Chamber of Mines of South Africa

MEMORANDUM

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SUBJECT:

CHAMBER OF MINES OF SOUTH AFRICA – CERTIFICATE IN MINE ENVIRONMENTAL CONTROL

PAPER 3

SUBJECT CODE: COMMEC P3 – ECONOMICS, PLANNING AND TECHNICAL LITERATIUE

EXAMINATION DATE: 12 OCTOBER 2017

TIME: 14:30 – 17:30
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EXAMINER: M. Coelho

MODERATOR: M. Beukes

TOTAL MARKS: 100

PASS MARK: 60%
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</table>

NUMBER OF PAGES: 17

SPECIAL REQUIREMENTS:

THIS IS NOT AN **OPEN BOOK EXAMINATION**.

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 **[20]**

A new shaft is planned for a mine in the Limpopo region. The following data is available:

- Maximum production planned 150 000 tons per month
- Average depth of work places 2000 m
- Predicted heat load for work places 210 kW per kton broken per month
- Station Twb at average depth 25,3ºC
- Down cast shaft average diameter 9 m
- Barometric pressure at 2000 m is 105 kPa

The Sigma Heat values at the different temperatures at the mean barometric pressure are given as follows:

Temperature	Sigma Heat (kJ/kg)
°C	kJ/kg
25.3	73.5
27.0	80.3
28.0	84.6
29.0	89.0

1.1 Calculate the air mass flow rate necessary to ventilate the mine, to ensure the following reject temperatures, if no cooling is supplied. (6)

1.1.a 27ºC

1.1.b 28ºC

1.1.c 29ºC

1.2 What is the mass flow rate of air that the shaft can handle if the average density of the air is given as 1,0kg/m^3 and the average velocity in the shaft is 10 m/s? (3)

1.3 With the mass flow rate as calculated in (1.2), determine the amount of cooling that will be needed to ensure that a reject temperature of 27ºC wet bulb will not be exceeded. (3)

1.4 List three factors that can influence the underground station wet bulb temperature. (3)

1.5 The chilled water use is 1,2 ton water/ton of rock mined. Assume a typical temperature for the chilled water and determine the approximate cooling that will be delivered by the water. (Hint use a 26 day measuring cycle) (5)

ANSWER:

1.1 Total heat load in mine = 210 x 150

= 31 500 kW

Let M_a = mass flow of air required to ventilate the mine

S_{as} = Sigma heat of ventilating air at station temperature

S_{ar} = Sigma heat of ventilating air at reject temperature

Q = Amount of heat to be dissipated

Q = 31 500 kW

Then M_a as follows:

$$Ma = \frac{Q}{Sar - Sas}$$

The Sigma Heat values at the different temperatures at the mean barometric pressure as follows:

Temperature	**Sigma Heat (kJ/kg)**	**∆ Sigma Heat (S_{ar}-S_{as})**
°C	**kJ/kg**	**kJ/kg**
25.3	73.5	
27.0	80.3	6.8
28.0	84.6	11.1
29.0	89.0	15.5

The mass flow of air can now be calculated for the different delta Sigma heat figures as obtained above:

Reject temperature	**Massflow**
°C	**kg/s**
27°C	4632
28°C	2838
29°C	2032

1.2 The shaft area can be calculated by the following formula:

Area = $\pi \times r^2$

$= 63.6\ m^2$

The massflow therefore as follows:

m = w x (V x A)…………..(Q = V x A)

= 1,0 x 10 x 63,6

= 636 kg/s

1.3 The delta Sigma heat for a reject temperature of 27ºC is 6,8 kJ/kg. The heat that can be removed by the air is therefore:

Heat removed = 636 x 6,8

= 4 324,8 kW

The heat to be removed by refrigeration = 31 500 – 4324,8

= 27 175,2 kW

1.4

- Temperature of the ambient air on surface (weather and seasonal changes)
- Whether the shaft is wet or dry
- (Depth below surface (auto compression)

1.5 The amount of chilled water can be calculated as follows:

$$Amount = \frac{150\ 000\ x\ 1.2\ x\ 1000}{26\ x\ 24\ x\ 60\ x\ 60}$$

$$= 80\ \text{litres/second}$$

Assume: $T_{wi} = 10°C$

$t_{wo} = 27°C$

The heat that is therefore removed by the water:

