Solid Particulates:

Filtration

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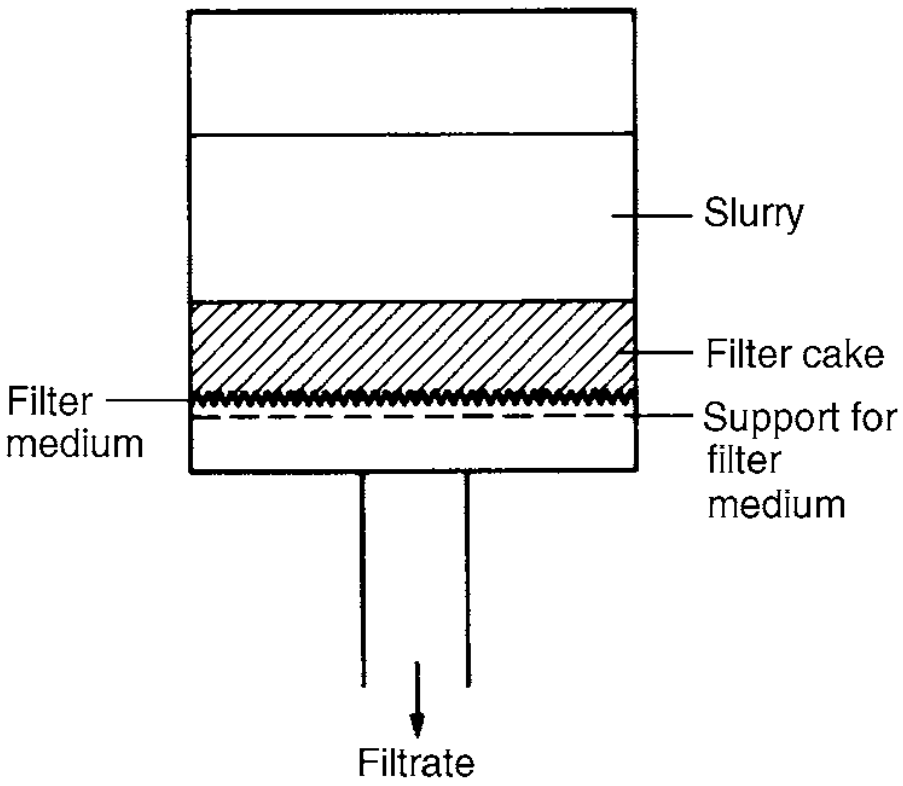
Introduction: concepts

- **Filtration** may be defined as the separation of solid from a fluid by means of a porous medium that retains the solid but allows the fluid to pass.
- The suspension of solid and liquid to be filtered is known as the **slurry**. The porous medium used to retain the solids is described as the **filter medium**;
- The accumulation of solids on the filter is referred to as the **filter cake**, while the clear liquid passing through the filter is the **filtrate**.
- Filtration is essentially a mechanical operation and is less demanding in energy than evaporation or drying where the high latent heat of the liquid, which is usually water, has to be provided.



Factors Affecting Filtration

Filtration is affected by the characteristics of the slurry, including:

1. The properties of the liquid , such as density, viscosity, and corrosiveness.

2. The properties of the solid, for example, particle shape, particle size, particle size distribution, and the rigidity or compressibility of the solid.

3. The proportion of solids in the slurry.

4. Whether the objective is to collect the solid, the liquid ,or both.

5. Whether the solids have to be washed free from the liquid or a solute.

Rate of Filtration

The most important factors on which the rate of filtration then depends will be:

a) The drop in pressure from the feed to the far side of the filter medium.

b) The area of the filtering surface.

c) The viscosity of the filtrate.

