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PHARMACEUTICAL ENGINEERING

UNIT 4

TOPIC :

- **Filtration :** Objectives, applications, Theories & Factors influencing filtration, filter aids, filter medias. Principle, Construction, Working, Uses, Merits and demerits of plate & frame filter, filter leaf, rotary drum filter, Meta filter & Cartridge filter, membrane filters and Seidtz filter.

Filtration

- Filtration is a mechanical or physical process used to separate solid particles from a liquid or gas.
- The mixture is passed through a filter medium which allows the fluid (filtrate) to pass while retaining the solid particles (filter cake).
- The principle is based on the difference in particle size and pore size of the filter medium.

Important Terms in Filtration

1. Slurry: Suspension of solid particles in liquid to be filtered.
2. Filter Medium: Porous material used to retain solid particles (e.g., cloth, paper, sand, membrane).
3. Filter Cake: The layer of solid particles accumulated on the filter medium.
4. Filtrate: The clear liquid or gas that passes through the filter medium.

Objectives of Filtration

- Separation of solids from liquids or gases.
- Clarification and purification of liquids.
- Concentration of desired components.
- Sterilization (removal of microorganisms).
- Waste management and pollution control.

Applications of Filtration

- Water purification (removing suspended solids, bacteria, impurities).
- Air purification (HVAC filters, surgical masks, clean rooms).
- Pharmaceutical industry (sterile filtration, separation of precipitates, preparation of injectables).
- Food & Beverages (beer, fruit juices, milk clarification).
- Chemical industry (separation of catalysts, purification of intermediates).
- Laboratory work (analytical separations, sample preparation).
- Environmental protection (wastewater treatment, dust collection).

Factors Affecting Filtration

1. **Particle Size:**
   - Larger particles are retained easily.
   - Very small particles may pass unless very fine filters are used.
2. **Filter Medium:**
   - The pore size and type of filter material determine retention capacity.
   - Finer pores = better separation but slower filtration.
3. **Viscosity of Fluid:**
   - High viscosity liquids flow slowly → reduce filtration rate.
   - Viscosity decreases with higher temperature → faster filtration.
4. **Filtration Pressure:**
   - Higher applied pressure forces fluid through faster.
   - Used in vacuum filtration or pressure filters.
5. **Temperature:**
   - Increases filtration by lowering viscosity and improving solubility of solids.
6. **Concentration of Solids:**
   - High concentration → filter clogging → slower filtration.
7. **Cake Formation:**
   - As filtration proceeds, a filter cake forms.
   - Cake increases resistance and reduces filtration rate.
8. **Filter Surface Area:**
   - Larger surface area → more fluid can pass at a time → faster filtration.

Theories of Filtration

Filtration involves the passage of liquid through a porous medium, leaving the solid particles behind as a filter cake.
The rate of filtration depends on the balance between the driving force (pressure/vacuum/gravity) and the resistance (filter medium + cake formed).

$$\text{Rate of Filtration (R)} = \frac{\text{Driving Force}}{\text{Resistance}}$$

Different mathematical models have been developed to explain and predict filtration behavior:

1. Poiseuille's Equation

- Based on laminar (streamline) flow of liquid through cylindrical capillaries (pore channels).
- Assumes incompressible, Newtonian fluid.

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

Where:

- V = Rate of flow (filtration rate)
- ΔP = Pressure difference across filter
- r = Radius of filter pores
- L = Thickness of filter medium or cake
- η = Viscosity of fluid

Key Point: Flow rate is proportional to the pressure difference and the fourth power of pore radius → even small pores drastically reduce flow.

2. Darcy's Equation

- Considers permeability of filter cake.
- Widely applied in practical filtration processes

$$V = \frac{K\,A\,\Delta P}{\eta\,L}$$

Where:

- V = Filtration rate
- K = Permeability coefficient of filter cake
- A = Surface area of filter medium
- ΔP = Pressure difference
- η = Viscosity of filtrate
- L = Thickness of cake

Key Point:

Rate is directly proportional to filter area and pressure difference, and inversely proportional to cake thickness and fluid viscosity.

