Minerals Council South Africa

MEMORANDUM

SUBJECT: MINERALS COUNCIL SOUTH AFRICA - CERTIFICATE IN MINE ENVIRONMENTAL CONTROL PAPER 1 - FLOW DYNAMICS, AIRFLOW, FANS, MINE WATER **SUBJECT CODE:** **COMMEC1** **EXAMINATION DATE:** 08 OCTOBER 2018 **TIME**: 14:30 – 17:30	**EXAMINER:** Tsietsi B Letanta **MODERATOR:** Frank von Glehn **TOTAL MARKS:** [100] **PASS MARK:** (60%)

NUMBER OF PAGES: 11

SPECIAL REQUIREMENTS:

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

INSTRUCTIONS TO CANDIDATES:

1. Answer all 4 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 The following measurements were made at an axial flow fan:

Fan Total Pressure	1200 Pa
Fan Velocity Pressure	400 Pa
Quantity	8.4 m^3/s
Motor Input Power	15 kW
Fan Input Power	12.4 kW

Determine:

i) The overall fan efficiency, (2)

Overall fan efficiency = (fan input power/ total fan output power) x 100%

= ((8.4 x 1.2)/12.4 x 100%

= 81.29 %

ii) The total fan total efficiency (2)

Total fan efficiency = (Total fan output power/motor input power) x 100%

= (8.4 x 1.2) / 15 x 100%

= 67.2 %

iii) Fan static efficiency. (2)

Fan static efficiency = Fan static pressure output power / fan input power x 100%

$= \frac{(1.2-0.4)x\ 8.4}{12.4}$x 100%

= 54.19 %

1.2 It is required to speed a fan up from 8.4 r/s to 10.5 r/s. The motor pulley diameter is 180 mm and the fan pulley diameter is 208 mm.

Use two accepted methods of achieving the desired speed and give the necessary pulley diameters (5)

i) Fan speed α inversely as the fan pulley diameter and directly as the motor pulley diameter.

New fan pulley size = (Old fan speed/new fan speed) x old fan pulley size

= (8.4/10.5) x 208 mm

= 166.4 mm

ii) New Motor pulley size = (New fan speed/old fan speed) x old motor pulley size
= (10.5/8.4) x 180 mm
= 225 mm

1.3 The resistances of three airways that are connected in series are:

i) A = 0.075 Ns^2/m^8
ii) B = 0.049 $Ns2/m^8$
iii) C = 0.06 Ns^2/m^8

A quantity of 60 m^3/s is measured in airway B. Calculate the pressure loss in each airway, the overall resistance and the overall pressure loss of the system. (7)

Airway B

$P = RQ^2 = 0.049 \times 60^2 = 176.4$ Pa (1)

Since the airways are in series the same volume will flow through each airway, assuming no leakage.

Airway A

$P = RQ^2 = 0.075 \times 60^2 = 270.0$ Pa (1)

Airway C

$P = RQ^2 = 0.06 \times 60^2 = 216.0$ Pa (1)

Pressure loss for airways in series = P Airway A + P airway B + P airway C

= (176.4 + 270.0 + 216.0) Pa (1)

= 662.4 Pa (1)

Overall resistance = Overall Pressure drop / total volume^2

= $662.4/60^2$ (1)

= 0.184 Ns^2/m^8 (1)

1.4 Give reasons why an evaseé is fitted to the outlet of a ventilation system. (3)

An evaseé is normally fitted to the discharge of a system to convert the wasted velocity pressure into useful static pressure. This is done by enlarging the area at the discharge of the system thus decreasing the air velocity and hence the velocity pressure. This reduction in velocity pressure then represents a gain in static pressure.

1.5 Mention 4 causes of shock losses in an airway. (4)

i) Intake of a duct/tunnel (entrance loss)
ii) Outlet of a duct/tunnel (exit loss)
iii) Bend in the airway
iv) Obstruction in the airway
v) Sudden changes in airway size

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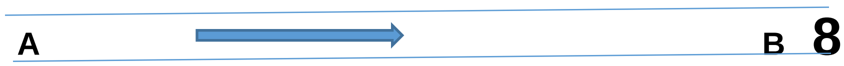
QUESTION 2

2.1 These measurements were taken from a fan/duct system depicted in the sketch below:

100m x 1016 mm Ø



Side tube reading at position A	-275 Pa
Facing tube reading at position B	-513 Pa
Quantity of air	14 m^3/s
Air density	0.98 kg/m^3

Calculate the k factor for the vent column (12)

The area of the column is 1.016^2 x π / 4 = 0.810 m². (1)

The circumference is 1.016 x π = 3.19 m (1)

