Settling Chambers and Performance Models

Settling Chamber

- Also known as **Gravity Settler**

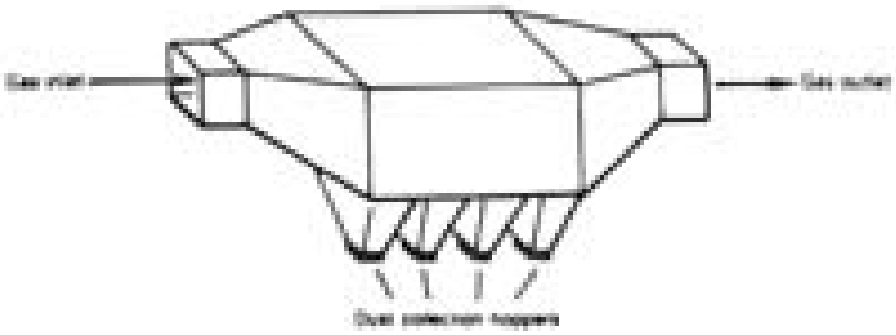
- **Operating Principle:**
  - Slow down the veocity of gas stream in a large volume having **large cross-sectional area** and sufficient length,
  - Thereby, provide a sufficient time for particles to settle down to the bottom of device under the effect of **Gravitational Force**.

Settling Chamber

- **Basic Features:**
  - Low Capital and Operating Costs
  - Low Pressure Drop, Very Low Energy Cost
  - No Moving Parts, Few Maintenance Requirements
  - Excellent Reliability
  - Device Not Subject to Abrasion
  - Provides Incidental Cooling of Gas Stream
  - Dry Collection and Disposal
- **Disadvantages**
  - Relatively Low PM Collection Efficiencies, not suitable for fine particles
  - Unable to Handle Sticky or Tacky Materials
  - Large Physical Size, needs large settlement area
  - Trays in Multiple-Tray Settling Chamber may Warp