Heat removed $= m \times c \times \Delta t$

$= 80 \times 4.187 \times (27-10)$

$= 5\,694$ kW

QUESTION 2 **[20]**

In a highly mechanised mine a minimum ventilation quantity is often set by supplying 0,06 m^3/s of air per kW of diesel equipment used. Comment on this value using the following information:

The fuel consumption of a rated 55 kW diesel LHD is 8,6 kg/hr when hauling and 2,3 kg/hr when idling. The following table gives the exhaust gas analysis for the two situations:

Equipment	Exhaust gas	% CO_2	% CO	% NO_x
Idling	12.6 m^3/kg of fuel	0.73	0.04	0.0022
Hauling	62.3 m^3/kg of fuel	4.71	0.058	0.0191

The following are the maximum allowable concentrations of diesel exhaust gases in the general air stream:

- CO_2 5000 ppm
- CO 100 ppm
- NO_x 5 ppm

Assume that normal air contains 300 ppm of CO_2 and 0 ppm CO or NO_x.

{HINT: You will need to calculate the quantity of exhaust gas produced as well as the quantity of the fresh air required in both situation when the LHD idling and hauling to be able to comment on the dilution factor}

Question 2 – Answer

Diesel equipment idling

Fuel used = 2,3 kg/hr

Gas produced = 12,6 m^3/kg

The quantity of gas produced = m^3/kg x fuel consumption

= (12,6 x 2,3)/3 600

= 0,00805 m^3/s

From this quantity of exhaust gas, the various quantities of CO2, CO and NOx must be calculated:

The quantity of $CO2$ = % $CO2$ x $Q_{exhaust}$

= 0,73/100 x 0,00805

= 0,0000588 m^3/s

The quantity of CO = % CO x $Q_{exhaust}$

= 0,04/100 x 0,00805

= 0,00000322 m^3/s

The quantity of NOx = % NOx x $Q_{exhaust}$

= 0,0022/100 x 0,00805

= 0,0000001771 m^3/s

The amount of fresh air for each of the above quantities of gas must be determined:

Q_{fresh} to dilute CO_2 $= \frac{Qgas\ x\ 10^6}{MAC-N} - Qgas$

$= \frac{0.0000588\ \ x\ 10^6}{5000-300} - 0.0000588$

= 0.0124 m^3/s

Q_{fresh} to dilute CO $= \frac{Qgas\ x\ 10^6}{MAC-N} - Qgas$

$= \frac{0.00000322\ \ x\ 10^6}{100-0} - 0.00000322$

= 0.0322 m^3/s

Q_{fresh} to dilute NO_x $= \frac{Qgas\ x\ 10^6}{MAC-N} - Qgas$

$$= \frac{0.0000001771 \ x\ 10^{6}}{5-0} - 0.0000001771$$

= 0.035 m^3/s

For idling the air quantities are very low

Diesel equipment hauling

Fuel used = 8,6 kg/hr

Gas produced = 62,3 m^3/kg

The quantity of gas produced = m^3/kg x fuel consumption

= (62,3 x 8,6)/3 600

= 0,14883 m^3/s

From this quantity of exhaust gas, the various quantities of CO_2, CO and NOx must be calculated:

The quantity of CO_2 = % CO_2 x $Q_{exhaust}$

= 4.71/100 x 0,14883

= 0,007 m^3/s

The quantity of CO = % CO x $Q_{exhaust}$

= 0,058/100 x 0,14883

= 0,00009 m^3/s

The quantity of NOx = % NOx x $Q_{exhaust}$

= 0,0191/100 x 0,14883

= 0,00009 m^3/s

The amount of fresh air for each of the above quantities of gas must be determined:

Q_{fresh} to dilute CO_2 $= \frac{Qgas\ x\ 10^6}{MAC-N} - Qgas$

$= \frac{0.007\ \ x\ 10^6}{5000-300} - 0.007$

$= 1.48\ m^3/s$

Q_{fresh} to dilute CO $= \frac{Qgas\ x\ 10^6}{MAC-N} - Qgas$

$= \frac{0.00009\ \ x\ 10^6}{100-0} - 0.00009$

$= 0.86\ m^3/s$

Q_{fresh} to dilute NO_x $= \frac{Qgas\ x\ 10^6}{MAC-N} - Qgas$

$= \frac{0.00003\ \ x\ 10^6}{5-0} - 0.00003$

$= 5.686\ m^3/s$

The results can be tabulated as follows:

