CH2407 Process Equipment Design II

www.msubbu.in

Evaporators

Dr. M. Subramanian

Associate Professor
Department of Chemical Engineering
Sri Sivasubramaniya Nadar College of Engineering
Kalavakkam – 603 110, Kanchipuram (Dist)
Tamil Nadu, India
msubbu.in[AT]gmail.com

Introduction

- An evaporator is used to evaporate a volatile solvent, usually water from a solution

- Its purpose is to concentrate non-volatile solutes such as organic compounds, inorganic salts, acids or bases

- Desired product can be precipitated crystals, concentrated solutions or the solvent (boiler feed water, distilled water)

Quintuple-Effect, Forced-Circulation NaCl Evaporator

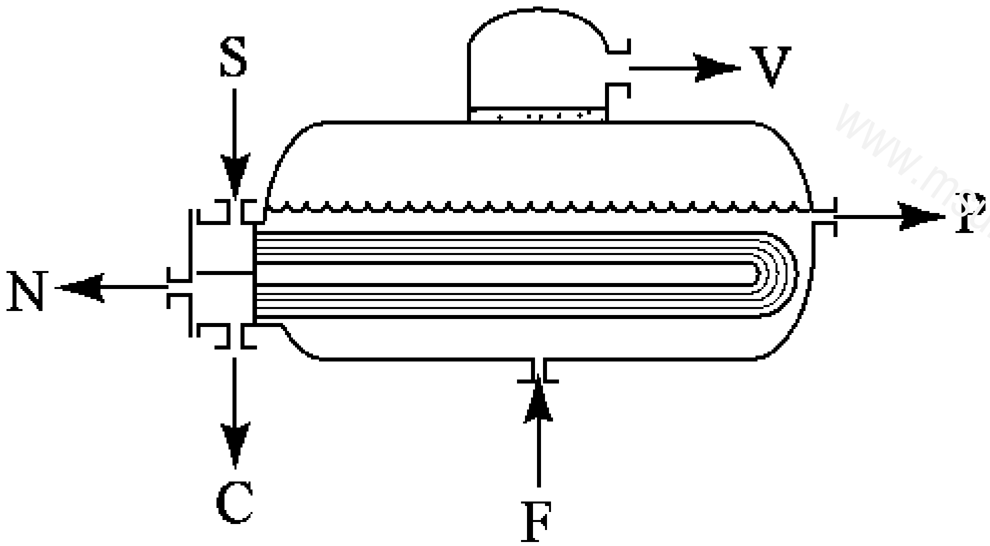
Three-stage, Forced-Circulation Evaporator used to concentrate wet process phosphoric acid

