

ENVR 754 Air Pollution Control Laboratory on Electrostatic Precipitator Performance

Objectives

The purposes of this laboratory are:

- (a) to measure the fractional efficiency curve for an electrostatic precipitator,
- (b) to determine how the efficiency curve changes with changes in air flow through the precipitator, and
- (c) to compare the results of these measurements with theory.

Background

The electrostatic precipitator used in this lab was developed to sample semivolatile aerosols – particles that exist in equilibrium with their vapor in such a way that a significant fraction is both in the vapor phase and in the droplet phase simultaneously. Hydrocarbons about C16 in length are semivolatile at room temperature. Because vapor pressure varies with temperature, hydrocarbons that are non-volatile or semivolatile at one temperature may be volatile at higher temperatures; similarly, volatile hydrocarbons become semivolatile or non-volatile if the temperature is low enough.

Sampling semivolatiles accurately is difficult because these compounds partition back and forth between the vapor and droplet phases according to local conditions. For example, if a filter is used to collect droplets of a semivolatile compound, the droplets can evaporate from the filter if the air passing through becomes unsaturated with vapor, if the temperature increases, or both. Methods to sample semivolatiles have received considerable study. Two of our doctoral students, Al Armendariz and John Volckens, did their PhD research on this topic.

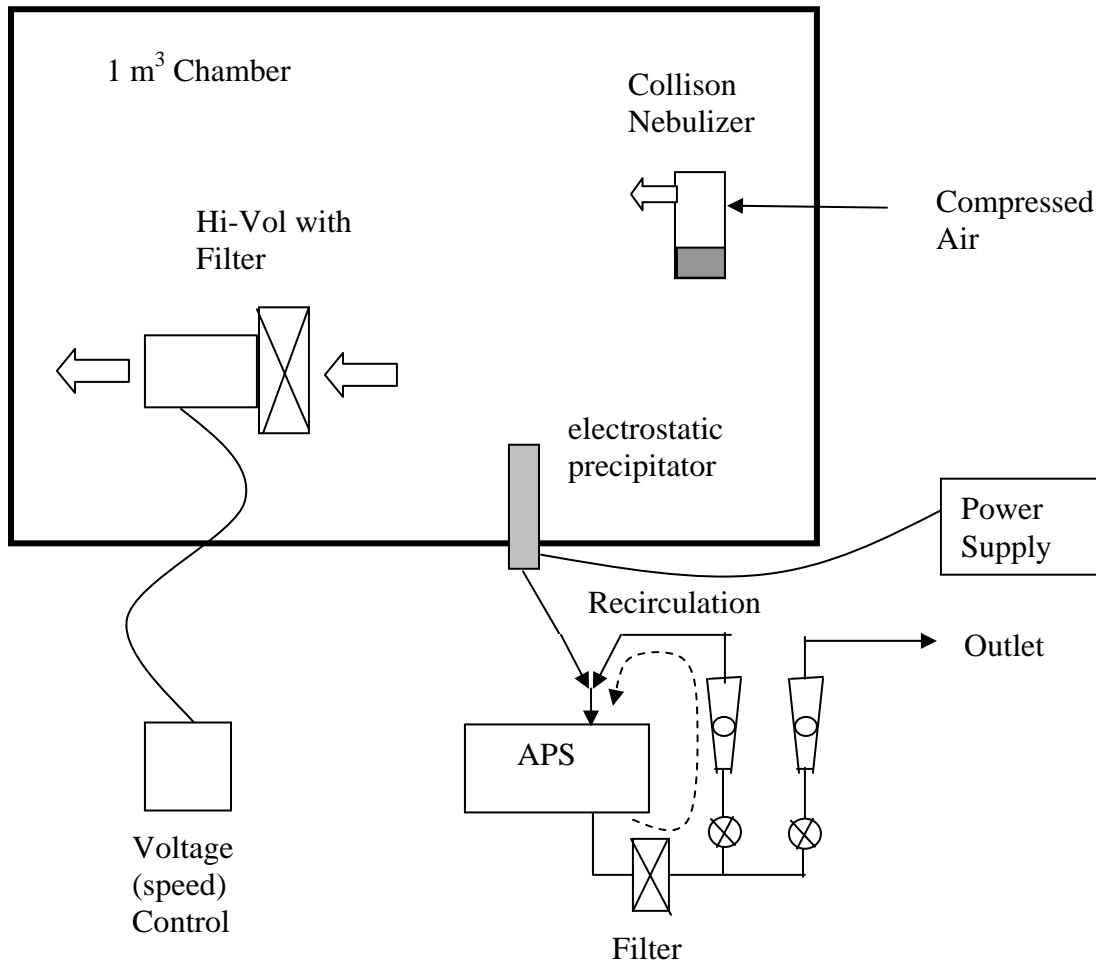
The electrostatic sampler you will evaluate in this lab is intended to collect semivolatile droplets in a way that helps prevent their subsequent evaporation. Droplets that collect in the precipitator are separated from the air stream, so are less affected by changes in the saturation state of the passing gas. Also, collected droplets coalesce on the walls of the precipitator to form a liquid film that has much less surface area than the individual droplets, with the effect that evaporation is again reduced.