Settling Chamber

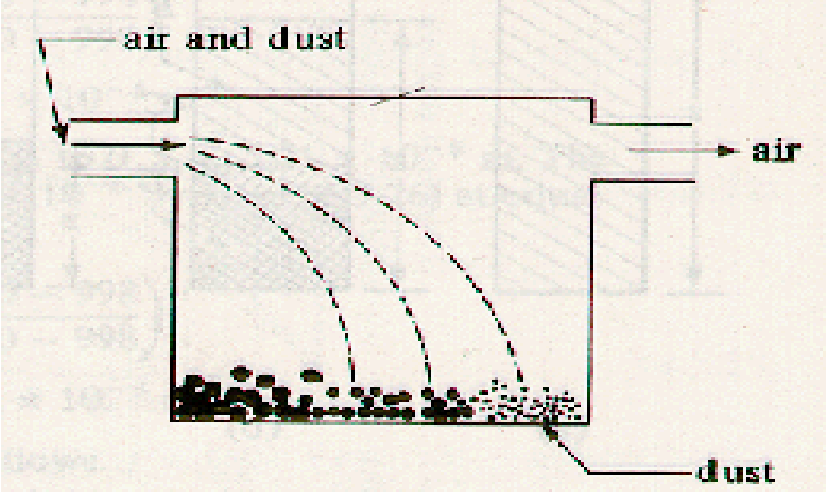
- A general Picture of its shape



Settling Chamber

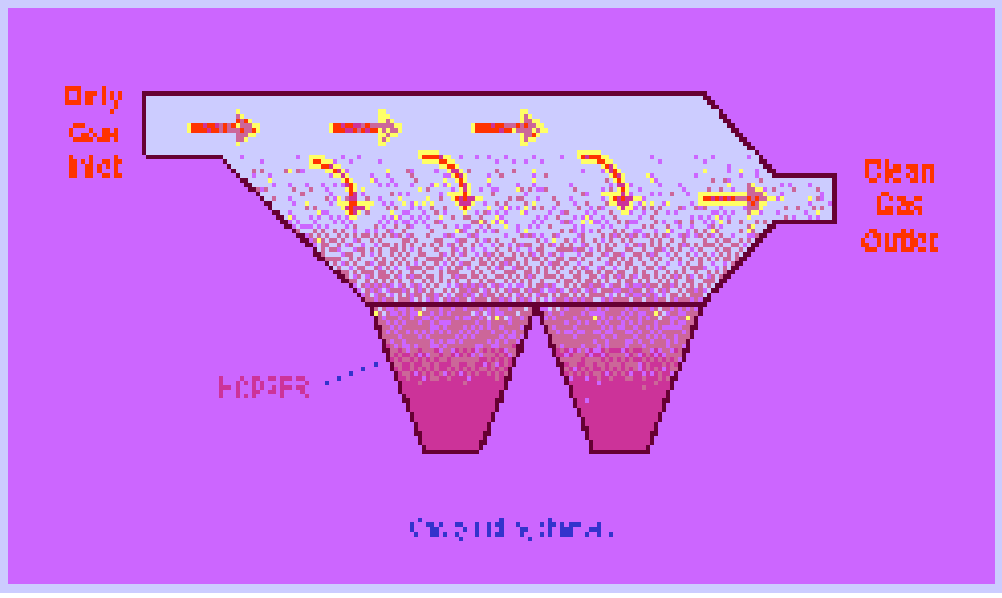
Settling Chamber

- Settling action of particles

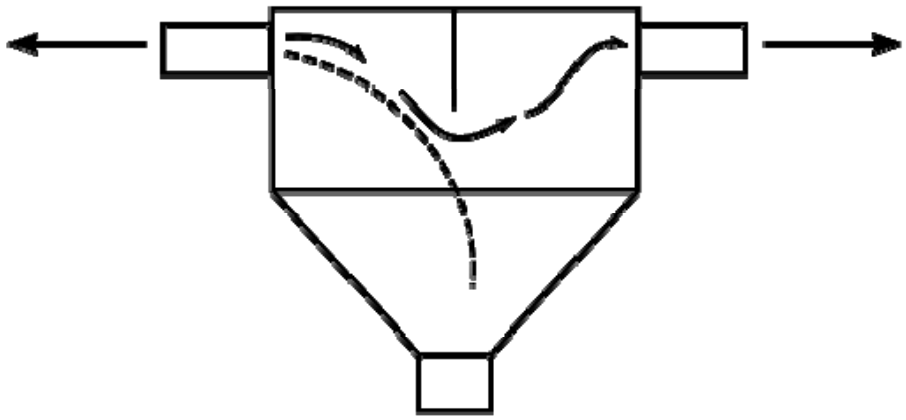


Settling Chamber

- Some design geometries



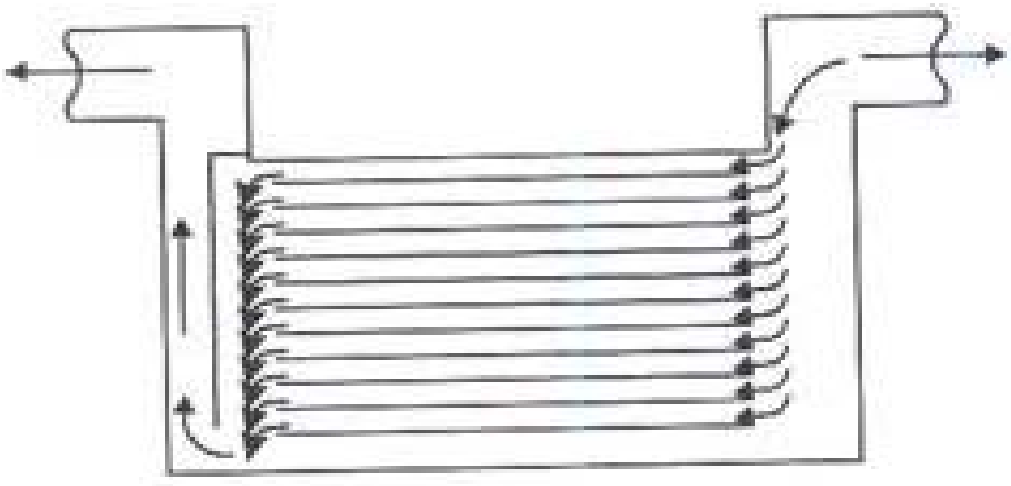
- Some design geometries



Baffle Chamber

Settling Chamber

- High efficiency settlers

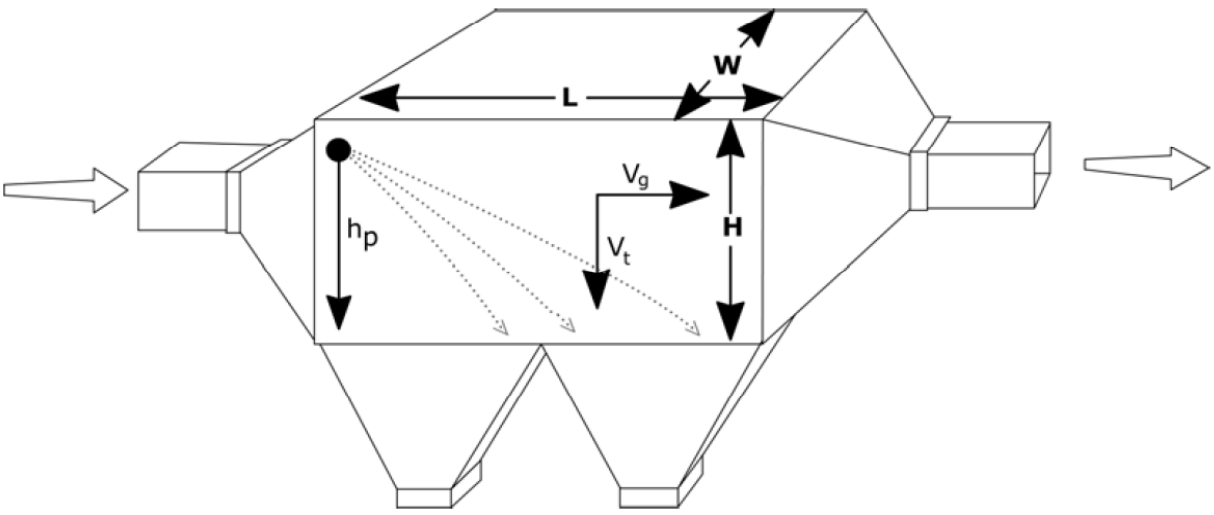


Performance Modelling in Settling Chamber

- Fundamental parameters of modelling:
- Particles will stay in settling chamber in a time period called **Residence time (t_R)**
- Particles will settle down to the bottom in a time period called **Collection time (t_C)**

Performance Modelling in Settling Chamber

- Dimensions and model parameters of settling chamber:



Performance Modelling in Settling Chamber

- **Residence Time**
  - $t_R = L / V_g$
- **Collection Time**
  - $t_C = H / V_t$
- **Theoretically speaking, for a particle to be collected:**
  - t_R *should be greater or equal to* t_C
    - The worst case is $t_R = t_C$
- **For an acceptable performance :**
  - ***V_t should be greater than 10 cm/s***
    - This corresponds to about 50 micron for low density particles and about 10 micron for high density particles
  - ***V_g should be less than 3 m/s***
    - *Preferably V_t should be less than 0,3 m/s*

Performance Modelling in Settling Chamber

- For a particle to be collected…
- Its route should point to the bottom (collecting plate)

