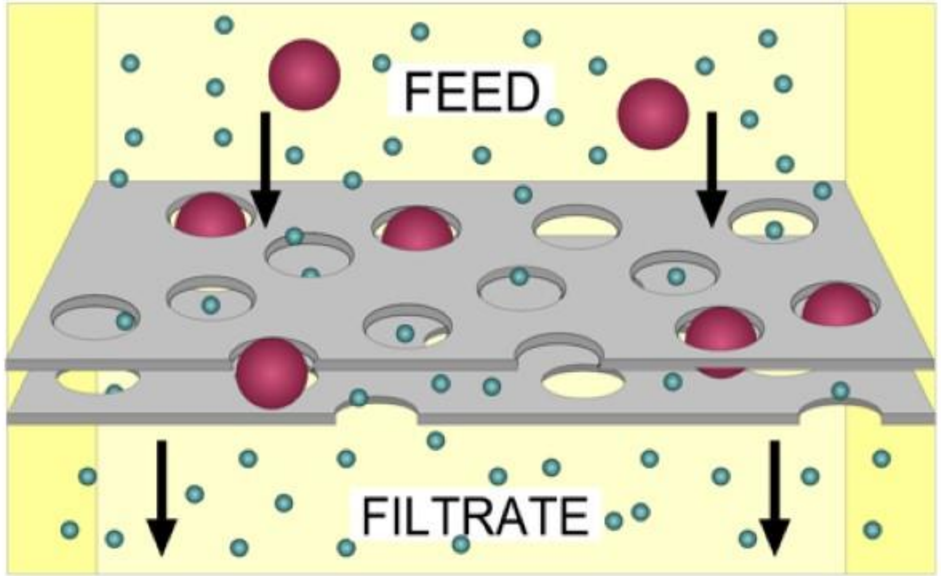
Filtration



Lecture 4

PRATIKSHA SHRESTHA

Mechanical Separation process

- Filtration
- Sedimentation
- centrifugation

Filtration

- Suspended solid particles in fluid are removed by porous medium
- Particles : spherical, irregular, aggregates, rigid, large/fine
- Fluid: liquid or air
- Solid accumulate: increased resistance to flow

Filtration

- Filtration is the removal of solid particles from a fluid by passing the fluid through a filtering medium or septum on which solids are deposited.
- The medium traps the suspended solids producing a clarified filtrate. Filtration is employed when the valuable component of mixture is filtrate.
- Fluid flow through a filter medium by virtue of a pressure differential across the medium
- Most industrial filters are pressure filters, vacuum filters or centrifugal separators and may be continuous or discontinuous.

Filter aids

- Slimy or very fine solids that form a dense impermeable cake quickly plug any filter medium that is fine enough to retain them. Pratcical filtration of such medium requires that the porosity of the cake be increased to permit passage of the liquor at a reasonable rate. This is done by adding a filter aid such as
- Diatomaceous silica
- Perlite
- Purified wood cellulose
- Other wooden porous solid

Surface and depth Filtration

- **Surface filtration:** is a process where the filtrate passes across the thickness of porous sheet while the suspended solids are retained on the surface of sheet. Surface filtration allows no cake accumulation

- **Depth filtration:** is a process where the filter medium is thick and solids penetrate the depth of the filter. Eventually, solids block the pores and stop filtrate flow or solids may break through the filter and contaminate the filtrate. Once the filtrate flow stops or slows down considerably, the filter must be replaced.
- In depth filtration, particle retention may occur by electrostatic attraction in addition to sieving effect

