Chamber of Mines of South Africa

EXAMINATION PAPER

SUBJECT:	EXAMINER:
CHAMBER OF MINES OF SOUTH AFRICA – CERTIFICATE IN MINE ENVIRONMENTAL CONTROL	Jacques Coetzee
PAPER 1 - FLOW DYNAMICS, AIRFLOW, FANS, MINE WATER	**MODERATOR:** Eugene Botha
SUBJECT CODE: **COMMEC1**	**TOTAL MARKS:** [100]
EXAMINATION DATE: 9 MAY 2022	**PASS MARK:** (60%)
TIME:	

NUMBER OF PAGES: 13

SPECIAL REQUIREMENTS:

THIS IS NOT AN **OPEN BOOK EXAMINATION**. **FORMULA HANDOUT IS AVAILABLE**

INSTRUCTIONS TO CANDIDATES:

1. Answer all 5 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 When considering the ventilation aspects of indoor heating, ventilation, and air conditioning systems (HVAC systems), the type of system and its components should be reviewed. Name any five components that make up a HVAC system and describe the purpose of each of these components.

Components: The components that make up HV AC systems generally include the following:

A. HVA C System: HV A C system refers to the equipment and distribution system used for heating, ventilating, cooling, humidifying, dehumidifying, and cleansing air for a building or building zone for the purpose of comfort, safety, and health of the occupants.
B. Dampers: Dampers are devices of various types used to vary the volume of air passing through an outlet, inlet, or duct.
C. Outdoor Air (Fresh Air; Replacement Air; Compensating Air): Outdoor air used to replace all or part of the air in a building or building space.
D. Return Air: Return air is air that has been in the building for a period of time and is returned to the HVAC system. Varying percentages of return air are exhausted outdoors with the remaining air (recirculated air) mixed with outdoor air for conditioning and distribution.
E. Mixing Plenum: A mlXlng plenum is a chamber within an HV AC system where outdoor air is mixed with returned air. The mixed air, after cleaning and conditioning, comprises the supply air for the building.
F. Air Cleaners: Air cleaners are devices designed to remove atmospheric airborne impurities such as dusts, gases, vapors, fumes, and smoke. (Air cleaners include air washers, air filters, electrostatic precipitators and charcoal filters.)
G. Heating Coils: Heating coils are heat transfer devices, which utilize hot water, steam, or electricity to heat the supply air.
H. Cooling Coils: Cooling coils are heat transfer devices, which utilize chilled water or a refrigerant to cool the supply air.
I. Condensate Pan (Drip Tray; Defrost Pan): A vessel or tray under the cooling coil to receive water extracted from the supply air by condensation from the cooling coil.
J. Humidifier/Dehumidifier: Humidifier/dehumidifiers are devices to add/remove moisture to/from the supply air.
K. Fans (Supply and Return): Fans are devices for moving ventilation air through the HV AC system.
L. Supply Air: Supply air is conditioned ventilation air delivered to zones within a building.
M. Control Zone: Control zone is a space or group of spaces within a building served by an HV AC system. Depending on the space requirements, the control zone may be designated as core or interior zone and/or perimeter zone.
N. Occupied Zone: The occupied zone is the region within an occupied space between 3 and 72 inches above the floor.
O. Control Box (Variable Air Volume, Bypass, Dual Duct): Control boxes are devices to which the supply air may be delivered by the HV AC system prior to delivery to the supply diffuser. These boxes may include means of controlling supply air temperature and volume to the diffuser or multiple diffusers within a HVAC zone.
P. Supply Air Diffusers: Supply air diffusers are devices whose function is to deliver the supply air to the occupied zone and to provide a desired distribution pattern.

The diffusers may be circular, square, rectangular, linear slots, louvered, fixed, adjustable, or a combination.

Q. Return Air Grilles: Return air grilles may be louvered or perforated coverings for openings located in the sidewall, ceiling or floor of a zone through which the return air enters. The return air grilles may be directly connected to an open return air plenum or to a ducted return air system.

R. Return Air Plenum: A return air plenum is the space usually located above the ceiling where the return air is collected from a zone prior to entering the return air system.

S. Economizer: An economizer is a control system which reduces the heating and cooling load through the use of outdoor air for free cooling when the total heat of the return air exceeds the total heat of the outdoor air.

