Indian Institute of Technology Kharagpur

Department of Chemical Engineering

TIME: 90 MINS

CLASS TEST-3

FULL MARKS - 40

Industrial Pollution Control (CH 62007)

Answer all the questions

(Open Book, Open Note examination. Assume suitable data whenever necessary with justification)

Write your name and Roll No on front page of answer script.

Upload neat and clean hand-written answer script only in A-4 size paper by using MS Team

1. A horizontal parallel plate ESP having dimension as 3m high, 4m depth with spacing between the plates as 25 cm. Flow rate of gas is 60000 m^3/hr. Inlet and outlet loadings are 27 gm/ m^3 and 40 mg/ m^3. Determine

(i)Efficiency of collection

(ii)Particle migration velocity

(iii)Efficiency when flow rate is changed to four times the original flow rate

(iv)Change in efficiency when spacing is increased 5 cm keeping all other parameters constant

[10]

2. Dust emitted from a cement plant is controlled by a conventional cyclone with a cyclone diameter of 90 cm. For air with a flow rate of 180 m^3/min at T = 375 K and 1 atm, containing particles with a density of 2.4 gm/cc and a size distribution as given below, calculate the overall collection efficiency and cut size particle diameter . The gas viscosity equal to 0.017 CP. The number of complete turns by the entering air within the cyclone is 5.

Particle Size Range, μm	Mass Percent in Size Range
0 – 2	1.0
2 – 4	9.0
4 – 6	10.0
6 – 10	30.0
10 – 18	30.0
18 – 30	14.0
30 – 50	5.0
50 – 100	1.0

[10]

3. A bag filter is operating at constant rate on an optimum cycle. The filtration equation is

$$V_G^2 = 2.2 \times 10^6 \times t \times P^{0.62}$$

Where V_G =volume filtered, m^3; t= time, min and P= pressure ,cm of water

The filtering time is 30 min with a maximum allowable pressure of 100 mm of water. Calculate

i) Maximum overall capacity

ii) It is necessary to increase the capacity of the filter. It has been suggested that two additional unit identical to the present one be installed. All units would work from the same compressor, which have ample capacity, and filtration would be carried out to the same maximum pressure as at present. The total time required to shake and clean three units is estimated as 20 min. What is the maximum percentage increase in the overall capacity that could be attained by adopting this suggestion?

[10]

4. A H_2SO_4 acid plant emitting SO_2 at 800 µg/m^3 in a flue gas at 450 K and 756 mm of Hg with a flow rate of 80000 m^3/hr. This is to be scrubbed with water as a solvent in an absorber. It is required to be maintained below 80 µg/m^3. Design a wet scrubber of your choice to meet the above requirements.

[10]

$800(1-x/1) = 80$

$\Rightarrow x = 90\%$

80000 m^3/hr

$Y_0 = 10$ ppm

$Y_e = 0.1$ ppm

Indian Institute of Technology Kharagpur

Department/Center/School: Chemical Engineering

Mid-Autumn Semester Examination 2022

Date of Examination: 23/09/2022 Session: (FN)
Duration: 2 Hrs Full Marks:30

Subject No. : CH 62007 Subject: Industrial Pollution Control

Answer all the questions.. (Assume suitable data whenever necessary with justification)

1. a) Explain the sampling technique for measurement of particulate matters ($PM_{2.5}$) and NOx in the ambient air.

   b) Derive lapse rate expression under adiabatic conditions.

   c) What are the types of inversion? How inversion affect the dispersion of air pollutants.

   d) Explain how Gaussian Dispersion Model can be used to calculate pollutant concentration at any point.

   e) A multi-tray settling chamber having 8 trays including the bottom surface, handles 25,000 M^3/hr of contaminated dust laden gas at 75 ^oC and 0. 15 kg/cm^2 gauge pressure. The particle size distribution is given in the following table The trays are spaced 30 cm apart and the chamber is to be 1.2 m wide and 3.5 m long. The viscosity of the gas is 0.0184 cp.

   Calculate

   I) $D_{P,Min}$ for particle of density 2350 kg/m^3.

   II) Efficiency of the settling chamber for 35 μ m particles.

