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: 7 OCTOBER 2021	**PASS MARK:** 60%
TIME: 14:30 – 17:30	

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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 Provide the approximate range for the air volume carried by:

- 305 mm column
- 406 mm column
- 570 mm column
- 760 mm column (4)

1.2 Provide the recommended design air speed for non-ventilation-dedicated excavations in which the velocity is constrained by other issues such as access for men, conveyance stability, dust entrainment, etc.:

- Intake airways
- Return airways
- Vertical unequipped upcast shafts
- Vertical equipped shafts (4)

1.3 Provide typical ventilation air leakage (%) for shaft systems and shaft brattice walls (2)

[10]

ANSWERS:

1.1

- 305 mm column - 0.6 m^3/s – 1.0 m^3/s ✓
- 406 mm column - 2.0 m^3/s – 3.0 m^3/s ✓
- 570 mm column - 3.5 m^3/s – 7.0 m^3/s ✓
- 760 mm column - 8.0 m^3/s – 14.0 m^3/s ✓

1.2

- Intake airways 5 m/s to 7 m/s ✓
- Return airways 6 m/s to 9 m/s ✓
- Vertical unequipped upcast shafts 16 m/s to 22 m/s ✓
- Vertical equipped shafts 10 m/s to 12 m/s ✓

1.3

- Shaft systems 5% ✓
- Shaft brattice walls 5% for concrete section and 10% for removeable steel panels (mark for either or) ✓

QUESTION 2

2.1 Define Diesel Particulate Matter (DPM)? (4)

2.2 What is a typical design personal exposure limit over an 8 hour period for Total Carbon (TC) and Elemental Carbon (EC) (State any assumptions)? (2)

2.3 What are the health effects of Diesel Exposure (DE)/DPM? (4)

2.4 How can DE/DPM be controlled? (10)

2.5.1 Calculate the DPM concentration provided the following: (3)

LHD rated power	74 kW
OEM diesel exhaust emission	0.1 g/kW/hr
Volume (density adjusted) of air supplied at point of application	12 m^3/s

2.5.2 What should the volume of air be to achieve a design exposure limit of 130 µg/m^3? (2)

[25]

ANSWERS:

Answer 2.1

- DPM is a component of diesel exhaust (DE) that includes soot particles made up primarily of carbon, ash, metallic abrasion particles, sulphates, and silicates. ✓ ✓
- Diesel soot particles have a solid core consisting of elemental carbon, with other substances attached to the surface, including organic carbon compounds known as aromatic hydrocarbons. ✓ ✓

Answer 2.2

- TC = 0.16 mg/m^3 or 160 µg/m^3 ✓
- EC = 0.1 mg/m^3 or 100 µg/m^3 ✓

Answer 2.3 ✓

- Short term exposure to high concentrations of DE/DPM can cause headache, dizziness, and irritation of the eye, nose and throat severe enough to distract or disable miners and other workers. ✓
- Prolonged DE/DPM exposure can increase the risk of cardiovascular, cardiopulmonary, and respiratory disease and lung cancer. ✓ ✓

Answer 2.4

Engineering controls are the most effective strategy for minimising worker exposure to DE/DPM. A combination of controls is often required. Examples include: ✓

- Performing routine preventive maintenance of diesel engines to minimise emissions
- Installing engine exhaust filters. ✓
- Installing cleaner burning engines ✓
- Installing diesel oxidation catalysts ✓
- Using special fuels or fuel additives (e.g., biodiesel) ✓
- Providing equipment cabs with filtered air.
- Installing or upgrading main or auxiliary ventilation systems, such as tailpipe or stack exhaust vents to capture and remove emissions in maintenance shops or other indoor locations. ✓

Administrative controls refer to changes in the way work tasks are performed to reduce or eliminate the hazard. Examples include: ✓

- Limiting speeds and using one-way travel routes to minimise traffic congestion
- Prohibiting and/or restricting unnecessary idling or lugging of engines ✓
- Restricting the amount of diesel-powered equipment and total engine horsepower operating in each area and ensure that the number of vehicles operating in an area does not exceed the capacity of the ventilation system. ✓ ✓
- Designate areas that are off-limits for diesel engine operation and/or personnel travel.

