INDIAN INSTITUTE OF TECHNOLOGY KHARAGPUR

Autumn Mid-Spring Semester Examination- 2024

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

Date: 20.09.2023 (FN) — *Time*: 2 Hrs — *Full Marks*: 60

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

---

1. a) What are the air pollutants present in the flue gas emitted through stack? Explain with required mathematical models how concentration of PM can be predicted at a distance of x from the plant with concentration profiles.

b) Prepare a sample EIA and EPM report for an industrial culture of 15 km radius of your choice.

c) Explain the sampling process for monitoring SO_2 concentration in stack with a neat diagram of instruments used with sample calculations.

d) A multi-tray settling chamber having 8 trays including the bottom surface handles 21600 m^3/hr of dirty gas containing dust particles of Sp. Gv. 2.0 at 20 ^oC. The trays are separated 25 cm apart and the chamber is 1 m wide and 4 m long. What is the minimum particle size than can be collected with 1000 % efficiency? What will be the efficiency of settling chamber if 50 μm particles are to be removed? Assume laminar flow condition within the chamber of gas. Viscosity of gas 0.018 cp. If it is desired that the same gravity settling chamber to be used for particles in the range of 40 to 200 μm prepare grade efficiency profile.

[4 + 3 + 3 + 10 = 20]

2. a) I) Explain the control strategy of fugitive emission and design considerations to be adopted for minimization.

II) Define primary and secondary pollutants with example.

III) What is the importance of adiabatic lapse rate.

b) A 500MW thermal power plant burns 18000 tons of coal per day containing 0.58% sulphur. The plant emits the flue gasses into the atmosphere through a stack of inside diameter of 1.5 m and height of 60 m. The velocity and the temperature of the plume at the exit are 5 m/s and 155 0C respectively. The ambient air temperature is 28 C and the wind speed at a 3 m altitude is 5 m/s. The barometric pressure is 825 mbar at the top of the stack. Assume a moderately stable plume. 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

a) Calculate the effective height of stack.

b) What is the downwind SO_2 concentration in the plume centerline at a distance of 2 km in the day time?

c) Calculate the maximum concentration of SO_2 along the centerline of the plume and at what downwind distance it will occur.

d) Show a concentration profile of SO_2 upto 10km downwind distance and 800m along the crosswind distance.

[9 + 11 = 20]

3. a) What are the limitations of bag houses for its use? What are the cleaning mechanism of bag houses?

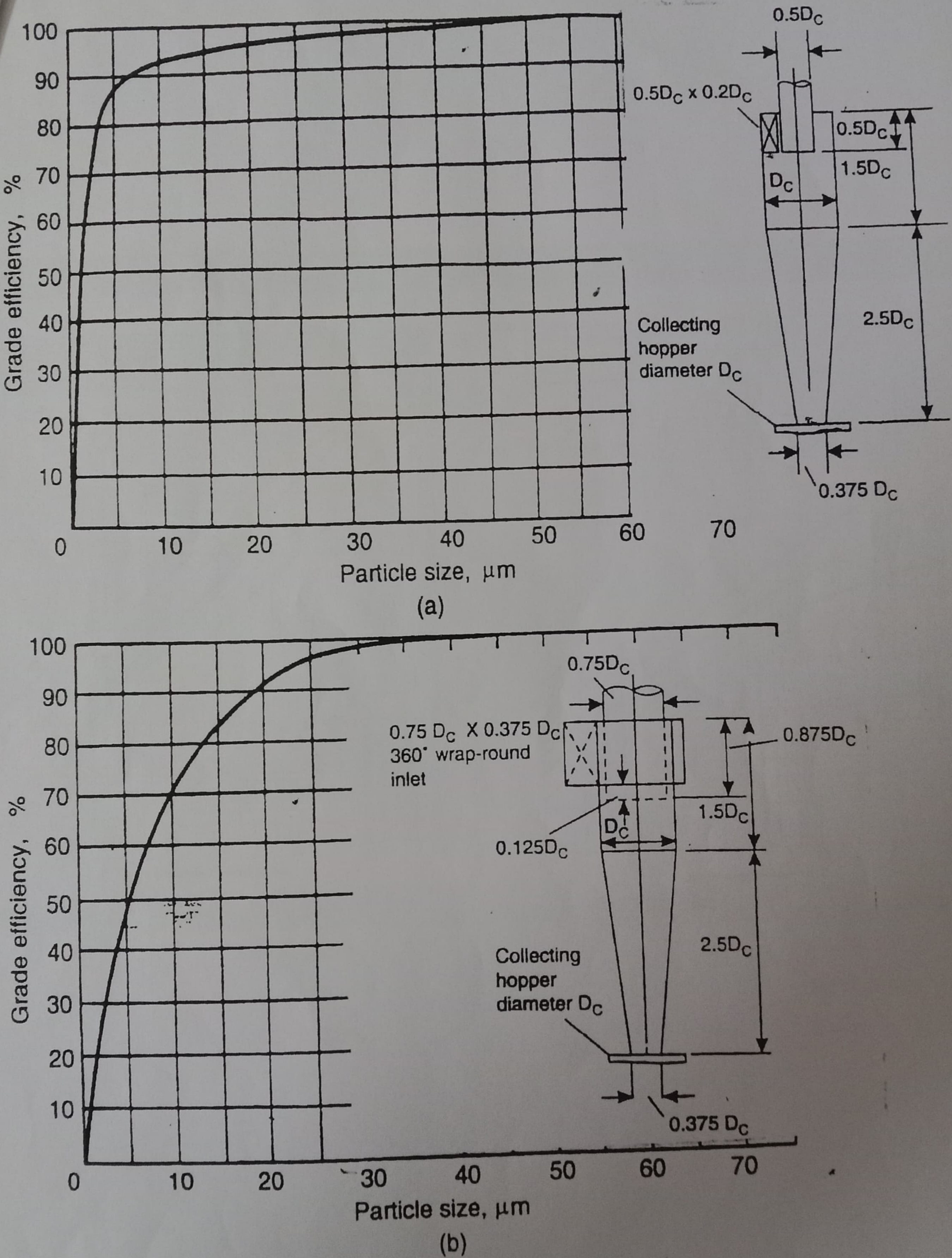
b) Explain how following parameters of wastewater can be measured as per CPCB guidelines