Equipment	**Quantity of air required to dilute (m3/s)**		
	CO_2	**CO**	**NO_x**
Idling	0.013	0.0322	0.0353
Hauling	1.5	0.86	5.7

If a quantity of 0,06 m^3/s of air per kW of diesel equipment was supplied, each diesel LHD would require the following amount of air:

Air quantity required = 55 x 0,06

= 3,3 m^3/s per LHD

As can be seen from table summary above, the amount of air (3,3 m^3/s) will not be sufficient to dilute the NOx

gases when the LHD is hauling.

A new quantity of air supplied per kW of equipment should be advised or the high NOx emissions must be investigated. In the case of the NOx gases being “normal” for that type and possible age of machinery, a new air factor (m^3/s/kW) can be determined as follows:

Air factor = Quantity of air / kW

= 5,7 / 40

= 0,143 m^3/s per kW

QUESTION 3 **[20]**

3.1 Two fans operate in parallel at the top of an Upcast shaft of a mine. Over the past 15 years the mines, the mines overall resistance has decreased far more rapidly than was originally designed for. As a result, these fans do not operate at the original design efficiency. The present operating conditions of these fans are:

Total fan inlet volume (both fans combined) = 660 m^3/s

Pressure at fan inlet = 6.0 kPa

Motor efficiency (including drive efficiency) = 95%

Fan efficiency = 60%

Motor input power = 6947kW

The remaining life of mine, is a further 15 years and the mine's overall resistance is not expected to decrease further. Bearing this in mind it is being considered to replace these existing fans with two new fans, designed to operate more efficiently under the prevailing conditions. These new fans would cost R 2 300 000 each, the efficiency of these fans would be 80%. It is estimated that the cost of changing the fans would be R 1 200 000 in addition to the purchase cost of the new fans.

The existing motors, will be used to drive the new fans. (the motor efficiency will remain unchanged.

An interest rate of 12% is applied and the power costs are R 1 752/kWhr. Will it be economically feasible to replace these fans submit comments with your answers? (10)

ANSWER 3.1

TOC current scheme

Capital cost = N/A

PV = 6.81 (R1.00@12% over 15 years) – *from the formula handout book*

Running costs = Input power x cost/kWhr

Running cost = 6947 x 1752 = R 12 171 144

PV of running costs = R 12 171 144 x 6.81 = R 82 885 490

TOC = Capital cost + Running Cost

= R 0 +R 82 885 490

=R 82 885 490

TOC new scheme

Capital cost = R 2 300 000 x 2 + R 1 200 000

Capital cost = R 5 800 000

Wi = P x Q/ (effmotor x efffan)

Wi = 6 x 660/ (.95 x.8)

