Minerals Council South Africa

EXAMINATION PAPER

SUBJECT: MINERALS COUNCIL SOUTH AFRICA - CERTIFICATE IN MINE ENVIRONMENTAL CONTROL PAPER 1 - FLOW DYNAMICS, AIRFLOW, FANS, MINE WATER **SUBJECT CODE:** **COMMEC1** **EXAMINATION DATE:** 04 OCTOBER 2021 **TIME**: 14:30 – 17:30	**EXAMINER:** Tsietsi B Letanta **MODERATOR:** Eugene Botha **TOTAL MARKS:** [100] **PASS MARK:** (60%)

NUMBER OF PAGES: 13

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.
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 Mention 6 advantages of using compressed air to power equipment underground. (6)

- i) It can usually be installed by unskilled labour.
- ii) It can usually be operated with minimal supervision.
- iii) There is no danger of electrocution.
- iv) Compressed air is usually available at all points underground.
- v) It gives greater flexibility of operation.
- vi) It is usually more robust.
- vii) It is a source of local cooling.

1.2 Describe the following concepts:

I. Ventilation on demand (2)

Providing ventilation to mining areas as and when required.

II. Controlled recirculation (2)

The re-introduction of part of the return air from an area into the intake air of the same area.

III. Natural ventilation (2)

When movement of air is caused by heat (normally from rock) or falling water (normally from fissure in the rock).

1.3 You are asked to acquire a ventilation simulation package for the mine. Which 6 features/aspects would you consider? (6)

- i) Hardware requirements of the package
- ii) Price and running costs of the package
- iii) Speed of the software
- iv) Scope and ease of use
- v) Stability and reliability of the package
- vi) Training and maintenance provided
- vii) Back-up assistance
- viii) Reputation of the package vendor/seller

4.1 Discuss the logical steps you would follow in implementing a dust and fume extraction system at a surface plant on your mine. (10)

1. Identify the problem.
2. Find out about any legal requirements (TLV; OEL: etc)
3. Limit the dust at source by minimising generation of fines and preventing fine particles from becoming airborne.
4. Select the most efficient enclosure for the transfer points.
5. Select the most appropriate dust or fume extraction system.

6 Calculate the extraction rate from the open areas of each hood/extraction point and the design capture of the particular pollutant.
7 Select the most efficient filter or collector.
8 Assess the suitability of the location of the collector/filter.
9 Select the most appropriate exhaust stack height.
10 Dispose of the collected waste.

[28]

QUESTION 2

The table below shows the pressure volume characteristic of a single fan serving a small mine (draw this fan curve on the graph paper provided in your answer book). It is driven by a motor running at 13,0 rps through a V-belt drive. The motor pulley diameter is 200mm and the fan pulley diameter is 354 mm. The resistance of the mine is 0,12Ns²/m8.

Q	0	10	20	30	40	50	60	70	80	90	100	11	12	13
P	1200	108	1045	112	121	1230	116	1060	920	740	560	36	14	20

2.1 What is the fan speed? (2)

Motor pulley diameter = 200mm
Fan pulley diameter = 354mm
Motor speed = 13rps

F_{speed} x F_{pulley} = M_{speed} x M_{pulley} (F= Fan; M=Motor) (1)

Current Fan Speed =

$$Current\ Fan\ speed = \frac{M\ diameter\ x\ Motor\ speed}{Fan\ Pulley\ diameter}$$

$$Current\ Fan\ speed = \frac{200\ x\ 13}{354}$$

= 7.3 rps (1)

2.2 What is the quantity of air flowing through the mine if NVP of 100 Pa assists the fan (ignore changes in air density)? (10)

Present resistance of the mine = 0,12 Ns^2/m^8

Assume a quantity of 60 m^3/s

P = RQ^2
= 0,12 x60^2
= 432Pa (2)