(i) BOD (ii) TDS (iii) Cr(VII) (iv) Nitrate

c) Dust emitted from a cement plant is controlled by a conventional cyclone with a cyclone diameter of 1.0 m. For air with a flow rate of 150 m^3/min at T = 350 K and 1 atm, containing particles with a density of 1.6 gm/cc and a size distribution as given below, calculate the overall collection efficiency. The gas viscosity equal to 0.09 CP. The number of complete turns by the entering air within the cyclone is 5.

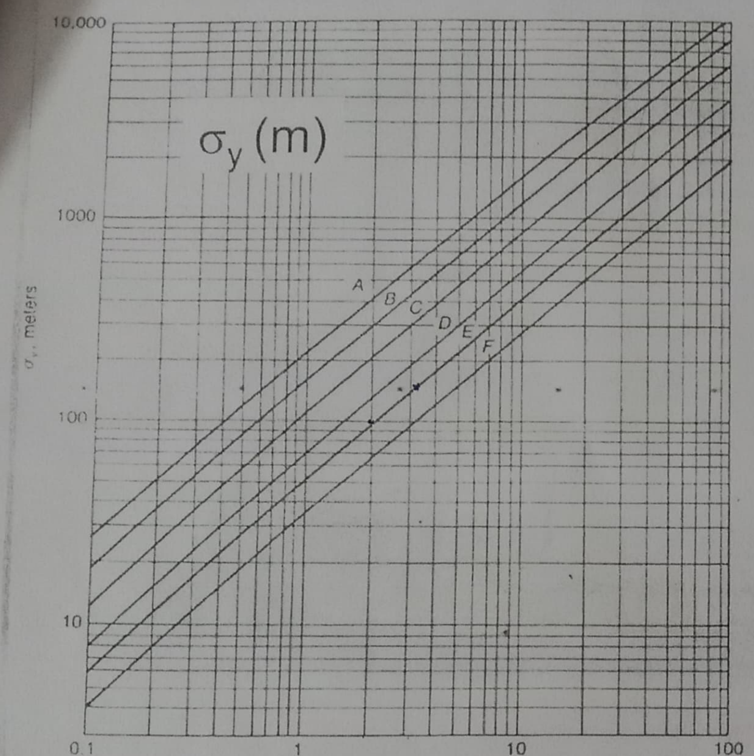
Particle Size Range, μm	Mass of Particle in Size Range (gm)
0 – 2	2.0
2 – 4	6.0
4 – 6	10.0
6 – 10	8.0
10 – 18	30.0
18 – 30	25.0
30 – 50	5.0
50 – 100	3.0