(Candidate to list any 5 components and to describe the purpose 5 x 2)

[10]

1.2 What are the fan laws with regard to

II. Changes in density

Quantity remains constant

Pressure varies directly as air density: P2=P1 x w2/w1

Power varies directly as air density: power2=power1 x w2/w1

Efficiency remains constant

III. Changes in speed

Quantity varies directly as fan speed: Q2=Q1 x s2/s1

Pressure varies directly as fan speed squared: $p2=p1 \times [s2/s1]^2$

Power varies directly as fan speed cubed: $power2 – power1 \times [s2/s1]^3$

Efficiency remains constant

(any 2 laws per change)

[4]

1.3 Compare Axial and Centrifugal fans. Discuss factors such as size, pressure range, flexibility, efficiency, stall characteristics, noise, etc.

- Axial fans less bulky, especially for less than 165 m^3/s and less than 3kPa
- Ease of installation: axial fans easier, no change in direction.
- Flexibility: axial with adjustable pitch blade more flexible and cover wider range of duty, even when centrifugal equipped with adjustable inlet guide vanes.
- Efficiency: axial not necessarily higher efficiency
- Larger volume/pressure: centrifugal generally cheaper for large flows and pressure greater than $235m^3/s$, 3kPa
- Reliability: centrifugal run at lower speed less wear and more reliable
- Stall characteristics: centrifugal mild stall, axial violent stall char.
- Noise: axial tend to be more noisy than centrifugal.

[6]

[20]

Question 2

2.1 Name and describe the method of operation three common water flow meters to measure flow in pipes.

Orifice Plates
An Orifice plate consists of a flat plate with a central hole cut into the plate. This plate forms a calibrated restriction and the pressure drop across the restriction and the pressure drop across the restriction is measured. Thereafter the pressure differential is related to a water flow rate.
Electromagnetic Flow Meters
The principle of operation is Faradays Law of Electromagnetic induction. This law states that a voltage will be developed when a conductor moves through a magnetic field and that the voltage will be proportional to the velocity at which the conductor moves through the magnetic field.
Ultrasonic Flow meters
These flowmeters used either the differential time principle or the Doppler principle to measure flows.

Full answer in the Ventilation and Occupational Environment Engineering in Mines P 61 to 72

[9]

2.2 40 l/s of water flows along a 150mm internal diameter pipe 1700 metres long. Using the Darcey-Weisbach equation, determine the head loss in meters along the pipe.

$$V = \frac{Q}{A} \quad ✓$$

$$V = \frac{0.040}{0.01768}$$

$$= 2.26 \text{ m/s} \quad ✓$$

$$Hf = \frac{\Upsilon L w v^2}{2gD}$$

$$= \frac{0.011 \times 1700 \times 2.26^2}{2 \times 9.79 \times 0.15} \quad ✓$$

$$= 32.5\text{m} \quad ✓✓$$

[5]

2.3 Calculate air density in a 50,29 m^2 circular shaft if the air volume is 300 m^3/s and the Reynolds number is 35000. The fluid dynamic viscosity is 0,0015 Ns^2/m^8.

$$r = \sqrt{\frac{50.29}{3.1429}}$$

$$= \sqrt{16}$$

$$= 4 \quad ✓$$

$D = 2 \times 4$

$= 8$ m

$v = \frac{300}{50.29}$

$= 5.97$ m/s ✓

$w = \frac{\text{Re} \times \text{dynamic viscosity}}{v \times D}$

$= \frac{35000 \times 0.0015}{5.97 \times 8}$ ✓

$= 1.099$ kg/m^3 ✓✓

[5]

2.4 What is the maximum Reynolds number for laminar flow of water in pipes?

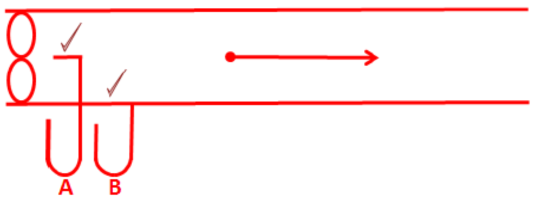
2500 ✓

[1]

[20]

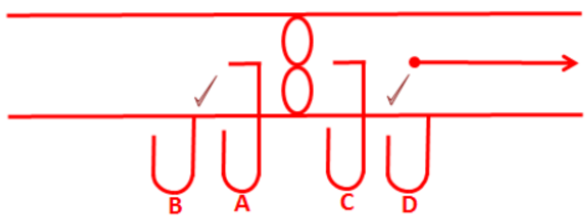
Question 3

3.1 With the aid of sketches, describe how fan total pressure and fan static pressure can be measured, when;
3.1.1 The fan is at the inlet to the ventilation column.