Wi = 5210.53 kW

Running cost = 5210.53 x 1752 = R 9 128 849

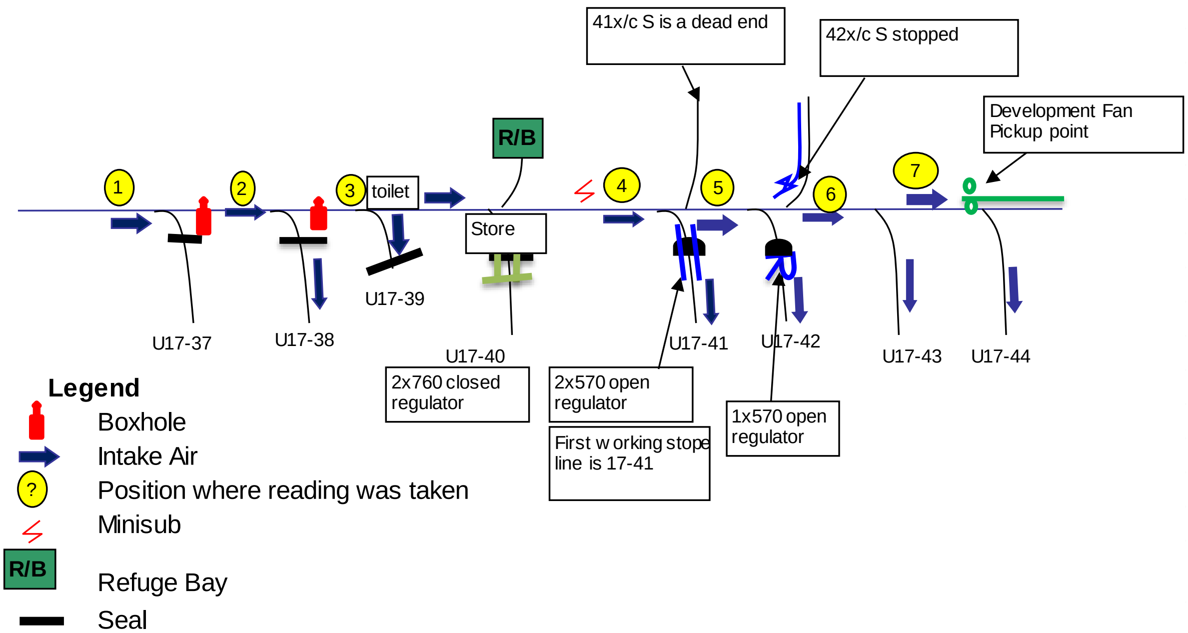
PV of running costs = R 9 128 849 x 6.81 = R 62 167 000

TOC = R 9 128 849 + R 62 167 000

= R 67 967 000

The difference in TOC = R20 718 490. The new scheme is economically more feasible.

3.2 The sketch below shows the result of a volume survey. (10)



Position	Temperature		BP	Velocity	Area	Density	Humidity	Quantity	Massflow
	WB (°C)	DB (°C)	kPa	m/s	m^2	m^3/kg	%	m^3/s	kg/s
1	16.3	24.0	94.0	6.4	8.2	1.11	46.55	52.5	58.3
2	16.4	23.6	94.0	6.2	7.4	1.11	49.12	45.9	50.9
3	17.3	23.4	94.0	5.5	7.6	1.11	55.83	41.8	46.4
4	17.3	23.4	94.0	4.3	8.8	1.11	55.83	37.8	42.0
5	17.5	23.1	94.0	3.7	9.1	1.11	58.81	33.7	37.4
6	17.3	23.4	94.0	3.3	8.1	1.11	55.83	26.7	29.7
7	17.0	23.3	94.0	1.7	10	1.11	54.45	17.0	18.9

3.2.1 Calculate the half level leakage (volume from split to first working stope)? Comment on the leakage figure (3)

3.2.2 What construction work would you recommend be done to reduce the leakage and improve the volume delivered to cross cut 44? (5)

3.2.3 At a cost of R 250 000 the construction work, which took 3 months to complete, resulted in a 5 m^3/s improvement in the volume delivered to crosscut 44. The cost of $1m^3/s$ of air is 1 000 000 per annum. Calculate the payback period? (2)