Evaporator Types

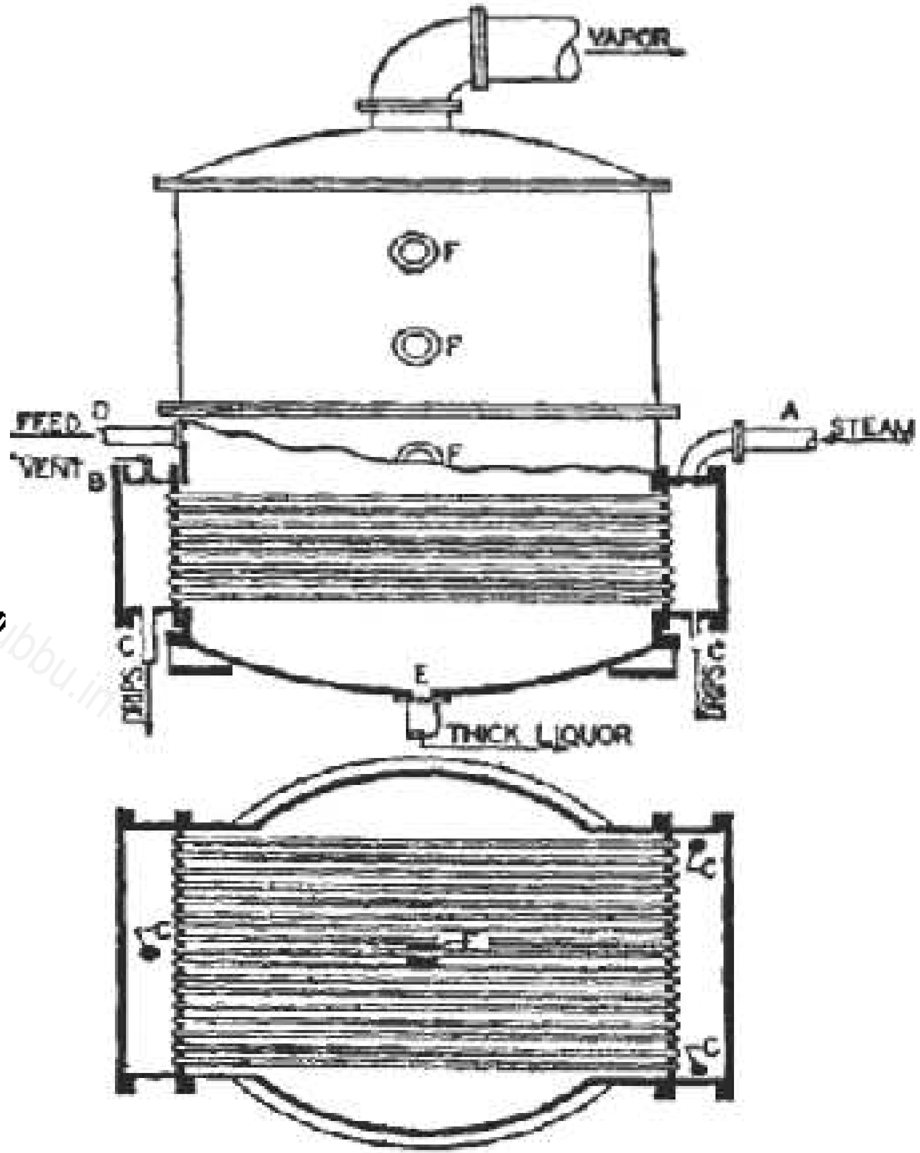
- Natural circulation
  - first developed commercially
  - represent the large number of units in operation
  - the density difference between the liquid and vapor generated is utilized to create circulations
  - tubes: horizontal or vertical with liquid inside or outside the tubes