Mechanism of Filtration

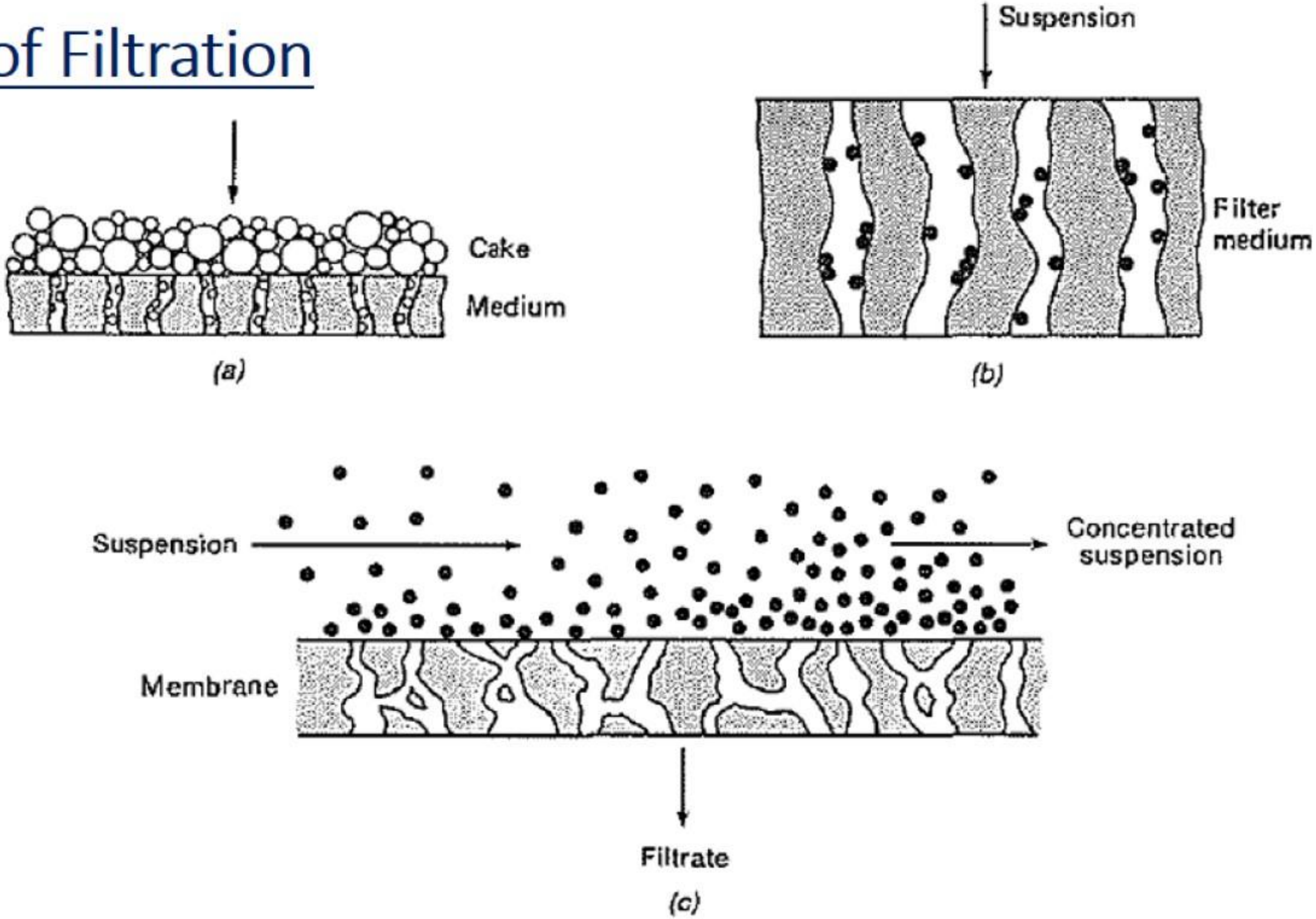