Determine the velocity in the column

V = Q / A = 14 / 0.810 = 17.28 m/s (1)

Calculate VP: VP = V^2 x w / 2 (1)

VP = 17.28^2 x 0.98 / 2 = 146 Pa (1)

Remembering that a side tube records static pressure and a facing tube records total pressure, use the formula TP = SP + VP and tabulate the various pressures:

Point	A	B
Static pressure	-275	-659
Velocity pressure	146	146
Total pressure	-129	-513

Subtracting, determine the difference in total or static pressure between points A and B (1)

SP = -275 – (-659) = -384 Pa (1)

TP = -129 – (-513) = -384 Pa (1)

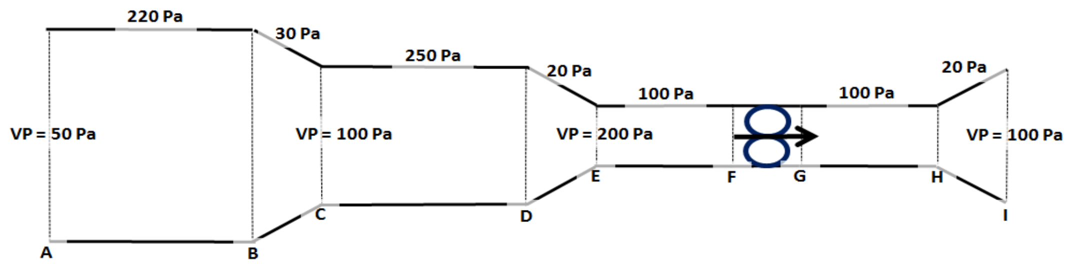
Rearranging Atkinson's formula, solve for k

$$K = \frac{Px\ A\text{^}3}{CxLxQ\text{^}2} \text{ x } 1.2/w \quad (1)$$

$$= \frac{384x\ 0.810\text{^}3}{3.19\ x\ 100\ x14\text{^}2} \text{ x } 1.2/0.98 \quad (1)$$

= 0.004 (1)

2.2 The sketch below depicts a fan handling air in a ventilation column. The various velocity pressures within the ventilation column are indicated on the sketch. Pressure losses in each section of the ventilation column are also indicated on the sketch. Assume there is no leakage throughout the entire duct.



At each point along the ventilation column, determine:

Total pressure, static pressure, velocity pressure. **(10)**

Tabulate your answer (in a table similar to that shown below);

	A	B	C	D	E	F	FAN	G	H	I
VP	50	50	100	100	200	200	200	200	200	100
SP	-50	-270	-350	-600	-720	-820	640	20	-80	0
TP	0	-220	-250	-500	-520	-620	840	220	120	100

2.3 Determine the Fan Total Pressure and fan static pressure. (3)

FTP = (220)-(-620) [dif. of 2 facing gauges]
= 840 Pa

Or

FTP = (20)-(-820) [dif. 2 side gauges, equal areas delivery]
= 840 Pa

FSP = (20)-(-620) [diff, facing gauge inlet, side gauge delivery)
= 640 Pa

2.4 How can the resistance on this system be reduced? (1)

This could be done by putting a bell mouth at the inlet, this would reduce shock losses at the inlet.

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QUESTION 3

3.1 Briefly describe the following water reticulation systems for an underground mine:

i) Open system (2)

This is a system where the water is discharged at the end of the pipe column into the air. The water then runs back towards a centralised collection point, where it is treated and pumped back to surface.

ii) Closed system (2)

This system is not open to the air. Water is re-circulated through a distribution network, such as the evaporator circuit of a cooling plant. Heat is transferred by means of air to water heat exchangers and the warmer water again re-cooled in the refrigeration plant.

iii) Integrated system (1)

A combination of the open and closed systems.

3.2 Briefly describe 5 ways you can control scaling in water reticulation systems (5).

i) Limit the concentration of scale forming minerals.
ii) Reduce the alkalinity of the water by treating with acid.
iii) Increase water velocity.
iv) Use chemical inhibitors that retard and distort the growth of sacle formation.
v) Air-rumble loosen and dissolve scale formation.