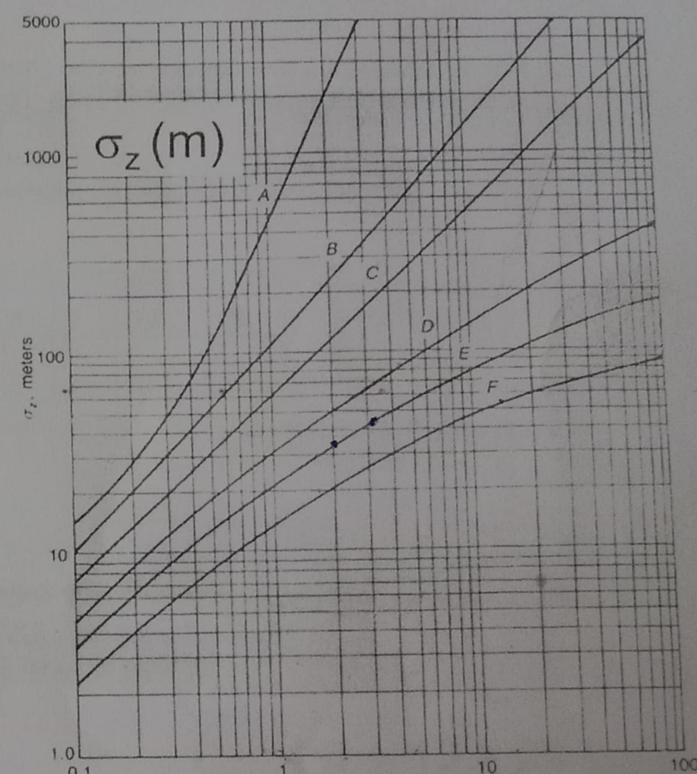
[2 + 8 + 10 = 20]



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

Horizontal and vertical dispersion coefficients





Stability class	Definition	Stability class	Definition
A	very unstable	D	neutral
B	unstable	E	slightly stable
C	slightly unstable	F	stable

INDIAN INSTITUTE OF TECHNOLOGY KHARAGPUR

End-Autumn Semester Examination 2024

Date of Examination:21-11-2024 Session: (FN) Duration: 3 Hrs Full Marks: 100

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 not in different places.

1. a) Explain the mechanism of particle charging in ESP and how efficiency of ESP related to such mechanism? How the different factors affects the performance of ESP?

b) An ESP having dimension as 4 m high, 5 m depth with spacing between the plates as 40 cm separate dust from a flue gas at a temperature of 175 ^oC and 1.01 kg/cm^2. The gas flows through the precipitator at a rate of 250000 m^3/hr where a voltage is varying as

$V_S = (4s^3 + 2.5) \times 10^5$ volt , where s is the spacing between discharge and collecting electrodes.

The particle size analysis shows the following distribution

Dp(Micron)	0.5	1	2	4	5	10	20
% Wight	5	22	27	23	8	4	Rest

Assume diffusional mechanism predominates the particle charging. C= 1.0 + 0.172/dp, where dp is particle dia in micron.

Calculate :

i) Particle migration velocity
ii) Overall collection efficiency of ESP
iii) if spacing is increased by 5 cm what would be % change in overall collection efficiency keeping all other parameters constant?
iv) Draw the migration velocity profile across the entire size range of particle.

[5 + 15 = 20]

2. a) Explain the cleaning mechanism of Bag filters. What are the challenges faced by industry using bag houses over other conventional techniques? Explain

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

$$V_G^2 = 2.623 \times 10^6 \times t \times P^{0.65}$$

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 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 two units is estimated at 10.0 min. What is the maximum percentage increase in the overall capacity that could be attained by adopting this suggestion?

c) Derive an expression for DP_C in a conventional cyclone separator from basic force balances. What is the significance of DP_C for selecting the cyclone separator?

[3+12+ 5 = 20]

3. a) Mention five wet scrubbers that are used for controlling gaseous emission from process plants. Explain the working principle of a multi-tray type wet scrubber with design modifications for large interfacial surface area with neat schematic diagram.

b) Discuss the design procedure of a packed column to remove soluble gaseous pollutants from a polluted gas stream with design equations.

c) A chemical process plant of approx. 193 acre plant area, manufacture products which generates toxic chemicals and surface run-off water cannot be discharged without treatment as per directions of State Pollution Control Board. It is required to construct a surface run off water pond for the plant area of various types as per Table -2. The past few years rainfall data from 2020 to 2024 as recorded is provided in Table 3. Design the surface run-off water pond required for further treatment in the ETP.

Table : 1

Surface Description	C- value
Asphalt and Concrete	0.70-0.95
Roof	0.75-0.95
Woodland	0.05-0.25
Sandy soil, Flat	0.05-0.10
Heavy Soil, Flat	0.13-0.17

Table: 2

Site Description	Site Area (in acres)
Buildings	25.09
Roads/ Pavements	71.87
Woodland	37.52
Sandy soil	53.06
Heavy soil	2.87
Drainage Area	2.42

Table: 3

Year	Rainfall (mm)
April 2019 - March 2020	1989
April 2020- March 2021	1920
April 2021 - March 2022	2287
April 2022 - March 2023	1575
April 2013 - March 2024	1122

[4 + 6 + 10 = 20]

4. a) It in required to supply domestic use water from the nearest river Kangsabati to IIT Campus through pipeline. Explain the various treatment techniques involved to purify and supply the water.

b) An industrial wastewater at the rate of 150 m^3/hr is discharged and an aerated lagoon is used for its treatment. The BOD_5 of a wastewater sample is determined as 400 mg/L at 20 ^oC. The first order BOD reaction rate constant (k) is 0.23 per day and temperature coefficient $\theta = 1.047$. What would be the BOD_{10} value if the treatment is conducted at 30 ^oC.

