History of Electrical Precipitation

Date	Significance
1600	William Gilbert, English court physician, publishes *De Magnete*
1745	Benjamin Franklin describes the effects of points "in drawing and throwing off the electric fire."
1824	M. Hohlfeld, German mathematician, describes the precipitation of fog in a jar containing an electrified point
1878	R. Nahrwold notes that the discharge from an electrified sewing needle surrounded by a tin cylinder greatly increases the collection of atmospheric dust. Nahrwold repeats the experiment with a glycerin coating to help particles adhere.
1885	Sir Oliver Lodge attempts, unsuccessfully, to remove lead fume from from a smelting works in North Wales

History of Electrical Precipitation

- Frederick Cottrell
  - Incorporated more reliable rectifier transformer circuits in ESP design - able to sustain higher voltages
  - Successfully collected sulfuric acid mist in Berkeley, CA laboratory in 1906
  - First successful commercial precipitator used to collect H_2SO_4 in Pinole, CA 200 cfm capacity
  - 1912, large scale ESP used to collect cement kiln dust at 1,000,000 cfm in Riverside CA

Frederick Cottrell
1877 - 1948

Source: U.S. Department of Agriculture

Advantages to Electrical Precipitation

Electrostatic Precipitators (ESPs):

- collect particles from 0.01 μm to 100 μm with 99% efficiency
- operate at high temperatures, up to 1200° F (650° C)
- operate at high gas pressures, up to 150 psi (10 atm)
- operate at high flow rates, up to 3,000,000 cfm (1500 m^3/s)
- operate at high particle loadings, 500 grams/m^3
- have low energy costs, 200 – 1000 Watts/1000cfm
- have low pressure drop

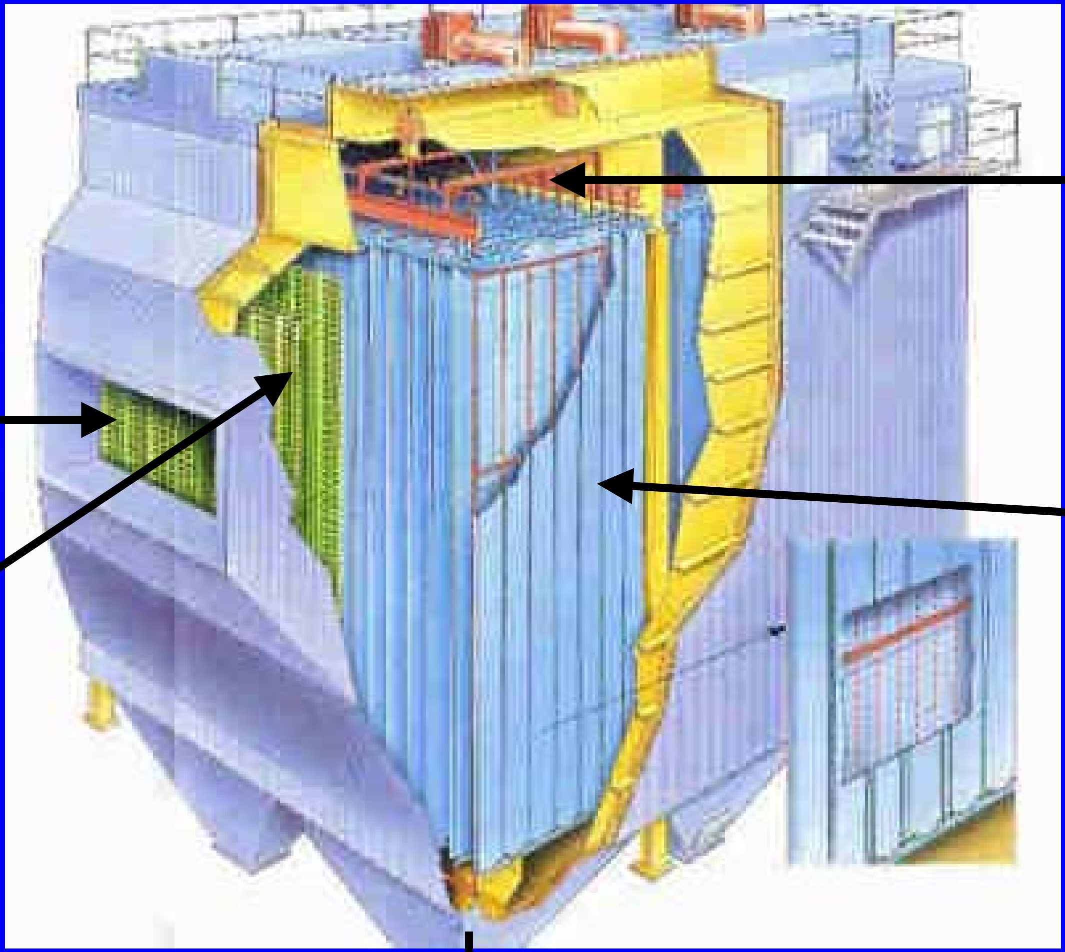
ESPs can be used when:

- large volumes of particulate air pollutants are produced
- no explosion hazard exists
- high efficiency needed
- continuous processes (expensive to build but inexpensive to operate)

Industries and their pollutants where ESPs are commonly used

Process	Principal Material Collected
Electrical Utility	Fly Ash (SiO_2, Al_2O, Fe_2O_3)
Industrial Boiler Houses	Fly Ash
Steelmaking Furnaces	Iron Oxide (Fe_2O_3)
Cement Kilns	Calcium Oxide, Silicon Oxide
Pulp and Paper	Sodium Sulfate
Metal Machining	Oil Mist

Multi-stage wire-plate ESP



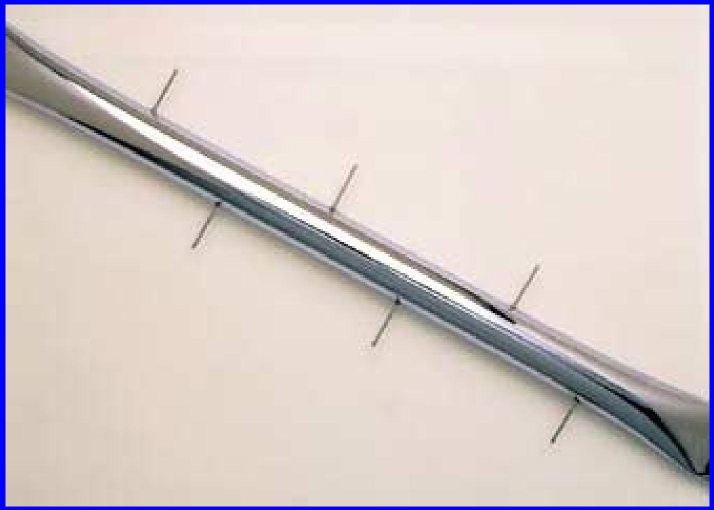
Electrical Precipitators in use

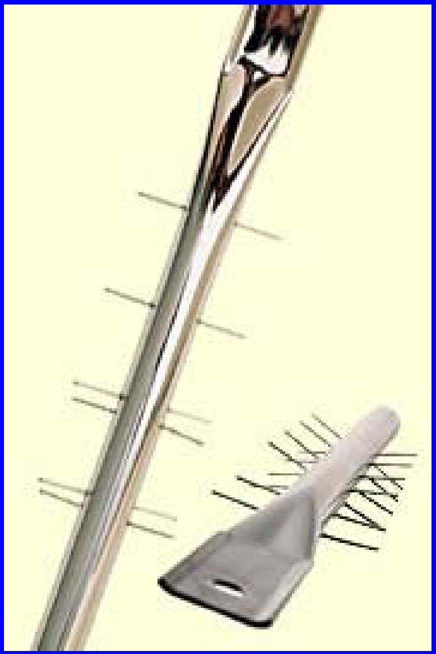
Wire plate type design

Electrical Precipitators in use

Courtesy of Dr. Wayne T. Davis, Univ. of Tennessee
http://members.aol.com/apcutk/esp.htm

Examples of discharge electrodes





Courtesy of Dr. Wayne T. Davis, Univ. of Tennessee

http://members.aol.com/apcutk/esp.htm

Practical considerations: Removing collected dust

- Collected particles must be disposed of properly
- Dust coated electrodes can
  - lower electric field strength
  - increase likelihood of spark
  - cause back corona
- Result: *Decreased collection efficiency*
- Methods used to clean collecting plates
  - Wire - cylinder design: washing
  - Wire - plate design: rapping