Subtracting 100 Pa for NVP assisting:

$$P = 432 - 100$$
$$= 332\text{Pa (1)}$$

Use other quantities to complete the point for the system resistance curve

	Quantity(m^3/s)						
	20	**40**	**60**	**80**	**100**	**120**	**140**
p	48	192	432	768	1200	1728	2352
p -NVP	-52	92	332	668	1100	1628	2252

(Use the resistance R = 0,12 Ns^2/m^8 as before) (2)

Using this method, plot the curve representing the new situation (system resistance minus NVP). Where this curve cuts the fan curve, read off the quantity through the mine (see graph at end of question):
2 marks for fan curve
2 marks for resistance curve

Quantity through the mine = 87 m^3/s @ 800 Pa (1)

NB 3 marks for the graph

2.3 Due to fall of ground in old areas the resistance of the mine has increased to an amount of 0,160 $Ns^2/m8$. It is, however, necessary to maintain the same quantity of air flowing through the mine and the fan speed is to be altered accordingly by changing the fan pulley. NVP will remain the same and the existing motor is large enough to drive the fan at the new duty point. What will be the new fan speed and what will be the diameter of the new fan pulley? (10)

New resistance of themine = 0,160 Ns^2/m^8

But a quantity of 87 m^3/s is still required through the m i n e :

Therefore the pressure required $= RQ^2$

$$0{,}160 \times (87)^2$$
$$= 1211\text{Pa (1)}$$

That is 1211 Pa is required to overcome the new mine resistance, but 100Pa NVP still assists so the new fan pressure will be;

(1211 – 100) Pa = 1111Pa. (1)

The operating point of the fan at its new speed will b e :

87 m^3/s @ 1 111 Pa (1)

With a fan speed change, points on a fan curve alter according to a square law. In order to find the point on the original fan curve ***which corresponds to the new fan operating point*** *(this is a very important aspect of this question)* draw a square law curve from the **new** fan operating point back to the original fan curve.The table below show the pressure results for the new resistance minus the NVP.

	Quantity(m^3/s)						
	60	70	80	90	100	110	120
p	576	784	1024	1296	1600	1936	2304

p -NVP	476	684	924	1196	1500	1836	2204

2 marks

Read off from the graph the corresponding pressure and quantity at the intersection with the old fan curve:

80 m^3/s @ 920Pa (1)

Therefore the new speed can be determined:

$\frac{S2}{S1} = \frac{Q2}{Q1}$ (1)

$S_2 = S_1 \times \frac{Q2}{Q1}$

$S_2 = 7.3 \times \frac{87.0}{Q80.0}$

7.9 rps (1)

Alternatively, the pressure varies the speed:

$\frac{P2}{P1}=(\frac{S2}{S1})^2$ (1)

$S_2 = 7.3 \times \sqrt{\frac{1111}{920}}$

$S_2 = 7.3 \times 1.098$

$S_2 = 7.3 \times 1.098$

$S_2 = 8.0$ rps (1)

From the formula below the new fan pulley size can be determined:

Fspeed old x Fpulley sizeold = Fspeed new x Fpulley sizenew (F =fan)

$New\ Pulley\ size = \frac{Fspeed\ old\ x\ FPulley\ size\ old}{Fan\ speed\ new}$ (1)

$New\ Pulley\ size = \frac{7.3\ x\ 354}{7.9}$

= 327.11 mm (1)

The new pulley diameter is therefore 327 mm.

2.4 What will be the approximate stall point at the new speed? (5)

From the graph, stall point at old fan speed is read off as follows:
46 m3/s @ 1 210 Pa (1)
To determine the new stall point it is important to establish what the air quantity at that point would be. We have the old stall point quantity and the new and old speeds of the fan and by using the fan laws the quantity for the new stall point can be determined.

