MODULE 2

SOLVED NUMERICAL PROBLEMS

Problem 1: A cyclone has an inlet width of 15 cm and the shortest length of 25 cm with diameter of 0.50 m, operates at **f**ive effective turns. The gas temperature is 345K and inlet velocity is 20m/s. Also, the average particle size is 10μm with particle density 1.2 g/cm^3. The viscosity of air at 345K is 0.0745 kg/m-h.

Determine: (a) the cut diameter,d_{pc} ; (b) the separation factor, S; (c) Pressure drop at 15 ^{o}C and 1 atm (ρ_g = 1.2041 kg/m^3).

Is this a high efficiency cyclone?

Solution:

(a) The cut diameter is given by:

$$d_{pe} = \sqrt{\frac{9\mu_g b}{2\pi N_e v_i \left(\rho_p - \rho_g\right)}}$$

We can assume that $\rho_g << \rho_p$,

$$d_{pe} = \sqrt{\frac{9\times 0.745\times 0.15}{2\times\pi\times 5\times 20\times 3600\times 1200}} = 13.6\mu m$$

(b) The separation factor is given by:

$$S = \frac{v_e^2}{gr}$$

$$S = \frac{20^2}{0.25\times 9.81} = 16310$$

(c) The pressure drop is given by :

$$\Delta P = \frac{K\rho_g v_i^2 (ab)}{2D_e^2}$$

$D_e = 0.5D = 0.25$ m ,

$$\Delta P = \frac{13\times 1.2041\times 20^2\times 0.15\times 0.15}{2\times 0.25^2} = 1.878\, kpa$$

Since , d is less than d_{pc} .it is a high efficiency cyclone.

Problem 2: A fabric filter has 2000 m^2 of filter area and treats 15 m^3/s of air carrying a dust of concentration 0.015 kg/m^3.Assume K_1=25 kPa-s/m and K_2= 10^{-5} s^{-1}.If filter must be cleaned when pressure drop reaches 3.0 kPa, after what period must cleaning occur?

Solution: Given: filter area =2000 m^2, air flowrate=15m^3/s

Therefore filteration velocity , $v = \frac{25}{2000} = 0.0075 m/s$

Dust mass , $w = C_i v t$,

Where: C_i is the concentration of dust in air, kg/m^3

From equation:

$$\Delta P = \Delta P_f + \Delta P_d = K_1 v + K_2 v w$$

$$\Delta P = K_1 v + K_2 v w = K_1 v + K_2 v C_i t$$

$$t = \frac{3000 - \left(25000 \times 7.5 \times 10^{-3}\right)}{10^5 \times 0.015 \times 0.075^2} = 33300 s = 9.26 h$$

Problem 3: A bag house filter having 20 compartments, 360 bags per compartment and each bag of diameter 11 m and bag length 30m, with gas flow rate of 1,200,000 m^3/min. Calculate the gross and net air to cloth ratios .Assume that 2 compartments are out service when calculating the net air to cloth ratio.

Solution:

$$\frac{\text{air}}{\text{cloth}} = \frac{\text{gas flow rate}}{\text{fabric area}}$$

Given: Gas flow rate=1,200,000 m^3/min

(i) To calculate the total fabric area , calculate the bag area using equation for area of cylinder:

A=πdh

$$\frac{area}{bag} = 3.14(11)(30) = 1036.2 \frac{m^2}{bag}$$

(ii) Calculate the total number of bags.

$$total\ no.\ of\ bags = (360) \times 20 = 7{,}200$$

(iii) Calculate the total fabric area.

Total fabric area = 7200(1036.2) =7.46 x 10^6

(iv) Calculate the air to cloth ratio (gross).

Air/Cloth (gross) = (1200000/7.46 x 10^6)=0.161 m^3/min

The net air to cloth ratio is calculated by subtracting out the compartments which are not in filtering service.

(v) Calculate the total no. of bags services.

$$\text{Total no. of bags} = (360)\times 18 = 6480 \text{bags}$$

(vi) Calculate the total fabric area with 2 compartments out of service.

Total Fabric area = (6480) (1036.2) =6.714 x 10^6 m^2.

(vii) Calculate net Air/Cloth (with two compartments out of service).

Air/Cloth (net) =(1200000)/(6.714 x10^6) =0.178

Problem 4: Dust has particles with migration velocity of 0.25 m/s. For a total air flow of 65 m^3/s, what must be the number of collecting plates each having area of 50 m^2.Assume collection efficiency to be 95%.

Solution: Given: V_{pm} =0.15 m/s; Q = 65 m^3/s; $\eta = 0.95$; A = 50 m^2

$$\eta = 1 - \exp\left(\frac{-V_{pm}\times A_c}{Q_g}\right)$$

$$0.95 = 1 - \exp\left(-\frac{0.25\times A_C}{60}\right)$$

$$1 - 0.95 = \exp\left(-\frac{0.25\times A_C}{60}\right)$$

$$A_C = 718.8 m^2$$

A single plate offers a collecting area of 2 x 50 =100 m^2 (counting both sides)

$$\text{Number of plates} = \frac{\text{Total area of collecting electrode, } A_C}{\text{Area of single plate, A}} + 1$$

Need to add 1 because in the two terminal plates each offers only a single collecting side.

$$\text{Number of plates} = \frac{718.8}{100} + 1 = 8.18 = 8 \text{ PLATES}$$

Problem 5: An electrostatic precipitator having plates each of length =6 m, width =3 m with air flow rate of 2000 m^3/min and average particle diameter of 1 μm and average particle charge of 10e. Each plate is subjected to an electric field of 50,000 V/m.Calculate the number of plates required to achieve an efficiency of 99%.