Practical considerations:
Removing collected dust: Rapping

Collecting plate rapping

Electrode rapping

Courtesy of Dr. Wayne T. Davis, Univ. of Tennessee
http://members.aol.com/apcutk/esp.htm

Practical considerations: Dust resistively

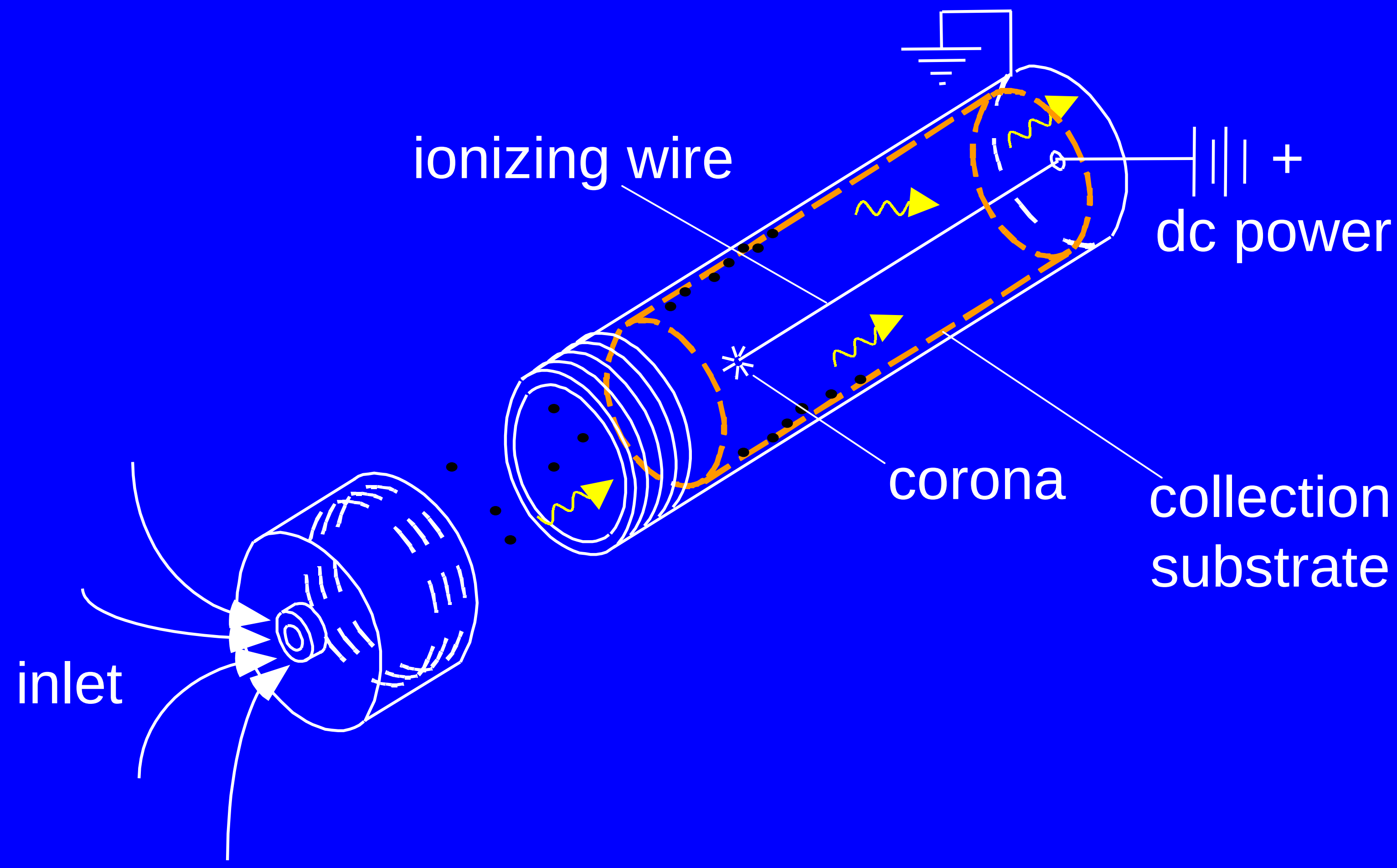
- Highly insulated particles are poor conductors
  - Resistive to charging
  - Not easily collected
- Particle resistivity (Ω-cm) related to:
  - Elemental composition
  - Moisture content of air
  - Gas temperature
  - Above 10^{10} Ω-cm, particle collection becomes difficult
- Conditioners
  - Added to gas stream to increase particle conductivity
  - Examples include: H_20, NH_3, H_2SO_4