- Forced circulation

Horizontal Tube Evaporator



For preparing distillated water for boiler feed

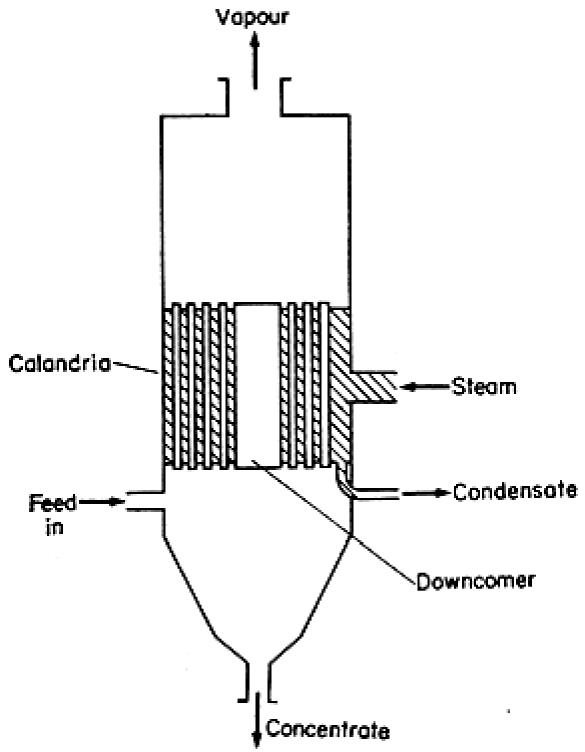


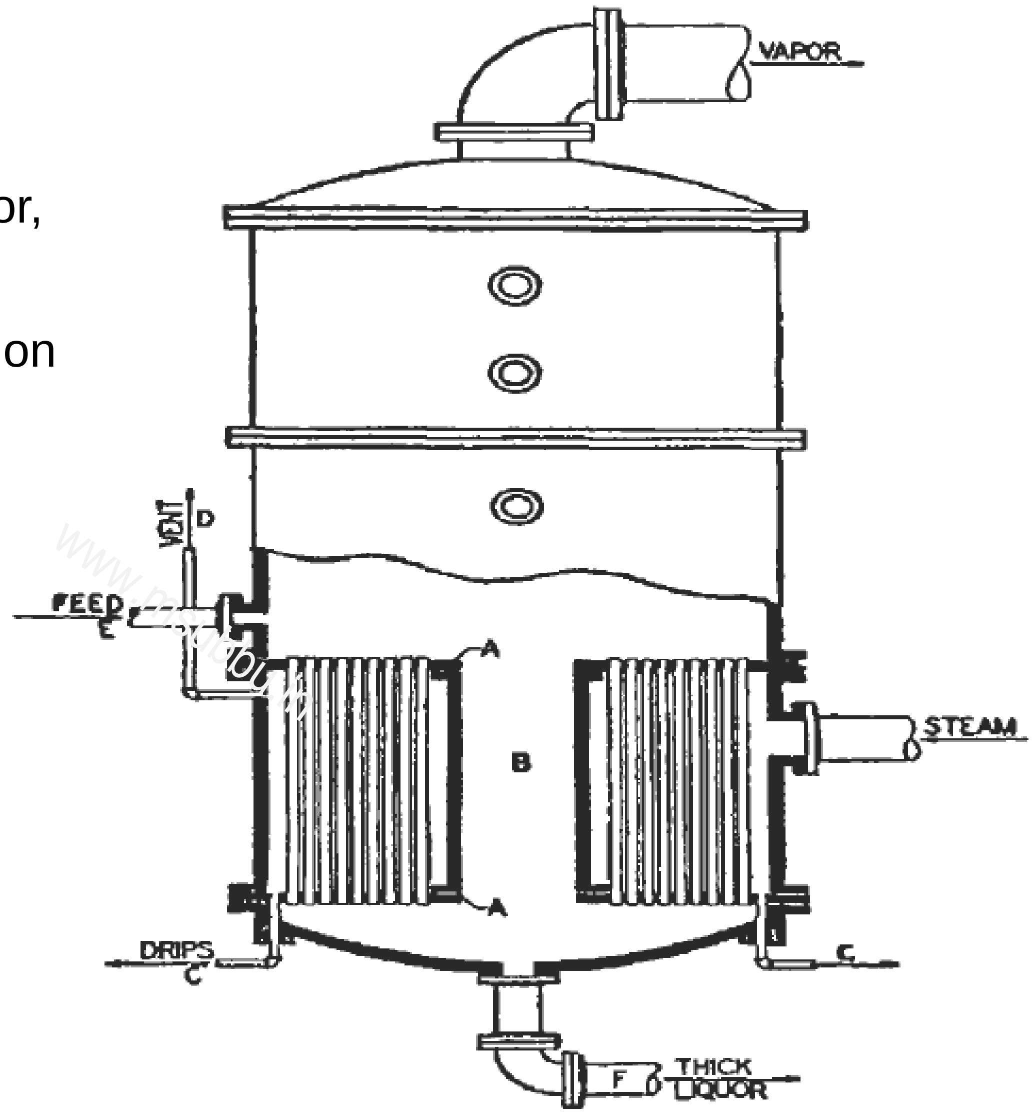
Horizontal tube evaporator: (A) Steam inlet; (B) Vent f non-condensed gas; (C) Condensate outlet; (D) Liquor inlet; (Liquor outlet; (F) Sight glass; (G) Vapor outlet.