Calculate the efficiency of the aerated lagoon for this wastewater.

[10 + 10 = 20]

5. a) An Activated sludge plant is used for the treatment of sludge from a plant at the rate of 250 m^3/hr. The BOD_5 of the waste is 300 mg/l. The plant consists of 4 aeration tanks each of 4 m depth, 5 m wide and 25 m long. The Mixed Liquor Volatile Suspended Solids (MLVSS) Concentration is 2800 mg/l.

Calculate

i) Detention time in Hrs
ii) Volumetric organic loading
iii) Sludge loading ratio

b) Select a specific water intensive chemical process industry and show with the help of flow sheet how Zero Liquid Discharge(ZLD) is possible to achieve.

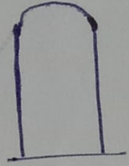
c) Explain how peak rate of surface runoff water is calculated with equations.

[8 + 7+ 5 = 20]

Design of Bag Filters

Total surface Area $= N \times A_s$

$$A_s = \pi D L + \pi r^2$$



Air to cloth ratio :- $\dfrac{Q}{N * A_s}$ (m/s)

[2.5 - 4]

Filter velocity $(V) = \dfrac{Q_G}{A_s}$

A/C ratio < 2.5 ⇒ more bag filters

A/C ratio > 4 ⇒ Less bag filters

$$Q_{optimum} = \frac{\text{Volume}}{t_f + t_c}$$

t_c - cleaning time

t_f - filtration time

$$Q_{max} = \frac{\text{Volume}}{t_f + t_c}$$

$t_f = t_c$ for optimum condition

(1) Constant pressure operations:-

$$t_f = \left(\frac{B}{2\Delta P}\right) V_G^2 + \underbrace{\left(\frac{C}{\Delta P}\right) V_G}_{\text{Resistance of bag filter}}$$

V_G - vol of gas filtered

ΔP - Press drop

(2) Constant Capacity Bag filter

$$\Delta P = BQ^2 + CQ$$

Q - vol flow rate

— x — x — x — x — x —

Electrostatic Precipitator:-

$\bar{D}_p = 0.1$ to $20\ \mu m$

$\eta = 99.9\%$ Temp:- 400-500°C

Mechanism/:

(1) Gas ionisation (charging particles)

(2) Migration of ionised particles to collector.

(3) Neutralisation of charge at collector.

(4) Removal of collected particles

Ionisation → 1. Bombardment

2. Diffusional Mechanism

$$\boxed{\eta = 1 - e^{-\frac{V_{PM} \times A_c}{Q}}}$$

A_c = Perimeter × Length

$$V_{PM} = \frac{q_{Lt} \cdot E \cdot C}{3\pi\mu D_p}$$

q_{Lt} → limiting discharge

E → Electric field

C → cunninghum Correction factor

D_p → particle dia

$$q_{Lt} = ne$$

n - no. of electronic charge

e - electron charge $= 1.6 \times 10^{-19}$

E = Avg electric field intensity = $\left(\dfrac{\text{Voltage}}{\text{Spacing}}\right)$

$$\boxed{E = \frac{V}{S}}$$

$$\boxed{\frac{V_{PM_1}}{V_{PM_2}} = \frac{E_1}{E_2} = \frac{V_1}{S_1} \times \frac{S_2}{V_2}}$$

$$\boxed{V_{PM} = 2.8 \times 10^5\ d_p}$$

Assumed correlation

overall efficiency $= \sum \eta_i w_i$

IPC END-SEM-2023-24

① b

$H = 4\ m$ $\qquad Q = 70{,}000\ \frac{m^3}{hr}$

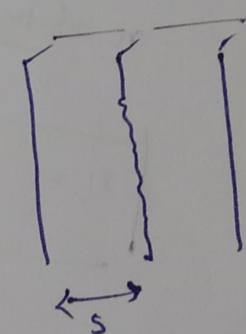
$\text{Depth} = 6\ m$ $\qquad V = 70{,}000\ \text{Volt}$ $\qquad \mu = 2.2\times10^{-5}\ \text{Pa s} \mid 130°C$