Practical Considerations: Particle re-entrainment

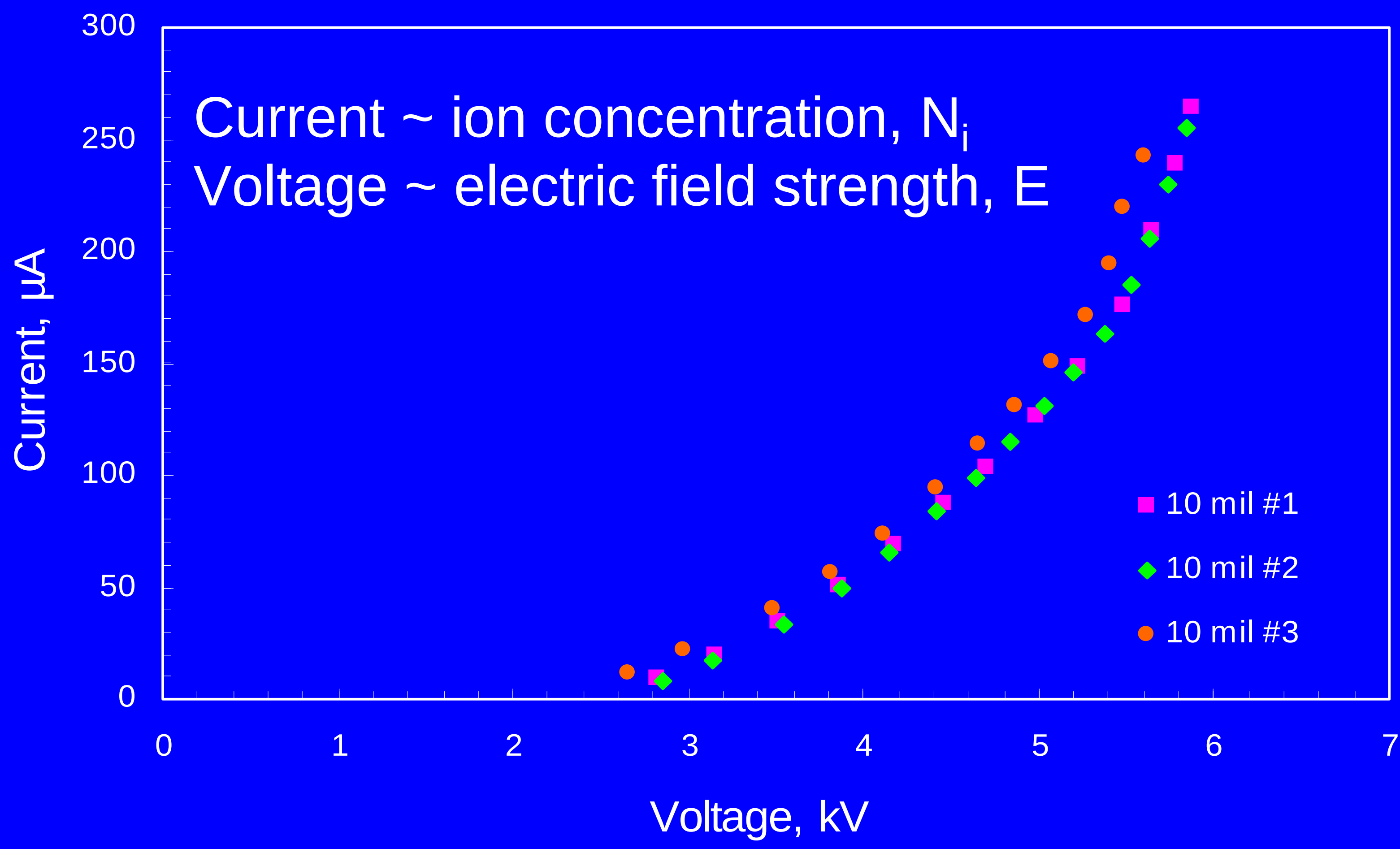
- Re-entrainment occurs when collected particles are re-released into the air stream
- Sources of re-entrainment:
  - Highly turbulent flow – velocity concentration
  - Rapping – observed as ‘puffs’ exiting the precipitator
  - Back corona

Take 5!