Answer 2.5.1

DPM concentration = 0.1 x 74 = 7.4 g/hr = 7 400 000 µg/hr = 2 055 µg/s
= 2055 / 12
= 171 µg/m^3

Answer 2.5.2

From Q 2.4.1 DPM concentration = 2055 µg/s
Q = 2055/ 130 = 15.8 m^3/s ~ 16 m^3/s

Question 3

3.1 An underground workshop is 40 m long, 15 m wide and 15 m high. Estimate the airflow required (State any assumptions regarding factor being applied):

3.1.1 To dilute exhaust fumes from diesel engines of 200 kW mechanical output (3)

3.1.2 On the basis of 10 air changes per hour (3)

3.2 The intake air entering a working area of a mine carries a mass concentration of 0.5 mg/m^3 respirable dust. Face operations produce 1000 tonnes of mineral over an 8-hour shift and add respirable dust particles to the airflow at a rate of 1300 mg per tonne of mineral mined. If the concentration of respirable dust in the return air is not to exceed 2 mg/m^3 , determine the required airflow. (6)

3.3 It has been predicted that during a 7 hour working shift, 2500 m^3 of methane will be emitted into a working face in a coal mine. If electrical power must be switched off at a methane concentration of 0.8 %, determine a recommended airflow to the face. (3)

[15]

Answer 3.1.1

Using an estimated airflow requirement of 0.06 m^3/s per rated kW of rated diesel power. (Factors form 0.05 – 0.12 were accepted if a reason was stated)

Air quantity required = 0.06 x 200 = 12 m^3/s

Answer 3.1.2

Volume of workshop = 40 x 15 x 15 = 9000 m^3
Air quantity required = (9000 x 10)/ (60x60) = 25 m^3/s

Hence, the larger value of 25 m^3/s should be employed.

Answer 3.2

Average rate of mineral production = (1000)/(8x3600) =0.0347 t/s
Average rate of emission of respirable dust = 0.0347 × 1300 = 45.14 mg/s
Dust removal capacity of air,
Cd = (allowable dust concentration - intake dust concentration)
= (2 - 0.5) = 1.5 mg/m^3

Required airflow = (45.14 / 1.5) = 30.1 m^3 /s ✓✓

Answer 3.3

The average rate of gas emission during the working shift is
Rate of emission = 2500/(7 x 60 x 60) ✓ = 0.0992 m^3/s ✓

Q = (100 x 0.0992)/ 0.8 = 12.4 $m^{3/}$s ✓

QUESTION 4

Your mine is planning an ore replacement project in a deeper mining block of your mine. The following information is available:

- Planned reef tonnage — 175 000 tonnes/month
- Mean mining depth below surface — 2500 m
- Average distance from shaft system — 3000 m

Production will come from mini-longwalls each having 8 panels, mined in series:

- Face length (per panel) — 40 m
- Face advance — 12 m/ month
- Stoping / tramming width — 1.5 m
- Reef / waste development ratio — 25 m^2 / meters of development
- Rock density — 2790 kg/m^3

Ventilation Design Criteria

- Heat produced from each mini-longwall — 1500 kW
- Air quantity required for each mini-longwall — 40 m^3/s
- Heat produced from development — 15 kW / meter
- Reject wet bulb temperature — 28.0 °C
- Thermal Gradient — 23.92 °C + 0.0192 °C / m
- Ventilation Curtain from face — 12.0 m
- Air Utilisation — 60 %
- Mean density of Air — 1.25 kg/m^3
- Ambient Surface Temperature — 18.0 ˚C WB / 30.0˚C DB
- Air cooling power factor — 2.07kJ/kg

4.1 From the parameters supplied, determine the number of mini-longwalls required to achieve the planned reef production output (6)

Planned tonnage / rock density / stoping width = total m^2 being mined

175 000 / 2.79 /1.5 = 41 816 m^2

No of mini-longwalls = total m^2 / face advance / panel length / no of panels in each mini longwall

No of mini-longwalls = 41 816.43m^2 / 12 m / 40 m / 8

No of mini-longwalls = 10.889 ~ 11

4.2 The Code of Practice (COP) stipulates a minimum stope face velocity of 1.0 m/s. Will the quantity supplied for each mini-longwall be sufficient to adhere to the COP requirements? (2)

Given the quantity supplied of 40 m^3/s the stope face velocity can be calculated at:

Face velocity = (Supply quantity x AUF) / (SW x Curtain distance from face)

Face velocity = (40 m^3/s x 0.6) / (1.5m x 12m)