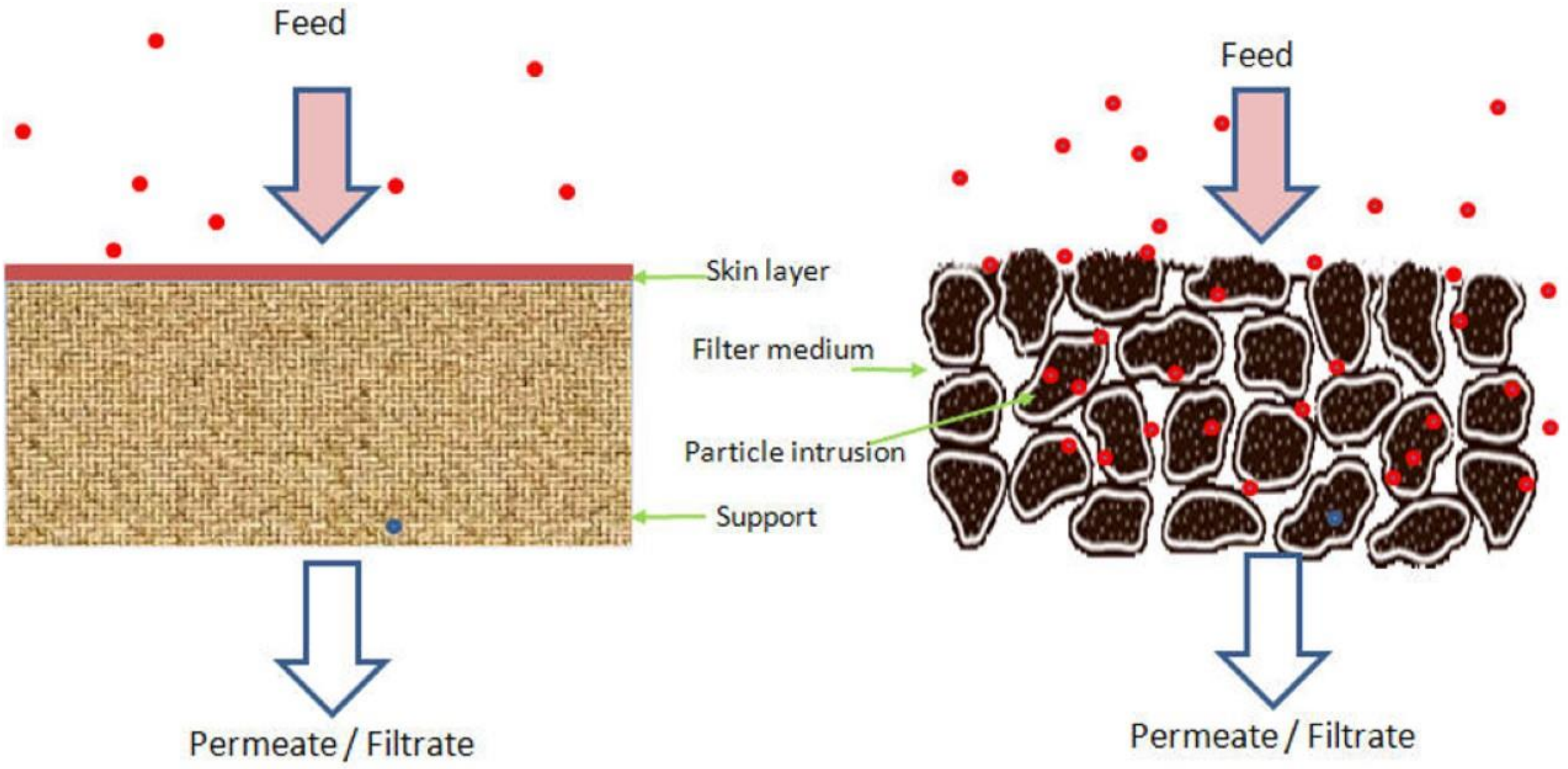
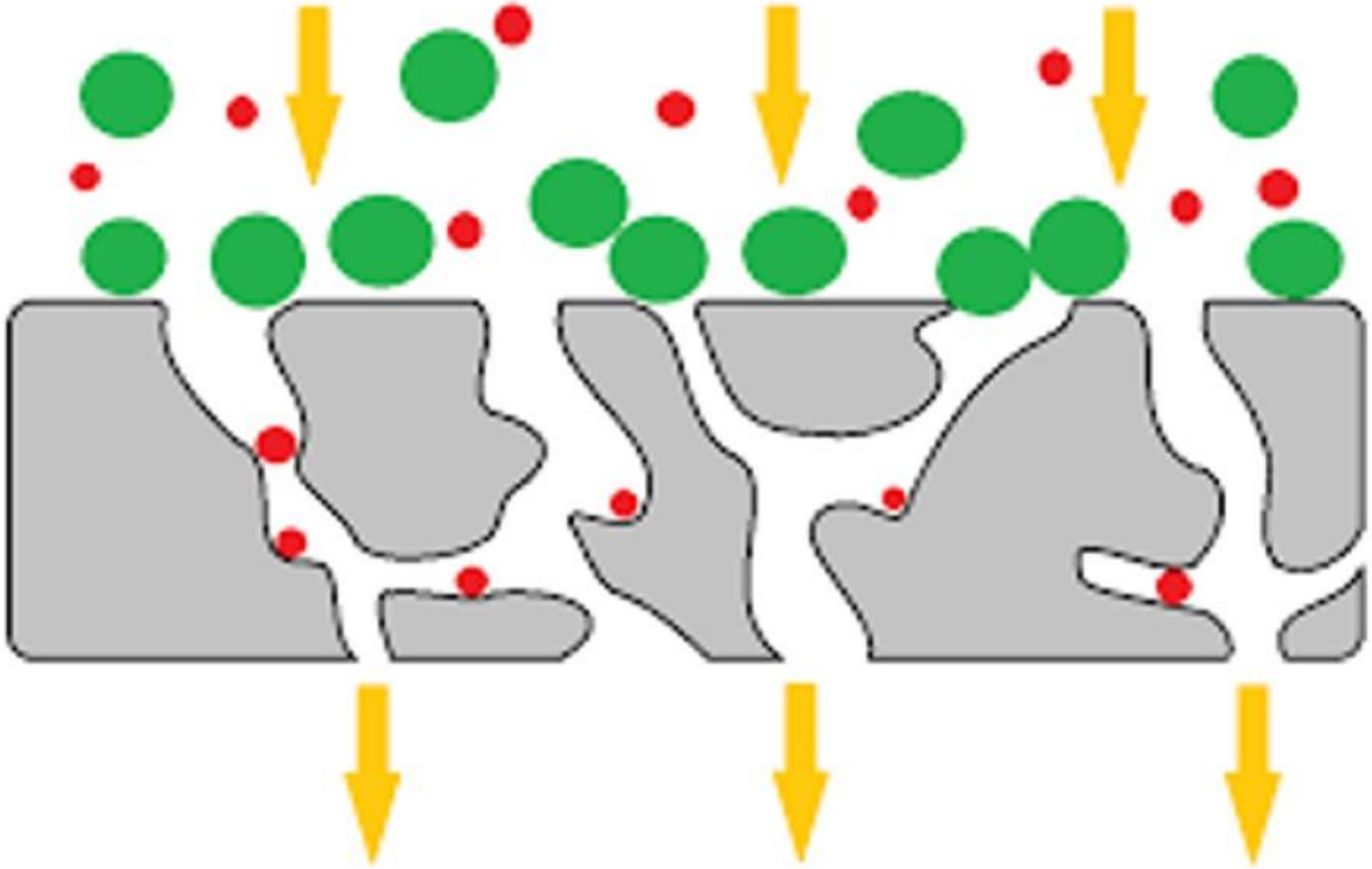


