Evaporation
Evaporation

**Evaporation** refers to the partial removal of water from a liquid food material through vapourisation.

Separation is achieved by exploiting the difference in volatility between water and solutes.

**Generally 80% water is removed and 20% is left.**
Objectives of evaporation

- To pre-concentrate foods prior to drying, freezing or sterilization, and hence to reduce weight and volume.
- To reduce container size and cost involvement in storage, transportation, handling and packaging.
- To save energy in subsequent operations.
- To enhance shelf life.
- To achieve greater convenience for consumer (e.g. fruit drinks for dilution, tomato puree, pastes, etc.) or for manufacturers (e.g. lignin, pectin, fruit concentrates for use in ice or baked goods)
- To impart an acceptable change in flavour and/or colour of a food (e.g. caramelized syrups for use in baked goods and sugar confectionary).
- Evaporation is used prior to drying to reduce energy cost.
Basic functions of an evaporator

1. Transfer of heat from steam to the food

2. Vapourisation of water

3. Removal of fluid droplets from the vapour before it leaves the evaporator.

Usually

• The latent heat is transferred from the heating medium (steam) to the food.
• The pressure in the food section is kept below atmospheric to achieve boiling at less than 100°C.
• The vapour leaving the evaporator is condensed.
Basic functions of an evaporator

Thus, the basic parts of the evaporator are:

- Heat exchanger,
- Means of separating vapour produced, and
- Mechanical or steam ejector vacuum pump,
- Condenser (in case the vapour is not used in a subsequent evaporator as heating medium).

Mechanical pumps have lower operating costs, but higher capital costs than steam ejector pumps.
Basic parts of an evaporator
# Types of evaporators

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<th>Natural circulation types</th>
<th>Forced circulation types</th>
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<td>Open or closed pan evaporators</td>
<td>Mechanical (or agitated) thin film evaporator</td>
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<td>Short tube (Calandria) evaporators</td>
<td>Plate evaporator</td>
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<td>Long tube vertical evaporator: Climbing/ Falling film type</td>
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In forced circulation evaporators, a **pump or scraper assembly** moves the liquor, usually in thin layers. It gives **higher heat transfer rates and short residence times**. It also gives **more compact equipment and higher production rates**.
Open kettle evaporator

Jacketed open kettle evaporator

Spiral coils used in open kettle evaporators
Short tube evaporator
Short tube evaporator

- Shell and tube type HE
- Tube bundles (Vertical/Horizontal)
- Steam generally in the shell
- Central down-comer large dia tube
- Liquid moves due to vapour pr difference
- Baffles at top
- Steam at atm. pr. or elevated pr (up to 2.8 kg/cm²)
- Single pass / Multi pass
- Basket evaporator
- External calandria evaporator
- Low viscosity products
- Almost obsolete now

Shell and tube type evaporators are also known as calandria
Long tube vertical evaporators

Falling film type

Climbing film type
Long tube vertical evaporators

Flow pattern in a Climbing film type evaporator
## Long tube evaporator

Shell and tube HE; 3-15 m; Entry air vel: 0.3-1.2 m/s

<table>
<thead>
<tr>
<th>Rising film type</th>
<th>Falling film type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tube dia: 5 cm</td>
<td>5-25 cm</td>
</tr>
<tr>
<td>Flow by buoyancy</td>
<td>Flow by gravity</td>
</tr>
<tr>
<td>Liquid almost heated to boiling point</td>
<td>Distributor at the top</td>
</tr>
<tr>
<td>Flow velocity increases in the rising column</td>
<td>Flow velocity at the end 200 m/sec</td>
</tr>
<tr>
<td>Return leg for recirculation</td>
<td>Recycling possible</td>
</tr>
<tr>
<td>Baffle/ vapour separators at top</td>
<td>Vapour separator at bottom</td>
</tr>
<tr>
<td>Low viscosity product: 0.1 Ns/m²</td>
<td>More viscous foods, heat sensitive foods</td>
</tr>
<tr>
<td>Effective for foaming fluids</td>
<td></td>
</tr>
<tr>
<td>Residence time is 3-4 min</td>
<td>5-30 sec residence time</td>
</tr>
</tbody>
</table>

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Forced circulation evaporators

with vertical heat exchanger

with horizontal tube two-pass heat exchanger
Forced circulation evaporators

- Horizontal or vertical heat exchanger
- Horizontal may have two passes
- Forced at air velocity of 2-5.5 m/s
- **Tubes are under static head so that no boiling in tubes**
- Vapour separator - Deflector plate/ baffle
- Part of liquid is recirculated
- Suitable for viscous foods 20 Ns/m²
Agitated thin film evaporators
Agitated thin film evaporators

- Steam jacketed vessel
- High speed rotor, fitted with short blades along its length
- Film thickness: 1.25 mm for scraped surface
  - 0.25 mm for wiped surface
- Residence time 0.5-100 s
- Extra capital / running cost (due to mechanical agitation, and more precise alignment)
- Only single effect is possible
- Up to 20 Ns/m²
- Used mostly for finishing of high viscous products
Agitated thin film evaporators

Scraped surface type evaporator
Centri-therm conical evaporator
Centri-therm conical evaporator

- Feed from a central pipe to underside of rotating cone
- Liquid moves by centrifugal force
- Film thickness : 0.1 mm
- Residence time : 0.6-1.6 sec
- Condensed steam flung from rotating cones and hence no boundary layer → high heat transfer rate
- High viscous fluid 20 Ns/m²
Plate type evaporator

Flow pattern in a Plate type evaporator
Expanding flow evaporators

- Stack of inverted cones
- Steam fed down in alternate channels
- Liquid moves by vapour pressure upward
- Vapour-concentrate mixture leaves tangentially
- Special design of shell, which induces cyclone effect, separates the vapour concentrate mixture
- Reduction of flow area of condensing steam maintains high heat transfer rate
Thank you