3. Kozeny–Carman Equation

- Modified form of Darcy's law.
- Takes into account the porosity and specific surface area of the filter cake.
- More accurate for porous beds (powders, gels, precipitates).

$$V = \frac{A}{\eta\,S^2} \cdot \frac{\Delta P}{kL} \cdot \frac{\varepsilon^2}{(1-\varepsilon)^2}$$

Where:

- V = Filtration rate
- A = Area of filter medium
- S = Specific surface area of cake particles
- ΔP = Pressure difference
- k = Kozeny constant (depends on cake structure)
- L = Thickness of cake
- ε = Porosity of cake

Key Point:
This equation explains how porosity and particle shape affect filtration efficiency.

Plate and Frame Filter

Principle

- The plate and frame filter press works on the principle of filtration under pressure.
- A slurry (suspension of solid particles in a liquid) is forced through a filter medium.
- The solid particles are retained on the filter medium, forming a filter cake, while the clear liquid (filtrate) passes through.
- The applied pressure enhances the rate of filtration and allows efficient separation.

Construction

1. **Plates and Frames**
   - Alternating plates and frames are stacked together.
   - Plates are covered with filter cloth, while frames form chambers to hold slurry.
   - Plates have drainage channels for filtrate collection.
2. **Filter Cloth**
   - A porous fabric or medium stretched over the plates.
   - Acts as the filtering surface to retain solids.
3. **Channels**
   - **Inlet channel**: for slurry feeding.
   - **Outlet channels**: for the discharge of filtrate.
4. **Closing Device**

- A mechanical or hydraulic device used to press plates and frames tightly together, preventing leakage.

5. **Pump**
    - Provides the required pressure to force slurry through the filter medium.

Working

1. The slurry is pumped into the filter press through the feed channel.
2. Under applied pressure, the liquid part of slurry passes through the filter cloth into drainage channels.
3. Solid particles remain on the cloth, forming a filter cake.
4. Filtrate (clear liquid) exits through outlet ports.
5. Once filtration is complete:
    - The press is opened.
    - The filter cake is removed manually or mechanically.

Advantages

- High filtration efficiency.
- Can handle high pressures.
- Customizable size and capacity depending on requirement.
- Produces clear filtrate suitable for pharmaceutical applications.

Disadvantages

- Time-consuming process.
- Large space requirement for installation.
- Manual labor needed for cake removal and cleaning.
- Not suitable for continuous operation (batch process).

Applications

- Widely used in pharmaceutical industries for clarification and purification.
- Filtration of liquid oral formulations and suspensions.

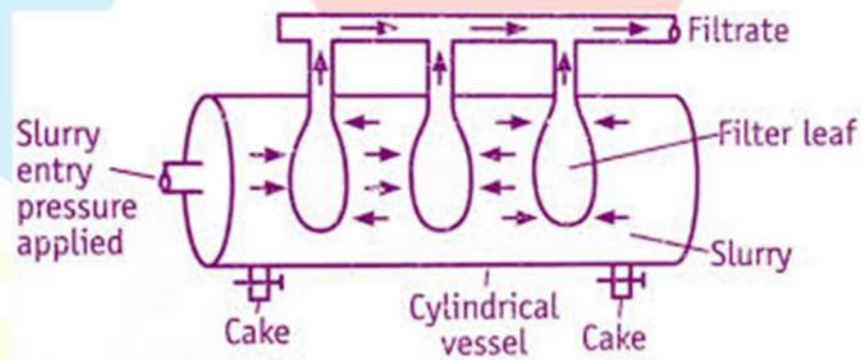
- Clarification of fruit juices and beverages.
- Removal of precipitated proteins from insulin and other biopharmaceuticals.
- General separation of solid–liquid mixtures in food, chemical, and fermentation industries.