   III) Overall collection efficiency

Size range(μm)	Wt. (gm)
0-10	5
10-20	10
20-40	8
40-60	9
60-90	22
90-125	18
125-150	8
>150	10

[2 + 2 + 1 + 2 + 4 = 11]

2. A 1200 MW coal-fired power plant burns 480 tones of coal per hour and an ESP is used to collect the fly-ash from power plant with an working efficiency of 99.9% which is located in an industrial cluster of Korba, C.G.. The coal has a sulfur content 0.4 % and total amount of fly ash generated is 5 kg /ton of coal burnt . The physical stack height is 270 m and inside diameter of 3.2 m with a stack gas velocity of 6 m/s. The stack gas leaves at 140 ^oC. The ambient temperature 30 ^oC. and barometric pressure of 890 milibars. A neutral plume is found at the exit of the chimney. The wind velocity measured at 5 meter height from the ground and the average wind velocity recorded as 3 m/s . The values of exponent p for various stability classes is given below.

Stability Ciass	A	B	C	D	E	F
Rural	0.07	0.08	0.10	0.15	0.35	0.55
Urban	0.15	0.17	0.20	0.25	0.30	0.35

Calculate:

i) Effective stack height

ii) Draw SO_2 concentration profile upto a distance of 15 km from the stack.

iii) The maximum concentration of fly-ash and SO_2 and how far is this form from the plant will occur. Is it acceptable as per NAAQS?

iv) Draw Fly-ash concentration profile upto a distance of 20 km from the stack

[1+3+4+3= 11]

Q1

3) a) A waste water contains 100 of mg/l glucose, 50 of mg/l methyl alcohol and 80 mg/l isophorone ($C_9H_{14}O$). Isophorene is a non-degradable compound. Estimate the COD, TOC and the BOD_5 assuming the k10 for the mixed waste water is 0.25/d.

b)The survey of the discharge from a pharmaceutical plant showed the following data:

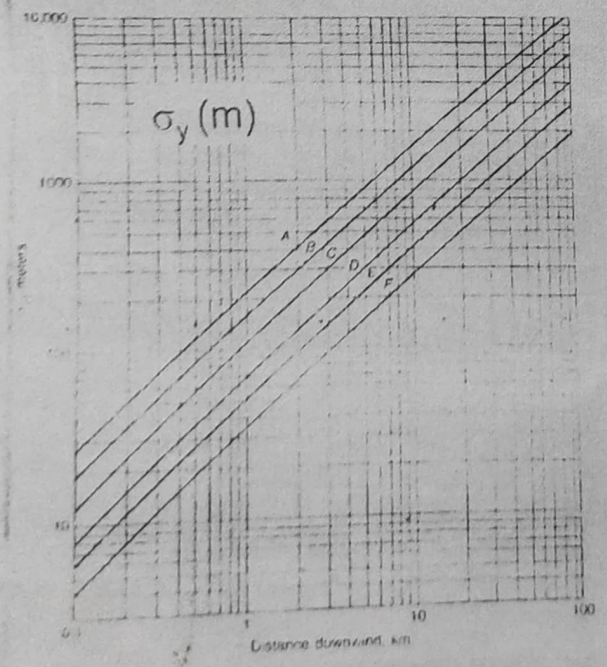
Time	Flow (gallons per hour)	COD (mg/l)
7.00AM	1025	80
11AM	720	95
2PM	1620	39
6PM	720	138
10PM	600	146
2AM	550	55

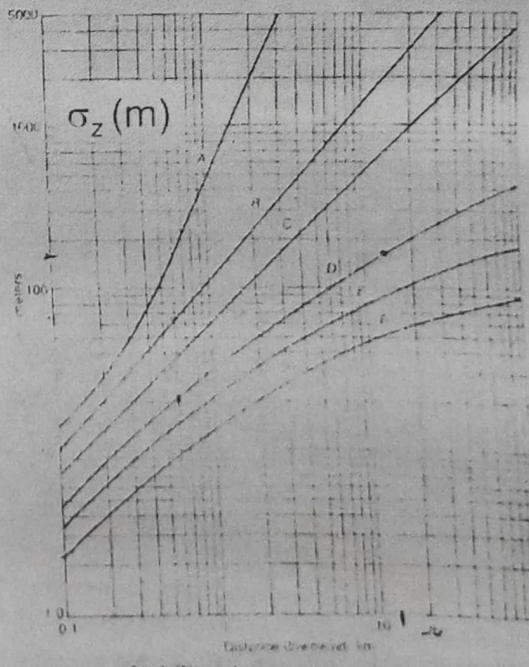
Compute the volume of equalization tank on constant discharge rate. Discharge rate can be assumed as mean inflow rate.

c) An effluent from paper mill shows below characteristics:
suspended solids: 1000 mg/l, Oil/grease content: 10 mg/L, pH: 7-8, Temperature: 29 °C and Heavy metal content: 0.001 mg/L
State pre-treatments methods needs to be used before introducing this effluent water to secondary treatment process.