Face velocity = 1.33 m/s – the quantity supplied is sufficient to adhere to the COP

4.3 Assuming an overall leakage factor of 25%, determine the massflow of air that will be required to circulate through the mine. (3)

Number of mini-longwalls = 11

Quantity supplied for each mini-longwall = 40 m^3/s

Thus, quantity required to supply each mini-longwall = 11 x 40 = 440 m^3/s

Total quantity required including leakage = 400 m^3/s + 25% = 550 m^3/s

Massflow of air to be circulated = total quantity x mean density

Massflow of air to be circulated = 550 x 1.25

Massflow of air to be circulated = 687.5 kg/s

4.4 Determine the total heat load produced from the mining activities and other sources. (10)

Total heat load = heat from stoping + heat from development + auto compression

Heat produced from mini-longwalls = 1500 kW x 11 (no of mini-longwalls) = 16 500 kW

Heat produced from development:

Determine total meters development at a ratio of 25 m^2 / m (given)

Development meters = total m^2 mined / 25

= 41 816 / 25

= 1672.64 m

Heat produced from development = total meters development x 15 kW (given)

Heat produced from development = 1672.64 x 15

Heat produced from development = 25 089.6 kW ~ 25 090 kW

Heat from auto compression = mass flow x (depth/1000) x g

Heat from auto compression = 687.5 x (2500/1000) x 9.79

Heat from auto compression = 16 826.56 kW

Total heat produced = 16 500 (stopes) + 25 090 (dev) + 16 826.56 (auto compression)

Total heat produced = 58 416.56 kW

4.5 Determine the amount of cooling (refrigeration) required, if any. (4)

Determine cooling power of air at mean mining depth from chart included

Cooling power = 2.07 kJ/kg (Given)

Cooling power of air = 687.5 kg/s x 2.07 kJ/kg

Cooling power of air = 1423.13 kW

Total cooling required = total heat produced – cooling power of air

Total cooling required = 56 993.44 kW ~ 56 993 kW

[25]

QUESTION 5

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

"Operational advantages of monitoring air cooling units in remote underground areas"., January/March Volume 73 No. 1

The authors discuss the various

5.1 The authors elaborate on spot cooling. Please discuss the following headings:

5.1.1 Brief overview of spot cooling (5)

5.1.2 Spot cooling performance factors and their challenges (10)

5.2 What conclusions did the authors arrive at from their work? (5)

5.3 Name 5 factors you would need to consider if you were to apply/adopt monitoring of air cooling units on your mine? (5)

[25]

NB! Elaborate on this section of the journal only

TOTAL MARKS: [100]

Question 5 Answer

Answer Q5.1

Max 5 Marks

2. SPOT COOLING

2.1 Brief overview

Localised cooling, also known as spot cooling, focuses on the cooling of specific underground working areas using localised or mobile cooling units.

These cooling units work in conjunction with traditional infrastructures such as fridge plants or ice plants, bulk air coolers (BACs) and chilled water reticulation systems to cool specific active working areas within the mine.

The two main types of localised cooling units that will be discussed in this section are chilled water cooling cars (CCs) and mobile refrigeration air cooling units (ACUs).

Cooling cars are air-to-water heat exchangers, combined with fans, mounted in a chassis on rolling stock which enables the units to be moved and installed in different areas of the mine (Potgieter, 2017). The performance of a cooling car is highly dependent on the chilled water supply temperature and flow rate.

The mobile refrigeration air cooling unit (ACU) is a mobile refrigeration unit which consists of a refrigeration gas cycle in a chassis mounted on rolling stock. The feasibility and energy efficiency of these cooling units was first investigated by Prof. van Eldik in 2007 (van Eldik, 2007) and further energy efficiency studies were done by Dr Rankin (Rankin, 2011) and Mr Potgieter (Potgieter, 2017). The units have a nominal cooling capacity of 100 kW or 250kW respectively and are selected depending on the requirement of the particular mine. An ACU can function with or without chilled water, increasing its applicability and performance in remote underground areas.

When supplied with chilled water the units were found to be a more energy efficient alternative than using CCs as the unit could remove more heat from an area while utilising a smaller amount of water. By decreasing the amount of water required during cooling operations, the water being pumped to the surface is reduced. This subsequently reduces the electrical consumption and pumping costs related to cooling (Potgieter, 2017).