$\frac{S2}{S1} = \frac{Q2}{Q1}$ (1)

$Q_2 = Q_1 \times \frac{S2}{S1}$

$= 46 \times \frac{7.8}{7.3}$

$= 49.15\ m^3/s$ (1)

The pressure varies with the speed and the new stall pressure can be determined:

$\frac{P2}{P1} = (\frac{S2}{S1})^2$ (1)

$P2 = P1 \times (\frac{S2}{S1})^2$

$P2 = 1210 \times (\frac{7.8}{7.3})^2$

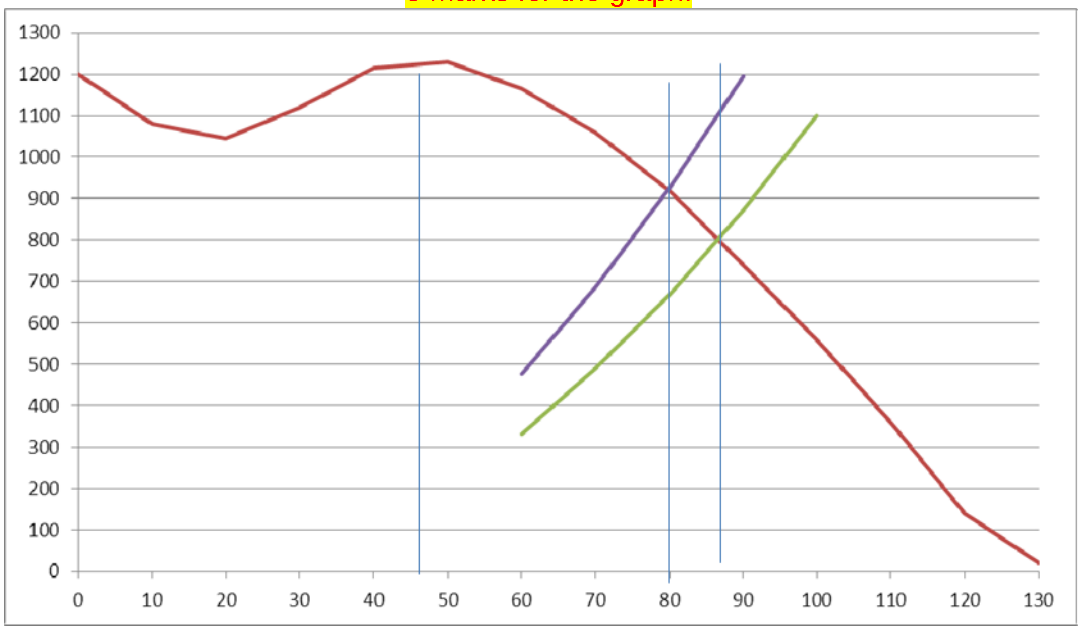
P2 = 1210 x 1.141

= 1381 Pa

(1)

The fan stall point at the new fan speed will be approximately:
49.15 m^3/s @ 1 1381Pa

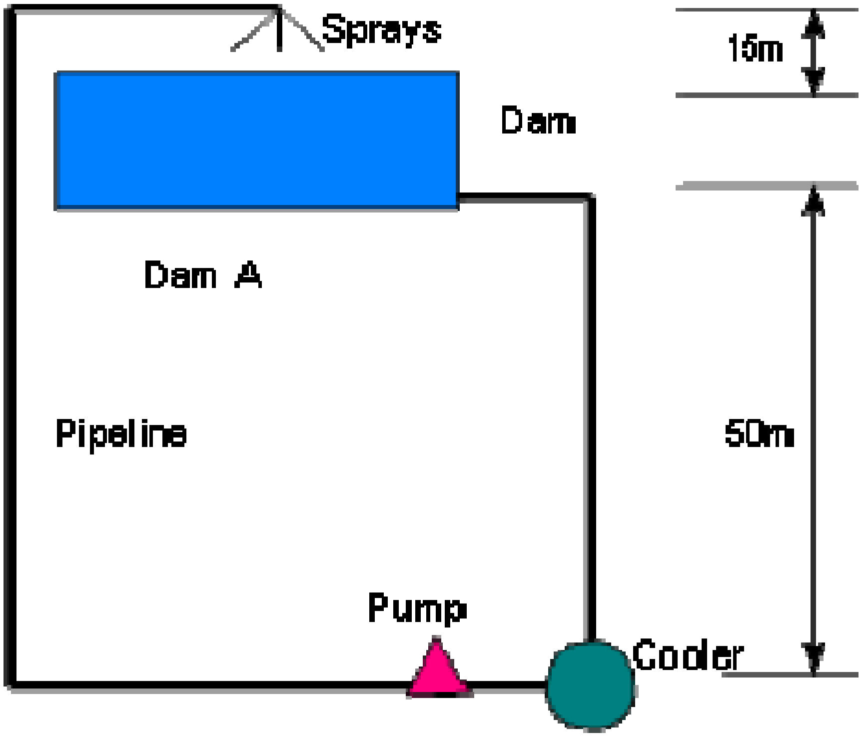
3 marks for the graph!