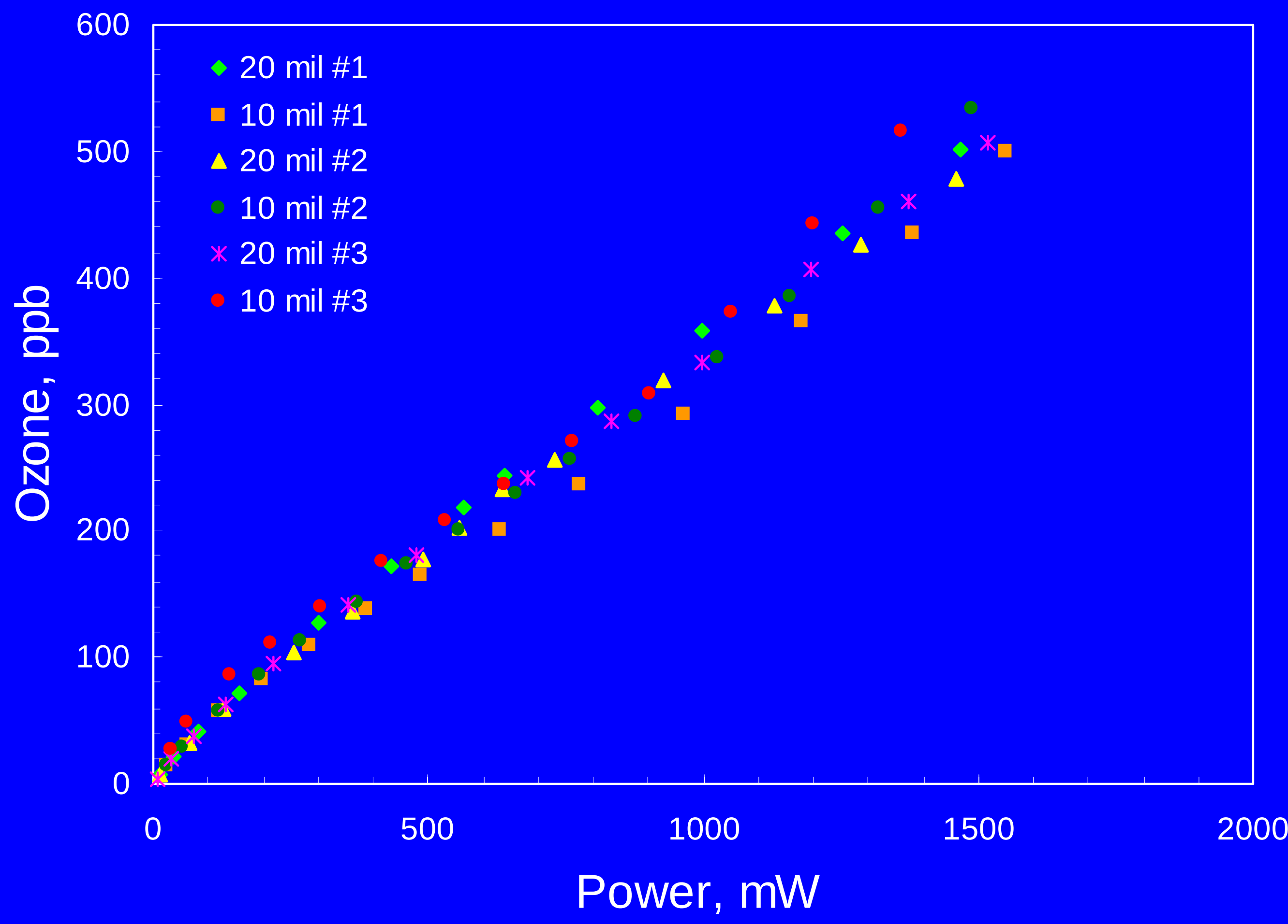
Personal ESP sampler developed at UNC



