Chamber of Mines of South Africa

EXAMINATION PAPER

SUBJECT: CHAMBER OF MINES OF SOUTH AFRICA – CERTIFICATE IN MINE ENVIRONMENTAL CONTROL PAPER 1 - FLOW DYNAMICS, AIRFLOW, FANS, MINE WATER **SUBJECT CODE: COMMEC1** **EXAMINATION DATE:** 3 OCTOBER 2022 **TIME**:	**EXAMINER:** Jacques Coetzee **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 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 Discuss the "effect of pulsating flow" when using a Vane Anemometer in an airstream with pulsating airflow:

Anemometers in pulsating airflow tend to overmeasure air speed (1) because of the insensitivity of the instrument to a sudden decrease in velocity (1). The effect is unimportant, however, provided the amplitude of the pulsation does not exceed 14% (1) of the mean observed value. When the pulsation exceeds this percentage, the errors rise rapidly and must be corrected according to the formula (1).

[4]

1.2 List and discuss 2 points to consider with Orifice plate construction.

1. Sharpness of the inlet edge of the orifice plate. (1)
   It is extremely important that the upstream edge of the orifice should be square and free from burrs or wire edges. (1)

2. Thickness of the bore of the orifice. (1)
   The thickness of the bore of an orifice should not be thicker than 0.02D. (1)

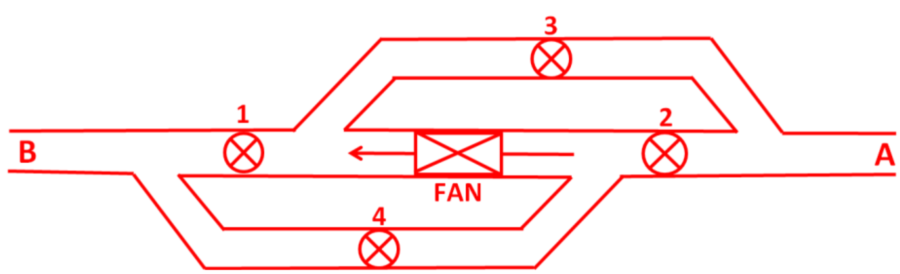
[4]

1.3 Discuss a Barometer survey.

This survey method involves the simultaneous measurement of barometric pressures and wetbulb and drybulb (1) temperatures at the two ends of the airway (1)

[2]

1.4 With the aid of a sketch, describe the principle of operation of a 4-gate system used in the ventilating of the development of a vertical shaft. Describe why such a system would be considered for use.



✓✓

The 4-gate system allows the direction of airflow in a ventilation column to be reversed without changing the direction of of air flow through the fan itself. ✓ If gates 1 & 2 are opened and gates 3 & 4 are closed, airflow direction will be from A to B.

If gates 3 & 4 are opened and gates 1 & 2 are closed, airflow direction will be from B to A. ✓

During the drilling, support and construction activities, fresh air is forced to the sinking shaft face. During the blast, the ventilation system is changed to exhaust – to ensure the rapid removal of the dust and gases liberated by blasting. ✓

[5]

[15]

Question 2

2.1 Calculate the energy recovered from a 70% efficient turbine when 100 L/s of water flows through a 10-inch diameter pipe, 2500m down a shaft.

Head loss = 1.5 m / 100m from pipe friction chart

= 1.5 x (2500/100)

= 37.5m head loss (2)

Therefore,
Energy recovered $= \dfrac{2500 - 37.5}{1000} \times 9.79 \times 100 \times 0.7$

= 1688 kW (2)

[4]

2.2 During prospect drilling, an Aquifer was discovered 4,2km away from the mine. The Aquifer is situated at an elevation of 95m below the mine. Water for the mine is required at a flow of 60L/s. Use the water flow chart and determine:

2.2.1 The economic pipe size to be used.

2.2.2 The head loss in meters required for the stipulated flow rate, allowing 10% extra for fitting losses.

2.2.3 Use the above answer to calculate the input power of a pump motor required to pump the water to the min dam. Assume the pump and motor efficiencies are 75% and 95% respectively.

