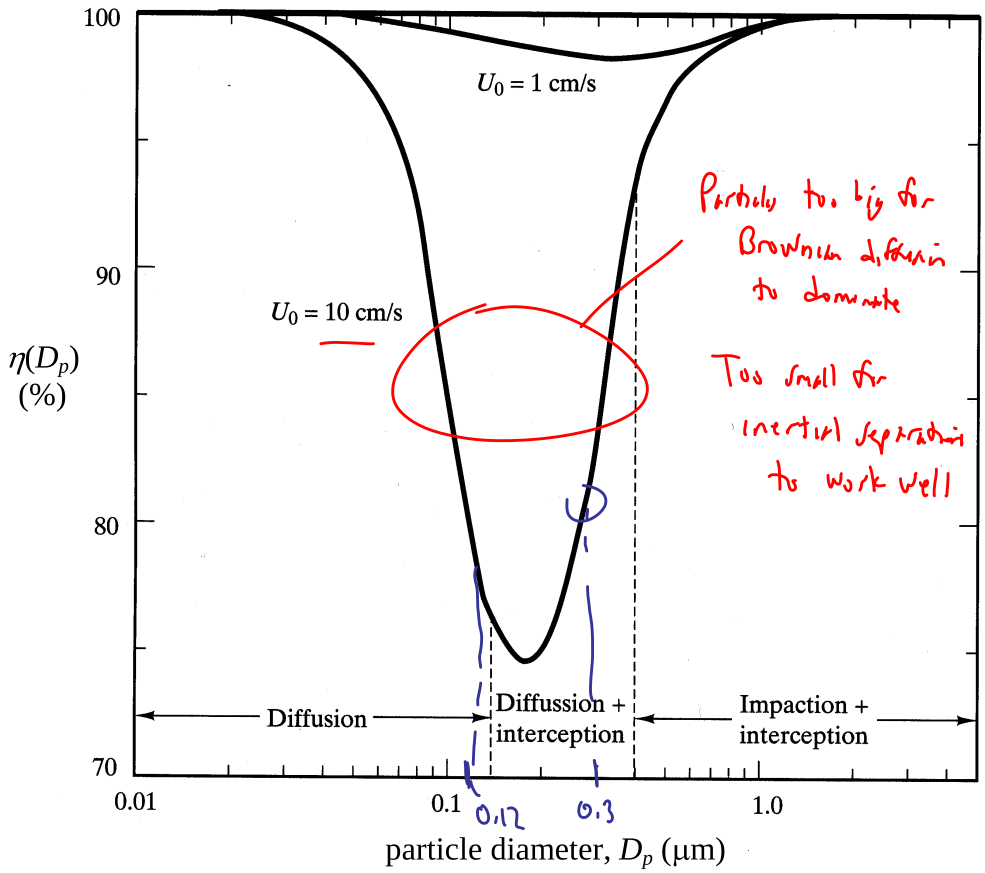
Today, we will:

- Define **HEPA** and **ULPA** air filters, and **pleated air filters**
- Discuss **baghouses** and various ways to remove dust cakes from the bags
- Briefly discuss **electrostatic precipitators** (**ESPs**)
- If time, begin discussing **particle statistics** and **particle distributions**

Example from a real air filter, showing the "dip" around 0.1 to 0.5 microns:

We use $E(D_p)$ instead of $\eta(D_p)$ →



Filter grade efficiency for two face velocities; filter thickness H = 1.0 mm, solids fraction f_f = 0.05 (porosity ε = 0.95), single fiber diameter D_f = 2 µm (adapted from Hinds, 1982).