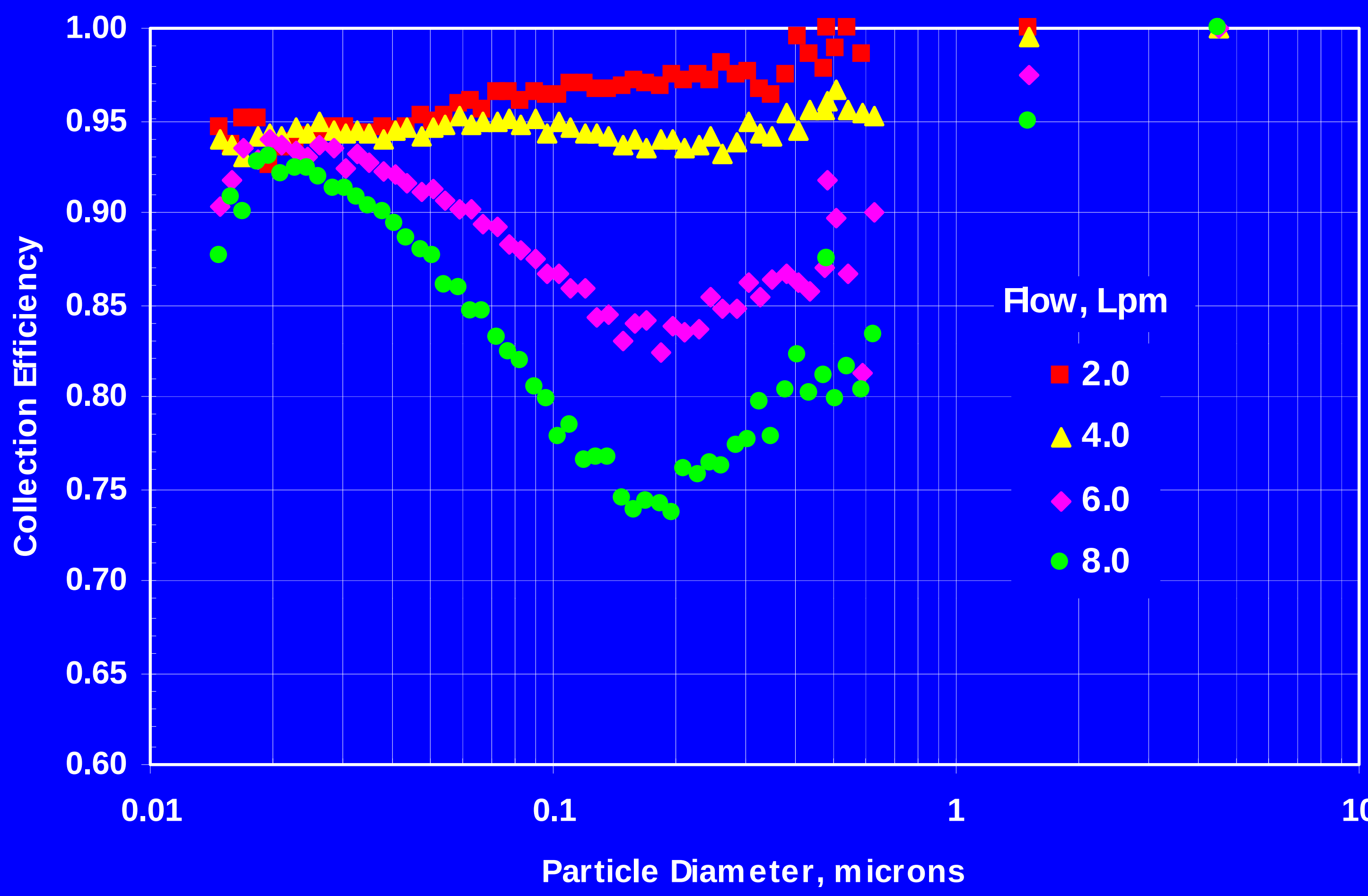
ESP sampler current-voltage characteristics



