

# Principles of Chemical Engineering

## Heat Transfer

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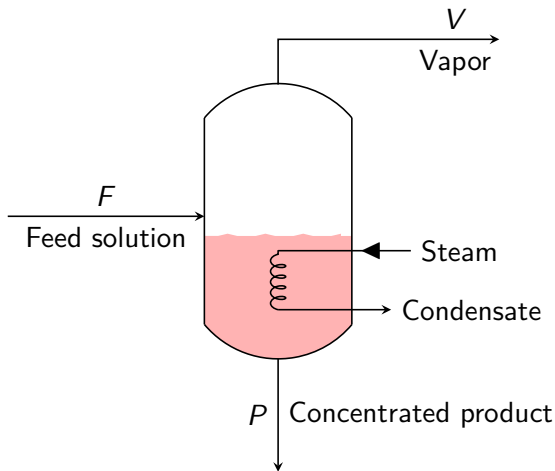
# Syllabus Contents

Evaporators - long tube vertical and forced circulation type evaporators, multiple effect evaporators.

# Objectives

- ▶ To understand the role of evaporation.
- ▶ To understand the performance parameters of evaporation system.
- ▶ To get an overview of different types of evaporation equipments.
- ▶ To understand the need of multiple effect evaporation.
- ▶ To get an overview of different types of multiple effect evaporation arrangement.

# Evaporation



The objective of evaporation is to concentrate a non-volatile solute in a solution by vaporizing the solvent. The solvent is usually water.

# Evaporators

- ▶ An evaporator consists of a heat exchanger for boiling the solution and a means to separate the vapor from the boiling liquid.
- ▶ Different types are categorized by the length (short-tube / long-tube) and alignment (horizontal / vertical) of the evaporator tubes. The evaporation tubes may be located inside or outside of the main vessel where the vapor is driven off.
- ▶ Because many materials cannot tolerate high temperatures, evaporators often operate at reduced pressure so that the boiling point will also be reduced.

# Evaporator Performance

There are three main measures of evaporator performance:

1. Capacity (kg water vaporized/time)
2. Economy (kg water vaporized/kg steam input)
3. Steam Consumption (kg/time)

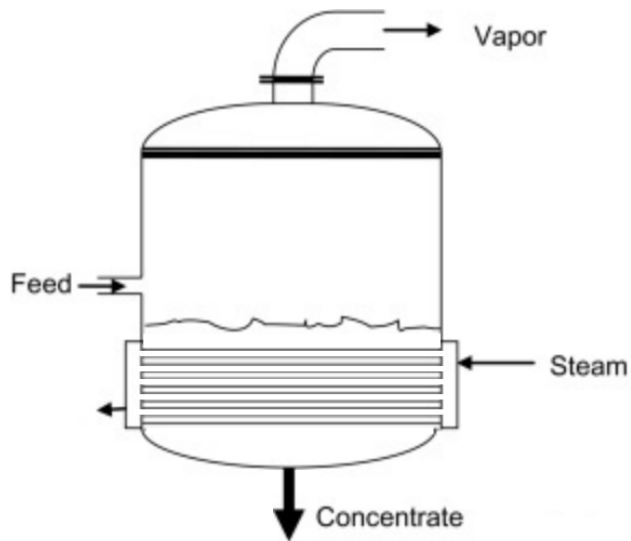
Note that the measures are related, since

$$\text{Steam Consumption} = \frac{\text{Capacity}}{\text{Economy}}$$

## Evaporator Performance (contd..)

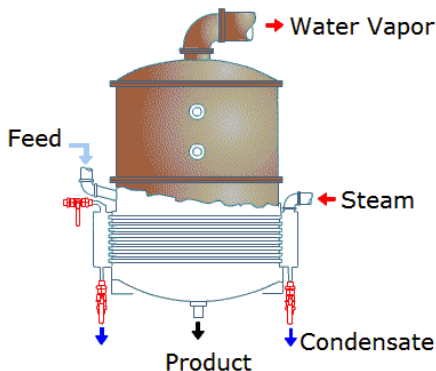
- ▶ Economy calculations are determined using material and energy balances.
- ▶ The key factor in determining the economy of an evaporator is the number of effects.
- ▶ The economy of a single effect evaporator is slightly closer to but less than 1. Multiple effect evaporators have higher economy in proportion to the number of effects.