$\text{Spacing}\ (S) = 0.3\ m$ $\qquad \text{press}\ (P) = 1.03\ kg/cm^2$ $\qquad V_{PM} = \dfrac{q_{Lt} \times E.C}{3\pi \mu D_p}$

$$E = \frac{V}{S} = \frac{70000}{0.3} = 233333.33\ \frac{V}{m}$$

D_{pm}	C	V_{PM}
0.05	4.4	
0.1	2.7	
0.2	1.85	
0.4	1.425	
0.8	1.2125	
1.2	1.142	
5.0	1.034	

$$q_{Lt} = n \times 10^{-19} \times 1.6$$



$$n = \frac{PV}{RT}$$

$$n = \frac{101.325\times10^{3} \times 14.4}{8.314 \times 403} = 435.47$$

$$q_{Lt} = 6.967 \times 10^{-17}$$

$v = H \times D \times 2S$

$= 4 \times 6 \times 0.6$

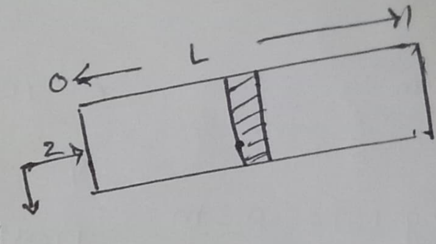
$= 14.4\ m^3$

$D_{pm} = 0.05$

$$V_{PH} = \frac{6.967\times10^{-17} \times 233333.33 \times 4.4}{\cancel{8.314}\ 3\pi \times 2.2\times10^{-5} \times 0.05\times10^{-6}}$$

$$V_{PM} = 6.63\ m/s$$

Mass Balance Over Control volume :-

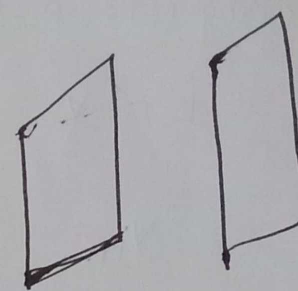


In = Out + dust collected

$$AV (C_{in} - C_{out}) = V_{PM}\, dz \cdot C$$

$$-AV \frac{dC}{dz} = V_{PM} \cdot P \cdot C$$

$$-\frac{AV}{C} dC = V_{PM} P \cdot dz$$



$$AV \cdot \int_{C_0}^{C_L} \frac{dC}{C} = -V_{PM} \int_0^L P dz$$

$$AV \ln\left(\frac{C_L}{C_0}\right) = -V_{PM}\, P.L$$

$$A_C = P \times L$$

$$Q = AV$$

$$\ln \frac{C_L}{C_0} = -\frac{V_{PM} A_C}{Q}$$

$$C_L = C_0 \exp\left(-\frac{V_{PM} A_C}{Q}\right)$$

$$\eta = \frac{C_{in} - C_{out}}{C_{in}} = \frac{C_0 - C_0 \exp\left(-\frac{V_{PM} A_C}{Q}\right)}{C_0}$$

$$\boxed{\eta = 1 - \exp^{-\frac{V_{PM} A_C}{Q}}}$$

In + out = acc

$$AV (C_i - C_{out}) = V_{PM} (P \cdot dz) C$$

$$AV \frac{dC}{dz} = -V_{PM} \cdot P \cdot C$$

$$Q \frac{dC}{dz} = -V_{PM}$$

$C_{in} - C_{out} =$ ~~Cout~~ dust coll

$$AV (C_{in} - C_{out}) = (P \cdot dz) \times V_{PM} \times C$$

$$Q \frac{dC}{dC} = -P\, V_{PM} \int_0^L dz$$

$$\ln \frac{C_f}{C_i} = -\frac{A V_{PM}}{Q}$$

$$C_f = C_i e^{-\frac{A V_{PM}}{Q}}$$

$$\boxed{\eta = 1 - e^{-\frac{A V_{PM}}{Q}}}$$

H = 5m

$\eta =$

(i)

$H = 5m$, $D = 6m$ $S = 0.3\ m$

$\eta = 94.4\%$ $Q = 108000\ \frac{m^3}{hr}$ $C_{inlet} = 10{,}000\ mg/m^3$

(1) Bulk fluid (gas) velocity:

$$V = \frac{Q}{A} = \frac{(108000/3600)}{5 \times 0.3} = 20\ m/s$$

(2) Outlet conc of gas

$$\eta = 1 - \frac{C_{out}}{C_{inlet}}$$

$$C_{out} = [1 - \eta] \times C_{inl}$$

$$= (1 - 0.944) \times 10{,}000$$

$$C_{out} = 560\ mg/m^3$$

(3) V_{PM}

$$\eta = 1 - e^{-\frac{V_{PM} \cdot A}{Q}}$$

$Q = 30\ m^3/s$

$A = 2 \times H \times W$

$= 2 \times 5 \times 6$

$$V_{PM} = -\frac{Q}{A} \ln(1 - \eta)$$

$$= -\frac{\cancel{30}}{2 \times \cancel{30}} \ln(1 - 0.944)$$

$$V_{PM} = 1.444\ m/s$$

(5)

$$\frac{V_{PM_1}}{V_{PM_2}} = \frac{S_2}{S_1}$$

$$\frac{1.444}{V_{PM_2}} = \frac{20}{30}$$

$$V_{PM_2} = \frac{3}{2} \times 1.444$$

$$V_{PM_2} = 2.166\ m/s$$

Q.3 A wire type ESP.