Solution: Given: Q=2000/60 =33.33 m^3/s; E = 50,000 V/m; Area of single plate, A=2×6×3=36 m^2

Since one micron size is quite small, so Cunningham slip correction factor is included:

$$C = 1 + \left(\frac{2\lambda}{d_P}\right)\left(1.257 + 0.4e^{-\frac{0.55 d_P}{\lambda}}\right)$$

With d_p = 1μm and λ = 0.066 μm , C=1.166

Electric charge on each particle , q =10e =10 ×1.6 × 10^{-19} =1.6 × 10^{-18} C

Migration speed, V_{pm}

$$V_{pm} = \frac{1.6\times10^{-18}\times5\times10^{4}\times1.166}{3\times3.14\times1.81\times10^{-5}\times10^{-6}} = 5.47\times10^{-4} m/s$$

For an efficiency of 99% (η=0.99)

$$1 - 0.99 = \exp\left(-\frac{5.47\times10^{-4} A_C}{33.33}\right)$$

A_C = 280,898 m^2

$$\text{Required number of plates} = \frac{280898}{36} + 1 = 7803 \text{ PLATES}$$

UNSOLVED PROBLEMS

1. What is air pollution? Discuss the causes and effects.
2. Give the classification of air pollutants along with suitable examples.

3. Classify various sources of air pollutants and discuss the control methods for each of them. Give examples.
4. Discuss about the new emerging areas for air pollution control in India.
5. Enumerate and explain the mechanism used in removal of particulate matter from gas stream.
6. Explain the objective of using control equipments.
7. List the various types of control equipment used in particulate removal.
8. With a neat sketch explain the principle, construction and working of a gravitational settling chamber. Suggest methods to improve its efficiency. Give advantages and disadvantages.
9. Explain the working and the principle of a cyclone separator with a suitable diagram.
10. Give the advantages and disadvantages of a cyclone separator and give its applications.
11. What is a fabric filter? Give its classification and explain fibre characteristics.
12. Explain fabric filter system along with a neat sketch. Give its advantages and disadvantages.
13. With a neat sketch explain the principle, construction and working of an electrostatic precipitator along with its advantages and disadvantages.
14. What do you understand by wet gas scrubbing and where is it used?
15. Name widely used scrubbers in industries.
16. Explain in detail about plate scrubber including its effectiveness.
17. Provide working of packed bed scrubber by diagram and tell where is it most effectively used? Explain working and major differences between spray scrubber and cyclone scrubber. Provide diagram.
18. Give detail working of venturi scrubber and provide schematic diagram.
19. What do you understand by impingement baffle plate? What is its importance in impingement-entrainment Scrubber?
20. On which principle fluidized bed scrubbers work and where are they used?
21. What do you understand by wet gas scrubbing and where is it used?
22. Name widely used scrubbers in industries.
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24. Provide working of packed bed scrubber by diagram and tell where is it most effectively used? Explain working and major differences between spray scrubber and cyclone scrubber. Provide diagram.
25. Give detail working of venturi scrubber and provide schematic diagram.
26. What do you understand by impingement baffle plate? What is its importance in impingement-entrainment Scrubber?
27. On which principle fluidized bed scrubbers work and where are they used?
28. What do you understand by electrostatic precipitator and where is it used?
29. What are major requirements of electrostatic precipitator? Explain steps in this process.
30. Explain electrostatic process by schematic diagram.
31. Explain basic principle used in ESP.
32. What is electric breakdown? Show it by graph in case of ESP.
33. Tell the size of particle for which diffusion charging predominates.
34. Name any five types of electrostatic precipitators.
35. Explain in detail about single stage precipitators and two stage precipitators and give difference between these two.
36. What is difference between flat plate precipitators and tubular precipitators?
37. How does wet precipitator work?
38. Name major type of industries where ESPs are used.
39. What are major operational issues related to ESP?
40. What are advantages and draw backs of ESP?
41. Explain working of plate- wire precipitators.
42. What do you mean by migration speed and how migration and precipitation of particle take place in ESP?
43. What is the difference between absorption and adsorption?
44. Write properties of a gas stream for selection of a control system.
45. Explain difference between physical adsorption & chemical adsorption.
46. Define salient features of adsorption process.
47. What is operating adsorption efficiency and its usual range?
48. Name major type of adsorbent with their physical properties.
49. Explain major steps of adsorption process by diagram only.

50. Define isotherm and explain isotherm graph for carbon tetrachloride.
51. Explain difference between isobars and isostere.
52. Explain adsorption isobar for benzene on carbon by plot.
53. How are adsorbents regenerated? Explain method of regeneration of adsorbent.
54. What is displacement cycle and when is it used?
55. Write main factors affecting performance of adsorption system.
56. How solubility of contaminants affects adsorption and give law which explains equilibrium solubility of gas in liquid.
57. Explain working of spray tower and packing tower in detail.