Theories of filtration

- The flow of liquid through a filter follows the basic rules that govern the flow of any liquid through the medium offering resistance.
- The rate of flow may be expressed as-

Rate = driving force / resistance

- The rate of filtration may be expressed as volume (litres) per unit time (dv/dt).
- Driving force = pressure upstream – pressure downstream
- Resistance is not constant.
- It increases with an increase in the deposition of solids on the filter medium.
- Therefore filtration is not a steady state.

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- The rate of flow will be greatest at the beginning of filtration process, since the resistance is minimum.
- After forming of filter cake, its surface acts as filter medium and solids continuously deposit adding to thickness of the cake.

Powder or granule bed visualized as a bundle of capillaries

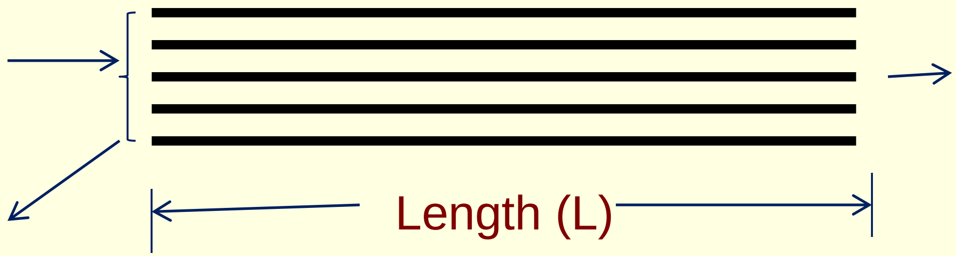

Fig.: Filtration process parameters.

- Resistance to flow is related to several factors given in fig.

Resistance to movement={pressure upstream- pressure downstream}/ length of capillaries

Poiseullie's Equation

- Poiseullie considered that filtration is similar to the streamline flow of liquid under pressure through capillaries.
- Poiseullie's Equation is-

$$V = \frac{\pi \Delta P r^4}{8L\eta}$$

- Where, V = rate of flow, m^3/s (l/s)

  ΔP= Pressure difference across the filter, Pa

  r = radius of capillary in the filter bed, m

  L = thickness of filter cake (capillary length), m

  η = viscosity of filtrate, Pa.s

- If the cake is composed of bulky mass of particles and the liquid flows through the interstice, then flow of liquids through these may be expressed by this equation.

Darcy's Equation

- Poiseullie's law assumes that the capillaries found in the filter are highly irregular and non-uniform.
- Therefore, if the length of capillary is taken as the thickness of bed, a correction factor for radius is applied so that the rate is closely approximated and simplified.
- The factors influencing the rate of filtration has been incorporated into an equation by Darcy, which is:

$$V = \frac{KA\Delta P}{\eta L}$$

- Where, K = permeability coefficient of cake, m^2

  A = surface area of porous bed (filter medium), m^2

Other terms are same as previous equation

- K depends on characteristics of cake, such as porosity, specific surface area and compressibility.

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- Permeability may be defined quantitatively as the flow rate of a liquid of unit viscosity across a unit area of cake having unit thickness under a pressure gradient of unity.
- This equation is valid for liquids flowing through sand, glass beds and various porous media.
- This model is applied to filter beds or cakes and other types of depth filter.
- This equation is further modified by including characteristics of K by Kozeny-Carman.

Kozeny-Carman (K-C) equation

- Kozeny-Carman equation is widely used for filtration.

$$V = \frac{A}{\eta S^2} \times \frac{\Delta P}{KL} \times \frac{\varepsilon^3}{(1-\varepsilon)^2}$$

- Where,

ε = porosity of cake (bed)

S = specific surface area of particles comprising the cake m^2 / m^3

K = Kozeny constant (usually taken as 5)

Other terms are same as previous equations

- Limitations:
  - It does not consider the fact that depth of granular bed is lesser than the actual path traversed by the fluid.
  - The actual path is not same through out the bed, but it is sinuous or tortuous.

Factors influencing filtration

Properties of solid	Properties of liquids	Properties of solid in slurry	Objectives	Temperature
• Particle shape • Particle size • Particle charge • Density • Particle size distribution • Rigidity or compressibility of solid under pressure • Tendency of particle to flocculate or adhere together	• Density • Viscosity • corrosiveness	• Rate of formation of filter cake especially in early stage of filtration	• Whether the solid or liquid or both are to be collected	• Temperature of suspension

Surface area of filter medium

Rate of filtration

- Inversely proportional to specific surface of filter bed (According to K-C equation)
- Directly proportional to surface area of filter medium (According to Darcy’s equation)

- Rate can be increased either using large filter or connecting a number of small units in parallel.
- Filter press works on principle of connecting units in parallel.