2.2.4 The total pump head in kPa.

2.2.5 Comment briefly on the importance of the correct design for the inlet pipe section at the discharge side of water dams and the effect it can have on dam capacity.

(Use the attached Pipe Friction Loss Chart for assistance)

P109 Selected questions and answers

2.2.1 The economic velocity in water pipes is 2m/s; therefore the required pipe size is 203mm (from the pipe friction diagram) for a flow rate of 60 l/s. (1)

2.2.2 Assuming 203mm diameter pipe:

From the pipe friction chart: Head loss due to friction is 1,8m/100m (1)

Adding 10% for fitting losses = 1.1 x 1.8/100

= 1.98m/100m (1)

For the total distance of 4.2km, the total losses for friction can be calculated:

$$H_f = 1.98 \times \frac{4200}{100}$$

= 83.16m (1)

The vertical height difference is given as 95m (static head): The total head can now be determined:

$$H_t = h_s + h_f$$

= 95 + 83.16

= 178.16m total head (1)

2.2.3 The pump input power can be calculated as follows:

$$\text{Pump input power} = \frac{Q \times h_t \times g \times \text{density of water}}{1000 \times \text{Efficiency}_{\text{pump}} \times \text{efficiency}_{\text{pump motor}}}$$

= 146.9kW (1)

2.2.4 The pump total head must now be expressed in kPa:

$$P = \frac{w \times g \times h_t}{1000}$$

$$= \frac{1000 \times 9.79 \times 178.16}{1000}$$

= 1744 kPa (1)

2.2.5 When designing dams, the outlet pipe is of great importance. If, for example, a straight 100mm pipe is used, then one may find that a head of water of +/- 1.3m above the pipe is required to create a flow. (1) This may create a false impression that water is available (dam may be 50% full), but nothing is flowing. On the other hand, the height or head can be reduced to 0.25m using the same pipe with a 30^0 tapered inlet having a diameter of 153mm. The phenomena are due to the adverse effect of the vena contracta. (1) The velocity at the inlet is very important as the head is calculated using the following formula:

$$H = \frac{V^2}{2 \times g}$$

For maximum capacity, dams should therefore be designed with a tapered inlet to reduce the inlet velocity and the effect of the vena contracta. (1) A tapered goose neck design is even more practical for maximum surge and handling of mud. The pipe must obviously also be as close to the floor as possible allowing for taper, etc.

[10]

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

2500 ✓

[1]

2.4 List 5 way to control fouling in mine water.

a) Water clarification ✓

b) System design ✓

c) Limiting concentrations ✓

d) Slipstream filters ✓

e) Air rumbling and back flushing ✓

f) Chemical dispersants ✓

[Any five]

[5]

[20]

Question 3

3.1 During a Barometric pressure survey of the intake portion of a divided shaft, the following observation were made:

Location	8:00 AM	9:15 AM	10:30 AM
Surface Barometric Pressure (kPa)	82,120		81,850
Surface air density (kg/m^3)	1,0102		1,0072
Shaft bottom barometric pressure (kPa)		100,021	
Shaft bottom air density (kg/m^3)		1,1720	
Downcast to upcast door pressure at shaft bottom (u/c negative)		1,12	

The shaft is 2220 m deep.

3.1.1Calculate the pressure loss in the downcast side of the shaft.

3.1.2If the surface fan operates at 4.52 kPa, and if the pressure across the doors between the down cast and upcast at the bottom of the shaft is 3.01 kPa, calculate an approximate value for the pressure in the upcast side of the shaft.

3.1.3What additional information is necessary to calculate a more accurate value for the pressure loss in the upcast side of the shaft.

3.1.4The doors between the upcast and downcast at the shaft bottom are 2,2m x 2,2m. calculate the force acting on one door when the other door is open.