Filter Leaf

Principle

- The filter leaf works on the principle of filtration under pressure or vacuum.
- A leaf-shaped frame is covered with filter cloth and immersed in a slurry tank.
- The liquid part passes through the cloth into the hollow frame (due to pressure or suction) and is collected as filtrate, while solids are retained as a filter cake on the cloth.
- After filtration, the cake is dried and removed by vibration or washing.

Construction



1. Leaf (Filtering Element)
   - Consists of a hollow metal frame (usually perforated) covered with filter cloth or wire mesh.
   - Acts as the main filtering surface.
   - Different shapes: circular, square, or rectangular.
2. Slurry Tank
   - A large vessel in which slurry is stored and into which the filter leaf is immersed.
3. Outlet Pipe
   - Each filter leaf has a pipe connected to a manifold for filtrate collection.
4. Agitator (Optional)
   - Used in the slurry tank to maintain uniform suspension of particles during filtration.

Working

1. The leaf filter is immersed vertically in a slurry tank.
2. Vacuum or pressure is applied inside the hollow leaf.
3. Liquid passes through the filter cloth into the hollow frame and is collected as clear filtrate.
4. Solid particles are deposited on the surface of the cloth as a filter cake.
5. After sufficient cake has formed:
    - The filter is removed from slurry.
    - The cake is washed (if required).
    - Cake is dried by passing air or steam.
    - Finally, the cake is removed by shaking or scraping.

Advantages

- Simple in design and easy to operate.
- Large filtering area in small space.
- Low cost and economical.
- Cake can be washed and dried before removal.

Disadvantages

- Filtration rate is relatively slow.
- Only suitable for slurries with low solid content.
- Cake removal can be difficult.
- Not ideal for very fine particles that may clog filter cloth.

Applications

- Widely used in pharmaceutical industries for clarification of liquids.
- Separation of crystals from mother liquor.
- Used in food industry for oils, juices, and beverages.
- Applied in chemical and fermentation industries.

Rotary Drum Filter

Principle

- The Rotary Drum Filter works on the principle of continuous filtration under vacuum.
- A rotating drum is partially immersed in a slurry.
- Vacuum inside the drum causes liquid to pass through the filter cloth (mounted on the drum surface), leaving behind solids as a filter cake.
- The drum rotation allows continuous cake formation, washing, drying, and removal in a single operation.

Construction

1. Rotating Drum
   - A large, hollow, cylindrical drum covered with filter cloth or mesh.
   - Drum surface is divided into compartments by perforated plates.
   - Connected to a vacuum system.
2. Slurry Tank
   - Holds the slurry in which the lower part of the drum is submerged.
3. Agitator
   - Keeps slurry particles uniformly suspended in the tank.
4. Vacuum System
   - Creates suction inside the drum, pulling liquid through the filter cloth.
5. Filtrate Outlet
   - Channels filtrate from the drum compartments to the collection system.
6. Cake Removal Mechanism
   - Scraper knife, belt, or string system continuously removes dried cake from the drum surface.

Working

1. The drum rotates slowly in the slurry tank.
2. Vacuum applied inside the drum pulls liquid through the filter cloth → filtrate collected.
3. Solids deposit on the drum surface forming a filter cake.
4. As drum rotates, cake passes through different zones:
    - Cake Formation Zone (in slurry tank)
    - Cake Washing Zone (sprays wash liquid over cake if required)
    - Cake Drying Zone (vacuum removes remaining liquid, sometimes with air blowing)
    - Cake Removal Zone (scraper removes the dried cake)
5. The cycle is continuous, making it suitable for large-scale filtration.

Advantages

- Continuous operation → high throughput.
- Suitable for large volumes of slurry.
- Cake can be washed and dried before removal.
- Efficient for slurries with high solid content.