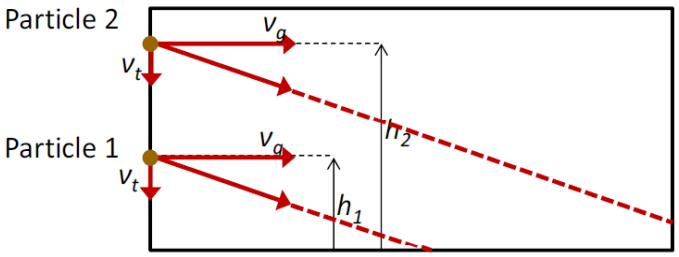
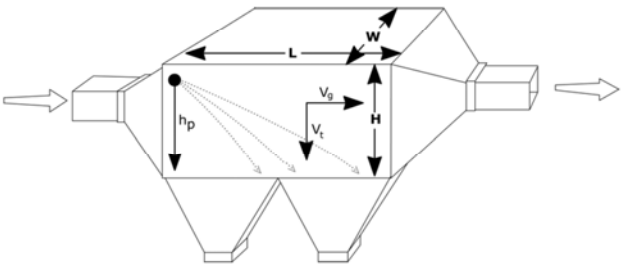


Figure 3. Two identical particles' behaviors in a settling chamber



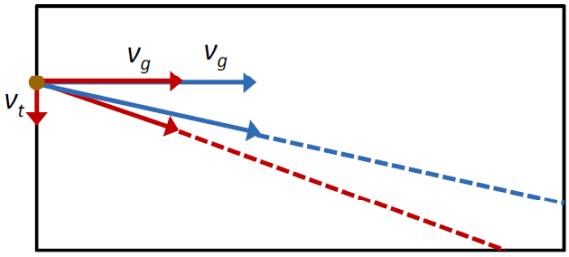


Figure 4. Effect of throughput velocity on particulate collection

Performance Modelling in Settling Chamber

- Think of a point at an entrance elevation of ***h*** from the bottom (distance to the collecting plate)….such that
  - All particles having elevation less than ***h*** will fall to the bottom and be collected…
    - Theoretically 100% efficiency for these particles,
  - All particles having elevation greater than ***h*** will escape to the exit and not be captured…
    - Theoretically 0 % efficiency for these particles

Performance Modelling in Settling Chamber

- Relying on these two cases and together with the following additional assumptions:
  - Horizontal gas velocity ($V_{avg} = V_g$) is constant throughout the chamber
  - Horizontal component of the velocity of particles is equalt to V_g
  - Vertical component of the velocity of particles is equal to V_g
  - Collected particles do not re-enter into the gas stream
  - All particles in this consideration are identical having the same diameter d_p

Performance Modelling in Settling Chamber

- An **efficiency** term is defined as follows:
- Efficiency : $\eta = h/H$……A
  - Here:
  - h is the settling distance $h = t_C \cdot V_t$……B
  - H is the total height of the settling chambe,
- t_C will be equal to t_R for the worst case:
  - $t_C = t_R = L / V_g$……C
- *Putting C into B and B into A, you get an efficiency equation called*
- *"**Plug-Flow Efficiency Equation**"*

  - $\eta = (L \cdot V_t) / (H \cdot V_g)$

- We may put V_t as "*the corrected stoke's settling velocity equation*" into above equation

Performance Modelling in Settling Chamber

- Efficiency variation of plug-flow model:
  - **Unrealistic**, because it estimates effiencies greater than 100%

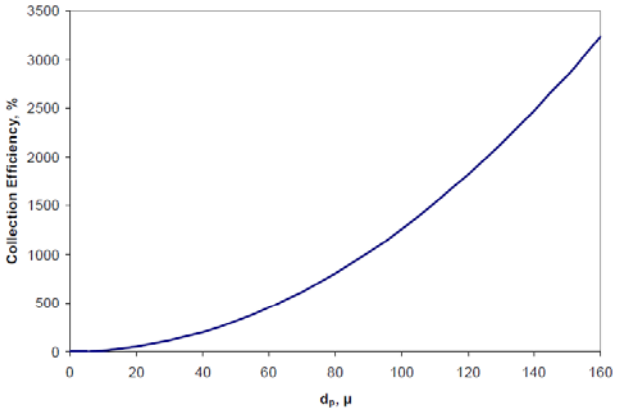


Figure 7. Change of particulate collection efficiency estimated by plug flow model of a settling chamber with respect to particle size

Performance Modelling in Settling Chamber

- **Mixed Model Efficiency:**
  - In plug flow model, no mixing in flow-cross section is assumed which is unrealistic.
  - Mized model assumes that there is well mixing in flow cross sectional area so that there is a concentration change as the gas flows through the chamber.
  - Change in PM concentration throughout the chamber should be defined and put into Efficiency equation….