Figure: Cake filter (a), clarifying (b) and crossflow (c) filters

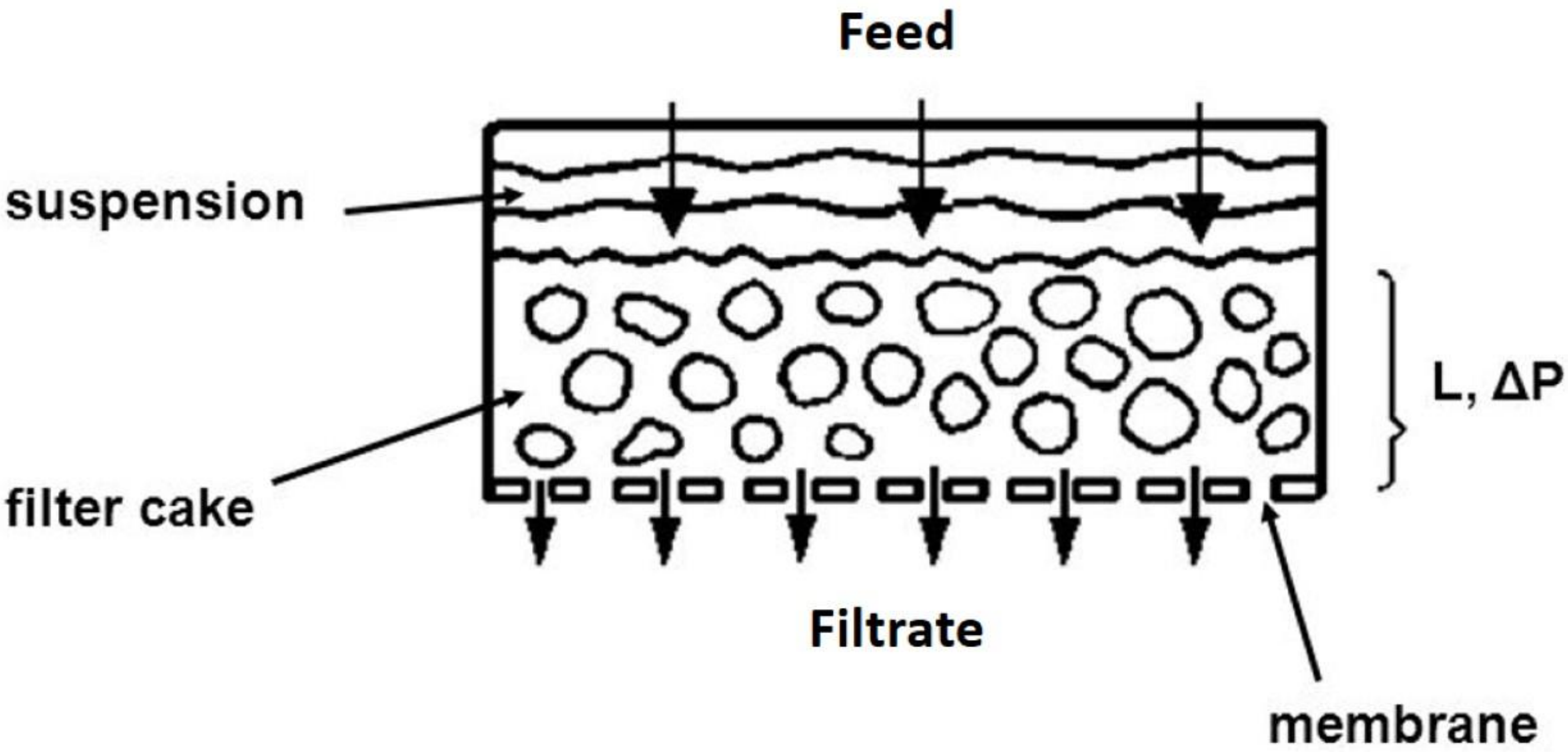
Surface and depth Filtration



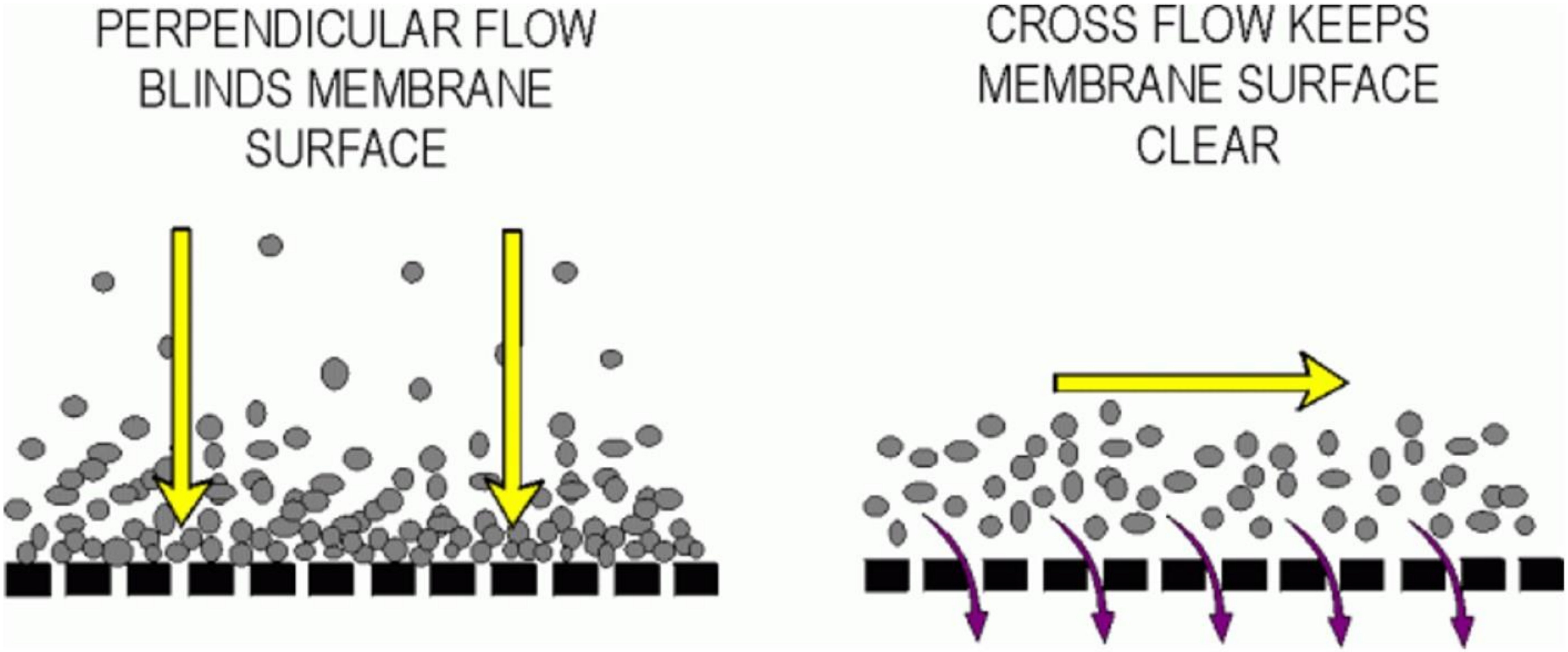
Depth Filter



Cake filter

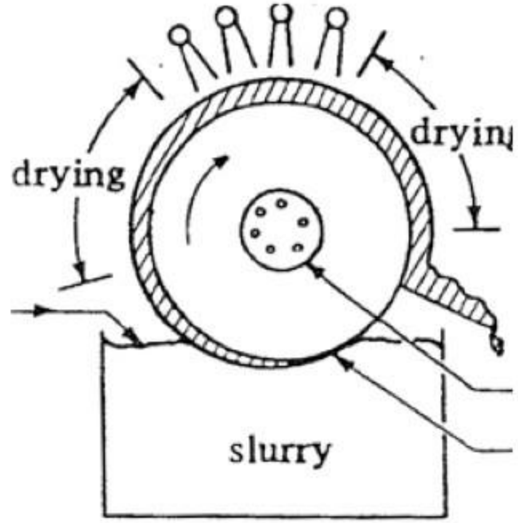


Crossflow filter

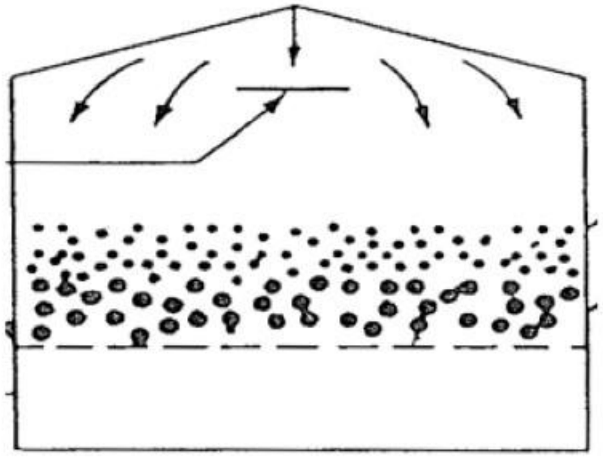


Types of filtration equipment:

- Bed filters
- Plate-and-frame filter press
- Leaf filters
- Continuous rotary filters



Continuous rotary filters



Bed filters

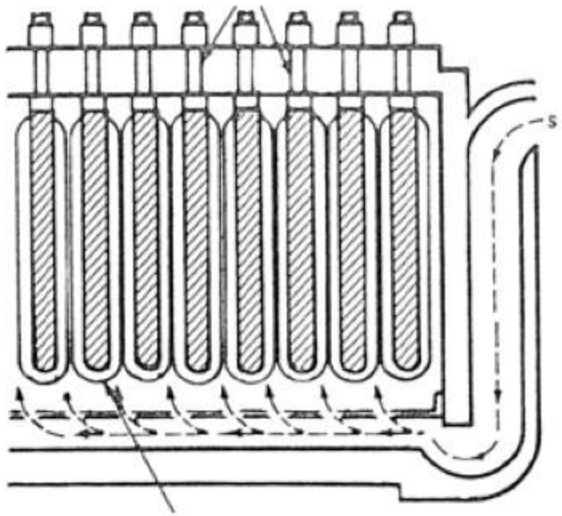
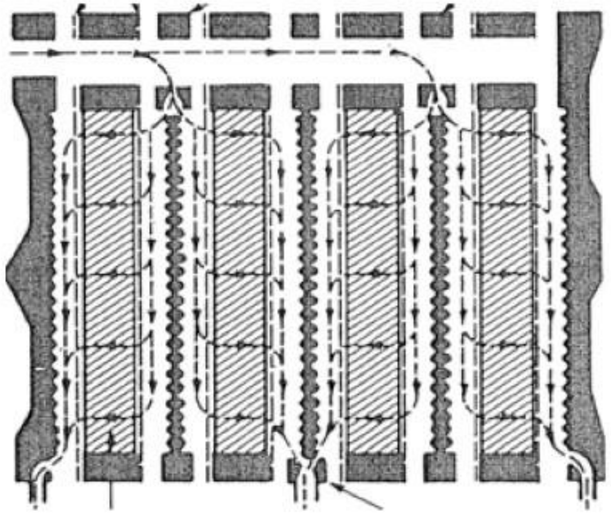