[27]

QUESTION 3

3.1 The water reticulation system below has a total piping length of 150 m. The pipe diameter is 203mm. There are three gate valves and 1 5 elbows in the pipe line. The spray pressure is 220kPa and the head lossthrough the cooler is 40 kPa. The water quantity to be circulated is 60l/s.The vertical lift above the water level in the dam is 15 m. One gate valvehead loss = loss through 1,3m of straight pipe, one standard elbow headloss = loss through 6 m of straight pipe.



Ignore the effect of the water in the dam and determine the totalhead in kPa against which the pump must operate. (10)

From the pipe friction chart: Head loss due to friction for a 203 mm pipe and a mass flow of 60 litres/second is 1,8 m/100 m

The total 'effective' pipe length (straight) for the system must be determined:

Total pipe length = 150 m + (1,3 m x 3 gate valves) + (6 m x 15 elbows) (1)

= 150 + 3,9 + 90

= 244 m straight pipe length (1)

The head loss to overcome frictional resistances:

Hf = 1,8/100 x 244

= 4,392 m (1)

The head loss due to elevation differences (vertical height difference):

hs = 15 m (1)

Note: A common mistake made is to add the 50 m as well, it is however cancelled by the 50 m down, therefore, 50 m +15 m – 50 m = 15 m. (1)

The total head loss through the water sprays (220 kPa, given) and cooler

(40 kPa, given) is:

Total head loss = 220 + 40

= 260 kPa (1)

This must be converted to an equivalent m pipe length and is done as follows:

$$P = \frac{w \text{ x } g \text{ x } h}{1000} \text{ (but density of water is 1000kg/m}^3\text{)} \quad (1)$$

$$= gh$$

$$h = p/g$$

$$= 260/9.79$$

$$= 26.6 \text{ m} \quad (1)$$

Total head of pump:

$$h_t = 4.392 + 15 + 26.6$$

$$= 45.99 \text{ m} \quad (1)$$

Converting head to kPa:

$$P = \frac{w \text{ x } g \text{ x } h}{1000}$$

$$= \frac{1000 \text{ x } 9.79 \text{ x } 45.99}{1000}$$

$$= 450 \text{ kPa} \quad (1)$$

3.2 Calculate the pump shaft power and pump motor input power (the necessary assumptions must be shown). (5)

The pump shaft power can be calculated as follows (pump efficiency assumed as 75%) (1)

$$\text{Pump shaft power} = \frac{\text{Q x g x h x density of water}}{\text{1000 x efficiency of pump}} \quad (1)$$

$$= \frac{0.06 \text{ x } 9.79 \text{ x } 45.99 \text{ x } 1000}{1000 \text{ x } 0.75}$$

$$= 36 \text{ kW} \quad (1)$$

Where;