$A = 300\ m^2$ $\quad Q = 72{,}000\ \frac{m^3}{hr}$, $T = 95^\circ C$

$V = 56{,}000\ V$ $\quad S = 0.125\ m$ $\quad \mu = 0.0225$ cpoise.

η for $1\ \mu m$ dia particles and V_{pm}

(a) $$V_{PM} = \frac{q_{it} E C}{3 \pi \mu D_p}$$

$$(q_{it})_b = 0.49 \times 10^{-19} \times \left(\frac{D_p}{2}\right)^2 \times E$$

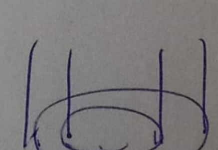
$$E = \frac{V}{S} = \frac{56{,}000}{0.125} = 448000\ \frac{V}{m}$$

$$(q_{it})_b = 0.49 \times 10^{-19} \times \left(\frac{1 \times 10^{-6}}{2}\right)^2 \times 448000$$

$$= 5.488 \times 10^{-27}$$

$$C = 1 + \frac{0.172}{D_p} = 1 + \frac{0.172}{1 \times 10^{-6}} =$$

$$V_{PM} = \frac{5.488 \times 10^{-27} \times 448000 \times 172001}{3 \pi \times (0.0225 \times 10^{-3}) \times 10^{-6}}$$



24CHG0R46
Lakshmana Reddi

Assignment - III

1. A conventional cyclone of diameter of 500 mm is used to treat the flue gases containing cement dust particles of 3.5 g/m³ at 165 °C and 1 atm. The inlet gas velocity is 17 m/s and no. of turns in cyclone is 5.

Data: $\rho_p = 2700\ kg/m^3$ & $\rho_{gas} = 1.09\ kg/m^3$ $\mu_{gas} = 0.019\ cp$

The particle size distribution

particle size (μm)	>50	50-40	40-30	30-20	20-15	15-10	10-5	<5
%wt	19.5	10	7.5	15	21	15	9.5	2.5

(i) Calculate Cut size (d_{pc})

(ii) Overall collection eff (η)

(iii) Overall dust conc from cyclone.

(i) $$d_{pc} = \left[\frac{9 \times \mu_f \times b}{2\pi \times N \times V \times (\rho_p - \rho_g)}\right]^{1/2}$$

for $d_p > 5\ \mu m$, wt % > 95%.
So we can consider high (η) cyclone parameters.
$b = 0.2D$

$\mu_f = 0.019 \times 10^{-3}\ kg/ms$; $V = 17\ m/s$
$\rho_p = 2700\ kg/m^3$ $\rho_f = 1.09\ kg/m^3$ $N = 5$
$D = 500\ mm = 0.5\ m$

$$d_{pc} = \left[\frac{9 \times (0.019\times10^{-3}) \times 0.2 \times 0.5}{2 \times \pi \times 5 \times 17 \times (2700 - 1.09)}\right]^{1/2}$$

$$\boxed{d_{pc} = 3.49\ \mu m}$$

D_p range (μm)	w_f	d_{p_i}	η_i (%)
<5	0.025	2.5	34.5
5-10	0.095	7.5	82.6
10-15	0.15	12.5	92.9
15-20	0.21	17.5	96.2
20-30	0.15	25	98.14
30-40	0.075	35	99.04
40-50	0.10	45	99.41
>50	0.195	75	99.56

where

$$\eta_i = \frac{\left(\frac{d_{p_i}}{d_{pc}}\right)^2}{1 + \left(\frac{d_{p_i}}{d_{pc}}\right)^2} \times 100$$

$\eta_{ov} = \sum \eta_i w_i$

$= (\cancel{34.5} \times 0.025) + (\overset{82.6}{\cancel{68.5}} \times 0.095) + (\overset{92.1}{\cancel{78.4}} \times 0.15) + (\overset{96.2}{\cancel{83.5}} \times 0.21)$

$+ (\overset{98.14}{\cancel{87.4}} \times 0.15) + (99 \times 0.075) + (\overset{99.41}{93} \times 0.10) + (\overset{99.52}{\cancel{95.6}} \times 0.198)$

$= \cancel{84.8\%} = 94.34\%$

(iii) $C_{inlet} = 3.5\ gm/m^3$

$\eta_{ov} = \frac{C_{in} - C_{out}}{C_{in}} \times 100 = 0.9434 = \frac{3.5 - C_{out}}{3.5}$

$C_{out} = 0.1981\ gm/m^3$

Q2. Design a cyclone separator to handle $3600\ m^3/hr$ of gases containing gypsum dust of $20\ g/m^3$ at $80°C$, emitted from a plant, where no. of turns is 5. $\rho_{gases} = 0.95$; $\mu_{gas} = 0.025\ cP$

The pressure lost in the cylinder is 8 times velocity head and is 7.5 cm of H_2O

(a) Calculate overall efficiency

(b) If 20 cyclones of equal size multi cyclone are used. Determine the overall efficiency. (Assume the head available in multicyclone to be 10% less than in single cyclone.