Plate and frame filters



Leaf filters

Press and Frame Filter

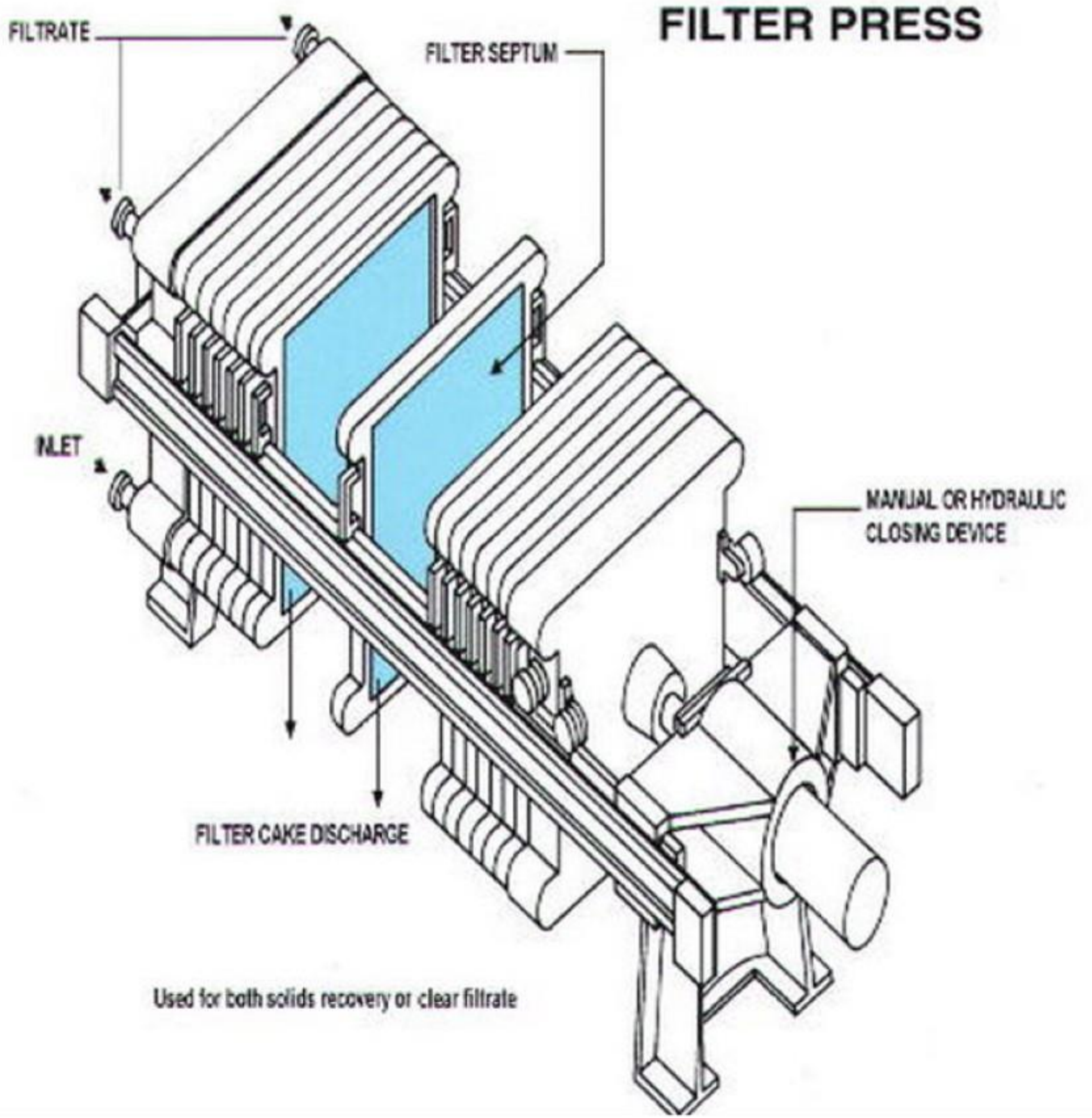