[4 + 2 + 2= 8]

Horizontal and vertical dispersion coefficients





Stability class	Definition
A	very unstable
B	unstable
E	slightly stable

INDIAN INSTITUTE OF TECHNOLOGY KHARAGPUR

Autumn Mid-Spring Semester Examination- 2023

Subject : Industrial Pollution Control — *Subject No.*: CH62007

Date: 21.09.2023 (AN) — *Time*: 2 Hrs — *Full Marks*: 60

Instructions: Answer **All Questions**. Assume any missing data suitably.

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1. a) How Environmental Impact Assessment is carried out in an urban area?

   b) Give a comprehensive list of the major sources and nature of various air pollutants from any five chemical and allied process industries of your choice.

   c) Explain the sampling and monitoring procedure for PM2.5, PM10 and SO_2 in ambient air.

   d) A NaOH spray in air at 30 ^oC at 1.0 atm. pressure is to be collected in a gravity settler. The unit is 2 m high,4 m wide, and 6 m long. The volumetric flow rate of the gas is 6000 m^3/hr. The Sp. Gv. of the mist is 1.30 and μ = 0,018 CP .
   Calculate

   i) The smallest spay that can be entirely collected.
   ii) If flow rate is reduced by 1/3rd of the flow rate what should be the $D_{P, Min.}$

   [4 + 4 + 6 + 6 = 20]

2. a) Derive lapse rate expression under adiabatic conditions. Explain how Gaussian Dispersion Model can be used to calculate pollutant concentration at any point.

   b) Discuss the operating principle of a Multi-Channel-Gravity Settling Chamber. Write down the design equation of such settler.

   c) A coal-burning power plant burns 40,000 tones of coal per day and an ESP is used to collect the fly-ash from power plant with an working efficiency of 99.5%. The coal has a sulfur content 0.45 % and total amount of fly ash generated is 4 kg /ton of coal burnt . The physical stack height is 150 m and inside diameter of 1.5 m. The stack gas leaves at 130 ^oC at a velocity of 4 m/s. The ambient temperature 27 ^oC. and barometric pressure of 930 milibars. A moderately unstable plume is found at the exit of the chimney. The wind velocity measured at 4 meter height from the ground and the average wind velocity recorded as 2.5 m/s . The values of exponent p for various stability classes is given below.

Stability Class	A	B	C	D	E	F
Rural	0.07	0.08	0.10	0.15	0.35	0.55
Urban	0.15	0.17	0.20	0.25	0.30	0.35

Calculate:

i. Effective stack height
ii. The maximum concentration of SO_2 and how far is this form the plant. Does this plant by itself causes concentrations in excess of the annual ambient air quality standards?
iii. The concentration of SO_2 at a distance of 3.0 km with a crosswind distance of 80 m on either side of the plume central line.
iv. The maximum concentration of fly-ash and how far is this form from the plant.
v. Fly-ash concentration profile upto a distance of 12 km from the stack.

[5+3+12 = 20]

3. a) Discuss the Scale-up procedure of cyclone design with design equations. How pressure drop of a cyclone can be calculated ?

b) What are the various types of inversion? How inversion influence the dispersion of air pollutants?

c) A conventional cyclone of diameter of 1200 mm is used to treat the flue gas containing particulate of 12.0 gm/m^3 at 125 ^oC and 1.0 atm. pressure. The Inlet gas velocity is 18 m/s and number of turn in the cyclone is 5.0. Data: Density of particle and gas are 2500 kg/m^3 and 1.29 kg/m^3 respectively. Viscosity of gas= 0.0117 CP

Calculate :

I) Cut Size particle diameter.
II) DP_{100}
III) Overall collection efficiency of the cyclone.

The particle size distribution .