Range from ≈ 0.02 to 0.5 µm are very hard to filter

HEPA filters = High Efficiency Particulate Air Filter

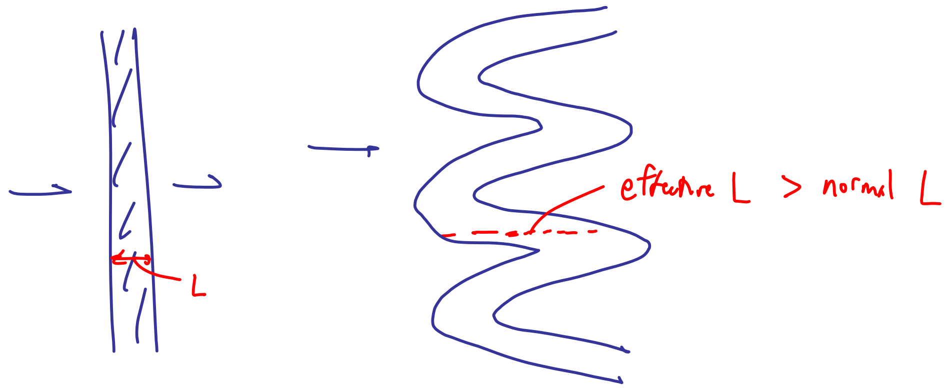
$E(D_p) > 99.97\%$ for $D_p = 0.3$ µm

ULPA filters = Ultra Low Penetration Air Filter

$E(D_p) > 99.999\%$ for $D_p = 0.12$ µm

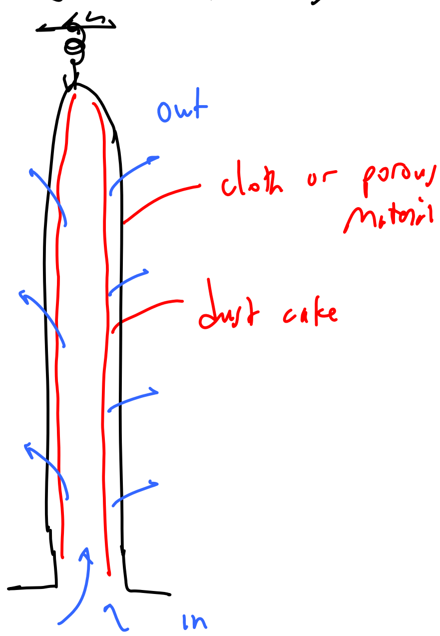
∴ Small fibers
long length

Pleated Filters



Large-scale applications of air filters

- **Baghouse** — e.g. coal plants, limestone & cement kilns



- Dusty air coming in must be dry
- "Friable" means dust cake is easy to break apart & remove
- Dust cake must be cleaned off every so often

How?

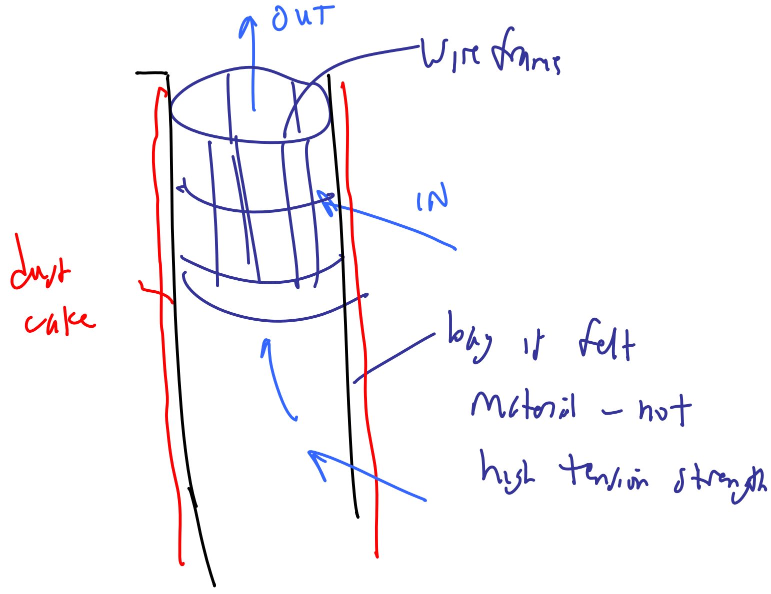
Shaking → mechanical device @ top to shake the bags