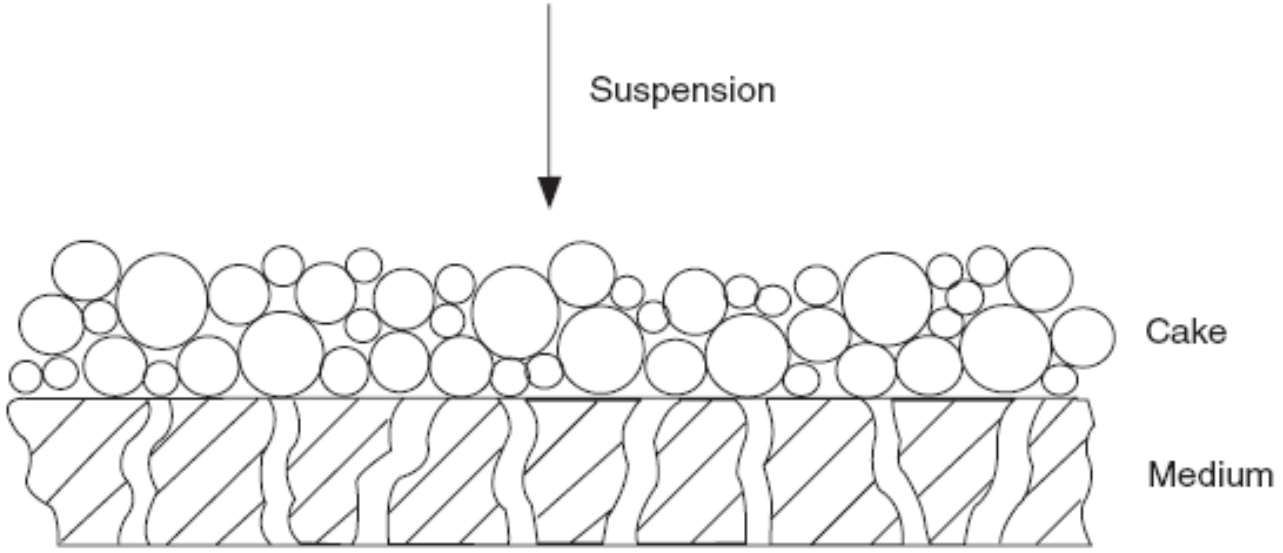
d) The resistance of the filter cake.

e) The resistance of the filter medium and initial layers of cake.

Rate of filtration = driving force/resistance

Two basic types of filtration processes

1. **Surface filters:**
   frequently referred to as ***Cake filtration***, the particles from the suspension, which usually has a high proportion of solids, are deposited on the surface of a porous septum which should ideally offer only a small resistance to flow. As the solids build up on the septum, the initial layers form the effective filter medium, preventing the particles from embedding themselves in the filter cloth, and ensuring that a particle-free filtrate is obtained.

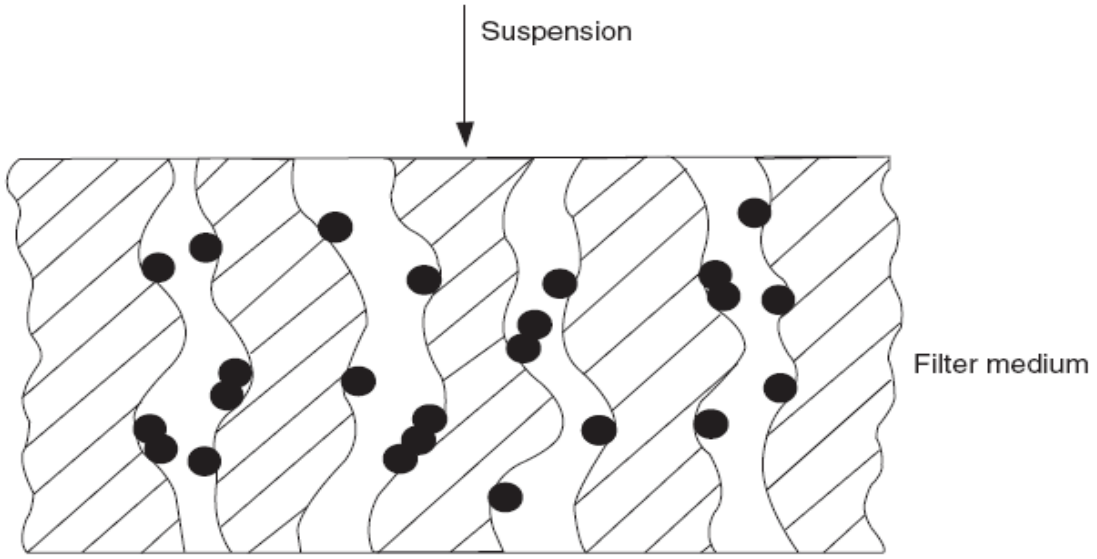


Two basic types of filtration processes

2. Depth filters

The particles penetrate into the pores of the filter medium, where impacts between the particles and the surface of the medium are largely responsible for their removal and retention.

This configuration is commonly used for the removal of fine particles from very dilute suspensions, where the recovery of the particles is not of primary importance.