Particle Size (μm)	>70	70-40	40-30	30-20	20-15	15-10	10-5	< 5
% by wt.	15.0	14.0	9.0	13.0	10.0	20.0	8.0	11.0

[5 + 5 +10= 20]

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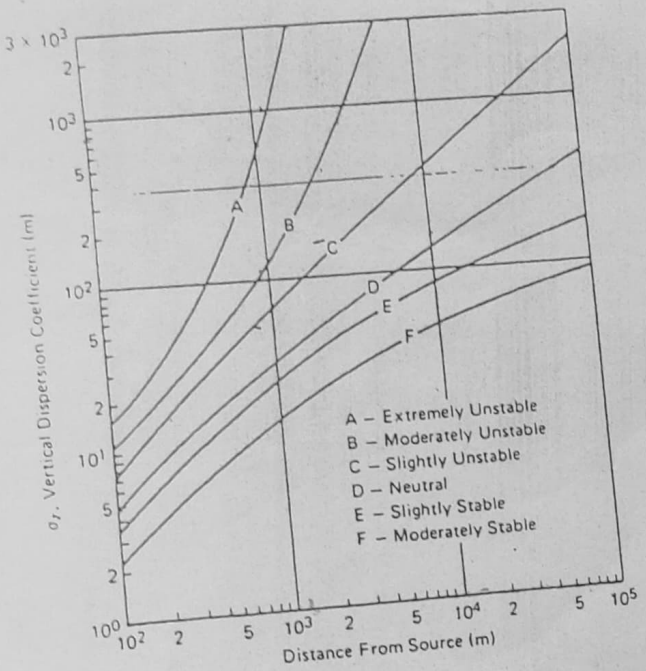
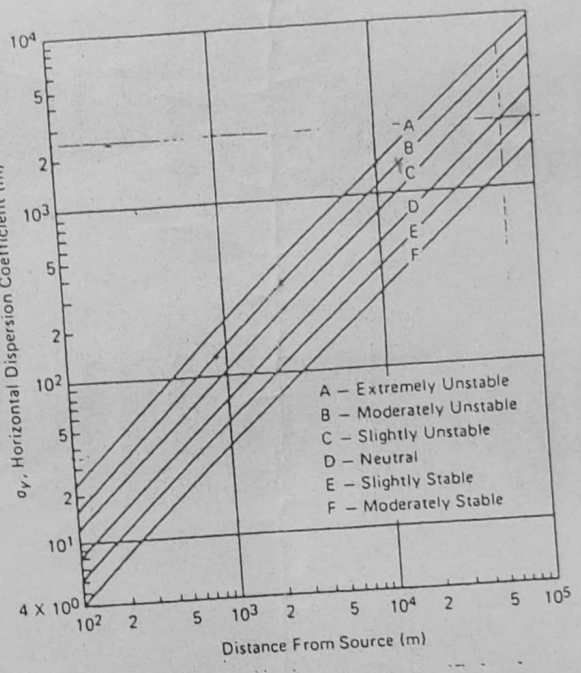
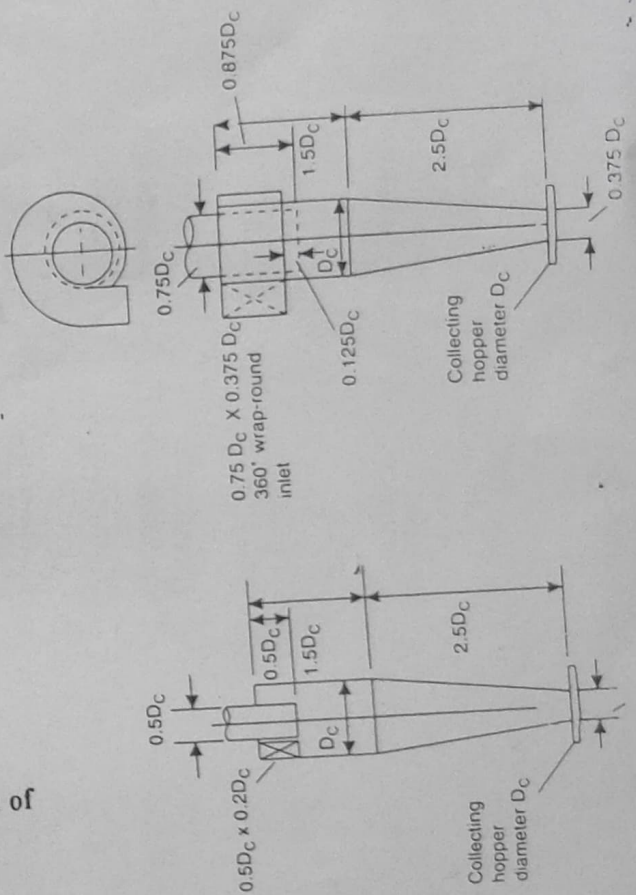