Reverse air flow (collapses the bag & breaks up dust cake)

→ dust falls down into a hopper

Must clean every few hours

Pulse-jet baghouse



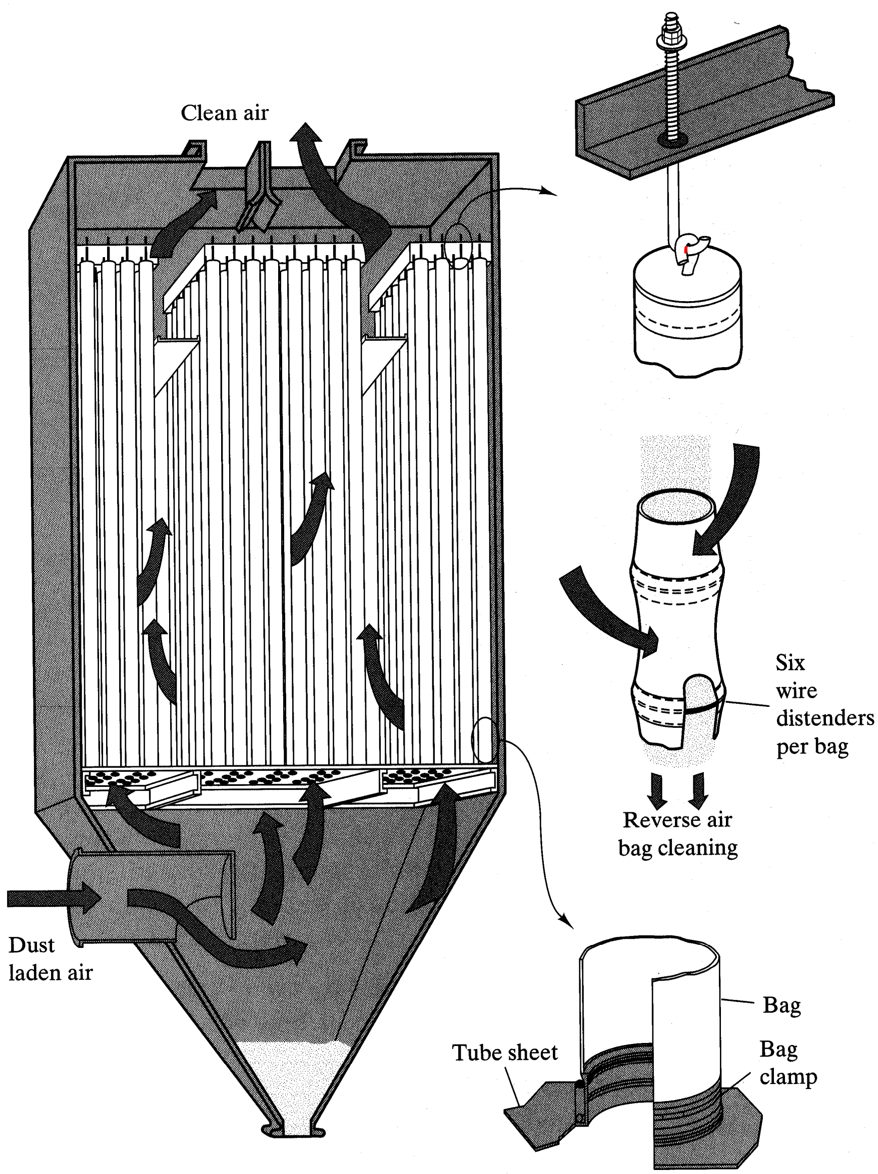
Pulse of air backwards every few minutes

PSU currently has a reverse-flow baghouse (the big brown building)