3.3 A pipe column is planned for a new section of a mine. The column will be installed in a portion of a vertical shaft for a distance of 150m and will then be installed in a horizontal haulage to a point 1600m away from the shaft. The vertical pipe will be of 200mm internal diameter, and the horizontal pipe will be 150mm internal diameter. The required water flow rate is 100l/s at a discharge pressure of 20 meters head. (Ignore pressure losses due to bends, valves, etc.).

i) Will this column be adequately sized, given that the dynamic viscosity of water is 10^{-3} kg/ms? (12)

Using the Darcy-Weisbach equation:

$H_{f:} = \frac{\lambda L V^2}{2gD}$ 100l/s = 0.1 m^3/s and 200mmØ = 0.031 m^2 (1)

$V = \frac{0.1}{0.031}$ = 3.183 m/s. (1)

Calculate Reynolds number:

$\text{Re} = \frac{wDV}{\mu} \qquad = \frac{1000\ x\ 0.2\ x\ 3.183}{10-3}$ (1)

= 636 600

From the Stanton Nikuradse diagram: (1)

λ=13.0 x 10^{-3}

$\text{Hf} = \frac{0.013\ x\ 150\ x\ 3.183^2}{2\ x 9.79\ x 0.2}$

= 5.0 m (1)

Now repeat the process for the horizontal section of the pipe:

$\text{Re} = \frac{wDV}{\mu} \qquad = \frac{1000\ x\ 0.15\ x\ 5.695}{10-3}$ (1)

= 849 000

$\text{Hf} = \frac{0.0125 x\ 1600\ x\ 5.659^2}{2\ x 9.79\ x 0.15}$ (1)

= 218 m

Total head loss:

218 + 5 = 223 m (1)

This system is not adequately sized. (1)

ii) If not, what pressure would a pump have to supply in order to overcome the friction? (3)

But only 150 m vertical head is available. (1)

A pump would be required to supply: (1)

223 + 20 – 150 = 93 m head at a flow rate of 100 l/s (1)

Hint: Assume that the water is delivered at the top of the column at 0m pressure.

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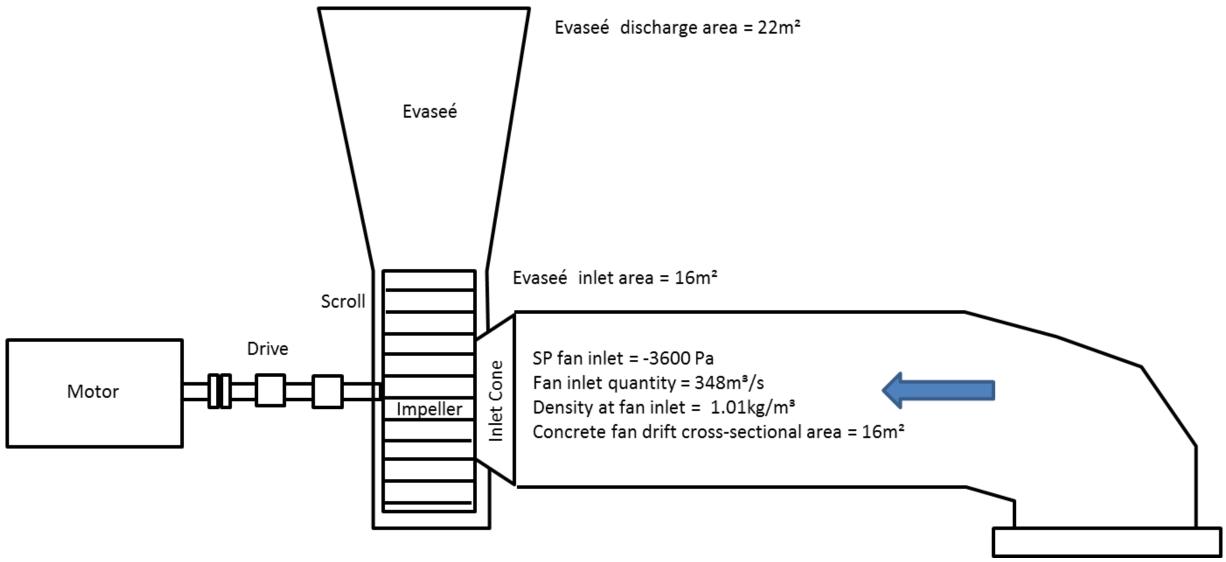
QUESTION 4

4.1 The sketch below represents a main surface fan on a large mine.



Given;

- The quantity measured at the fan inlet = 348 m^3/s.
- The air density at the fan inlet = 1.01kg/m^3 (assume no change in air density across the fan).
- The cross-sectional area of the concrete duct leading to the fan inlet = 16m^2.
- The static pressure measured at the fan inlet = -3600 Pa.
- The evaseé efficiency = 93%
- The inlet and discharge areas of the evaseé are 16m^2 and 22m^2 respectively.