Fan total Pressure = A ✓
Fan static pressure = B ✓
Fan velocity pressure = A – B ✓

3.1.2 The fan is in the middle of the ventilation column.



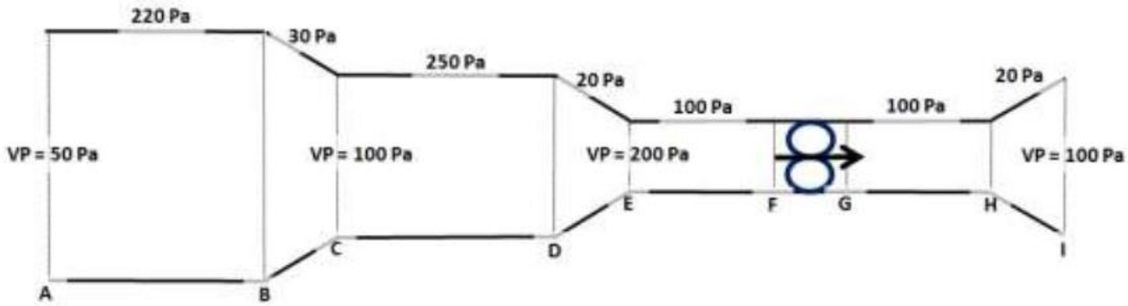
Fan total Pressure = C – A ✓
Fan static pressure = D – B ✓
Fan velocity pressure = (A – B) = (C – D) ✓

3.1.3 The fan is at the discharge of the ventilation column.

Fan total Pressure = B ✓
Fan static pressure = A ✓
Fan velocity pressure = (B – A) ✓

[15]

3.2. 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;
3.2.1 Total pressure.
3.2.2 Static pressure
3.2.3 Velocity pressure
Tabulate your answer (in a table similar to that shown below);

	A	B	C	D	E	F	FAN	G	H	I
VP										
SP										
TP										

Answer:

	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 ✓	**1020** ✓	200 ✓	-80 ✓	0 ✓
TP	0 ✓	-220 ✓	-250 ✓	-500 ✓	-520 ✓	-620 ✓	**1020** ✓	400 ✓	120 ✓	100 ✓

[10]

[25]

Question 4

4.1 Briefly discuss five factors, which can contribute towards the fouling of the inner surface of a water pipe.
i. Water characteristics – dissolved and suspended materials can cause fouling.

ii. Temperature – increased temperature can lead to increased fouling.

iii. Flow velocity – low flow velocity can lead to settling out of suspended material.

iv. Microbiological growth – these form deposits on surfaces, these bacteria can cause corrosion to occur with the corrosion products subsequently deposited as foulants.

v. Corrosion – can cause insoluble products, which can result in fouling.

vi. Contamination – materials that leak from the process side of heat exchangers can result in fouling.

[5]

4.2 Briefly discuss five places where dynamic (shock) losses occur in a water reticulation system and give examples of how these losses can be avoided.
i. Elbows (bends) – avoid sharp elbows (bends) completely.
ii. Valves – correct sizing, positioning, and maintenance of valves.
iii. Number and type of bends – design bend with the correct radius.
iv. Number and type of junctions – avoid T-junctions completely.
v. Number of orifice plates – orifice plates must be correctly designed and installed.

[5]

[10]

Question 5

5.1 A horizontal and vertical 6–position pitot tube survey is taken across a main fan drift of 3.0 metre diameter. The manometer used was inclined at 1 in 10, and its scale was such that it would read directly in Pascals if vertical. The
density in the fan drift is 1.1 kg/m 3. The incline manometer readings in Pa are shown below. What is the average air velocity and air quantity in the drift?