3.1.1To calculate the pressure loss in the downcast side of the shaft it is necessary to relate all the available data to one common time, as there was a change in BP and density during the survey period.

i) Change in BP = 82,120 – 81,850 in 150 minutes

= 0,27 kPa/150 minutes ✓

Therefore at 09:15 the BP would have been:

$$= 82,120 - \frac{0,27 \times 75}{100}$$

= 82,120 – 0.203

= 81,917 kPa ✓

ii) Change in density = 1,0102 – 1,0072 kg/m^3 in 150 minutes

= 0,003 kg/m^3/150 minutes ✓

Therefore at 09:15 the density would be:

$$= 1{,}0102 - \frac{0.003 \times 75}{100}$$

= 1,0102 – 0,0023

= 1,0079 kg/m^3 ✓

The theoretical pressure increase = $(9{,}79 \times h \times w_m)$ Pa

= $9{,}79 \times 2220 \times w_m$

The average density at 09:15:

$$W_{m\ 09:15} = \frac{(1{,}0079 + 1{,}1720)}{2}$$

= 1,0900 kg/m^3 ✓

Therefore theoretical pressure increase = 9,79 x 2220 x 1,0900

= 23,690 kPa ✓

Actual pressure increase = 100,021 – 81,917

= 18,104 kPa ✓

Therefore p_{loss} in downcast portion of shaft = 23,690 – 18,104

= 5,586 kPa @ 1,0900 kg/m^3 ✓

3.1.2Upcast fan pressure is 4,52. This pressure indicates the total pressure loss across the system.

The door pressure of 3,01 kPa indicates the pressure loss across the system excluding the shaft.

Thus total shaft pressure losses = 4,52 – 3,01

= 1,51 kPa ✓

3.1.3Additional information required for the calculation of the pressure loss in the upcast shaft would be:

i) Calculation of densities at top and bottom of shaft. ✓
Temperatures are therefore needed. ✓

ii) It might be advisable to take additional readings in the shaft for more accurate results. ✓This applies to both the upcast and downcast shafts. ✓

3.1.4The unit of force is the Newton (N)

The pressure on the door is 1,12 Pa or N/m^2

The area of the door is $4{,}84m^2$ ✓

Force	=	P x A
	=	1120 x 4,84
	=	5421 N
	=5,421 kN	✓

[15]

3.1.5 Explain what is meant by NVP assisting.

a) When NVP assists a fan, it tends to move air in the same direction as the fan. ✓

b) The NVP can be said to lower the system resistance curve against which the fan operates. ✓

c) This means the fan will handle more air at a lower pressure. ✓

[3]

3.1.6What are the advantages of having the main fans situated underground in the return airways?

a) No heat is added to the ventilation circuit. ✓

b) Can be used where the ventilation shaft is temporary equipped with rope guides. ✓

[2]

[20]

Question 4

4.1 A compressed air fan draws 0,12 kg/s of compressed air from the mains through 20m of 25mm diameter plastic hose. The air temperature is 30^0C with an absolute pressure of 700kPa at the beginning of the hose.

4.1.1what is the pressure loss through the pipe? (Show all assumptions)

4.1.2What is the gauge pressure at the fan, assuming a barometric pressure of 100kPa?

4.1.1The compressed air density must first be calculated, with the mass flow being low through hoses, other pressure losses can be expected. Hoses with a diameter of 25mm and 32mm are in common use and resistance factors are normally 2 000 000 m^{-5} and 500 000 m^{-5}. The pressure loss can be calculated:

$$W = \frac{P \times 10^3}{RT} \quad ✓$$

$$= \frac{(700) \times 10^3}{287 \times (273 + 30)}$$

$$= 8{,}0 \text{ kg/m}^3 \quad ✓$$

$$\text{Delta P} = \frac{R_f \times m^2\ L \times 10^{-3}}{w} \quad ✓$$

$$= \frac{2\ 000\ 000 \times (0.12)^2 \times 20 \times 10^{-3}}{8}$$

$$= 72 \text{ kPa} \quad ✓$$

4.1.2 The gauge pressure at the fan = (700 – 100) – 72

$$= 528 \text{ kPa} \quad ✓$$

[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]

4.3 What is the typical L.C. figures for a 760mm diameter duct?

Excellent	0,38	✓
Good	0,76	✓
Fair	1,14	✓
Poor	1,52	✓

[4]

4.4 During 2022 a new Guideline for a MCOP for Thermal stress was issued to the mining industry. Part of the new MCOP gives a guideline for Heat stress classification and monitoring frequency. List the Classification, Temperature Ranges (WRT Wetbulb Temperature) and the monitoring frequencies.