Q the volume flow of water and assumed that 1 m^3 =1000kg=1000 litres

The pump motor input power can be calculated as follows (pump motor efficiency assumed as 95%)

$$\text{Pump motor input power} = \frac{\text{Pump shaft power}}{\text{Pump motor efficiency}} \quad (1)$$

$$= \frac{36}{0.95}$$

$$= 37.9 \text{ kW} \quad (1)$$

3.3 What is the Joules Thompson effect and how does it affect 120 liters/second of water in a 1200 m long 203 mm diameter pipe discharging into a dam at the bottom of the shaft? Assume the head lossis 3,5 m/100m of pipe. (5)

The Joule Thompson effect is the increase of the water temperature as it flows downwards in a vertical column.

The head loss was given for a specific reason (to be used in the arguments to solve the problem). The head loss has been given as 3,5m per 100 m and is therefore 3,5 x 1200/100 = 42 m (1)

The available head is therefore = 1200 – 42
= 1158 m (1)

By using the formula: p = wgh
= 1000 x 9.79 x 1158
= 11336820 Pa (1)

As this pressure is dissipated (used up) when the water is discharged into the dam, the temperature difference of the water at the bottom of the shaft can be calculated as follows:

$\Delta T = \mu\, \Delta T$ (1)

$= -2.4 \times 10^{-7} \times (-11336820)$

= 2.72 or 27 Kelvin (1)

A common mistake made by the student is the pressure is used as kPa, which will give a very small temperature rise answer and the “-“sign is also forgotten.

3.4 The temperature of water entering the above column is 6,5ºC. A turbine, which is 71% efficient is installed at the bottom of the column. Ignoring all other heat transfer taking place in the column, what is the temperature of the water discharging from the column? (3)

Without the turbine the temperature increase is 2,7 K (or ºC). The turbine is 71% effective and this will have the effect that the temperature increase of the water will be much less, and can be determined as follows: (1)

Net $\Delta T_{\text{with turbine}} = \Delta T_{\text{without turbine}} - (\text{efficiency}_{\text{with turbine}} \times \Delta T_{\text{without turbine}})$ (1)

$= 2.7 – (071 \times 2.7)$

$= 0.783$ Kelvin (1)

3.5 How much energy is recovered from the system? (2)

Energy recovered $= \frac{\text{m x g x available head x efficiency(with turbine)}}{1000}$ (1)

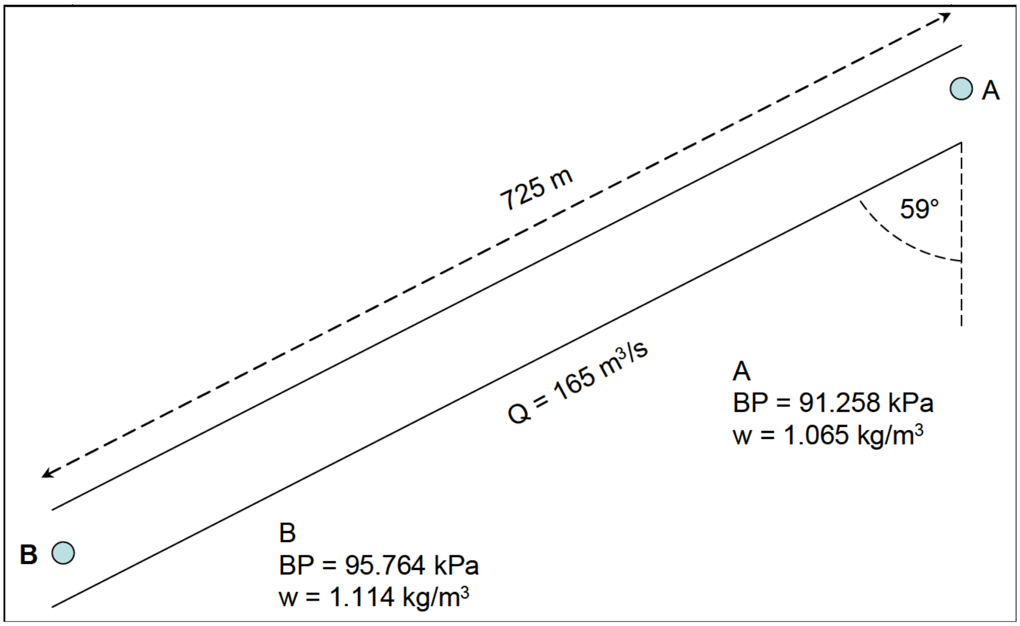
$= \frac{120 \text{ x } 9.79 \text{ x} 1158 \text{ x } 0.71}{1000}$