Vertical dispersion coefficient as a function of Down-wind distance from the source



Horizontal dispersion coefficient as a function of Down-wind distance from the source



Indian Institute of Technology Kharagpur

Department/Center/School: Chemical Engineering

End-Autumn Semester Examination 2022

Session: (AN)
Full Marks:50

Date of Examination: 21/11/2022
Duration: 3 Hrs

Subject No. : CH 62007 Subject: Industrial Pollution Control

Answer all the questions. of both Part A and Part B. (Assume suitable data whenever necessary with justification)

PART-A

1. a) Give a comprehensive analysis of selecting an appropriate air pollution control device keeping in all engineering design considerations in mind.

b) How cleaning and maintenance of Bag House is carried out? Explain how chocked and ruptured bag filters are detected?

[3+2= 05]

2. A bag filter is operating at constant rate on an optimum cycle. The filtration equation is

$$V_G^2 = 2.45 \times 10^6 \times t \times P^{0.65}$$

where V_G =volume filtered , m^3: t= time, min and P= pressure ,cm of water
The filtering time is 45 min with a maximum allowable pressure of 10.0 cm of water.
Calculate
i) Maximum overall capacity

ii) It is necessary to increase the capacity of the bag filter. It has been suggested that one additional unit identical to the present one to be installed. Both units would work from the same compressor which have ample capacity, and filtration would be carried out to the same maximum pressure as at present. The total time required to shake and clean two units is estimated to 5.0 min. What is the maximum percentage increase in the overall capacity that could be attained by adopting this suggestion?

[08]

3. A 50000 TPD Sponge Iron Plant has installed bag filter as pollution control device without providing sufficient suction in Product Separation Unit containing 144 bags of 30 cm ID and 3 m length. The capacity of ID Fan provided is 40,000 m^3/hr with 05 hoods of 450 mm/600 mm/ 800 mm in size. The Pressure drop across the bag filter is 70 mm of water. Hoods are connected with main duct of ID 50 cm and branch duct of ID 30 Cm and length 30 m and 12 m respectively for each hood. The velocity of the gas in main duct is 3.5 m/s . Prepare a ducting layout of the plant and calculate air to cloth ratio. State whether the capacity of ID fan is adequate or not?

[05]

4. A horizontal parallel plate ESP having dimension as 3 m high,5 m depth with spacing between the plates as 20 cm. Flow rate of gas is 9000 m^3/hr. Inlet and outlet loadings are 15 gm/ m^3 and 1gm/ m^3. Determine
   i. Efficiency of collection
   ii. Particle migration velocity
   iii. Efficiency when flow rate is changed to 30000 m^3/hr
   iv. Change in efficiency when spacing is decreased by 5 cm keeping all other parameters constant

[06]

5. What are the various wet scrubber used in industry? It is essential to remove H_2S from a flue gas from ore-smelting plant at 150000 m^3/hr. Give a detailed step-wise design procedure of a Wet Scrubber of your choice to remove H_2S from a flue gas with design equations. **[05]**

$$1 - \exp\left[-3\,\frac{Q_e}{Q_f}\,\frac{Z_e}{Z_f}\,\frac{(S_p - S_f)}{S_f}\right]$$

6. Cement dust emitted from a cement plant is controlled by a conventional cyclone with a cyclone diameter of 60 cm. For air with a flow rate of 10000 m^3/hr at T = 330 K and 1 atm, containing particles with a density of 2.3 gm/cc and a size distribution as given below. The gas viscosity equal to 0.09 CP. The number of complete turns by the entering air within the cyclone is 5. Calculate the overall collection efficiency.