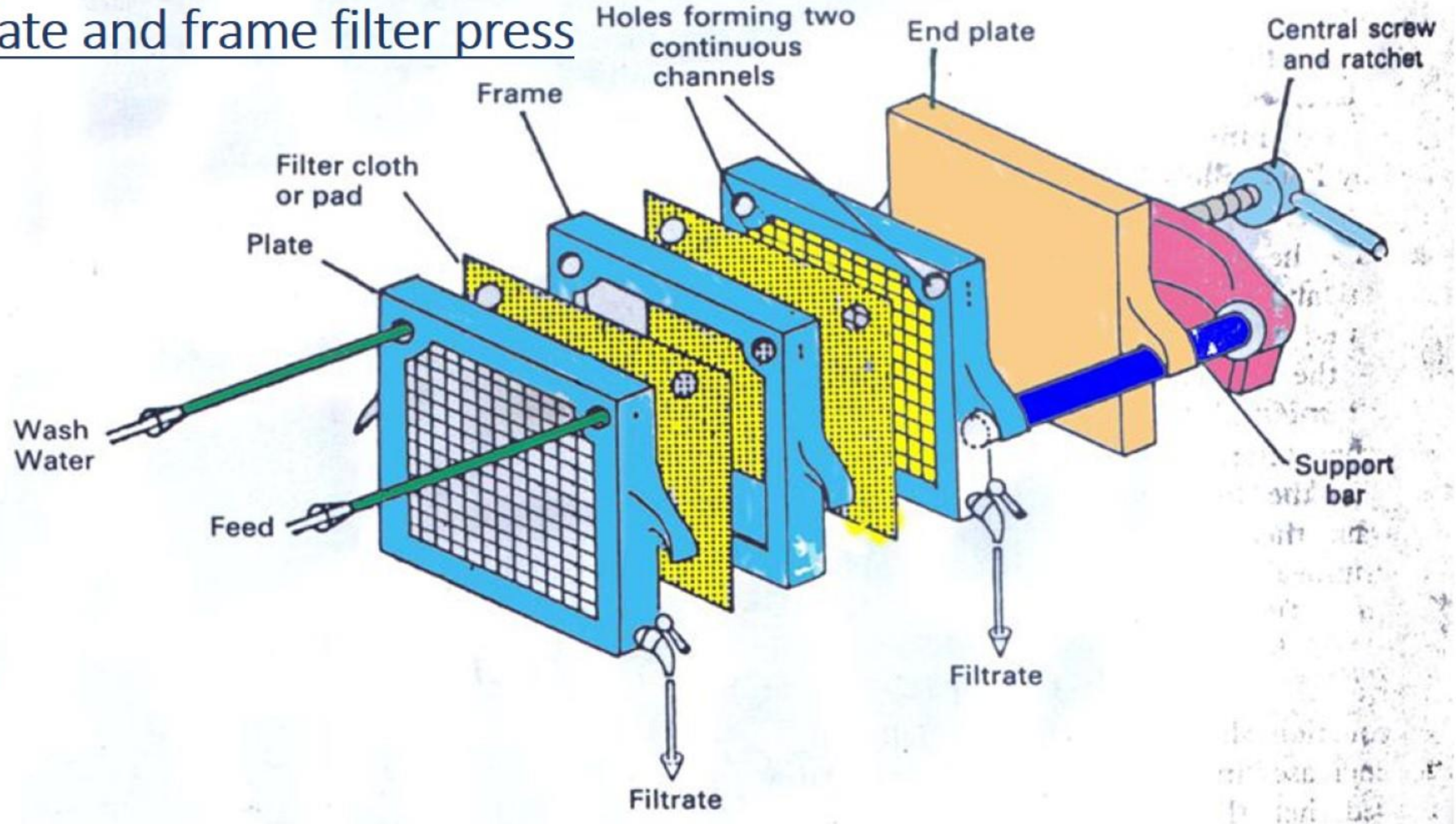
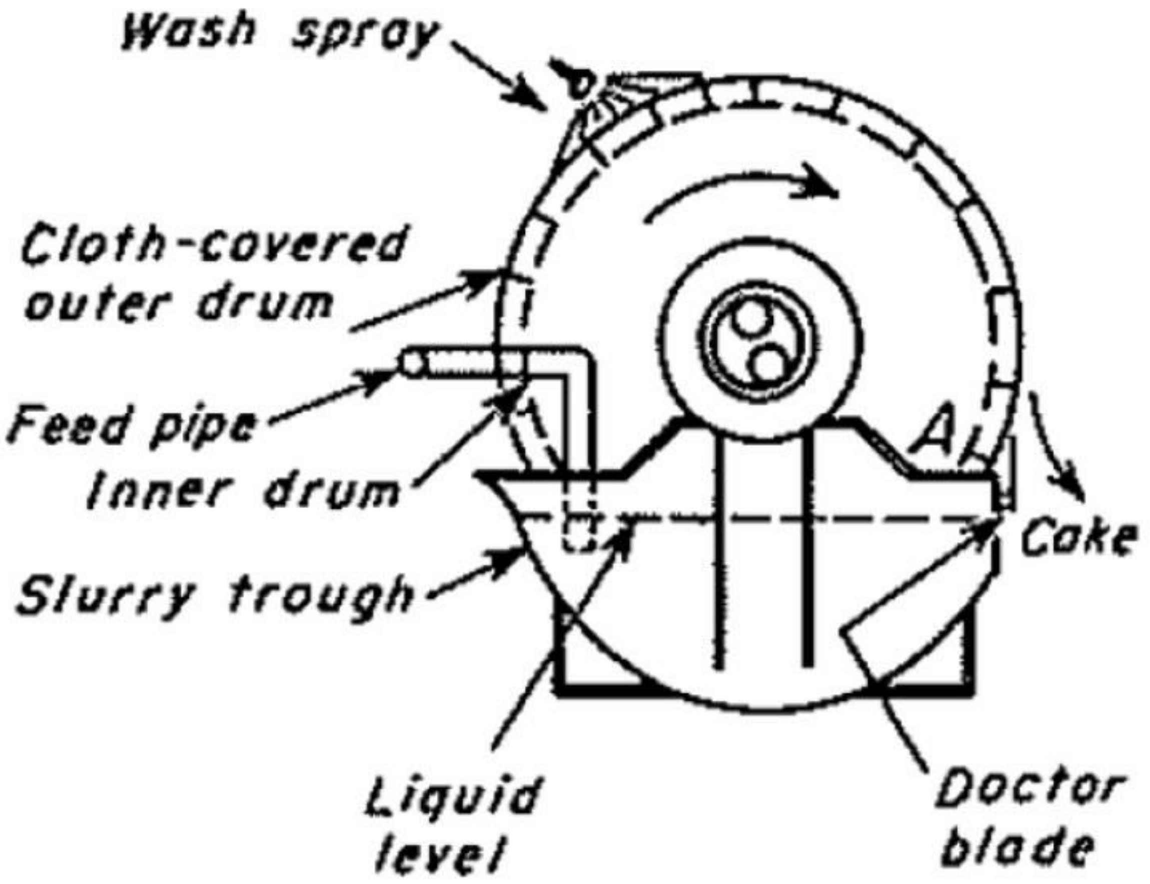
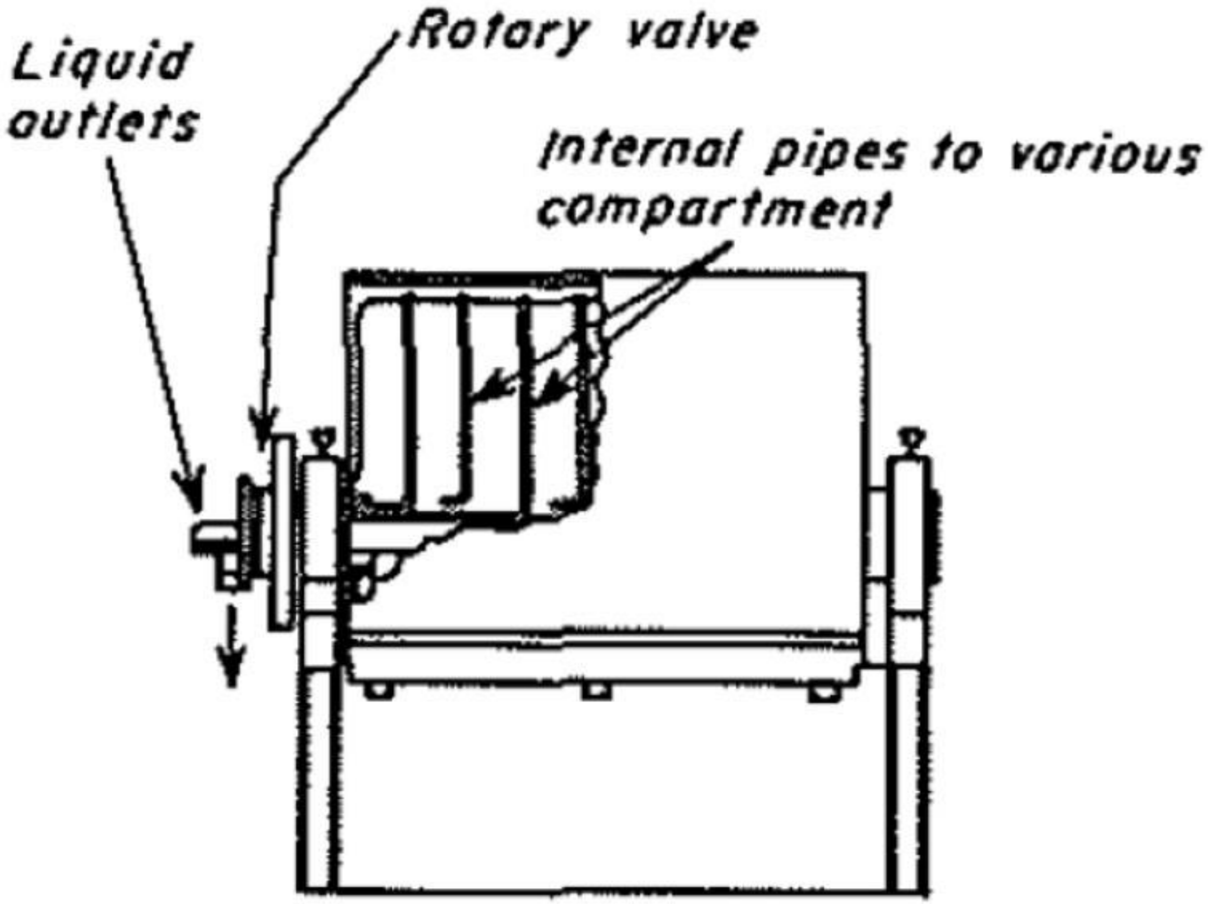