Performance Modelling in Settling Chamber

- **Mixed Model Efficiency:**
  - There will be a concentration change, *dc*, in the *dx* travel of gas stream in a time period *dt*
  - *This will cause a change in efficiency defined as follows:*
    - ***Efficiency in the section dx:***
    - $\eta = h / H = V_t\, dt / H$
  - Concentration change is defined as:
    - dc = - c (***Efficiency in the section dx)***
    - $dc = - c\, V_t\, dt / H$

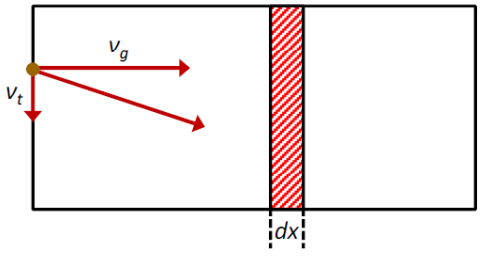


Figure 8. Incremental mixing in settling chambers

Performance Modelling in Settling Chamber

- **Mixed Model Efficiency:**
  - We know that
    - $dt = dx / V_g$
  - *This time definition is combined with*
    - $dc = - c V_t d_t / H$
  - **Resulting Differential Equation:**

$$\frac{dc}{c} = -\frac{v_t}{Hv_g} dx$$

Performance Modelling in Settling Chamber

- **Mixed Model Efficiency:**
  - Solution of the differential equation:

$$\int_{C=C_0}^{C=C_e} \frac{dc}{c} = -\int_{x=0}^{x=L} \frac{v_t}{Hv_g} dx$$

$$C_e = C_0 \exp\left[-\frac{Lv_t}{Hv_g}\right]$$

Performance Modelling in Settling Chamber

- **Mixed Model Efficiency:**
  - Recall the definition of efficiency in terms of inlet and outlet concentrations,
  - The efficiency of mixed model is:

$$\eta_M = 1 - \exp\left[-\frac{Lv_t}{Hv_g}\right]$$

  - A relation between mixed-flow model and plug-flow model may also be written:
  -

$$\eta_M = 1 - \exp\left[-\eta_{PF}\right]$$

Performance Modelling in Settling Chamber

- **Mixed Model Efficiency:**
  - Efficiency estimate of mixed-model which is realistic

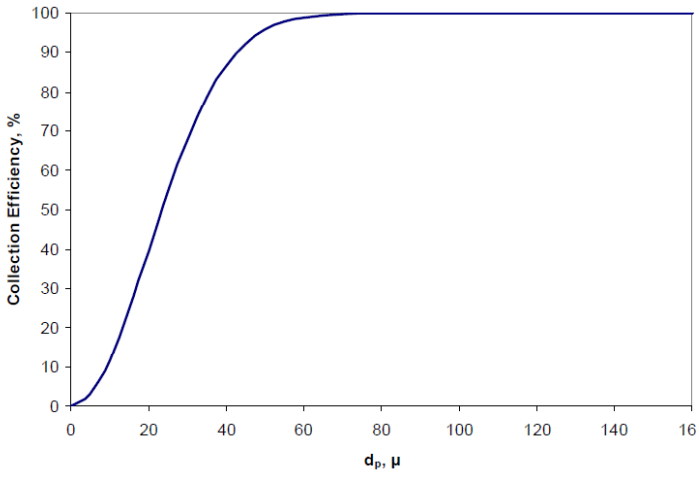


Figure 9. Change of particulate collection efficiency estimated by mixed model of a settling chamber with respect to particle size