= 965.9 kW 0r 966 kW (1)

TOTAL 25

QUESTION 4

4.1 A pressure survey was carried out in the inclined airway shown in the sketch below. Relevant information is shown on the sketch.



Determine:

I. The pressure loss in the airway (6)

First determine the difference in elevation: The dip of the airway is 90 – 59 = 31°.

The elevation difference is 725 x sin 31° = 373.4, say 373 m (1)

The mean density in the airway is (1.065 + 1.114) / 2 = 1.0895 (1)

The theoretical pressure at B is PA + gwH = 91 258 + (9.79 x 1.0895 x 373) = 95 236 Pa or 95.236 kPa (1)

The actual pressure at B is 95.764 kPa (1)

The pressure loss in the airway is 95.764 – 95.236 = 0.528 kPa or 528 Pascals.(1)

C = 16 m; A = 16 m2; L = 725m; Q = 165 m3/s; w = 1.0895 kg/m3 (1)

II. The Atkinson's k-factor of the if the dimensions are 4.0m by 4.0m (3)

Rearranging Atkinson's formula to solve for k,

$$k = \frac{P \; x \; A^3}{C \; x \; L \; x \; Q^2} \; x \; \frac{1.2}{w}$$

$$k = \frac{528 \; x \; 16^3}{16 \; x \; 725 \; x \; 165^2} \; x \; \frac{1.2}{1.0895}$$

$$k = 0.0075$$

III. The direction of airflow in the airway (3)

The actual pressure at B is lower than the theoretical pressure, therefore the flow is from B to A (upcasting)

4.2 A barometric pressure survey was carried out to determine the pressure loss in a downcast shaft The results are tabulated below:

Time	14:00	15:15	16:20
Surface BP (kPa)	84.158		83.969
Surface density (kg/m3)	0.968		0.960
Shaft bottom BP (kPa)		94.202	
Shaft bottom density (kg/m3)		1.105	

The shaft is 1105 meters in depth. Stating all the assumptions you made, calculate the pressure loss in the shaft. (8)

Assume a linear change in BP and density with time. The time difference between the first surface and the shaft bottom reading is 75 minutes. The time difference between the shaft bottom and second surface reading is 65 minutes (total time elapsed surface to surface is 140 minutes). (1)

The difference in surface readings is 84.158 – 83.969 = 189 Pa. (1)

Therefore,

the assumed decrease in surface BP reading at 15:15 is 189 x 75/140 = 101.25 Pa. (1)

The assumed surface BP reading at 15:15 is thus 84158 – 101.25 = 84056.75 Pa or 84.05675 kPa. (1)

Similarly, the difference in density on surface is 0.968 – 0.960 = 0.008 kg/m3. (1)

The surface density at 15:15 is assumed to be 0.968 – 0.008 x 75/140 = 0.9637 kg/m3. (1)

The mean shaft density at 15:15 is therefore (1.105 + 0.9637)/ 2 = 1.03435 kg/m3

The theoretical pressure at shaft bottom is thus

P = 84056.75 + (9.79 x 1.03435 x 1 105) = 95246 Pa or 95.246 kPa. (1)

The actual pressure is 94.202 kPa.

The pressure loss is 95.246 – 94.202 = 1.044 kPa or 1 044 Pa. (1)

[20]

TOTAL MARKS: 100