Plate and frame filter press



Continuous Rotary vacuum filter

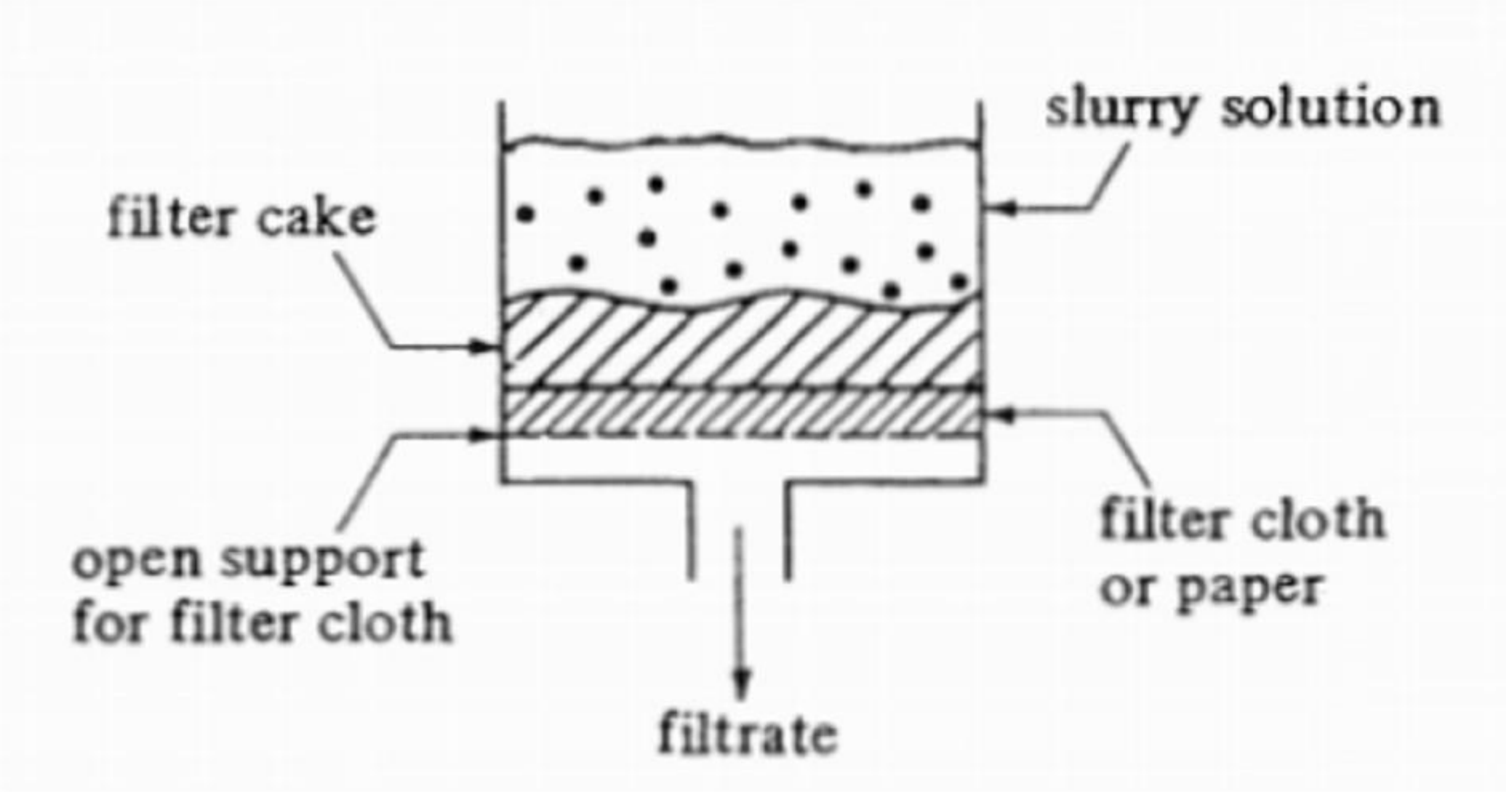




Basic Concept/Defination

$$\text{Rate of filtration} = \frac{\text{Driving force}}{\text{Resistance}}$$

$$\text{Overall resistance} = \text{Cake} + \text{Filter medium}$$



Typical filtration operation

Rate of Filtration depends on

1. Pressure drop across the filter medium
2. Area of filtering surface
3. Viscosity of the filtrate
4. Resistance of filter cake
5. Resistance of filter medium

- Laminar flow of Newtonian fluids

$$\frac{\Delta P}{l}\frac{D}{4} = \mu\left(\frac{8V}{D}\right)$$

$$\Rightarrow \frac{\Delta P}{l} = \frac{32\mu V}{D^2}$$

- For filtration, modified equation is given by Carman-Kozeny

$$\frac{\Delta P}{l} = k_1 \mu V \frac{(1-\varepsilon)^2}{\varepsilon^3} s_0^{\ 2}$$

s_0: specific area in the cake m^2/m^3

k_1: constant

$$V = \frac{\Delta P}{l} \cdot \frac{1}{k_1 \mu \frac{(1-\varepsilon)^2}{\varepsilon^3} s_0^{\ 2}}$$

- Volumetric flow rate

$$Q = \frac{\Delta V_{vol}}{\Delta t} = \frac{dV_{vol}}{dt} = VA$$

$$\Rightarrow V = \frac{\left(\frac{dV_{vol}}{dt}\right)}{A}$$

Estimate ℓ using mass balance

Negligible

$$l \cdot A(1-\varepsilon) \cdot \rho_p = (V_{vol} + l \cdot A \cdot \varepsilon) C_s$$

Volume of wet solids — Total volume of filtrate

ρ_p: kg dry solid/m^3 wet solids

C_s: kg dry solid/m^3 of slurry

$$l \cong \frac{C_s V_{vol}}{A(1-\varepsilon)\rho_p}$$

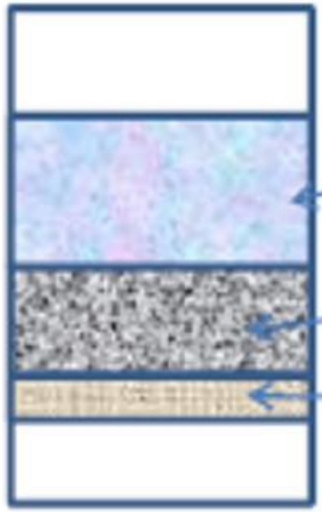
$$V = \frac{\Delta P}{l} \cdot \frac{1}{k_1 \mu \frac{(1-\varepsilon)^2}{\varepsilon^3} s_0}$$

$$V = \frac{\Delta P}{\frac{C_s V_{vol}}{A(1-\varepsilon)\rho_p}} \cdot \frac{1}{k_1 \mu \frac{(1-\varepsilon)^2}{\varepsilon^3} s_0^{\ 2}}$$

$$= \frac{\Delta P}{\frac{k_1 (1-\varepsilon) s_0^{\ 2}}{\varepsilon^3 \rho_p} \cdot \frac{\mu C_s V_{vol}}{A}} = \frac{\Delta P}{\alpha \cdot \frac{\mu C_s V_{vol}}{A}}$$