Ozone output vs. ESP power



ESP collection efficiency vs. flow

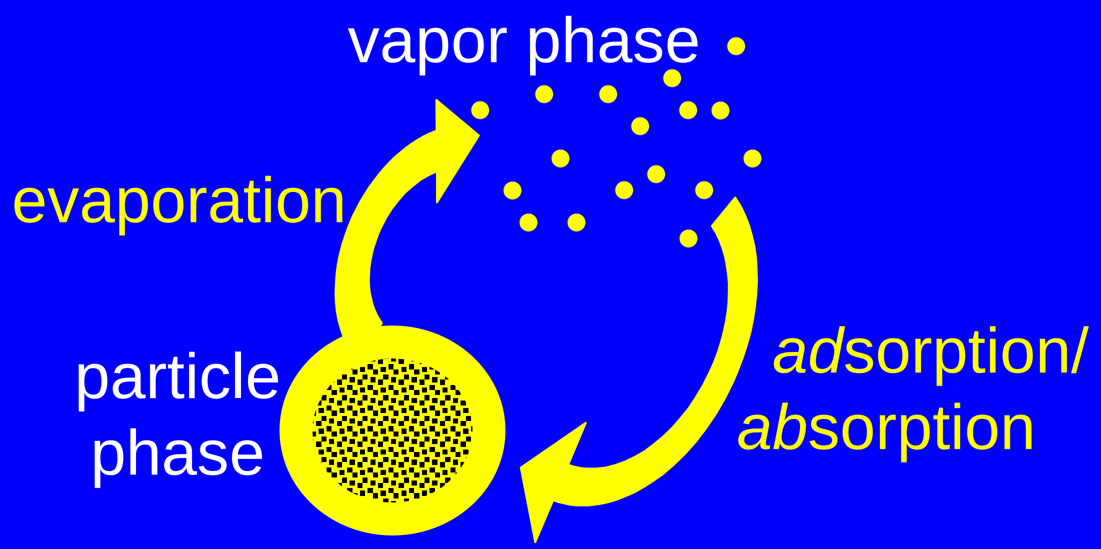


Review: Semi-Volatile Compounds

10^{-8} torr < vapor pressure < 10^{-2} torr

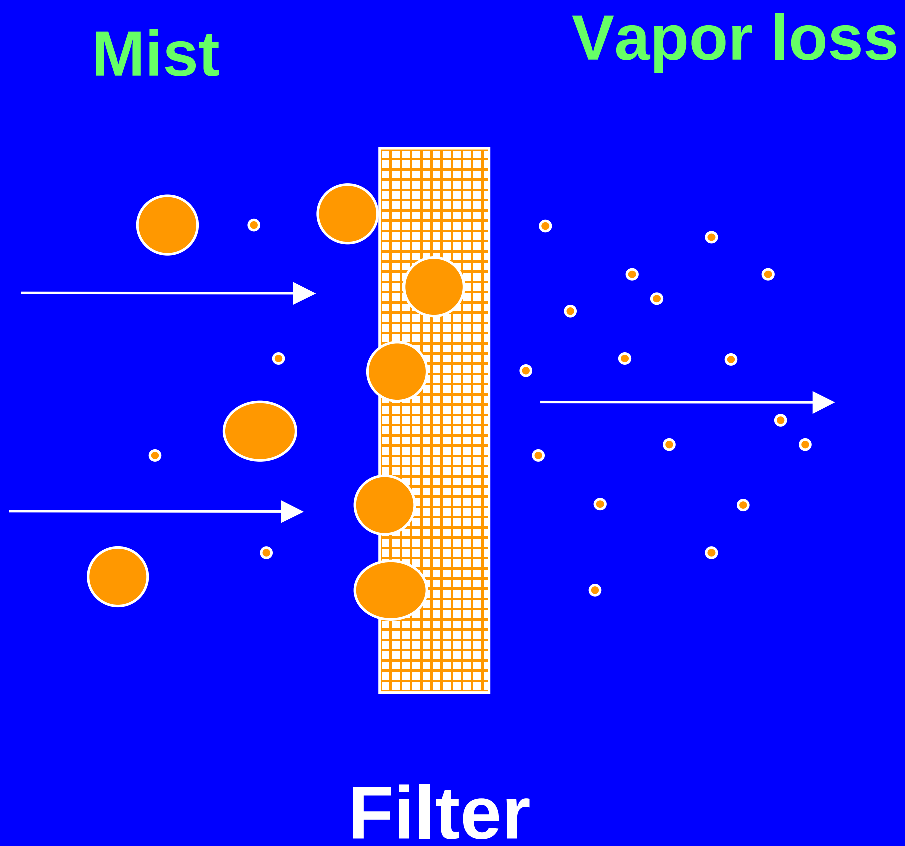
<u>Semi-volatile aerosols:</u>

- exist in both particle and vapor phases
- can readily transfer mass between phases
- important for exposure – health effect studies
- lung deposition behavior
- atmospheric transport
- emission regulations



Filters cannot sample semi-volatile mists accurately

- Metalworking fluids are semi-volatile
- Particles evaporate from filter over time
- Underestimation of worker exposure