The electrostatic sampler you will evaluate here was developed to assess exposure to oil mist produced from metalworking fluids used in the auto industry. This sampler was also used to assess exposure to mist of unburned jet fuel produced when Air Force jet engines start up in cold weather. The jet fuel, mainly kerosene, is mostly in the droplet phase when produced in cold climates. But mist droplets sampled using a filter outdoors in cold weather will evaporate when the filter is brought indoors to weigh in a warm lab.

For more background on these topics see the articles listed at the end of this writeup.

Procedure

The procedure for this lab will be similar to the one we used to measure cyclone performance earlier this semester. We will use the Aerodynamic Particle Sizer (APS) model 3321 to measure the efficiency of the precipitator. A schematic drawing of the setup is shown below.



Look at the electrostatic precipitator. Measure the inside diameter and length of the collection tube. The diameter of the central wire electrode is 0.020". Without air flow going through the precipitator, turn on the power supply and look briefly at the blue corona that forms at the end of the central electrode. Do not look for long; the corona produces UV light that contributes to formation of cataracts on the eye. Sniff the inlet of the precipitator and notice the smell of ozone. This precipitator uses positive corona that produces less ozone than negative corona, but some ozone does form.

Note that the APS has an internal pump and mass flow controllers that will maintain flow through the APS at 5.0 Lpm under all conditions. We wish to sample through the electrostatic precipitator at flows of 2, 3, and 4 Lpm. To accomplish this, we can recirculate part of the flow through the APS so that its 5 Lpm flow will be maintained.

The difference between the recirculated flow and the 5 Lpm flow through the APS will be the flow through the electrostatic precipitator. The flow through the precipitator will exit through the Outlet line, where its value can be read using the rotameter on that line. The sum of the flows from the rotameters on the Recirculation line, and the Outlet line, will always total 5 Lpm.

Follow the steps below to manage the system.

1. Generate an oil mist aerosol using the Collison nebulizer. Pressure to the nebulizer should be about 6 psig.
2. The Hi-Vol has a filter that will remove aerosol and allow control of the concentration. Adjust the voltage to the Hi-Vol until the concentration measured by the APS, when sampling with the electrical power to the precipitator turned off, is about 500 particles/cm³.
3. We will determine the effect of the electrostatic collection by turning on and off the power for the electrostatic precipitator. With everything else the same, the effect of electrostatic collection can be determined by turning the power on.
4. To increase flow through the electrostatic precipitator, close the valve on the Recirculation line and open the valve on the Outlet line.

To conduct an experiment, first establish the desired flow through the electrostatic precipitator. Be sure the power to the precipitator is turned off to start. Measure the concentration and size distribution of the aerosol that goes through the turned-off precipitator and to the APS. A one-minute sample is sufficient. Then turn the precipitator on and repeat the measurement. Make five measurements as follows:

- (1) no power, (2) power, (3) no power, (4) power, (5) no power (1)

Then change the air flow through the precipitator and repeat the APS measurements at each of the three flow conditions: 2, 3, and 4 Lpm.

Data Processing

Download all data from the APS into an Excel file. For data at each flow, calculate electrostatic precipitator penetration as a function of particle size by taking the ratio of particle counts with power on divided by counts with power off.

$$Pt(d) = \frac{N(d)_{\text{power on}}}{N(d)_{\text{no power}}} \quad (2)$$

where $P_t(d)$ is penetration for particles of size “d”, $N(d)_{\text{power on}}$ is the number of particles of that size counted in one minute with the power turned on, and $N(d)_{\text{power off}}$ is the number of particles of that size counted in one minute with the power turned off.

By making five measurements in the order given by line (1) above, you will be able to determine four values for penetration for particles of each size, one for each pair of measurements. That is, your first penetration measurement will come from (1)/(2), the second from (3)/(2), then (3)/(4) and (5)/(4). From these measurements, determine the average penetration and the standard deviation, for particles of each size.

Repeat these measurements for all three flows through the electrostatic precipitator. Note that the rotameters in this lab utilize units of ft^3/hr .

Report

Outline briefly what you did. Plot collection efficiency versus particle diameter for the electrostatic precipitator. Make three figures, one for each air flow. Plot confidence intervals for your data from the four efficiency measurements.

Calculate the expected efficiency for the electrostatic precipitator according to theory we discuss in class. Plot theoretical efficiency at each air flow on the same three figures.

Your report must not exceed three pages. The first page should contain only your name, the date, and a brief paragraph that summarizes your work and findings. The second and third pages should present your results, including your figures. You may attach appendices if necessary to present your data or details of your calculations.

Background Material

McAneny, John J., David Leith and Maryanne G. Boundy, “Volatilization of Mineral Oil Mist Collected on Sampling Filters”, *Appl. Occup. Environ. Hyg.*, **10** (9): 783-787 (1995).

Leith, David, Frank A. Leith and Maryanne G. Boundy, “Laboratory Measurements of Oil Mist Concentrations Using Filters and an Electrostatic Precipitator”, *Am. Indust. Hyg. Assoc. J.*, **57**: 1137-1141 (1996).

Volckens, John, Maryanne Boundy, David Leith and David Hands, “Oil Mist Concentration: A Comparison of Sampling Methods”, *Am. Indus. Hyg. Assoc. J.*, **60**: 684-689 (1999).

Armendariz, Alfredo J., David Leith, Maryanne Boundy, Randall Goodman, Les Smith and Gary Carlton, “Development and Field Demonstration of an Electrostatic Personal Particle Sampler”, *Am. Indust. Hyg. Assoc. J.* **64**: 777-784, (2003).