$Q = 3600$

Dp	<5	5-10	10-30	30-50	>50
wt%	15	15	30	25	15

a) $D_{pc} = \left[\frac{9 \mu_g b}{2\pi N v (\rho_p - \rho_g)}\right]^{1/2}$

$D_{pi} > 5\ \mu m$ & $wt > 90\%$

Choose High efficiency cyclone

$b = 0.2D$

$h = 0.5D$

$= \left[\frac{9.81 \times 0.025 \times 10^{-3} \times 0.1695}{2\pi \times 5 \times 13.91 \times (2000 - 0.95)}\right]^{1/2}$

$\boxed{D_{pc} = 6.6\ \mu m}$

head loss of h_{air} $= \frac{v^2}{2g} \times 8 = 78.94$

$h_{air} = \frac{\rho_w \times h_w}{\rho_{air}} = \frac{1000 \times 7.5}{0.95} = 7894\ cm$

$= 78.94\ m$

$v = 13.91\ m/s$

$Q = b \times h \times \bar{v} = 0.2D \times 0.5D \times 13.91 = \frac{3600}{3600}\ (m^3/s)$

$D = 0.847\ m$

Efficiency

wt%	$\bar{d}_{p_i}$ (μm)	η_i (%)
0.15	2.5	12.5
0.15	7.5	56.36
0.30	20	90.2
0.25	40	97.35
0.15	75	99.2

$\bar{D}_{pc} = 6.6\,\mu m$

$$\eta_i = \frac{\left(\frac{d_p}{d_{pc}}\right)^2}{1+\left(\frac{d_p}{d_{pc}}\right)^2} \times 100$$

$\eta_{overall} = \Sigma \eta_i W_i$

$= (12.5 \times 0.15) + (56.3 \times 0.15) + (90.2 \times 0.30) + (97.3 \times 0.25) + (99.2 \times 0.15)$

$= 76.6\%$.

(b) For 20 cyclone.

Accurate D_{pc} required D_{pc} //

$Q_{new} = \frac{Q}{20} = \frac{3600}{20} = 180\,m^3/hr$

single column $\frac{8v^2}{2g} = 78.94$

↳ 10% less $= \frac{8v^2}{2g} = 71.046$ $v = 13.2$ m/s

$Q = 0.2D \times 0.5D \times \cancel{13.9}^{13.2} = \frac{180}{3600}$

$D = 0.194\,m$

$$D_{pc} = \left[\frac{9 \times 0.025 \times 10^{-3} \times 0.2 \times 0.194}{2\pi \times 5 \times 13.2 \times 2000}\right]^{1/2} = 3.25\,\mu m$$

D_{p_i}	wt(%)	η_i (%)
2.5	0.15	37.3
7.5	0.15	84.3
20	0.30	97.4
40	0.25	99.3
75	0.15	99.8

$$\eta_i = \frac{\left(\frac{dp_i}{d_{pc}}\right)^2}{1+\left(\frac{dp_i}{d_{pc}}\right)^2} \times 100$$

$\eta_{over} = \Sigma \eta_i w_i$

$\eta_{over} = 87.255\%$.

Efficiency of 20 cyclones > Efficiency of single cyclone

Q3. In multitray settling chamber having 8 trays including bottom surface handles 6 m^3/s of air at 20°C. The trays are 25 cm apart. The chamber is 1m wide and 4m long.

$\rho_p = 2000 \, kg/m^3$

(i) Calculate $D_{p\,min}$ that can be collected

(ii) what will be efficiency of settling chamber if 50 μm particles are to be removed. (laminar flow region). $g = 9.81 \, m/s^2$

$\mu_g = 1.81 \times 10^{-5} \, \frac{kg}{m \cdot s}$ Neglect ρ of gas to particle.

$$D_{p\,min} = \left[\frac{18 \mu Q}{(\rho_p - \rho_g) g W L} \times \frac{S}{H}\right]^{1/2}$$

S: spacing = 0.25 m

H: no. of trays × spacing = 8 × 0.25 m

L = 4 m   W = 1 m   Q = 6 m^3/s

$$= \left[\frac{18 \times 1.81 \times 10^{-5} \times 6}{2000 \times 9.81 \times 1 \times 4 \times 10^{-2}} \times \frac{0.25}{2}\right]^{1/2}$$