2.2 Performance factors and their challenges

The cooling capacity of CCs and ACUs are dependent on, although the ACU is less sensitive to, four inputs namely the air mass flow rate, the water mass flow rate, air temperature (dry bulb and wet bulb) and the water supply temperature. The challenge is, therefore, keeping these input parameters within the required limits for maximum cooling and efficiency.

The monitoring system investigated within this study aims to monitor, identify, manage and thereby reduce the major challenges with regards to performance and efficiency.

2.2.1 Supplying chilled water to the localised cooling unit

One of the challenges of underground cooling operation is the supply of the correct amount of chilled water to the localised cooling units situated at remote mining areas. The water travels down long pipe networks; heat is picked up increasing the inlet water temperature to the localised cooling unit. A higher inlet water temperature means an increased water flow rate required to maintain a certain cooling duty. This also has a negative effect on the unit's efficiency as a higher water flow rate results in higher pumping costs. The water flow rate can however be too high further increasing pumping costs with no benefit to cooling performance.

The ACU is also affected by a higher inlet water temperature but the effect is limited because of the refrigeration cycle, which enables the condenser water to be heated to a temperature higher than the supply air temperature.

The approach temperature between inlet air temperature of the water and the air outlet temperature seen in a CC, which is dependent on the air and water flow rates, are replaced in the ACU by an operating envelope (minimum inlet air temperature and maximum water outlet temperature) due to the refrigeration cycle. By monitoring the inlet water temperature, the water flow rate for CCs and ACUs can be manually adjusted or mechanically regulated to give the optimal flow rate or desired outlet water temperature. Manually adjusting hand valves are limited in their effectiveness as infrastructure surrounding the spot cooling unit affects pressure and subsequently water flow rate. The water flow rate can, however, be regulated using a pressure regulating valve ensuring the pressure or flow rate remains practically constant. By supplying only the required flow rate maximum performance and efficiency can be obtained if the supplied water flow rate and pressure are sufficient.

2.2.2 Fouling of the air heat exchanger

The localised cooling units are located close to active mining areas, which typically result in higher amounts of dust and other contaminants. Dust or other particles in the air causes fouling on the heat exchanger's finned surface. This causes a decrease in heat transfer affecting the performance of both the CCs and the ACUs. The decreased heat transfer lowers the amount of cooling delivered or increases the amount of water required to obtain the target amount of cooling. By monitoring the water flow rate, temperatures and overall performance of the localised cooling unit, reduction trends can be studied to ensure maintenance is done as and when required.

Max 10 Marks

2.2.3 Scaling inside a heat exchanger

Due to the hardness of the cooling water supplied to localised cooling units, scaling of the unit's heat exchanger is a challenge faced by both CCs and ACUs (even more so in ACUs due to the higher water temperatures reached). Various chemical elements such as carbonates cause scaling on the heat exchanger surface, resulting in a decrease in heat transfer. By monitoring the performance of the system, preventative maintenance can be planned to reduce performance limitations or downtime by scheduled descaling of the heat exchangers. An added benefit of the monitoring system is that a performance baseline is established to determine if the descaling operation was successful or if

Other points mentioned by students were also considered provided it came from the relevant section.

For Question 5.1.2 the breakdown was typically 6 marks for Supplying chilled water and 3 marks each for comments on fouling and scaling.

Answer Q5.2

8. CONCLUSION

There are numerous advantages that can be obtained with continues monitoring of localised spot cooling units. Most of the advantages are retained even if the system is not monitored in real time.

Continuous monitoring systems have proven to be an effective tool for maintaining target performance.

The monitoring system successfully identified factors that reduced the cooling performance of the spot cooling units. A strategy could then be developed to reduce or eliminate the effect that these factors have on the performance of the localised spot cooling unit.

The data gathered could be effectively used for trend studies. The trend studies provided the inputs required to create preventative maintenance schedules minimising or eliminating performance limiting factors found in the specific area of the mine.

The continuous monitoring system assisted in identifying specific areas to be investigated during fault finding. By identifying the specific areas, investigation time could be greatly reduced, resulting in increased availability of the localised spot cooling units. The monitoring system further assisted investigations with evidence ruling out possibilities or supporting investigation results.

Max 5 Marks

Answer Q5.3

Is an open question to determine if the students can apply what they have learnt from the paper to their own working environment.

1 mark per fact with a max of 5 marks.

Typically the students applied the factors from Question 5.1.2 and 5.1.3.