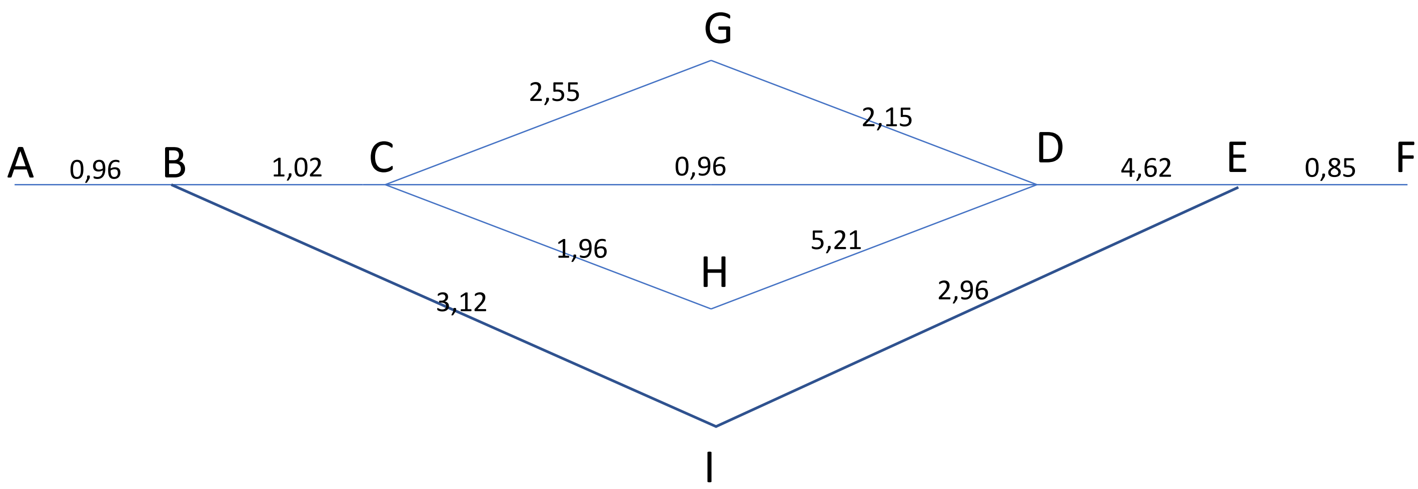
CLASSIFI-CATION	**TEMPERATURE RANGE** (FOR CATEGORISATION)	**MONITORING FREQUENCY**
A ✓	**WB ≥ 32.5°C** ✓	▪ Continuously monitor until the environmental conditions have improved to acceptable limit(s). ✓
B ✓	**WB ≥ 27.5°C - < 32.5°C** ✓	▪ Monitoring must be conducted within every 30 days. ✓
C ✓	**WB ≥ 25.0°C - < 27.5°C** ✓	▪ Monitoring must be conducted within every 45 days. ✓
D ✓	**WB < 25.0°C** ✓	▪ As determined by the risk assessment ✓

(1/2 point per fact)
[6]

[20]

Question 5

5.1 The network below shows a series of airways with their resistances values:



5.1.1 If the pressure difference between A and F is 1500 Pa, calculate the Quantity of air flowing in each airway.

5.1.2 If the pressure difference is reduced to 500 Pa, what will be the total Quantity through the circuit.

5.1.3 What is the overall resistance of the network.

Due to the complexity of the network, to calculate the quantity of each airway, the overall resistance of the network first needs to be calculated:

5.1.3 $R_{CGD} = R_1 + R_2$

$= 2{,}55 + 2{,}15$

$= 4{,}7\ Ns^2/m^8$ ✓

$R_{CHD} = R_1 + R_2$

$= 1{,}96 + 5{,}21$

$= 7{,}17\ Ns^2/m^8$ ✓

$$\frac{1}{\sqrt{R_{CD}}} = \frac{1}{\sqrt{R_1}} + \frac{1}{\sqrt{R_2}}$$

$$= \frac{1}{\sqrt{4{,}7}} + \frac{1}{\sqrt{0{,}96}} + \frac{1}{\sqrt{7{,}17}}$$

$$= 0{,}461 + 1{,}021 + 0{,}373$$

$R_{CD} = 0{,}291\ Ns^2/m^8$ ✓

$R_{BIE} = 3{,}12 + 2{,}96$

$= 6{,}08\ Ns^2/m^8$ ✓

$R_{BCDE} = 1{,}02 + 0{,}291 + 4{,}62$

$= 5{,}931\ Ns^2/m^8$ ✓

$$\frac{1}{\sqrt{R_{BE}}} = \frac{1}{\sqrt{R_1}} + \frac{1}{\sqrt{R_2}}$$

$$= \frac{1}{\sqrt{6{,}08}} + \frac{1}{\sqrt{5{,}931}}$$

$= 0{,}406 + 0{,}411$

$R_{BE} = 1{,}498\ Ns^2/m^8$ ✓

$R_t = R_1 + R_2$

$= 0{,}96 + 1{,}498 + 0{,}85$

$= 3{,}308\ Ns^2/m^8$ ✓

Therefore, the total Quantity can be determined

$P = RQ^2$

$Q = \sqrt{(P/R)}$

$= \sqrt{(1500/3{,}308)}$

$= 21.3\ m^3/s$ ✓

5.1.1Now the Quantities can be determined

Q_{AB} ✓= Q_{EF} ✓= $Q_t = 21.3\ m^3/s$

$P\ loss_{BE} = RQ^2$

$= 1{,}498 \times 21{,}3^2$

$= 680\ Pa$

$Q_{BIE} = \sqrt{(680/6{,}08)}$

$= 10,58\ m^3/s$ ✓

$Q_{BCDE} = Q_t - Q_{BIE}$ $= Q_{BC} = Q_{DE}$ ✓

$= 21,3 - 10,58$

$= 10,72\ m^3/s$ ✓

$P\ loss_{CD} = RQ^2$

$= 0,291 \times 10,72^2$

$= 33,44\ Pa$

$Q_{CGD} = \sqrt{(33,4/4,7)}$

$= 2,67\ m^3/s$ ✓

$Q_{CD} = \sqrt{(33,4/0,96)}$

$= 5,90\ m^3/s$ ✓

$Q_{CHD} = \sqrt{(33,4/7,17)}$

$= 2,16\ m^3/s$ ✓

5.1.2 If P=500 Pa

$Q = \sqrt{P/R}$

$= \sqrt{(500/3,308)}$

$= 12,29\ m^3/s$ ✓

[15]

5.2 Define Kinematic Viscosity

Kinematic Viscosity is defined as the ratio of dynamic viscosity✓ to density✓. The unit is square meter per second ✓ (m^2/s)

[3]

5.2 What is the Friction factor for the following:

5.3.1 Empty concrete lined circular shaft
5.3.2 Glass fibre ducts
5.3.3 Timber lined shaft

5.3.1 Empty concrete lined circular shaft 0.0037 ✓

5.3.2 Glass fibre ducts 0.0025 ✓
5.3.3 Timber lined shaft 0.018 ✓

[3]

5.4 List the disadvantages of using an orifice plate as an airflow measuring instrument

i) Needs involved calculation work ✓
ii) Increases resistance of system ✓

[2]