	1	2	3	4	5	6
Horizontal	2 875	3 360	3 920	3 899	3 405	2 900
Vertical	2 960	3 450	3 980	3 980	3 410	2 980

To convert the incline manometer reading to Pa:
Velocity Pressure (VP) = reading / 10 Pa
Velocity = (2 x VP / w) 0.5
For Position 1 horizontal: VP = 2875 / 10 = 287.5 Pa
Velocity = (2 x 287.5 / 1.1) 0.5 = 22.86 m/s
Similarly, all can be tabulated:

Position	*VP Horiz*	*VP Vert*	*Vel Horiz*	*Vel Vert*
1	*287.5*	*296.0*	*22.86*	*23.20*
2	*336.0*	*345.0*	*24.72*	*25.05*
3	*392.0*	*398.0*	*26.70*	*26.90*
4	*389.9*	*398.0*	*26.63*	*26.90*
5	*340.5*	*341.0*	*24.88*	*24.90*
6	*290.0*	*298.0*	*22.96*	*23.28*
Sum			*148.75*	*150.22*

✓✓✓

✓✓✓

V average = (148.75 + 150.22) / 12 = 24.91 m/s ✓
Drift area = 3.0 x 3.0 x 3.14 / 4 = 7.07 m2
Q = A x V = 7.07 x 24.91 = 176.1 m3/s ✓

[8]

5.2 The measured pressure of the fan operating on the above duct is 5 100 Pa. The fan efficiency is 78% and the fan is direct drive (drive efficiency is 100%). The motor efficiency is 95% and the power factor is 0.91. The motor is 3-phase, operating at 3 300 Volts. What is the motor input power and current?

Air power is 176.1 x 5.1 = 898.1 kW ✓
Fan input power is 898.1 / 0.78 = 1 151.4 kW ✓
Drive input power (motor output power) = 1 151.4 kW ✓
Motor input power = 1 151.4 / 0.95 = 1 212 kW ✓
Motor input power: W = E x I x pf x √3, therefore
I = W / (E x pf x √3) = 1 212 / (3.3 x 0.91 x 1.73) = 233 Amperes ✓

[5]

5.3 An airway handles 61.3 m^3/s of air and the pressure drop in the airway is 635 Pa. It is necessary to increase the flow in the airway to 85.0 m^3/s by installing a booster fan in the airway.
1) Determine the new pressure drop in the airway

2) Determine the duty of the booster fan
3) Determine the input shaft power to the booster fan if the efficiency is 73%

1. P=RQ2
   , but R is unchanged,

therefore P 2 = (85/61.3) 2 x 635 Pa = 1 221 Pa ✓

2. Fan duty is 85 m^3/s @ (1 221 – 635) = 586 Pa ✓

3. Air power is 85 x 0.586 = 49.8 kW.
Fan Shaft power = 49.8 / 0.73
= 68.2 kW ✓

[3]

5.4 The motor driving a belt-driven fan rotates at a 6-pole speed of 970 rpm. The motor pulley diameter is 350 mm. What diameter must the fan pulley be to ensure that the fan runs at 25 r/s?

970 rpm is equal to 16.167 r/s
The fan speed is greater than the motor speed; therefore the fan pulley must be smaller than the motor pulley. ✓
Fan pulley diameter = motor speed x motor pulley / fan speed
= 16.167 x 350/ 25
= 226.3 mm ✓

[2]

5.5 The speed of a fan operating at 20 m^3/s, 1 500 Pa, and 40 kW is increased by 10% - what is the new duty (quantity, pressure, and power)?

Q varies directly as fan speed
P varies directly as fan speed squared
Power varies directly as fan speed cubed

20 x 1.1 = 22 m^3/s ✓
1 500 x 1.1 2 = 1 815 Pa ✓
40 x 1.1 3 = 53.2 kW ✓

[3]

5.6 Explain the four general principles of a Mine Ventilation system

1. Fresh air enters via downcast shafts or other surface connections.
2. Air flows along the intake airways to working areas where most pollutants are added.
3. Contaminated air returns back through the system along return airways.
4. The return air passes back up to surface via upcast shafts or other surface-return connections.

[4]

[25]

TOTAL MARKS: [100]