

INTRODUCTION TO ENVIRONMENTAL ENGINEERING

HOMEWORK #6

Assigned: Friday 11 November 2011

Due: 10:00 a.m., Friday 18 November 2011

1. (10 points) (Mihelcic & Zimmerman, Problem 12-17) A $20 \text{ m}^3/\text{s}$ airstream from a cement kiln carries $120 \text{ mg}/\text{m}^3$ of particulate matter to an electrostatic precipitator for air-quality control. The ESP has four plates, each measuring 8 m by 5 m. The particles have a drift velocity of 0.15 m/s. Estimate the particle concentration in the ESP exhaust (mg/m^3).
2. (10 points) An electrostatic precipitator with $6,000 \text{ m}^2$ of collector plate area is 97% efficient in treating $200 \text{ m}^3/\text{s}$ of flue gas from a 200 megawatt power plant. How much more plate area would be required to increase the efficiency to 98% and to 99%, with unchanged voltage? Alternatively, if the plate area must remain constant (because the ESP has already been built), by how many percents does the voltage have to increase to reach the same efficiencies of 97% and 98%? Assume that the various particles all share the same drift speed.
3. (10 points) Determine the total plate area required for a 97% efficient electrostatic precipitator treating $150 \text{ m}^3/\text{s}$ of dusty air. Air viscosity is $1.81 \times 10^{-5} \text{ kg}/\text{m}\cdot\text{s}$, and the electrical field is $8 \times 10^5 \text{ V}/\text{m}$. Assume that half the particles (on a mass basis) have a diameter of $0.50 \text{ }\mu\text{m}$ and acquire 12 electrons, and the other half have a diameter of $0.60 \text{ }\mu\text{m}$ and acquire a charge of 17 electrons.
4. (10 points) A flue-gas desulfurization unit (scrubber) removes 95% of the SO_2 from combustion fumes containing 0.5% of sulfur dioxide (moles of SO_2 per moles of gas) blowing at the rate of $4.75 \text{ m}^3/\text{s}$ at a temperature of 25°C and pressure of 1 atmosphere. What are the inlet and outlet values of the variable Y (moles of SO_2 per kg of gas), the gas flow rate V (in kg/s) and the minimum possible liquid flow rate L necessary (in kg/s)? [*Hint:* The gas is almost pure air, with molecular weight of 28.8 grams per mole. For the chemical conversion factor, take $c = 6$.]
5. (10 points) A scrubber is designed to operate with $V = 12 \text{ lb}/\text{s}$, $L = 21 \text{ lb}/\text{s}$, gas density = $0.0728 \text{ lb}/\text{ft}^3$, liquid density = $62.15 \text{ lb}/\text{ft}^3$, and liquid viscosity = 0.80 cp . The packing material consists in 1-inch Berl Saddles. What is the flooding gas velocity?

If the gas velocity is set at 50% of the flooding value, what should be the inner diameter of the tower?

6. (10 points) Summarize in a couple of paragraphs the scrubber technology described on the YouTube video titled “New scrubber online at Gulf Power’s Plant Crist in Pensacola”, at:

<http://www.youtube.com/watch?v=EGNa5pioGUg>

Which fumes are being treated? How much of what chemicals is being removed? What is innovative about the way water is being used? What is the cost of the installation?