Disadvantages

- Expensive and complex equipment.
- Requires large space.
- High maintenance cost.
- Not suitable for small-scale operations.
- Difficult to handle very fine particles (may clog).

Applications

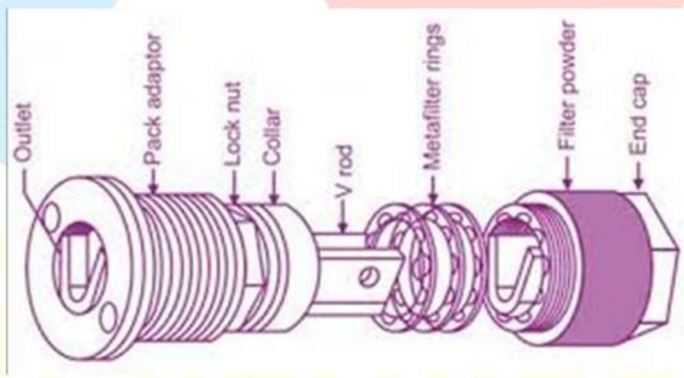
- Pharmaceutical industry – separation of crystals (antibiotics, vitamins, etc.) from mother liquor.
- Food industry – for filtration of juices, oils, and beverages.
- Fermentation industry – recovery of biomass or products.
- Chemical industry – filtration of slurries containing large solids.

Meta Filter

Principle

- The Meta filter works on the principle of surface filtration under pressure.
- A slurry is forced through a filter medium (usually stainless steel wire mesh or filter cloth).
- Solids are retained on the medium to form a filter cake, while the clear filtrate passes through.
- The filter medium is supported by specially designed filter leaves or screens arranged in a circular housing.

Construction



1. Filter Housing
   - A vertical cylindrical vessel made of stainless steel.
   - Designed to withstand high pressure.
2. Filter Elements (Filter Leaves/Discs)
   - Circular discs (plates) mounted on a central shaft.
   - Each plate is covered with filter medium (mesh or cloth).
   - The shaft is hollow and connected to filtrate outlet.
3. Feed Inlet
   - Slurry enters the filter housing from the bottom or side.
4. Filtrate Outlet
   - Clear liquid passes through filter leaves and exits via the central shaft.
5. Cake Discharge System
   - After filtration, the unit is opened and the filter cake is removed manually or by washing with back pressure.

Working

1. Slurry is pumped into the filter housing under pressure.
2. Filtration occurs on the surface of the filter medium.
3. Solids deposit as a cake on the leaves/discs.
4. Filtrate passes through filter medium → into the hollow shaft → collected at the outlet.
5. Once filtration cycle is complete, pressure is released.
6. The unit is opened and cake is removed from the leaves.
7. Filter medium is washed and prepared for the next cycle.

Advantages

- Provides large surface area for filtration in compact design.
- Handles high solid load slurries.
- Operates at high pressure, giving fast filtration.
- Filter leaves are reusable and easy to clean.

Disadvantages

- Operation is not continuous (batch process).
- Labor-intensive due to manual cake removal.
- Not suitable for very fine particles (risk of clogging).
- Requires skilled handling to maintain efficiency.

Applications

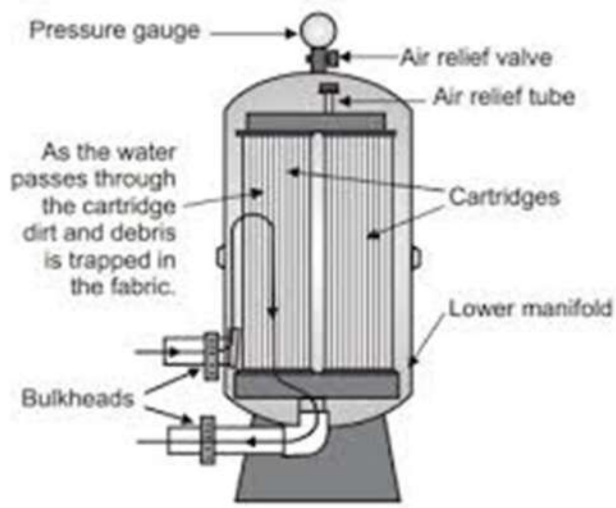
- Widely used in pharmaceutical industry for clarification of syrups, tinctures, and solutions.
- Used in chemical and food industries for separation of suspensions.
- Suitable for bulk drug manufacturing where high solid load slurries are handled.