Particle Size Range, μm	Mass Percent in Size Range
0 – 10	2.0
10 – 20	8.0
20 – 30	12.0
30 – 40	28.0
40 – 60	25.0
60 – 80	16.0
80 – 120	7.0
> 100	Rest

[06]

PART- B

7. Derive an expression for estimating the residence time in an activate sludge process with recycle stream. A completly mixed activated sludge system with recycle is used to treat wastewater contains 100 g/m3 glucose and 50 g/m3 methanol. Flow rate is 1200 m^3/day. Biomass concentration in the aeration tank is 2600 g/m3. If SRT is 5 days, what will be the bCOD concentration in the effluent? Also, estimate the residence time? **[06]**

8. A laboratory settling data of a sludge in waste water is given below table. Estimate the volume of settling tank requited to remove suspended solids in a wastewater steams having a solids concentration of 2000 mg/L. Solids concentration is desired to be 7810 mg/L in the sludge. Waste water flowrate is 2000m3/day.

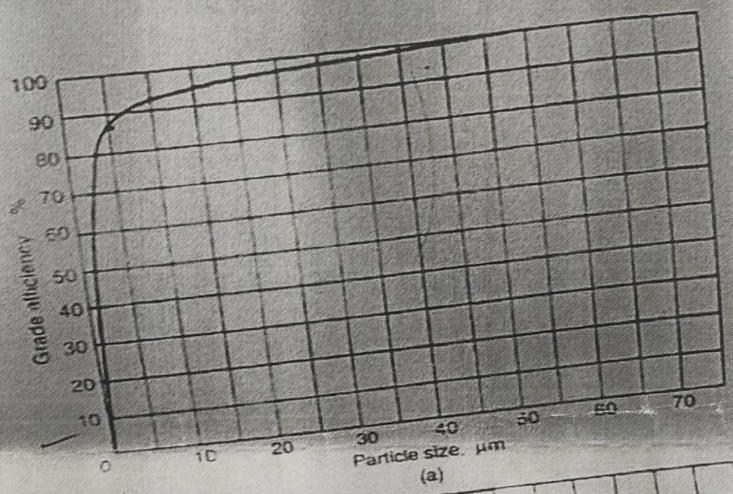
Time(min)	0	0.5	1	2	3	4	8	15	20
Height in the measuring cylinder (cm)	25	23	21	18	15	13	10	9	8.8

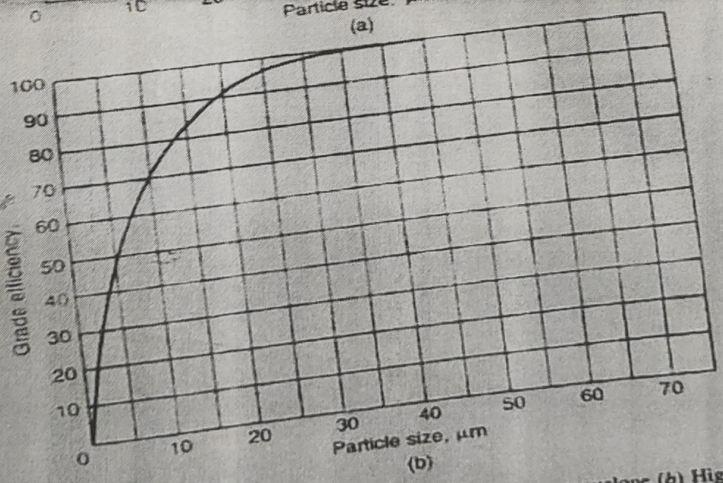
[02]

9. Short answer questions (each carry 1 mark)

I. Why flue gases are used to neutralize alkaline waste water?
II. State two basic agents used in neutralizing strong acidic waste water. KOH NH_4CO_3
III. State the uses of flotation in waste water treatment.
IV. What will be the common method to prepare asymmetric polymeric membrane? non-woven membrane
V. What is the separation mechanism of an ultra-filtration and micro-filtration methods? → size elution
VI. A waste water from a mining site contains majorly Fe and Mg ions. what of type of membrane filtration do you recommend for this? → nano & RO
VII. State two process represents fixed growth biological treatment process.
↳ membrane bio reactor
↳ moving bed biofilm reactor

[1x7 = 07]





