Air Pollution Control Equipment
Homework Problems and Solutions Manual
Chapter 10: Electrostatic Precipitators - Problems

1. An increase in the collecting area of an electrostatic precipitator will
   a. increase flow rate
   b. decrease migration velocity
   c. have no effect
   d. increase efficiency

2. A major advantage in using an electrostatic precipitator is that the force for collection is
   a. impaction on the collection plate, resulting in good collection efficiency
   b. centrifugal, causing particle collection on the walls of the chamber
   c. interception on the discharge electrode
   d. applied only to the particle, enabling low pressure drops through the collector

3. The specific collecting area of an electrostatic precipitator is given by
   a. the electrical wind
   b. migration velocity
   c. resistivity of the particle
   d. area divided by the gas volume flow rate

4. Particles are charged in an ESP by
   a. subjecting the particles to high humidity
   b. corona produced by the discharge electrode when a high voltage is applied
   c. positive corona generated by the collection electrode
   d. an intense electrical field created by applying a-c voltage to the discharge wire

5. Give 5 reasons why the Deutsch equation of electrostatic precipitation usually cannot be used to accurately predict efficiencies in practical cases.

6. Provide advantages of ESPs.

7. Discuss the design of the discharge electrodes.

8. Discuss the design of the collection plates.

9. Briefly describe resistivity's impact on electrostatic precipitator design and performance.

10. Discuss the shell structure of an ESP.

11. A 10,000 acfm gas laden with 12.0 gr/ft^3 of particulate impurities passes through an ESP operating at 98.5% efficiency. There are 12 plates in the precipitator; each plate is 20ft high and 20ft deep.
    a. Calculate the drift velocity.
    b. Calculate the outlet loading in gr/ft^3.

12. Refer to problem 10.11 above

    a. Suppose the flow rate is increased to 16,000 acfm. What is the new outlet loading and efficiency?
    b. What design adjustments would have to be made to achieve the original outlet loading?

13. An electrostatic precipitator is being designed to operate at an efficiency of 97%. Using the modified Deutsch-Anderson equation, calculate the area of each plate for exponents of 0.4, 0.6 and 0.7 for the modified Deutsch equation. The following information is given:
    Volumetric flow rate = 10,000 acfm (evenly distributed)
    Drift velocity = 0.5 ft/s
    Plate spacing = 6 in
    Number of ducts (passages) = 20

14. A horizontal parallel plate electrostatic precipitator consisting of three gas passages 16 ft. high x 16 ft. deep with a12 in. plate spacing is to treat 19,200 acfm of air containing 2.2 gr/ft^3 of carbon black. Using an average drift velocity for the system, calculate the collection efficiency of the unit. Assume the carbon black particle-size distribution may be represented by an average particle diameter of 20 μm. Assume an average drifty velocity of 0.2723 ft/s.

15. Obtain the collection efficiency for the unit described in Problem 14 if the particle-size distribution and drift velocity are employed. The following data is provided:

Wt % < d_p	Wt %	Mean particle diameter (μm)	Drift velocity (w_i) (ft/s)
10	10	8.2	0.165
50	40	15.0	0.232
90	40	26.3	0.307
>90	10	49.0	0.397

16. Obtain the collection efficiency for the unit described in Problem 14 if both particle-size distribution data and drift velocity variation from theory are employed in the calculation.

17. Due to a rapid expansion just before the inlet to the precipitator, the velocity profile is not fully developed. The result of this is that the volumetric flow rate of the middle duct is twice the rate in the outer duct. Calculate a revised collection efficiency for the unit described in Problem 14 under these conditions. Use the same average particle-size and drift velocity.

18. Further complications are introduced to the calculations because of variations in the particle-size distribution at the inlet to the precipitator. Due to inertial effects, none of the particles larger than 40 μm enter the outer passages. The remaining (smaller) particles, however, are uniformly distributed. Calculate a revised collection efficiency for the unit described in Problem 14 under these conditions. Use an appropriate average drift velocity for each passage. It is known that 10 wt% are greater than 40 μm and that $\langle d_p \rangle_o$ at 50 wt% for the remaining particles under 40 μm is 18.9 μm.

19. Outline a method to calculate the collection efficiency for the Problem 14 unit if particle-size distribution and flow rate variations exist in both the horizontal and vertical direction.

20. As a recently hired engineer for an equipment vendor company, you have been assigned the job of submitting a preliminary (process) design of an electrostatic precipitator to treat 78,000 acfm of gas with solids from a gypsum plant operation. The inlet loading of 33.46 gr/ft^3 is to be reduced to 0.50 gr/ft^3. Submit your design.

21. An electrostatic precipitator is to be designed for a collection efficiency of 99.5% for a 250 megawatt coal-fired power plant. The gas flow rate upstream of the air heater is 215,000 lb/hr at 700^{o}F. The downstream temperature is 330^{o}F and the air heater in-leakage is 8%. The flue gas density in either case may be assumed to be 0.075 lb/ft^3 at 70^{o}F. An electrostatic precipitator upstream of the air heater can be sized with a migration velocity of 9 cm/s. A precipitator downstream of the air heater must be sized according to the coal sulfur content.

Percent sulfur in coal	0.5	1.0	2.0
Specific collecting surface area for 99.5% efficiency (ft^2 / 1000 acfm)	400	330	230

The cost of an installed precipitator per ft^2 of collecting surface is $12 upstream of the heater and $10 downstream.

a. Select the size of a precipitator for location upstream of the air heater.
b. Select the size of a precipitator for location downstream of the air heater for coal with 0.5, 1.0, and 2.0% sulfur.
c. Evaluate the cost of the precipitator for each location in (b) and calculate the cost of the precipitator vs. the sulfur content of the coal.
d. Where should the precipitator be located? Present arguments for each location.