ESP Advantages, Disadvantages

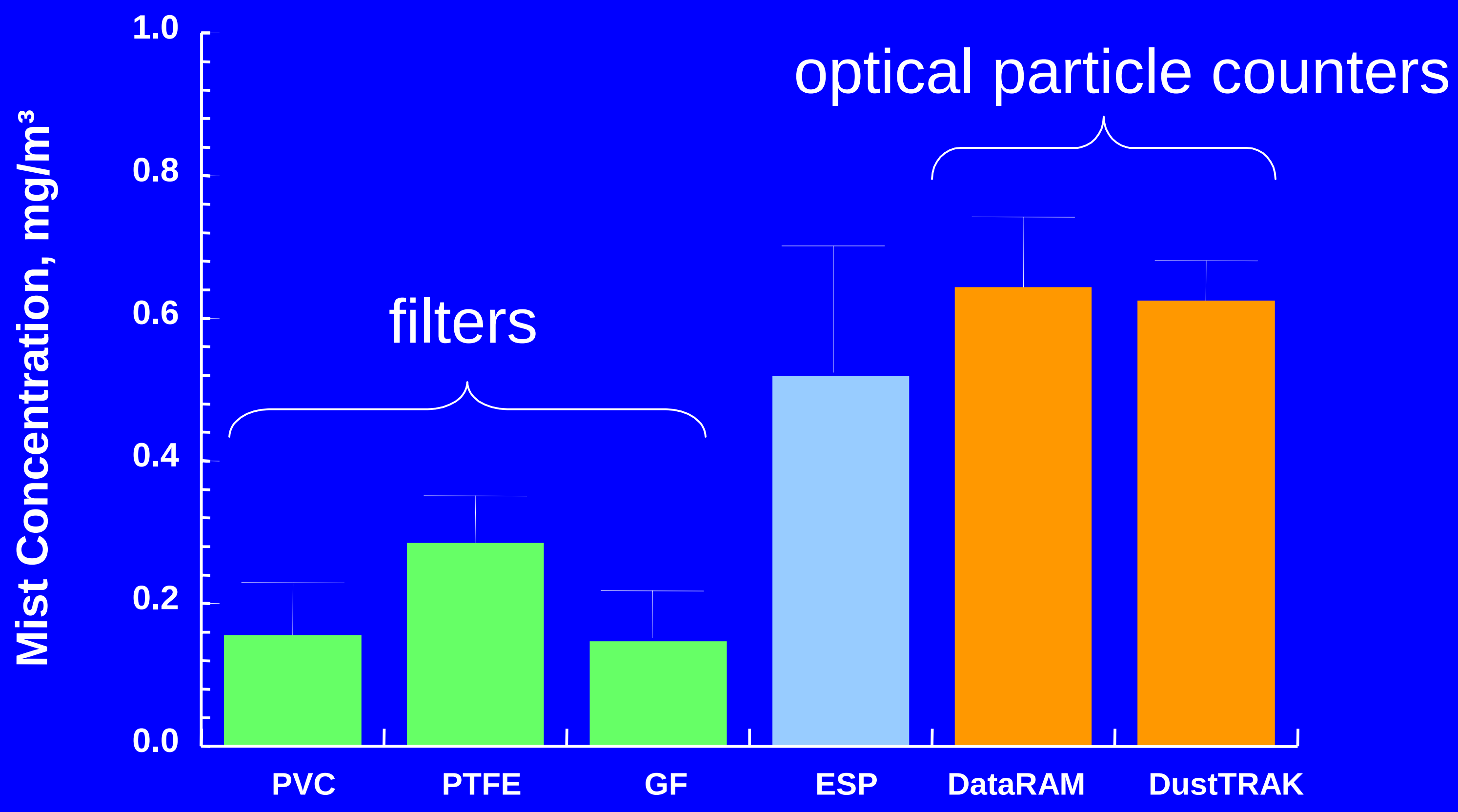
Advantages

- Collection substrate has low surface area
  - lower vapor adsorption artifact
- Collected particles coalesce together
  - less potential for particle evaporation artifact

Disadvantages

- Corona discharge generates $\mathbf{O_3}$
  - some potential for chemical artifact

Comparison of sampling methods for mineral oil mist



Sampling semi-volatile aerosols

Sampling semi-volatile aerosols

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