Determine the total pressure (FTP) at which this fan is operating. (9)

Velocity at fan inlet (v);

$v = \frac{Q}{A}$, $v = \frac{348 \text{ m}^3/s}{16 \text{ m}^2}$, $v = 21.75 m/s$

Velocity pressure at fan inlet (VPFI)

$VP = \frac{w \times v^2}{2}$, $VP = \frac{1.01\text{kg/m}^3 \times 21.75 m/s^2}{2}$, $VP = 238.9 Pa$

Velocity pressure at fan inlet (VP_{FI}) = 239 Pa

(1)

Total pressure at fan inlet (TP_{FI});

$TP_{FI} = VP_{FI} + SP_{FI}$

TP_{FI} = 239 + (- 3 600) Pa

TP_{FI} = - 3 361 Pa

Total pressure at fan inlet (TPFI) = - 3 361 Pa

(1)

Velocity at evaseé outlet (v);

$v = \frac{Q}{A}$, $v = \frac{348 \text{ m}^3/s}{22 \text{ m}^2}$, $v = 15.8m/s$

Velocity pressure at evaseé outlet (VP_{EO});

$VP = \frac{w \times v^2}{2}, VP = \frac{1.01\text{kg/m}^3 \times 15.8\ m/s^2}{2}, VP = 126Pa$

Velocity pressure at evaseé outlet (VP_{EO}) = 126Pa

(1)

Velocity at evaseé inlet (v);

$v = \frac{Q}{A}$, $v = \frac{348 \text{ m}^3/s}{16 \text{ m}^2}$, $v = 21.75m/s$

Velocity pressure at fan inlet (VPFI)

$VP = \frac{w \times v^2}{2}, VP = \frac{1.01\text{kg/m}^3 \times 21.75m/s^2}{2}, VP = 238.9Pa$

Evaseé static pressure (SP) regain (theoretical) = 113 Pa

(1)

Evaseé static pressure (SP) regain $_{(actual)}$;

SP regain $_{(actual)}$ = (SP) regain $_{(actual)}$ x evaseé efficiency

SP regain $_{(actual)}$ = 113 Pa x 0.93

SP regain $_{(actual)}$ = 105 Pa

Evaseé static pressure (SP) regain (actual) = 105 Pa

(1)

Consider that static pressure at evaseé outet (SPEO) = 0 Pa

Static pressure at evaseé inlet (SP_{EI});

SP_{EI} = SP_{EO} - SP regain (actual)

SPEI = 0 – 105 Pa

SPEI = – 105 Pa

Static pressure at evaseé inlet (SPEI) = – 105 Pa

(1)

but;

Velocity pressure at evaseé inlet (VP_{EI}) = velocity pressure at fan outlet (VP_{FO})

and;

Static pressure at evaseé inlet (SP_{EI}) = static pressure at fan outlet (SP_{FO})

Velocity pressure at fan outlet (VP_{FO}) = 239 Pa

Static pressure at fan inlet (SP_{FO}) = - 105 Pa (1)

total pressure fan outlet (TP_{FO});

TP_{FO} = VP_{FO} + SP_{FO}

TP_{FO} = 239 + (- 105) Pa

TP_{FO} = 134 Pa

Total pressure fan outlet (TP_{FO}) = 134 Pa (1)

total fan pressure (FTP);

(FTP) = TP_{FO} – TP_{FI}

FTP = 134 – (- 3 361) Pa
FTP = 3 495 Pa

Total fan pressure (FTP) = 3 495 Pa (1)

4.2 For a constant volume flow at the same pressure loss over identical lengths and friction factors, what percentage of excavation size can be saved if a square airway is replaced with a circular airway? Make any assumptions you deem necessary. (10)

Pressure loss, length, and friction factors are constant, therefore:

$C_1 / A_1^3 = C_2 / A_2^3$, where the subscripts indicate the different shaped airways. (1)

Assume airway 1 is a square with sides B, and airway 2 is circular with diameter D, then (1)

$4B / (B^2)^3 = \pi D / (\pi D^2/4)^3$ (1)

$4B / B^6 = \pi D \times 64 / \pi^3 D^6$

$4 / B^5 = 64 / \pi^2 D^5$ (1)

Assume B = 3 metres, then $4 / 3^5 = 64 / 9.86D^5$ (1)

Rearranging, we get: $D^5 = 64 \times 3^5 / (4 \times 9.86)$

$D^5 = 15552 / 39.44 = 394.3$ (1)

$D = 394.30^{0.2} = 3.3$ metres (1)

Area of square airway = 3 x 3 = 9 m^2 (1)

Area of round airway = $\pi(3.3)^2 / 4 = 8.5$ m^2 (1)

Saving in airway area = 0.5 / 9 = 5.5 percent (1)

4.3 Name 5 hazards you will consider when conducting a risk assessment for a workplace (5)

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

Risks such as flammable materials, distance to refuge bay, amongst others, could also be considered.

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TOTAL MARKS: [100]