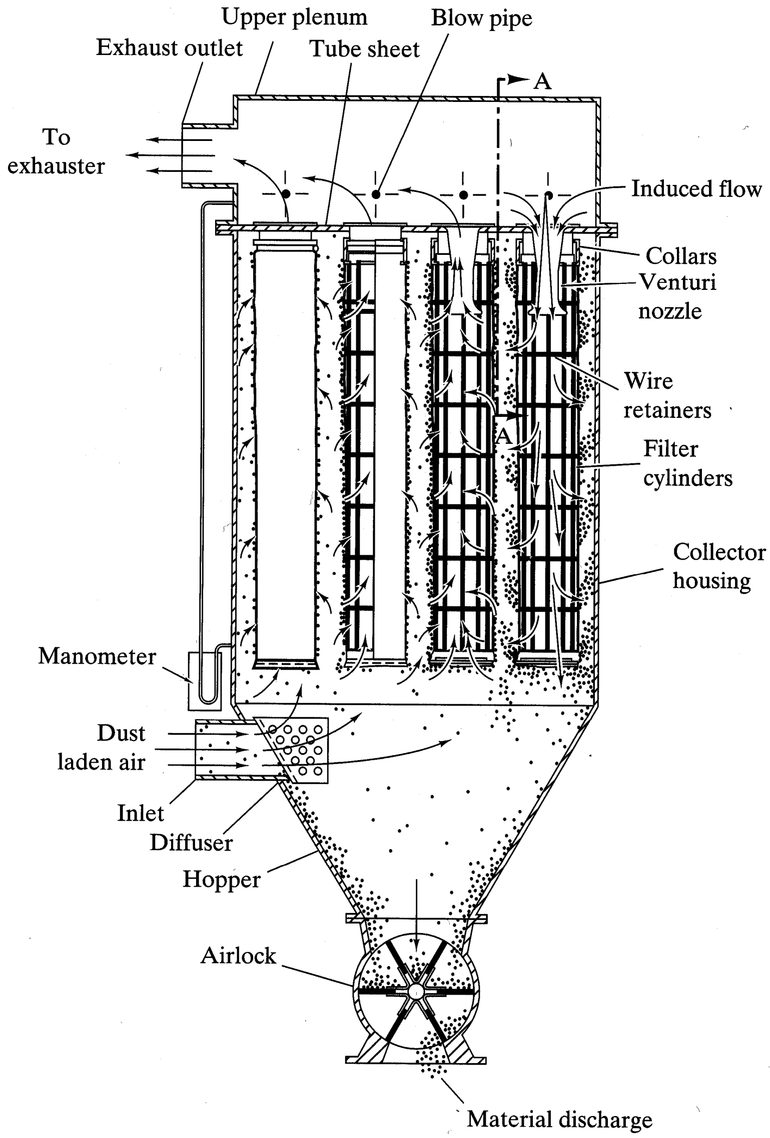
AND

a pulse-jet baghouse (a smaller unit in the other building)

Reverse-flow baghouse:



Pulse-jet baghouse:

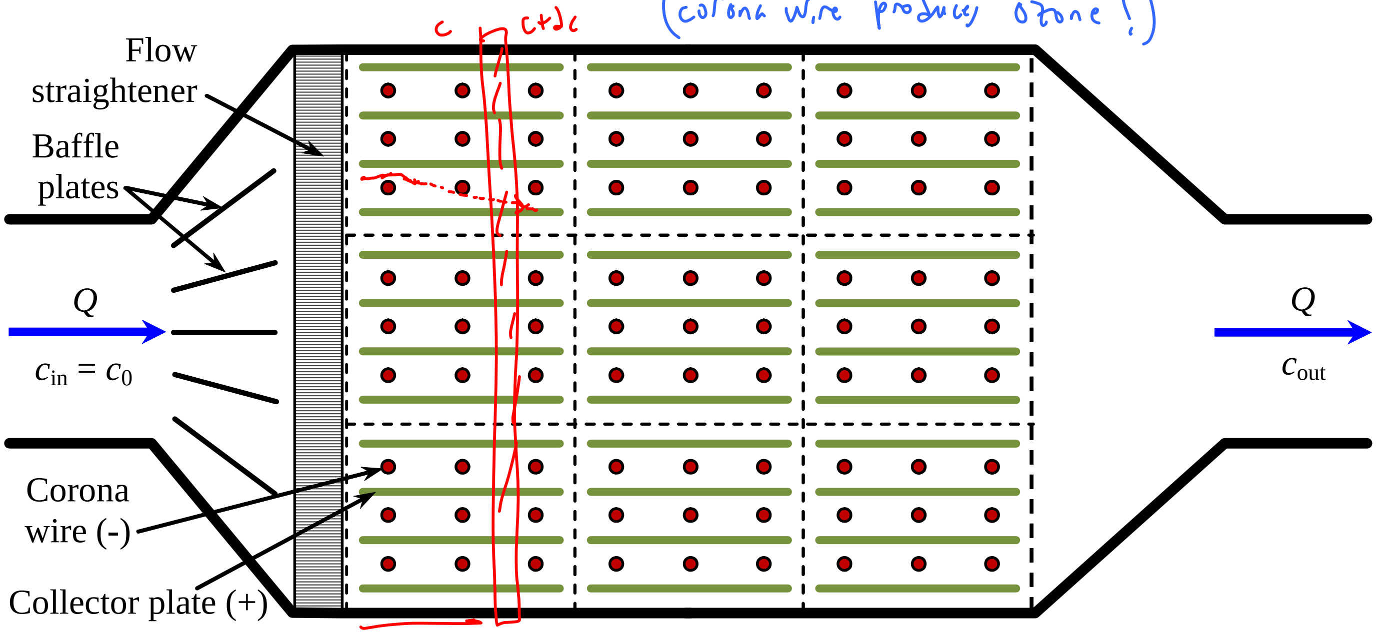


Electrostatic Precipitators (ESPs):

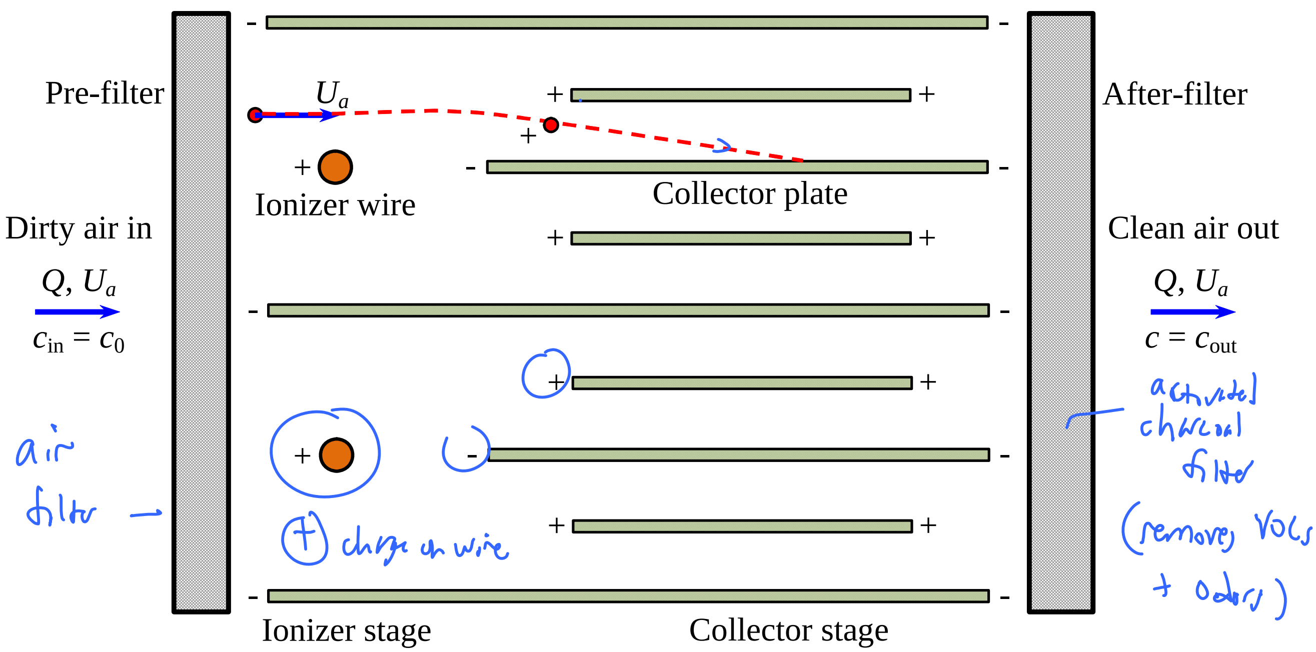
- Do not work by inertial separation → not as affected by the "dip" we have for air filters & spray chambers