Cartridge Filter

Principle

- The cartridge filter works on the principle of depth filtration and surface filtration.
- The liquid (slurry/solution) is passed through a porous cartridge element under pressure.
- Suspended particles are trapped on the surface and within the pores of the cartridge material.
- Clear filtrate passes through and is collected at the outlet.

Construction



1. Filter Housing
   - A stainless steel (SS) or plastic cylindrical shell.
   - Designed to withstand pressure.
2. Cartridge Element
   - Cylindrical filter made of materials like cellulose, ceramic, sintered glass, polypropylene, or stainless steel.
   - Can be pleated to increase surface area.
   - Available in various pore sizes (0.2 µm – 100 µm).
3. Inlet & Outlet Connections
   - Inlet for unfiltered liquid (feed).
   - Outlet for clear filtrate.
4. Sealing Arrangement
   - Gaskets or O-rings prevent leakage.

Working

1. The unfiltered liquid enters the housing through the inlet.
2. The liquid passes through the cartridge element.
3. Suspended particles are retained within the depth of the filter medium or on its surface.
4. The clear filtrate is collected at the outlet.
5. When the cartridge becomes clogged, it is replaced with a new one.

Advantages

- Provides very clear filtrate (high filtration efficiency).
- Cartridges are easily replaceable.
- Available in a wide range of pore sizes.
- Compact design and easy to install.
- Suitable for sterile filtration (0.2 μm pore cartridges).

Disadvantages

- High cost due to frequent replacement of cartridges.
- Not suitable for liquids with high solid content (clogging occurs quickly).
- Cartridges are not reusable in most cases.
- Limited use for large-scale bulk filtration.

Applications

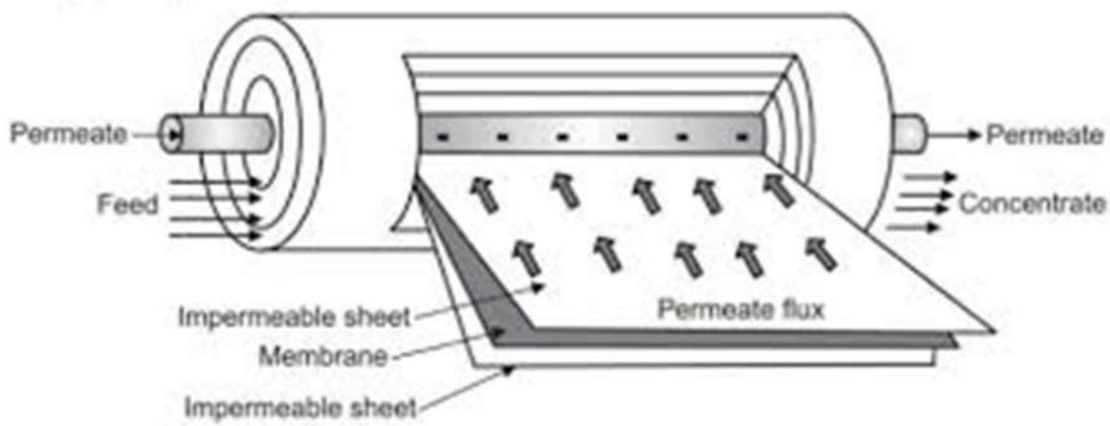
- Pharmaceutical industry: Sterilization of liquids (antibiotic solutions, injectables, ophthalmic preparations).
- Water purification (RO pre-filtration).
- Food industry: Clarification of beverages like beer, wine, juices.
- Chemical industry: Filtration of corrosive solutions, solvents, and process fluids.

