A person panicking because of any of the above-mentioned issues, could lead to disastrous consequences. Through proper training in an underground setting with real equipment, underground personnel will learn:

- how to slow down their breathing rate;
- the importance of walking a steady pace;
- the importance of remaining with the crew and watching out for each other;
- not removing the mouthpiece or the nose clip;

and,

- only removing the SCSR when reaching fresh air or when switching to a different unit.

Biffi and Sehlabana (2018) emphasise the importance of hands-on training in the complete donning of all types of SCSRs in use in the mine, as well as hands on training in transferring between self-rescue devices at change-over stations.

5.3 Lifeline®, Escape Routes, Ventilation, Signage and Alarms

Mining personnel should have hands-on knowledge and skills with regards to the use of Lifeline®, the escape routes in their sections, how ventilation flow works in the mines, emergency signage and alarms. When time is of the essence during an emergency, mining personnel should be able to use their Lifeline® with confidence. Knowledge of the air flow / ventilation would help trapped miners to plan the appropriate escape route. Knowledge of the signage and emergency alarms will quickly guide miners in the right direction.

All emergency evacuation equipment should be well maintained and correctly installed. Delays are not an option in an emergency situation.

5.4 Leadership Skills

Kowalski et al, did research on three actual mine fires, considering leadership roles in these emergency escape scenarios. They found that a profile of leadership in crisis emerged from the analysis of these escapes. The data suggests several characteristics based on the behaviour of the leaders. The leader of each escape may be described as an aware, knowledgeable person or as an individual who is alert to his environment, attentive, and discerning.

The leader notices things more so than do other mining personnel. This astute quality is probably not limited to the mine environment or to crisis circumstances.

This individual is naturally curious all the time and is the type of individual who excels at incidental learning. Each of the leaders retained information that was instrumental to the escapes.

Traits that stood out were:

1. They recalled specific details and repeatedly referred to the fact that they "knew" through information or deduction;
2. They took charge. In the groups where the authority led the subjects out of the mine, the leadership was a natural evolution of the group dynamics. It was a continuation of the social order before the disaster. Yet, the same dynamic occurred in the groups where there was a definite emerging leader. These leaders did not force themselves and their suggestions on the group - the leadership developed in a natural way;
3. They were decisive, yet flexible. They made decisions; yet if circumstances changed, they adapted;
4. They were open to input from others. There is evidence that in most of the escape groups there was a second in charge who offered worthwhile suggestions and support. In instances where there was emergent leadership, many times the leader began in a consulting function to the authority;
5. Effective leaders seemed to have a calming effect on their group. They were aware of others' levels of fear and offered reassurance when it was needed.

Miners in each group had confidence in the leader's ability to direct them to safety; and, 6. There was a Logic to their leadership. Decisions were appropriate and congruent with the available information.

6. CONCLUSION

6.1 Learnings

Considering research on emergency preparedness and response and some practical learnings in the development of emergency preparedness and response training, the following has been identified:

1. Classroom training and even mock mine training is not