# Horizontal-tube Evaporator





# Horizontal-tube Evaporator

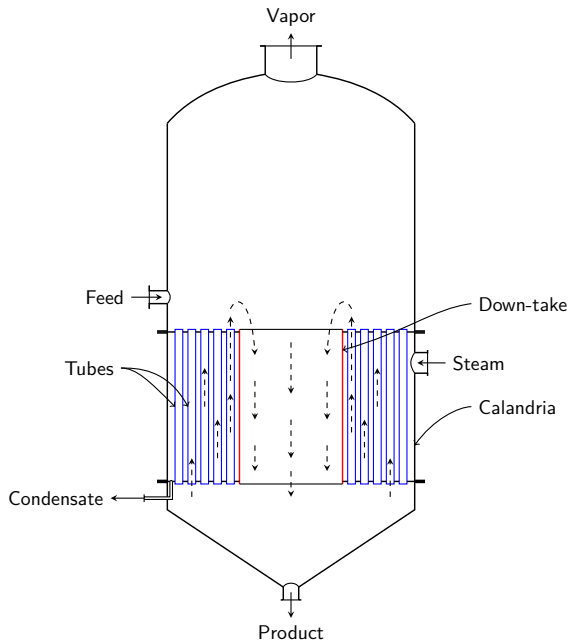


- ▶ The horizontal tube evaporator is the only type of chemical evaporator in which the heating medium is inside the tubes.
- ▶ The major use of this type of evaporator is for making distilled water for boiler feed.

## Horizontal-tube Evaporator (contd..)

- ▶ This type has smaller capacity than other evaporators.
- ▶ The principal advantage of horizontal tube evaporators lies in the relatively small headroom they require.
- ▶ The horizontal evaporator is least satisfactory for fluids that form scale or deposit salt (which would build up on the outside of the tube).
- ▶ It is well-suited for processes where the final product is a liquid instead of a solid, such as sugar syrups where the large volume of liquid stored in the evaporator allows a close adjustment of the final density by changing the hold-up in the evaporator.

# Standard Calandria Evaporator

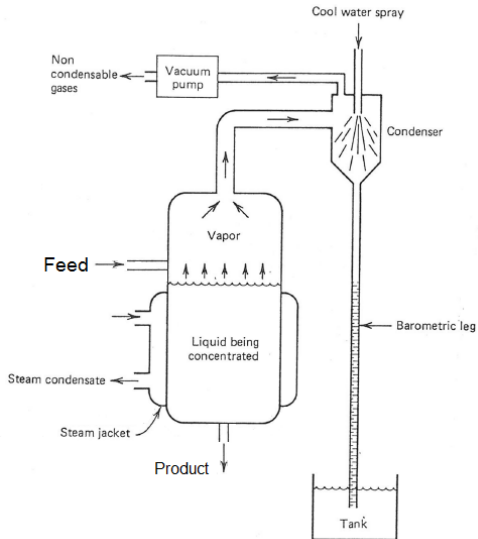


# Standard Calandria Evaporator

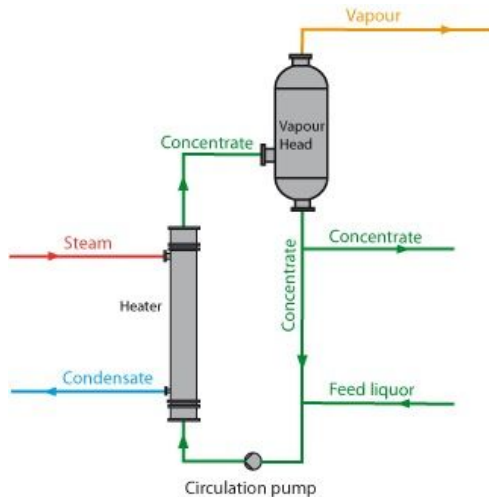
- ▶ The calandria evaporator has vertical tubes usually less than six feet long.
- ▶ The liquid level is maintained above the top tubesheet, and the circulation pattern is up through the tubes and down through a central pipe called a “downcomer”.
- ▶ Circulation is created by the difference in specific gravity between the body liquor and the heated liquor and vapor generated inside the tubes, plus a vapor lift effect.
- ▶ The circulation rate through the downcomer (also known as downtake) is many times the feed rate.
- ▶ The flow area of the downtake is normally approximately equal to the total tubular flow area.

# Standard Calandria Evaporator

## Vacuum Arrangement

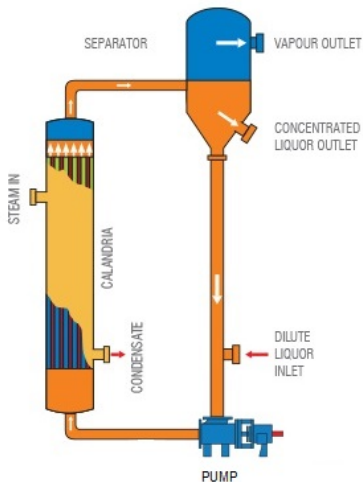


# Long-tube Vertical Evaporators



Carefully balanced flow and hydrostatic head truly suppress boiling and scaling in the tubes.