5. Performance curves, standard conditions (*a*) High efficiency cyclone (*b*) High gas rate

Cyclone Efficiency Chart

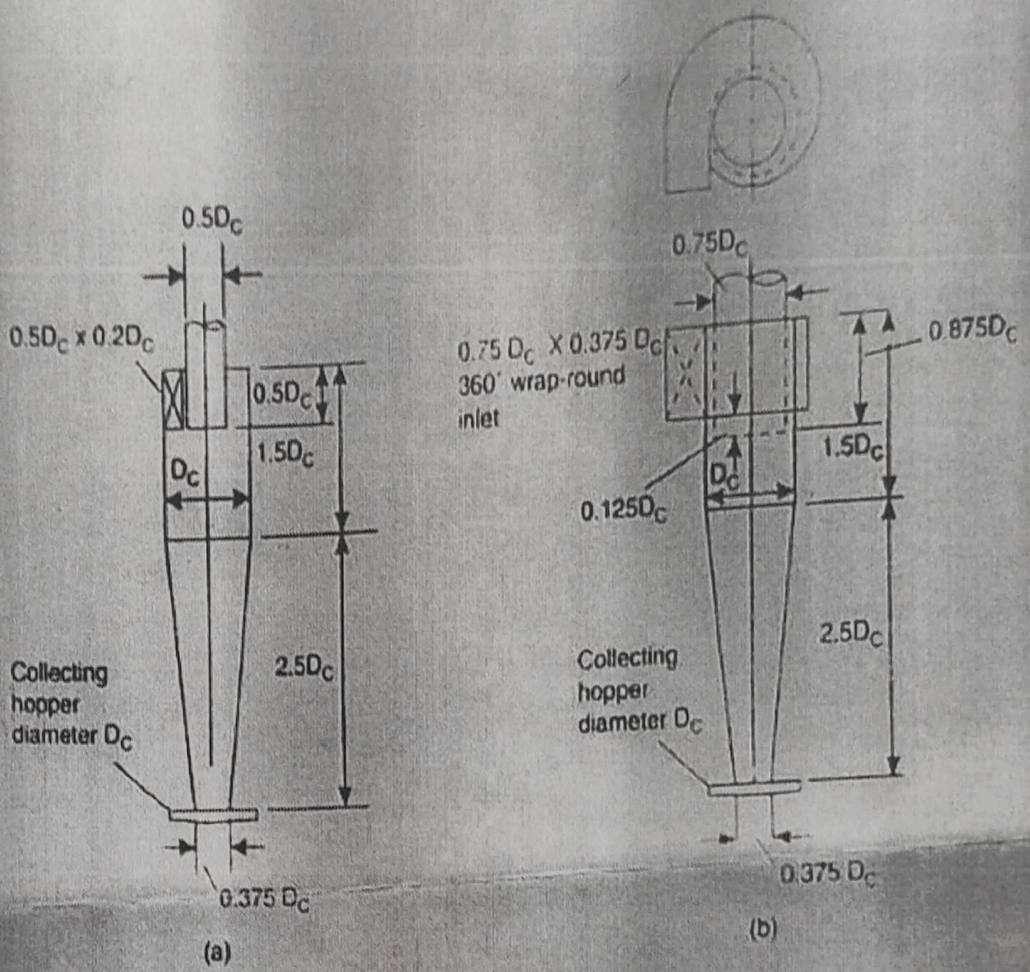


Figure 10.44. Standard cyclone dimension (*a*) High efficiency cyclone (*b*) High gas rate cyclone

Standard Cyclone Dimensions

INDIAN INSTITUTE OF TECHNOLOGY KHARAGPUR
End-Autumn Semester Examination 2023-24

Date of Examination: Session: (FN/AN) Duration: 3 Hrs Full Marks: 50
Subject No. : CH 62007 Subject : Industrial Pollution Control
Department: Chemical Engineering Graph Paper required

Answer all the questions (Assume suitable data whenever necessary with proper justification). Answer all parts of a question continuously and in different places.