$D_{p\,min} = 55.8 \, \mu m$

(ii) Efficiency of 50 μm particles

$$\eta = \left(\frac{h}{H}\right) \times 100$$

$h = v_t \times t$ (v_t: terminal, t: settling time)

$$v_t = \frac{g d_p^2 (\rho_p - \rho_f)}{18 \mu} = \frac{9.81 \times (50 \times 10^{-6})^2 (2000 - 0)}{18 \times 1.81 \times 10^{-5}} = 0.15 \, m/s$$

$$t = \frac{vol}{vol. \ flowrate} = \frac{L \times W \times H}{Q} =$$

$$h = v_t \times t = \frac{L \times W \times H}{Q} \times 0.15$$

$$\eta = \frac{h}{H} = \left[\frac{\frac{L \times W \times H}{Q} \times 0.15}{H}\right] \times 100$$

$$= \left[\frac{L \times W}{Q} \times 0.15\right] \times 100$$

$$= \left[\frac{4 \times 1}{6} \times 0.15\right] \times 100$$

$$\eta = 10\%$$

A conventional cyclone of diameter (1.5m) is used to treat the flue gas containing particulates of 8.5 g/m³ at 165°C and 1 atm. The gas velocity is 17.4 m/s. and no. of turn is 5. $\rho_p = 2350\ kg/m^3$

$\mu_g = 0.0118\ cp$

Calculate

(i) Cut size particle diameter

(2) Overall Efficiency

Particle size distribution:-

D_p	>50	50-40	40-30	30-20	20-15	15-10	10-5	<5
wt%.	35	15	20	9	6	5	6	4

high efficiency cyclone is preferred.

(i) As $D_{pi} > 5\ \mu m$ & wt% 95%.

$$D_{pc} = \left[\frac{9 \mu b}{2\pi \times N \times V(\rho_p - \rho_g)}\right]^{1/2}$$

$$= \left[\frac{9 \times 0.0118 \times 10^{-3} \times 0.2 \times 1.5}{2\pi \times 5 \times 17.4 \times (2350 - 0.0032)}\right]^{1/2}$$

$$D_{pc} = 4.98 \times 10^{-6}\ m = 4.98\ \mu m$$

$\bar{D}_p$ range	$\bar{D}_{pi}$	wt fr	η_i
0-5	2.5	0.04	20
5-10	7.5	0.06	69.4
10-15	12.5	0.05	86.3
15-20	17.5	0.06	92.5
20-30	25	0.09	96.2
30-40	35	0.20	98
40-50	45	0.18	98.7
>50	75	0.35	99.56

$$\eta_i = \frac{\left(\frac{d_{pi}}{d_{pc}}\right)^2}{1 + \left(\frac{d_{pi}}{d_{pc}}\right)^2}$$

$$\eta_{over} = \Sigma \eta_i (wt\%) = \Sigma \eta_i x_i$$

$$= (20 \times 0.04) + (69.4 \times 0.06) + (86.3 \times 0.05) + (92.5 \times 0.06) + (96.2 \times 0.09) + (98 \times 0.2) + (98.7 \times 0.15) + (99.56 \times 0.35)$$

$$\eta_{overall} = 92.73\%$$

Qu A coal burning power plant burns 24,000 TPD. The coal has a sulphur content of 1.7%. The physical stack heights(h) is 200ft inside diameter of stack at exit is 0.8 m. stack gas exist velocity is 18.3 m/s which leaves the chimney at a temp of 1400°c. Ambient air temp. 280c The atmospheric pressure is 1000 mbar and wind speed = 4.5 m/s

(a) Calculate effective stack height,

(b) what is the maximum conc of SO_2 at the ground level? (use moderately unstable condition of the plume).

(c) Calculate the conc. of SO_2 at a distance of 5 km away from chimney plant. Also show the concentration profile of SO_2 upto 3 km from

(a) $H_{eff} = h_{stage} + h_{plume} = H + \Delta H$

Using Hollied's method:

$$\Delta H = \frac{V_s D}{u}\left[1.5 + 2.68\times10^{-3} \times PD \times \frac{T_s - T_a}{T_s}\right]$$

$$= \frac{18.3\times0.8}{4.5} \times \left[1.5 + 2.68\times10^{3} \times 1000 \times 0.8 \times \frac{1400-280}{280}\right]$$

$$= 10.46 \text{ m}$$

$\therefore H_{eff} = H + (\Delta h)_p$

$= 60.96 + 10.46 = 71.42$ m

concentration profile ?

?

(c).

(b) Maximum concentration occurs at:

$\sigma_z = 0.707\,(H_{eff})$

$= 0.707 \times 71.42$

$\sigma_z = 50.5$ m

for moderately unstable, $x = 420$ m $= 0.42$ km

$$C_{max} = C(x,0,0) = \frac{Q_{SO_2}}{\pi \times u \times \sigma_z \times \sigma_y}$$

$= \frac{24000\times10^3}{24 \times 60 \times 60}$ (kg/s)

$= 277.77$ kg

$$Q_{SO_2} = (Q)_{sulpur} \times \left(\frac{32+32}{32}\right)$$

$= 2\times(Q_{sulpur})$

$= 0.017 \times 277$

$Q_{SO_2} = 4.77 \times 2$ kg/s $= 9.44$ kg/s

$$C_{max} = \frac{9.44}{\pi \times 4.5 \times 50.5 \times 80}$$

$\boxed{C_{max} = 0.165\ g/m^3}$