Factors affecting the filtration

- Pressure drop (ΔP)
- Area of filtering surface (A)
- Viscosity of filtrate
- Resistance of filter cake (α)
- Resistance of filter medium (R_m)
- Properties of slurry (μ)

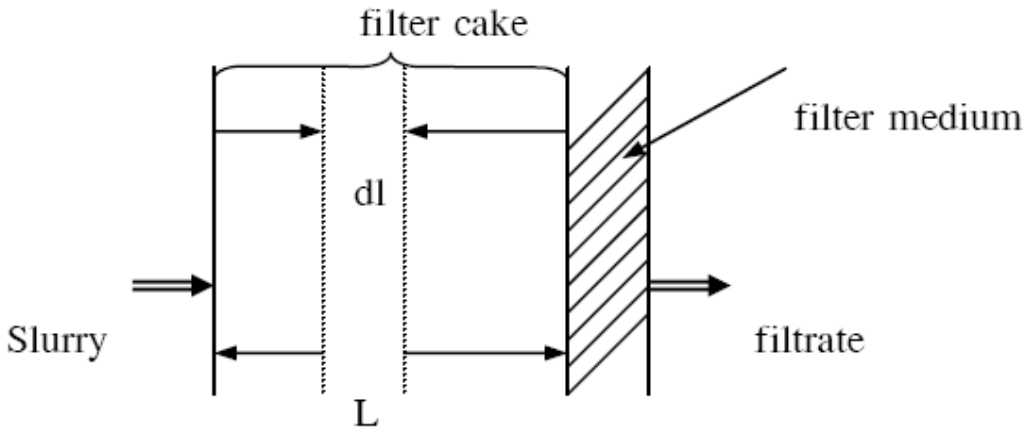
-(ΔP) or Pressure drop

rate of filtration = driving force/resistance

Filter cake (α)

Filter medium (R_m)

Viscosity (μ)



Filtration Equation

Because the particles forming the cake are small and the flow through the bed is slow, streamline conditions are almost invariably obtained, and, at any instant, the flowrate of the filtrate may be represented by the following form of equation

$$u_c = \frac{1}{A}\frac{dV}{dt} = \frac{1}{5}\frac{e^3}{(1-e)^2}\frac{-\Delta P}{S^2 \mu l} \qquad (7.1)$$

where V is the volume of filtrate which has passed in time t, A is the total cross-sectional area of the filter cake, u_c is the superficial velocity of the filtrate, l is the cake thickness, S is the specific surface of the particles, e is the voidage, μ is the viscosity of the filtrate, and ΔP is the applied pressure difference.

- In deriving this equation it is assumed that the cake is uniform and that the voidage is constant throughout.
- For any filtration pressure, the rate of flow is greatest at the beginning of the process since the resistance is then a minimum.

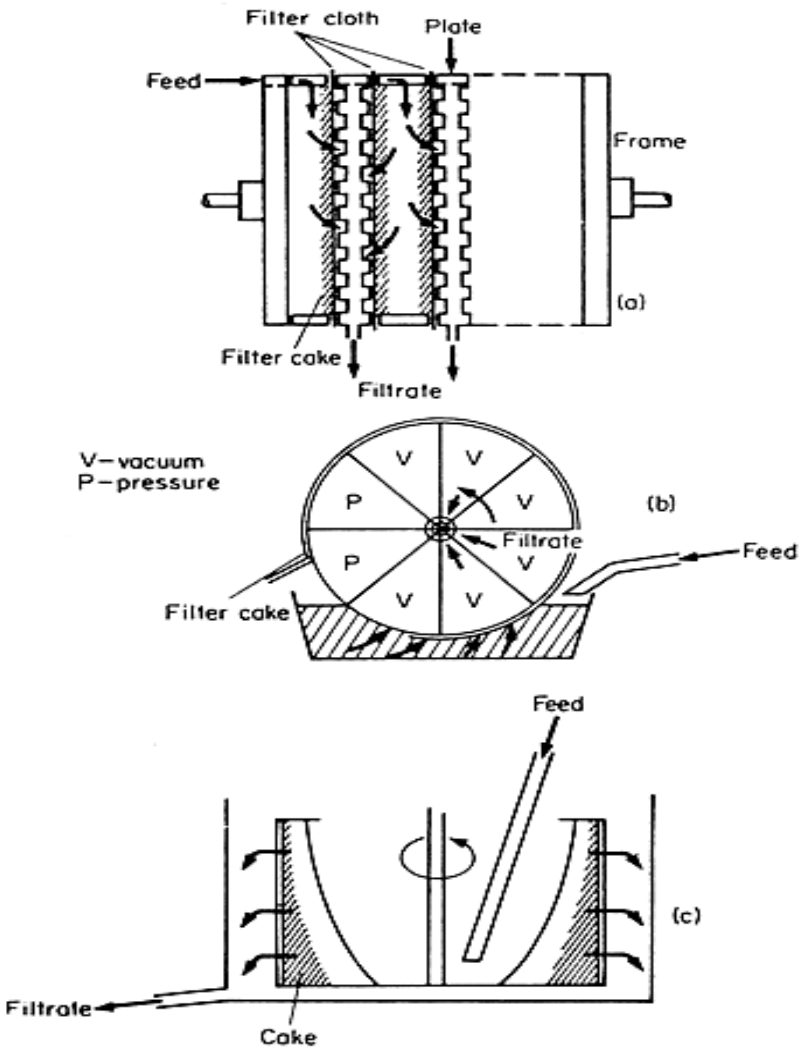
Filtration Equipment

The basic requirements for filtration equipment are:

- mechanical support for the filter medium
- flow accesses to and from the filter medium
- provision for removing excess filter cake.