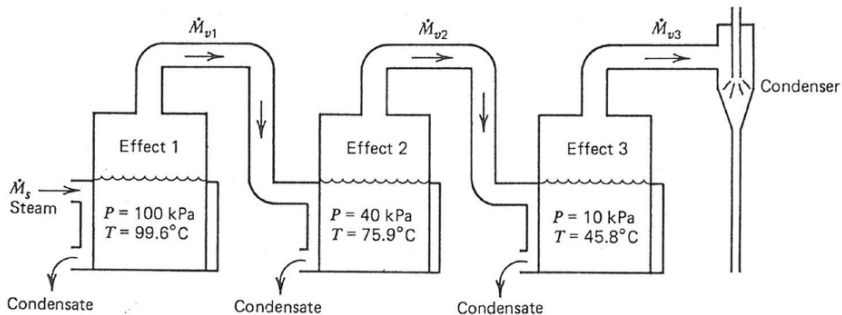
# Long-tube Vertical Evaporators



Advantages of the long-tube vertical evaporator are:

- ▶ Reduced floor space requirements.
- ▶ Relatively high heat-transfer coefficients.
- ▶ Ability to handle foamy liquids.

# Multiple Effect Evaporation



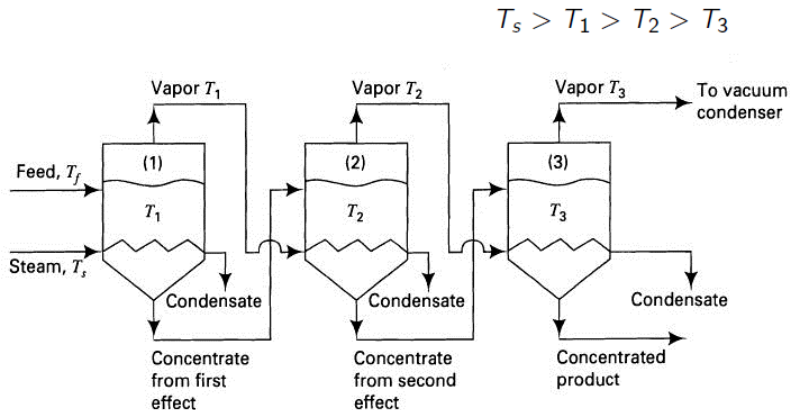
Vapor from first effect can be used as steam for the second effect and so on.



## Multiple Effect Evaporation (contd..)

- ▶ Effects are thus numbered beginning with the one heated by steam. It will have the highest pressure.
- ▶ Pressure drops through the sequence so that the hot vapor will travel from one effect to the next automatically.
- ▶ Normally, all effects in an evaporator will be physically the same in terms of size, construction, and heat transfer area. Unless thermal losses are significant, they will all have the nearly the same capacity as well.

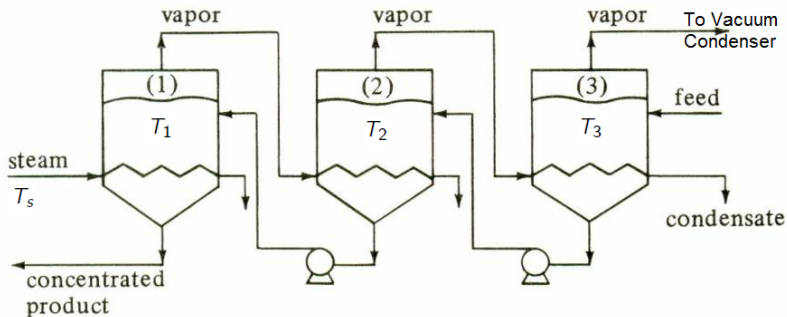
# Forward Feed



Concentrated product is at low temperature.

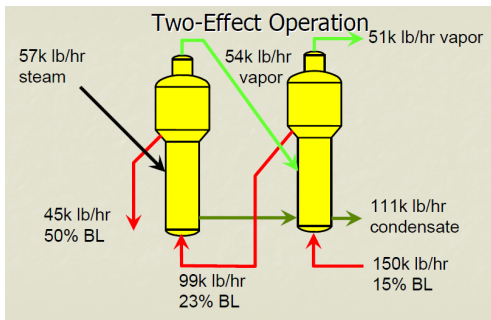
# Backward Feed

$$T_s > T_1 > T_2 > T_3$$



# Quiz

1. What are the advantages / disadvantages with multiple effect evaporation over single effect evaporation?
2. Answer the following questions based on the schematic:



- (a) What is the arrangement here — forward / backward feed?
- (b) What is the economy of the system?
- (c) What if the capacity of the system?