Corona wire causes particles to acquire a ⊖ charge
(1000's of Volts)
Plates are ⊕ charged → particles veer into the plate & stick

(corona wire produces ozone!)

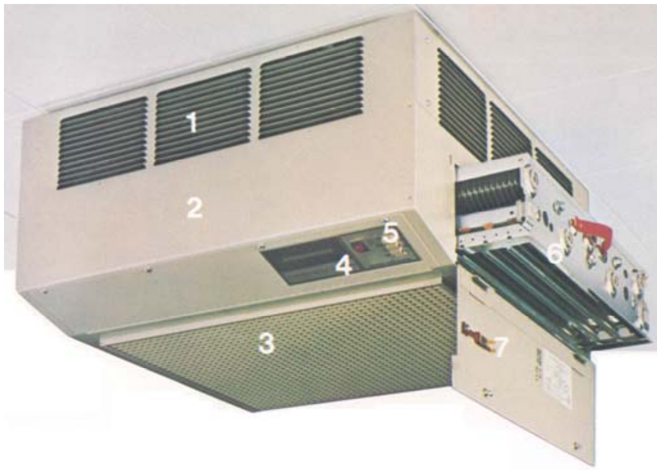


Top view of a negative ionization, single-stage, plate-wire ESP, with three parallel legs, each of which has three modules in series; circles represent the negatively charged corona wires, lines represent the positively charged collector plates. From Heinsohn and Cimbala (2003).



Schematic diagram of a positive ionization, two-stage, plate-wire ESP; dashed line indicates a particle trajectory. From Heinsohn and Cimbala (2003). (typ. for indoor applications & smaller units)

Ceiling mounted ESP eg. in a restaurant



Positive ionization (used indoors) → produces less ozone

Smokemaster ceiling-mounted two-stage electrostatic precipitator that removes smoke, fume and small particles from public places; 1 – discharge louvers, 2 – housing, 3 – prefilters and grille, 4 – indicator lamp, 5 – speed control, 6 – ESP cells, 7 – access door. From Heinsohn and Cimbala (2003).

Analysis → we get well mixed in our little CV slice

$$E(D_p) = 1 - \exp\left(-\frac{L}{L_c}\right)$$ ☆

L_c = fnc. of D_p, voltage, gaps between plates, U_a, type of particle, etc.

Surprise! Same Eq for many other types of APCs, when we use the well-mixed approximation in the analysis of a slice – get a 1st-order ODE that is easy to integrate

Also, I forgot to mention in class, but the collector plates also need cleaned regularly. The plates are *vertical,* and when they need cleaned, most of the big ESPs have a hammer mechanism called a "rapper" that bangs against the metal collector plate to knock off the dust cake, and the dust falls into a hopper. Not elegant, but it works!