5.5 What is meant by Dynamic similarity?

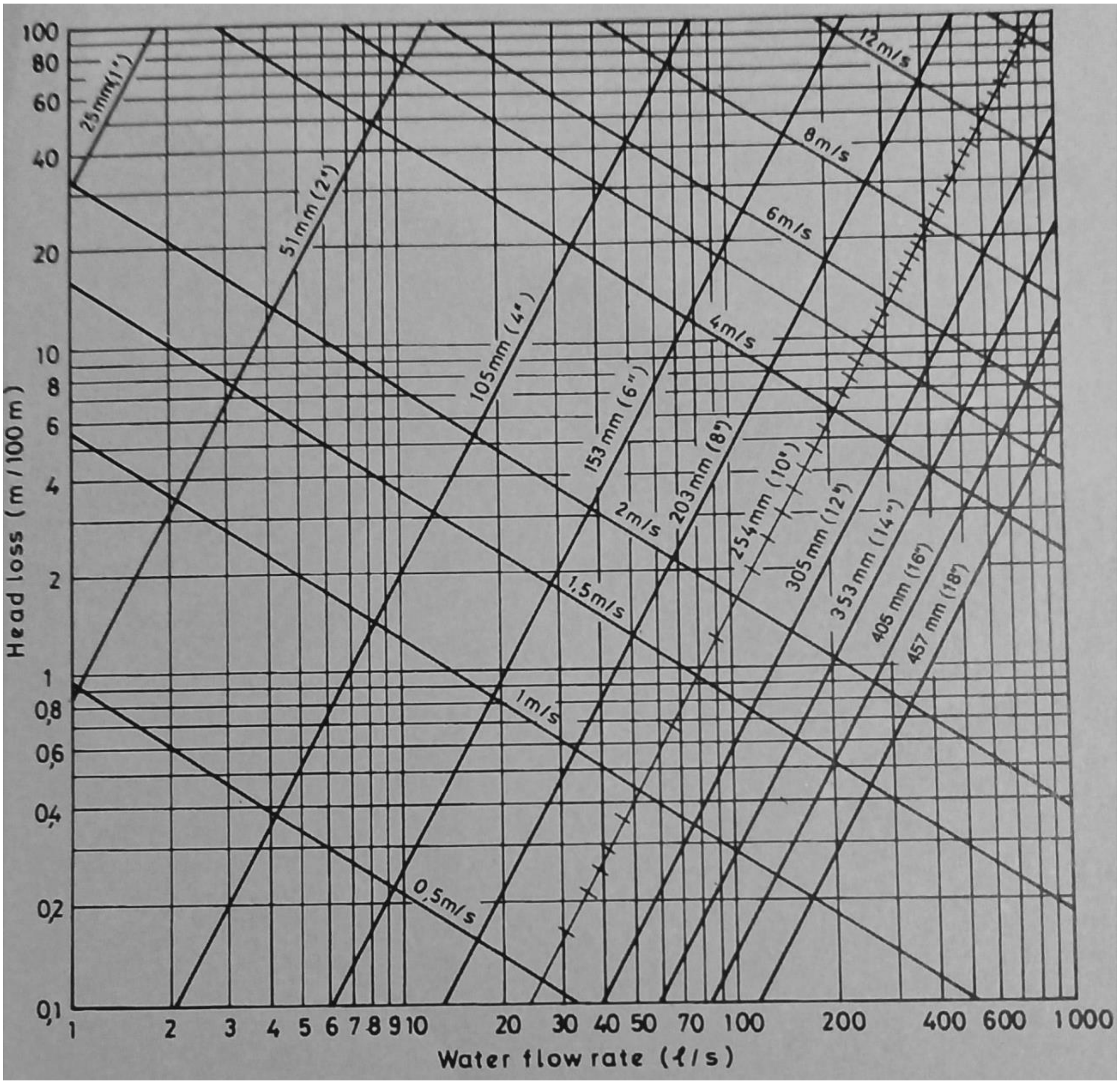
The flow patterns in the scale model and in the in-situ shaft must be similar✓. If the Reynolds numbers are the same, it implies the dynamic similarity had been obtained and that the flow patterns in the two systems are the same. ✓

[2]

[25]

TOTAL MARKS: [100]

Annexure A



Head loss (m / 100 m)
Water flow rate (ℓ/s)
100
80
60
40
20
10
8
6
4
2
1
0,8
0,6
0,4
0,2
0,1
1
2
3
4
5
6
7
8
9
10
20
30
40
50
70
100
200
400
600
1000
25mm (1")
51mm (2")
105mm (4")
153mm (6")
203mm (8")
254mm (10")
305mm (12")
353mm (14")
405mm (16")
457mm (18")
0,5m/s
1m/s
1,5m/s
2m/s
4m/s
6m/s
8m/s
12m/s