Pressure drop across the filter medium

- According to K-C equation the rate of filtration is proportional to the overall pressure drop across both the filter medium and filter cake.
- The pressure drop can be achieved in a number of ways:

Gravity
- A pressure difference could be obtained by maintaining a head of slurry above the filter medium.
- The pressure developed will depend on the density of the slurry

Vacuum (Reducing pressure)
- The pressure below the filter medium may be reduced below atmospheric pressure by connecting the filtrate receiver to a vacuum pump and creating a pressure difference across the filter.

Pressure
- The simplest method being to pump the slurry into the filter under pressure.

Centrifugal force
- The gravitational force could be replaced by centrifugal force in particle separation

Viscosity of filtrate

- According to K-C equation rate of filtration is inversely proportional to the viscosity of the fluid.
- Reason behind this is an increase in the viscosity of the filtrate will increase the resistance of flow.
- This problem can be overcome by two methods:
  - The rate of filtration may be increased by raising the temperature of the liquid, which lowers its viscosity. However, it is not practicable if thermolabile materials are involved or if the filtrate is volatile.
  - Dilution is another alternative but the rate must be doubled.

Filter Media

- The surface upon which solids are deposited in a filter is called the “Filter medium”
- Properties of ideal filter medium:
- It should-

1) be capable of delivering a clear filtrate at a suitable production rate.
2) have sufficient mechanical strength.
3) be inert.
4) retain the solids without plugging at the start of filtration.
5) Not absorb dissolve material.
6) Sterile filtration imposes a special requirement since the pore size must not exceed the dimension of bacteria or spores.

Material used as filter media

Woven material

- Made up of wool, silk, metal or synthetic fibres (rayon, nylon etc.).
- These include a- wire screening and b- fabrics of cotton, wool, nylon.
- Wire screening e.g. stainless steel is durable, resistance to plugging and easily cleaned.
- Cotton is a common filter ,however, Nylon is superior for pharmaceutical use, since it is unaffected by mold, fungus or bacteria and has negligible absorption properties .
- The choice of fibre depends on chemical

Perforated sheet metal

- Stainless steel plates have pores which act as channels as in case of meta filters.

Bed of granular solid built up on supporting medium

- In some processes, a bed of graded solids may be formed to reduce resistance of flow.
- Ex. Of granular solids are gravel, sand, asbestos, paper pulp and keiselgur.
- Choice of solids depends on size of solids in process.

Prefabricated porous solid units

- Used for its convenience and effectiveness.
- Sintered glass, sintered metal, earthenware and porous plastics are used for fabrication.

Membrane filter media

- These are cartridge units and are economical and available in pore size of 100 μm to even less than 0.2 μm.
- Can be either surface cartridges or depth type cartridges.
- **Surface cartridges**
- These are corrugated and resin treated papers and used in hydraulic lines.
- Ceramic cartridges and porcelain filter candles are examples.
- Can be reuse after cleaning.
- **Depth type cartridges:**
- Made up of cotton, asbestos or cellulose.
- These are disposable items, since cleaning is not feasible.

Filter Aids

- The objective of filter aid is to prevent the medium from becoming blocked and to form an open, porous cake, hence, reducing the resistance to flow of the filtrate.
- Filter aid forms a surface deposit which screens out the solids and also prevents the plugging of supporting filter medium.

Characteristics of filter aids:

- Chemically inert and free from impurities.
- Low specific gravity, so remain suspended in liquids.
- Porous rather than dense, so that pervious cake can be formed.
- Recoverable.

Disadvantages:

- Remove the coloured substances by absorbing them.
- Sometimes active principles such as alkaloids are absorbed on filter aid.
- Rarely, filters are source of contamination such as soluble iron salts, which can provoke degradation of sensitive ingredient.

Handling of filter aids

- Filter aids may be used in either or both two ways:

1) Pre- coating technique: by forming a pre-coat over the filter medium by filtering a suspension of the filter aid .
2) Body- mix technique: A small proportion of the filter aid (0.1-0.5 %) is added to the slurry to be filtered. This slurry is recirculated through the filter until a clear filtrate is obtained, filtration then proceeds to completion.

- Different flow rates can be achieved depending on grade of aid-

1. Low flow rate: fine grade filter aids- mainly used for clarity
2. Fast flow rate: coarse grade filter aids- acceptable filtrate.

Examples of filter aids

- Diatomite (Keiselgur) , obtained from natural siliceous deposits.
- Perlite , it is an aluminium silicate. Cellulose, Asbestos, charcoal, talc, bentonite , fullers earth etc.