Membrane Filters

Principle

- Membrane filters work on the principle of surface filtration.
- The liquid is passed through a thin microporous membrane under pressure or vacuum.
- Suspended particles, microorganisms, and other impurities are retained on the surface of the membrane according to the pore size.
- The clear filtrate passes through the membrane.

Construction



1. Filter Membrane
   - Thin films of polymers such as cellulose acetate, cellulose nitrate, polycarbonate, nylon, PVDF (polyvinylidene difluoride), Teflon (PTFE).
   - Thickness: ~100–150 µm.
   - Available pore sizes: 0.01 µm – 10 µm.
   - Common sterile filtration size: 0.22 µm.
2. Support Pad/Disc
   - Provides mechanical support to prevent rupture of delicate membranes.
3. Filter Holder / Assembly
   - Stainless steel, plastic, or glass housing.
   - Contains inlet and outlet connections.

Working

1. The liquid (solution/suspension) is introduced into the filter holder.
2. Pressure or vacuum is applied to force the liquid through the membrane surface.
3. Particles and microorganisms larger than the pore size are retained on the surface.
4. The sterile filtrate is collected at the outlet.
5. After use, the membrane can be discarded or sterilized (depending on material).

Advantages

- Provides sterile filtration (removes bacteria, spores, particles).
- No chemical interaction with the filtrate (chemically inert).
- Available in precisely controlled pore sizes.
- Maintains pharmaceutical product stability (no heat, suitable for thermolabile substances).
- Easy to use, disposable, and portable.

Disadvantages

- Clogging occurs rapidly when filtering solutions with high solid content.
- Expensive for large-scale use.
- Fragile, may tear or rupture under high pressure.
- Cannot be used for very viscous liquids.

Applications

- Pharmaceutical industry:
    - Sterile filtration of antibiotic solutions, injectables, ophthalmic preparations, and heat-sensitive products.
- Microbiology:
    - Sterility testing, microbiological analysis (colony counting after passing sample through filter).
- Water testing:
    - Detection of microbial contamination.

Seitz Filter

Principle

- The Seitz filter works on the principle of depth filtration.
- The liquid (suspension) passes through a thick filter pad made of asbestos and cellulose fibers.
- Particles and microorganisms are entrapped within the depth of the filter pad rather than only on the surface.
- Provides both clarification and sterilization of liquids.

Construction

1. Filter Pads
    - Made from asbestos + cellulose fibers.
    - Thickness: 2–3 mm.
    - Available in different grades of porosity (coarse, medium, fine).
    - Disposable type.
2. Filter Holder/Chamber
    - Stainless steel or aluminum body.
    - Designed to hold filter pads securely.
3. Supporting Base Plate
    - Provides support to the filter pad.
4. Inlet and Outlet Channels
    - Inlet: For feeding the solution.
    - Outlet: For collecting filtrate.

Working

1. The liquid is introduced under pressure or vacuum.
2. It passes through the Seitz filter pad.
3. Suspended solids and microorganisms are trapped inside the depth of the filter.
4. The clear sterile liquid passes out through the outlet.

Advantages

- Provides effective sterilization of pharmaceutical solutions.
- Pads are disposable, avoiding contamination risks.
- Available in various porosity grades for selective filtration.
- Can handle large volumes of liquids compared to membrane filters.

Disadvantages

- Pads are fragile and may break if pressure is too high.
- Risk of shedding fibers (asbestos/cellulose) into the filtrate if not properly handled.
- Not reusable (pads must be discarded after use).
- Cannot be used for very viscous liquids.

Applications

- Sterilization of serum, plasma, injectables, antibiotics, and heat-sensitive solutions.
- Filtration of beer, wine, and beverages (for clarification and sterilization).
- Used in pharmaceutical quality control laboratories for sterility testing.