- In some instances, washing of the filter cake to remove traces of the solution may be necessary.

- Pressure can be provided on the upstream side of the filter, or a vacuum can be drawn downstream, or both can be used to drive the wash fluid through.



Filtration equipment: (a) plate and frame press (b) rotary vacuum filter (c) centrifugal filter

1.Plate and frame filter press

- In the plate and frame filter press, a cloth or mesh is spread out over plates which support the cloth along ridges but at the same time leave a free area, as large as possible, below the cloth for flow of the filtrate.

- The plates with their filter cloths may be horizontal, but they are more usually hung vertically with a number of plates operated in parallel to give sufficient area.

- In the early stages of the filtration cycle, the pressure drop across the cloth is small and filtration proceeds at more or less a constant rate.

- As the cake increases, the process becomes more and more a constant-pressure one and this is the case throughout most of the cycle.

- When the available space between successive frames is filled with cake, the press has to be dismantled and the cake scraped off and cleaned, after which a further cycle can be initiated.

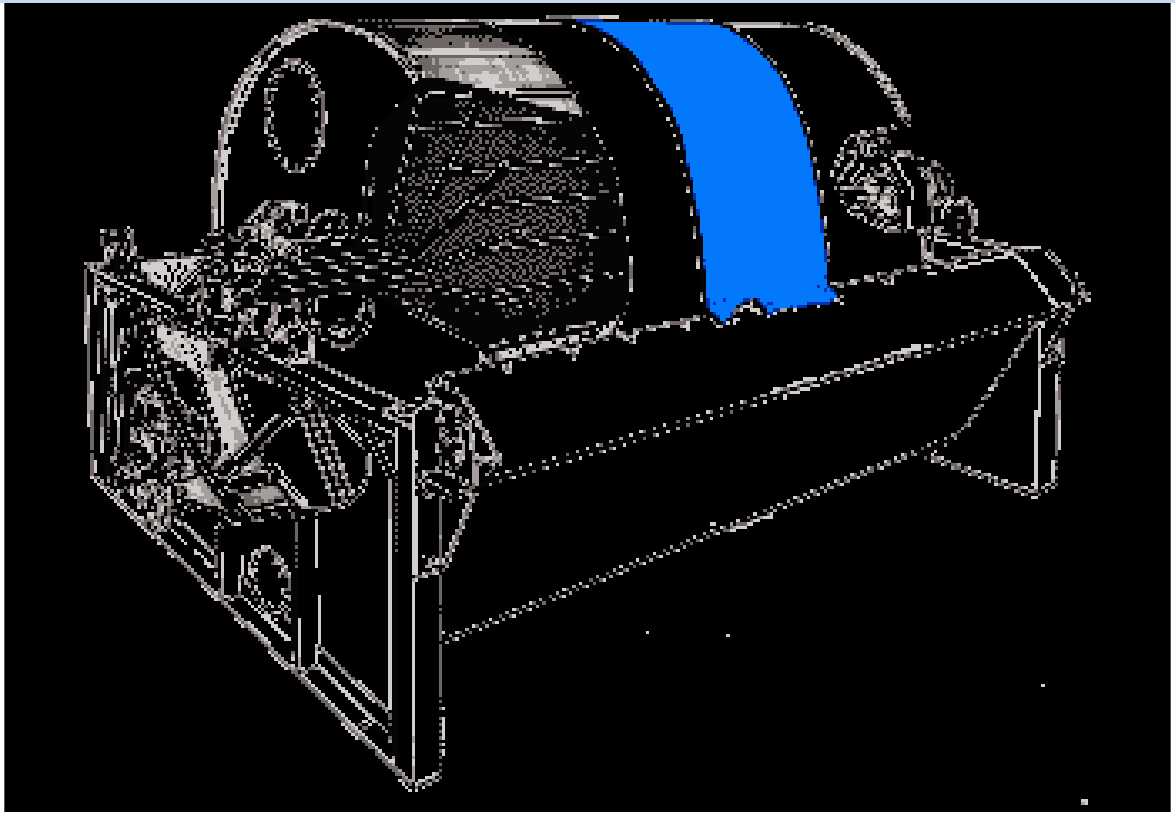
- The plate and frame filter press is cheap but it is difficult to mechanize to any great extent.
- Filtration can be done under pressure or vacuum.
  - The advantage of vacuum filtration is that the pressure drop can be maintained whilst the cake is still under atmospheric pressure and so can be removed easily.
  - The disadvantages are the greater costs of maintaining a given pressure drop by applying a vacuum and the limitation on the vacuum to about 80 kPa maximum.
  - In pressure filtration, the pressure driving force is limited only by the economics of attaining the pressure and by the mechanical strength of the equipment

