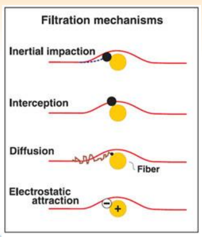
EVE 402
Air Pollution Generation and Control

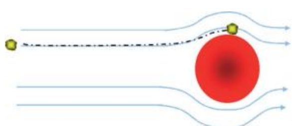
Chapter #5 Lectures (Part 3)

Recall: Particle Collection Mechanisms

Mechanical removal of particles:
1. Inertial Impaction
2. Interception
3. Diffusion (Brownian motion)
4. Gravitational Settling

Enhancement of these mechanisms can occur by using external forces such as electrostatic attraction and/or centrifugal forces





Notice the streamlines

Particle Collection/Removal Devices

Particulate contaminants are typically removed from industrial gas streams using:

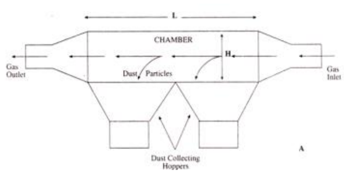
- Settling Chambers (gravitational force)
- Cyclones (centrifugal force)
- Wet Collectors (Brownian motion, interception, and impaction)
- Electrostatic Precipitators (electrostatic force)
- Fabric Filters (Brownian motion, interception, and impaction)

Gravity Settling Chamber

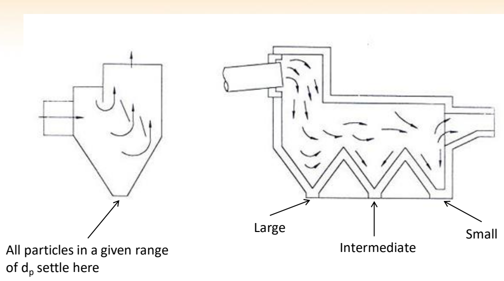
- The simplest and oldest mechanical particle collectors
- Used to remove large particles (d_p > 50 µm)
- Form: long, horizontal, rectangular chambers
- Flow within chambers must be uniform
- Hoppers used to collect settled material
- Two types:
  - Expansion chamber (cheaper, less efficient)
  - Multiple-tray chamber (more expensive and efficient)

Expansion Chamber

- Gas stream velocity significantly reduced as the gas expands in a large chamber
- The velocity reduction allows larger particles to settle out



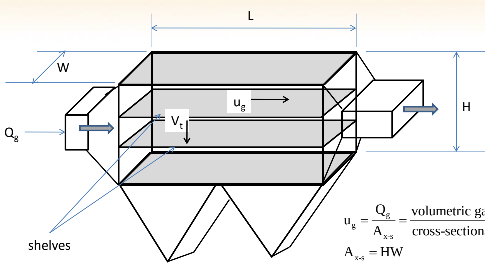
More Expansion Chamber Images



Multiple-Tray Chamber

- An expansion chamber with a number of thin, closely-spaced trays
  - Trays cause gas to flow horizontally between them
  - Gas velocity is unchanged
    - Collection efficiency improves, however, since particles have less distance to fall before they are collected
- The overall volume (space) requirement for a multiple-tray chamber is less than for an expansion chamber for the same d_p

Schematic of a Multiple-Tray Chamber

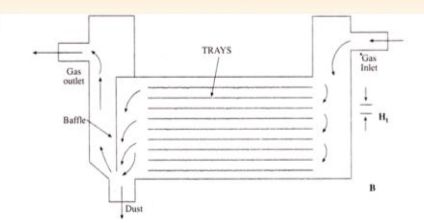


$$u_g = \frac{Q_g}{A_{x\text{-}s}} = \frac{\text{volumetric gas flow}}{\text{cross-sectional area}}$$

$$A_{x\text{-}s} = HW$$

$n =$ number of channels

Another Multiple-Tray Chamber Image



Note:
Re < 1000 → Laminar flow
Re > 10000 → Turbulent flow

Characteristics of Settling Chambers

Advantages	Disadvantages
No moving parts	Large volume requirement—large footprint
Low capital cost	Low collection efficiency for $d_p < 50\mu m$
Low operating cost	Trays may warp at high temperatures
Does not require use of additional materials	

What do you think are the most important advantages/disadvantages?

Settling Chamber Analysis

- $d_{p,min}$ for which 100% removal is achieved can be determined (refer to exp. chamber schematic)
  - The time required to fall the distance H equals the time required to travel the distance L (for $d_{p,min100\%}$)
  - Thus

$$t = \frac{H}{V_t} = \frac{L}{u_g}$$

  - Using Figure 5-8, we can relate d_p to V_t:

$$V_t = \frac{u_g H}{L} = \frac{Q}{LW} = f(d_p)$$

Analysis (2)

- And finally, using Stokes' Law:

$$d_{p,min100\%} = \left(\frac{18\mu Hug}{gL\rho_p}\right)^{1/2}$$

- Note: $d_{p,min100\%}$ decreases as H/L decreases
- Also note: there is fractional removal efficiency for $d_p < d_{p,min100\%}$

Analysis (3)

- Fractional collection efficiency, η_d:

$$\eta_d = \frac{V_t L}{H u_g} = \frac{V_t L W}{Q}$$

- To incorporate the number of trays, *n*, (for a multi-tray chamber):

$$V_t = \frac{H u_g}{nL} = \frac{Q}{nLW} \quad and$$

$$\eta_d = \frac{n V_t L}{H u_g} = \frac{n V_t L W}{Q}$$

Example (Gravitational Settling Chamber)

Calculate the collection efficiency of a gravitational settling chamber for 20 µm diameter particles with density of 1 g/cm^3. Total gas flow rate for the chamber is 5 × 10^4 m^3/hr. The carrier gas for the particles is dry air at 298 K and 1 atm. The chamber has 20 shelves that are 10 m long and 10 m wide with vertical shelf spacing of 0.2 m.