Where $\alpha = \frac{k_1 (1-\varepsilon) s_0^{\ 2}}{\varepsilon^3 \rho_p}$ Specific cake resistance

$$V = \frac{\left(\frac{dV_{vol}}{dt}\right)}{A}$$



$$\frac{dV_{vol}}{dt} = VA = \frac{\Delta P \cdot A}{\mu}\left[\frac{1}{\frac{\alpha C s V_{vol}}{A}}\right]$$

Consider resistance of filter medium

$$\frac{dV_{vol}}{dt} = VA = \frac{\Delta P \cdot A}{\mu}\left[\frac{1}{\frac{\alpha C s V_{vol}}{A} + R_m}\right]$$

Constant rate filtration

$$Q = \frac{dV_{vol}}{dt} = \frac{V_{vol}}{t} = \text{constant}$$ ➡ Pressure increases with time

$$\frac{dV_{vol}}{dt} = \frac{\Delta P \cdot A}{\mu}\left[\frac{1}{\frac{\alpha C s V_{vol}}{A} + R_m}\right]$$

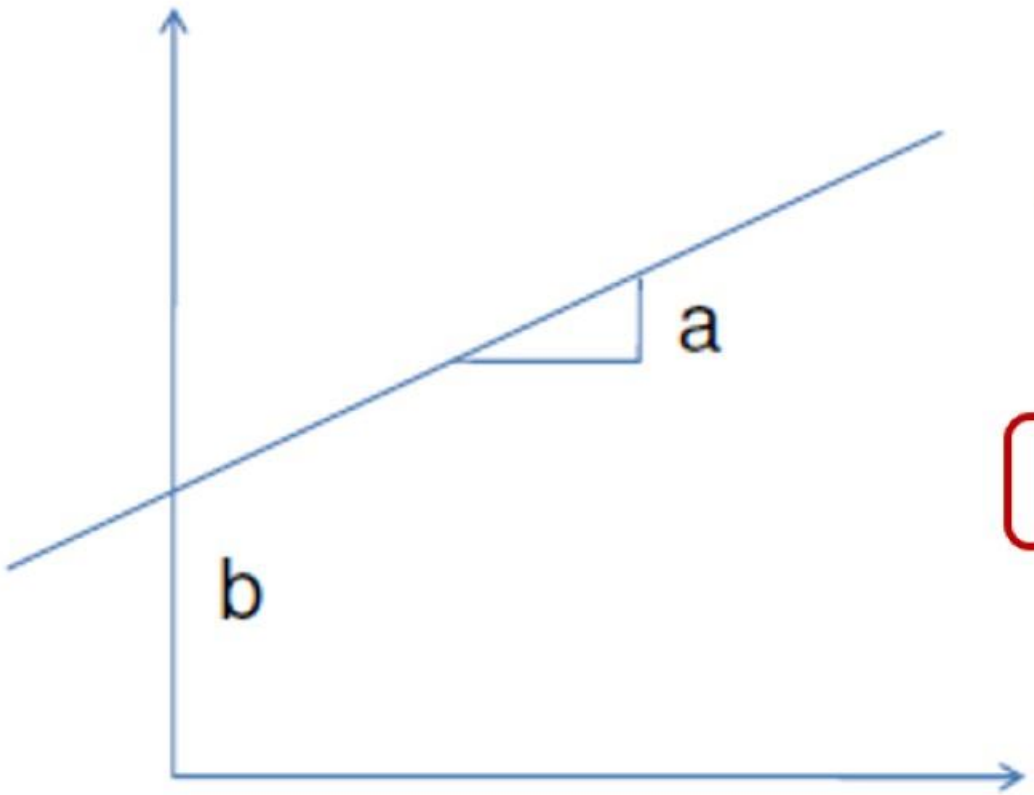
$$\Rightarrow \Delta P = \frac{\alpha C_s \mu}{A^2} \cdot \frac{V_{vol}^{\ 2}}{t} + \left(\frac{V_{vol}}{t}\right)\frac{\mu}{A^2} A R_m$$

α, R_m: determined experimentally

$$\Delta P = \frac{\alpha C_s \mu}{A^2} \cdot \left(\frac{V_{vol}}{t}\right)^2 t + \left(\frac{V_{vol}}{t}\right)\frac{\mu}{A^2} A R_m \Rightarrow \boxed{\Delta P = at + b}$$

constant

Determine α, R_m by fitting experimental data



$$\Delta P = \frac{\alpha C_s \mu}{A^2} \cdot \left(\frac{V_{vol}}{t}\right)^2 t + \left(\frac{V_{vol}}{t}\right)\frac{\mu}{A^2} A R_m$$

$$\Delta P = at + b$$

Constant pressure filtration

$$\frac{dV_{vol}}{dt} = VA = \frac{\Delta P \cdot A}{\mu}\left[\frac{1}{\frac{\alpha C s V_{vol}}{A} + R_m}\right]$$

$$\frac{\mu \alpha C_s}{A}\int_0^{V_{vol}} V_{vol}\,dV_{vol} + \mu R_m \int_0^{V_{vol}} dV_{vol} = \Delta P A \int_0^t dt$$

Integrating

v= 0, t= 0 to v= $v_v$ol, t=t

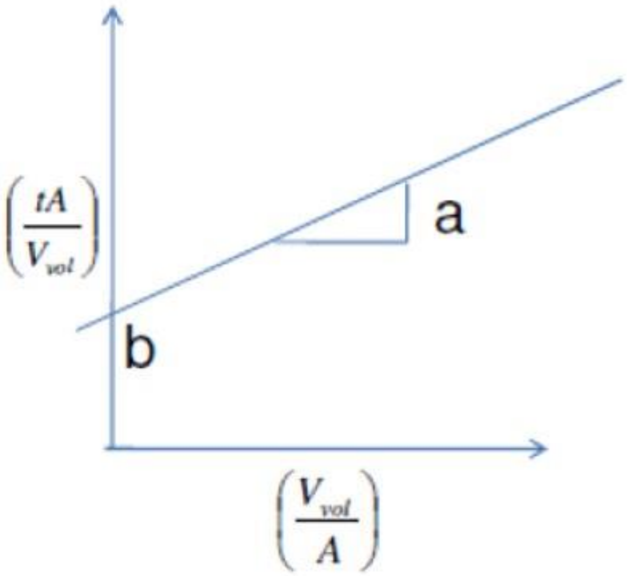
$$\frac{\mu \alpha C_s}{A}\frac{V_{vol}^{\ 2}}{2} + \mu R_m V_{vol} = \Delta P A t$$

Determine α and R_m:

$$\frac{tA}{V_{vol}} = \frac{\alpha C_s \mu}{2\Delta P}\cdot\frac{V_{vol}}{A} + \frac{\mu R_m}{\Delta P}$$

$$(Y = aX + b)$$

Plot: $\left(\frac{tA}{V_{vol}}\right) vs \left(\frac{V_{vol}}{A}\right)$



Thank you