ANSWER Question 3.2

3.2.1

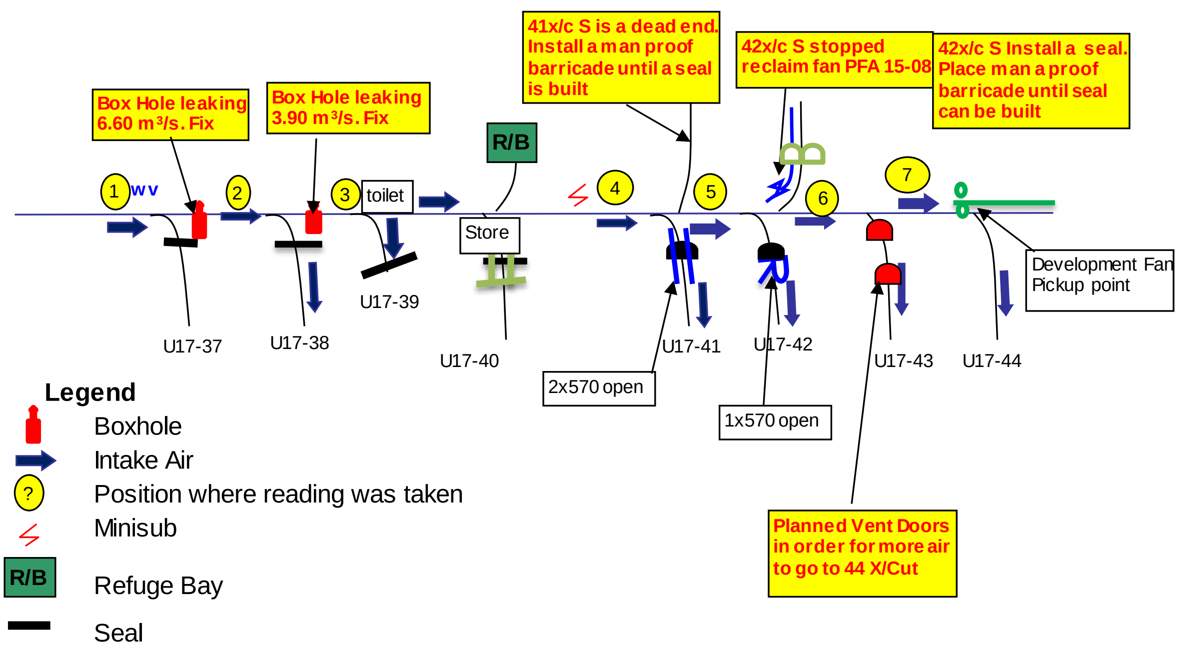
Leakage = Point 1 – Point 4

= (58.3 – 42.0)/58.3 x 100%

= 28.0%

Leakage should be reduced typically it is planned that there is 10-20% leakage from split to development fan pick up.

3.2.2



3.2.3

R 1 00 000/12 = R8333.33 per month per 1m^3/s

5m^3/s improvement = 833.33 x 5 = R416 666.67

Payback period = 250 000/416 666.67 = 0.6 months from the completion of the construction work

QUESTION 4 **[20]**

4.1 Name six (6) factors that govern the air volume requirements when designing a shaft system (6)

4.2 Name five (5) factors to be considered when designing an up-cast shaft and a fan drift. (5)

4.3 When testing ventilation systems use is made of airflow and pressure readings. Why are these tests performed on these systems (name 5)? (5)

4.4 Name four (4) factors to considered when planning a recirculation station? (4)

ANSWER Question 4

Question 4.1

EE (pg 266-267)

- Desired working conditions
- Depth of mining operations
- Mining method
- Development programme
- Down and up cast facilities
- Economics/ Cost

Question 4.2

EE (pg 272)

Any five:

- Amount of air required-
- Economic air velocity = 18-20 m/s
- Critical velocity of between 7-12 m/s
- Up cast shafts are normally concrete lined and free of steel work
- Velocity in the excess of 12m/s is necessary (terminal velocity)
- Area considerations

4.3

Any five

- To ensure that a new system adheres to design requirements
- To build up data on systems which work properly for future use in similar circumstances
- To determine whether the requirements set by authorities have been met
- To balance the system properly
- To determine if maintenance or repair is required
- Determine quantities
- Determine pressures

4.4

Any four

- Max dust loads
- Max gas loads
- Effect on radiation exposure
- Method of filtering/removing contaminants
- Contingency planning

QUESTION 5 **[20]**

Comment on and discuss the content of the article related to mine environmental control and occupational hygiene, which have appeared in the following publications:

PLEASE NOTE - ADDRESS ONLY *ONE* OF THE FOLLOWING TWO TECHNICAL PUBLICATIONS:

5.1 Practices for conveyor roadway segregation and designation of escape ways in Australian underground coal mines

(M.J. Olsen. January/March Volume 70 No 1)

Use the following headings in your answer:

1. Abstract
2. Introduction
3. History in Australia
4. International Practice
5. Different schools of thought
6. Mine Scenarios
7. Conclusion

OR

5.2 Ventilation planning at the P.T. Freeport Indonesia's GBC Mine

(K.G. Wallace, Jr., B.S. Prosser, R. Sani, T. Semestario. April/June Volume 70 No 2)

Use the following headings in your answer:

1. Abstract
2. Introduction
3. Design Criteria
4. General ventilation design layout

ANSWER Q5

20 facts from the journal paper to award full marks

TOTAL MARKS: [100]