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

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

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 °C 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 °C at a velocity of 4 m/s. The ambient temperature 27 °C. 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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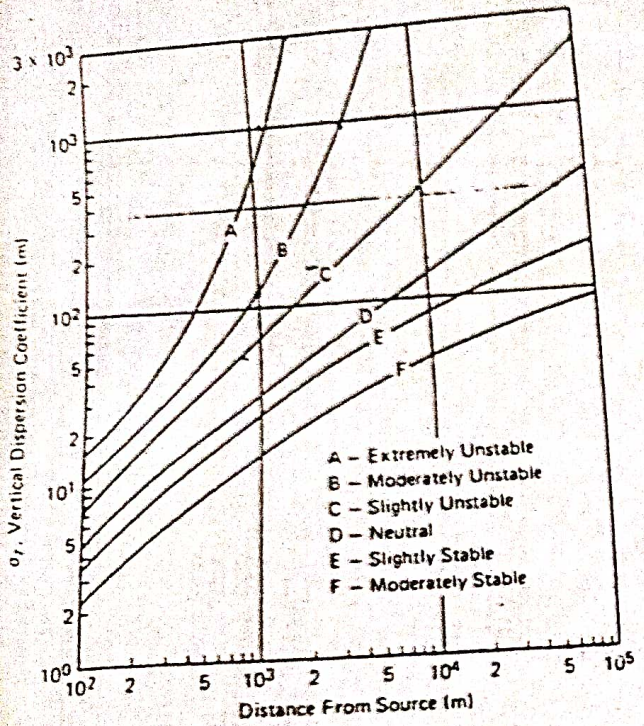
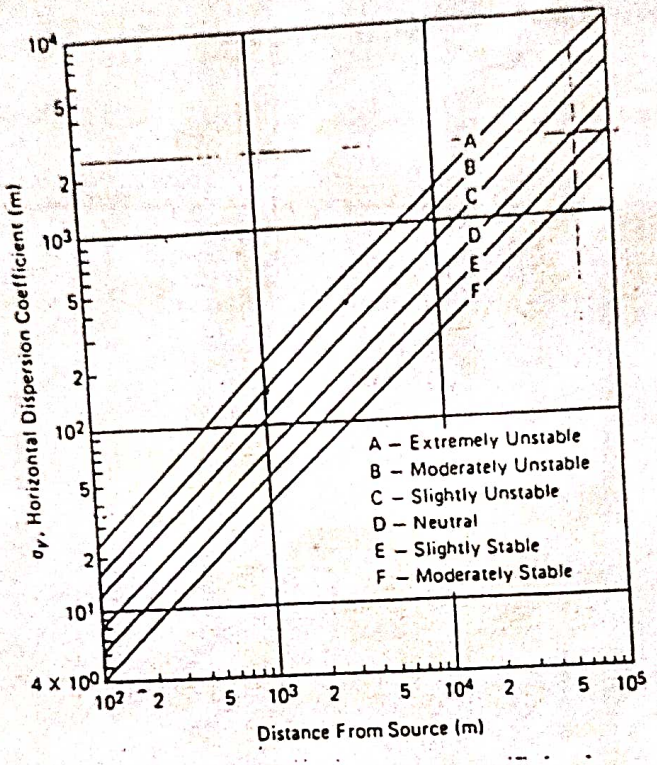


Vertical dispersion coefficient as a function of Down-wind distance from the source



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