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1. a) Derive an expression for collection efficiency of particle in an ESP from fundamentals of operations. Describe the challenges faced by installation and operation of ESP?

b) A parallel plate type ESP having dimension as 4 m high, 6 depth with spacing between the plates as 30 cm separate dust from a flue gas at a temperature of 130 ^{o}C and 1.03 kg/cm^2. The gas flows through the precipitator at a rate of 70000 m^3/hr where a voltage 70,000 V is applied. The particle size analysis shows the following distribution

Dp(Micron)	0.05	0.1	0.2	0.4	0.8	1.2	5.0
% Weight	1	16	25	28	10	16	2

$q_B = 0.15 \times 10^3 \gamma_p^2 \cdot e$

$V_{pm} = \frac{q_B \cdot E \cdot c}{3\pi\mu d_p}$

C= 1.0 + 0.170/dp , where dp is particle dia in micron.
Calculate :

a) Particle migration velocity
b) Overall collection efficiency
c) Overall collection efficiency , If the temperature of the flue gas increased to 150 ^{o}C due to malfunctioning of heat recovery system
d) if spacing is increased by 10 cm what would be % change in overall collection efficiency keeping all other parameters constant?
e) Prepare a grade efficiency profile of the entire range of particles.

[4+6 = 10]

2. a) An old bag filter from a discontinued process is to be utilized for constant pressure filtration at 140 mm of water. The filter has 60 bags of 8000 cm^2 each. The cleaning and shaking time is observed as 20 mins. For the given pressure filtration equation is as follows:

$$t = 674.82 V_G^2$$

Where t= time, min and V_G= Volume gas filtered per unit area of filter (m^3/cm^2)
Determine:
a) Optimum overall capacity of the filter under the given conditions.
i) Maximum overall capacity
ii) If another two additional identical old units are installed to increase the capacity, what is the maximum percentage increase/decrease in the overall capacity for new arrangement? Assume total cleaning time as 25 minutes.

b) Explain how scale-up of cyclone design is performed with design equation with an example of your choice. What is the basic difference between high efficiency and high throughput cyclone? What are the various parameters on which the cyclone performance depends?

[6+4 = 10]

3. a) Which type of wet scrubber is preferred in handling large raw materials processing unit and re-cycling? Explain the working principle of operation with diagram.

b) In a zinc smelter plant the flue gas emitted after sulfur recovery is 150000 m^3/hr and contain SO_2 . The inlet concentration of SO_2 is 600 $\mu g/m^3$. This flue gas need to be treated in an wet scrubber with recycled water as a solvent to meet the stringent discharge limit of SO_2. It is required to remove SO_2 in such a way that the exit gas should not contain more than 100 $\mu g/m^3$ of SO_2. The equilibrium relationship between SO_2-water system governed by the equation $x = 11.534 * y$ where x, y are in mole fraction (vol %). The temperature of gas is at 120 ^oC and pressure of 1.06 kg/cm^2 . Design a suitable wet scrubber with dimensions, minimum amount of water required for this scrubbing and quantity of discharge wastewater generated in the plant.

[3 + 7 = 10]

4. a) Explain with the help of a flow sheet the treatment of industrial wastewater , so that the treated wastewater can be recycled back to the plant. What are the different types of flocculants used for large quantity of wastewater? Explain the mechanism of TSS separation in n ETP. Explain how COD and TSS in measured in wastewater sample.

b) The ultimate BOD of a wastewater sample is measured as 76 % of COD. The COD of this wastewater is 550 mg/L. Considering first order BOD reaction are constant (k) is 0.23 per day and temperature coefficient θ=1.043, calculate the BOD of wastewater after three days of BOD incubation at 27^oC for this wastewater.

[6 + 4 = 10]

5. a) An industrial wastewater from a city is discharged at 8.5865 MGD and this wastewater is collected and a standard 300 ml BOD bottles are used to BOD incubation at 20 ^oC for 5 days. The following data of initial and final DO were reported as given in the table.

Sr of No of BOD Bottles	c.c. of raw wastewater used	Initial DO (mg/L)	Final DO (mg/L)
1	2	7.87	4.86
2	4	7.90	3.21
3	8	7.93	2.74
4	16	7.82	1.32
5	32	7.88	0.0
6	64	7.84	0.0

i) Calculate the average BOD of wastewater.
ii) If the BOD of 0.08 kg/capita per day is used , calculate population in that city.

b) An industrial wastewater is discharged at a rate of 100000 gallons per day to a common ETP. The BOD_5 of the wastewater is 250 mg/L. After the treatment the BOD of treated effluent is 40 mg/L Calculate

i) kg of BOD entering the ETP.
ii) % removal of BOD in ETP
iii) BOD discharged per day from the ETP of the plant

[6 + 4 = 10]