BAS stainless steel plate and frame filter press

2.Rotary filters

- In rotary filters, the flow passes through a rotating cylindrical cloth from which the filter cake can be continuously scraped.

- Either pressure or vacuum can provide the driving force, but a particularly useful form is the rotary vacuum filter.



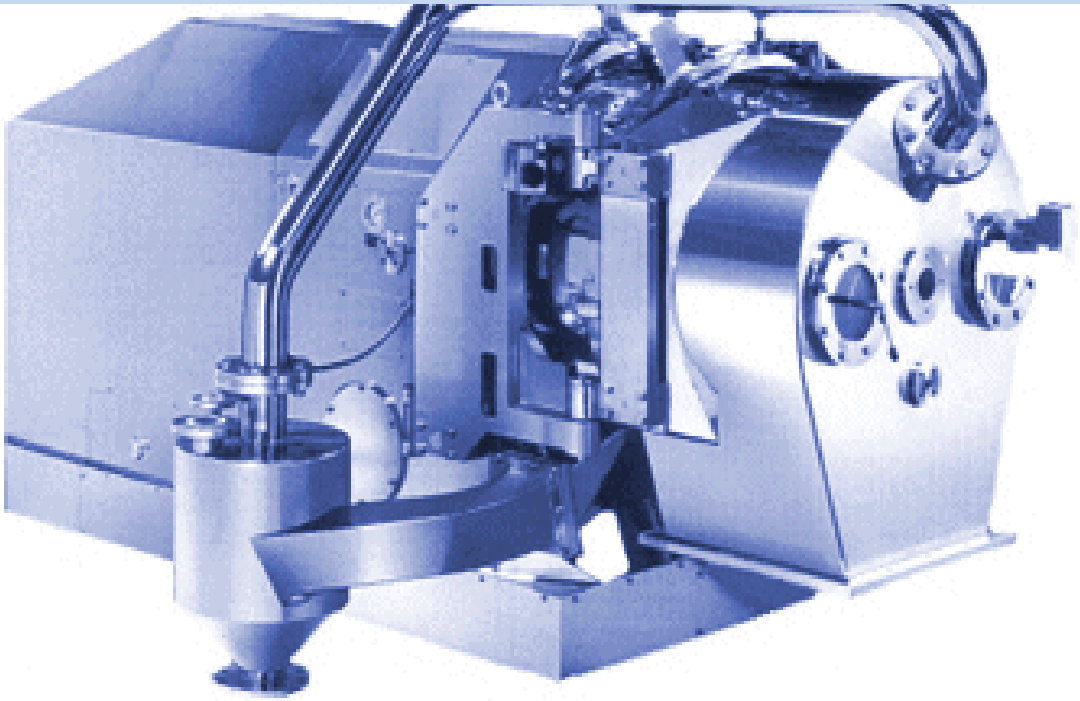
The rotary vacuum drum filter

- A suitable bearing applies the vacuum at the stage where the actual filtration commences and breaks the vacuum at the stage where the cake is being scraped off after filtration. Filtrate is removed through trunnion bearings.

- Rotary vacuum filters are expensive, but they do provide a considerable degree of mechanization and convenience.

3.Centrifugal filters

- Centrifugal force is used to provide the driving force in some filters.
- These machines are really centrifuges fitted with a perforated bowl that may also have filter cloth on it.
- Liquid is fed into the interior of the bowl and under the centrifugal forces, it passes out through the filter material.



Centrifugal filters

4.Air filters

- Filters are used quite extensively to remove suspended dust or particles from air streams.
- The air or gas moves through a fabric and the dust is left behind. These filters are particularly useful for the removal of fine particles.
- The air passing through the bags in parallel. Air bearing the dust enters the bags, usually at the bottom and the air passes out through the cloth

- A familiar example of a bag filter for dust is to be found in the domestic vacuum cleaner. Some designs of bag filters provide for the mechanical removal of the accumulated dust.