Calandria Evaporator

It was the "Standard Evaporator", now called as calandria evaporator, or vertical short tube evaporator

Used mainly for batch concentration of liquids



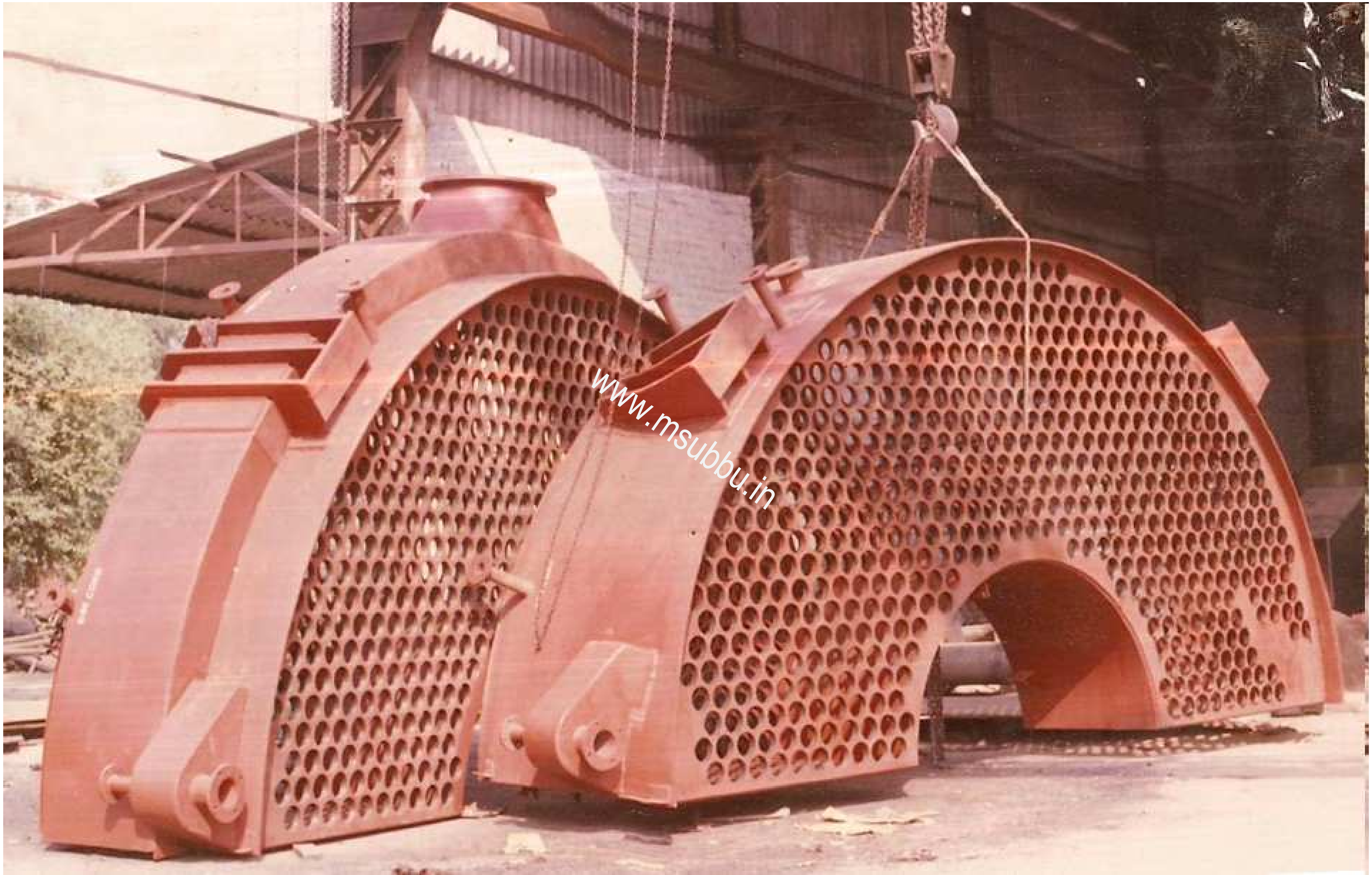


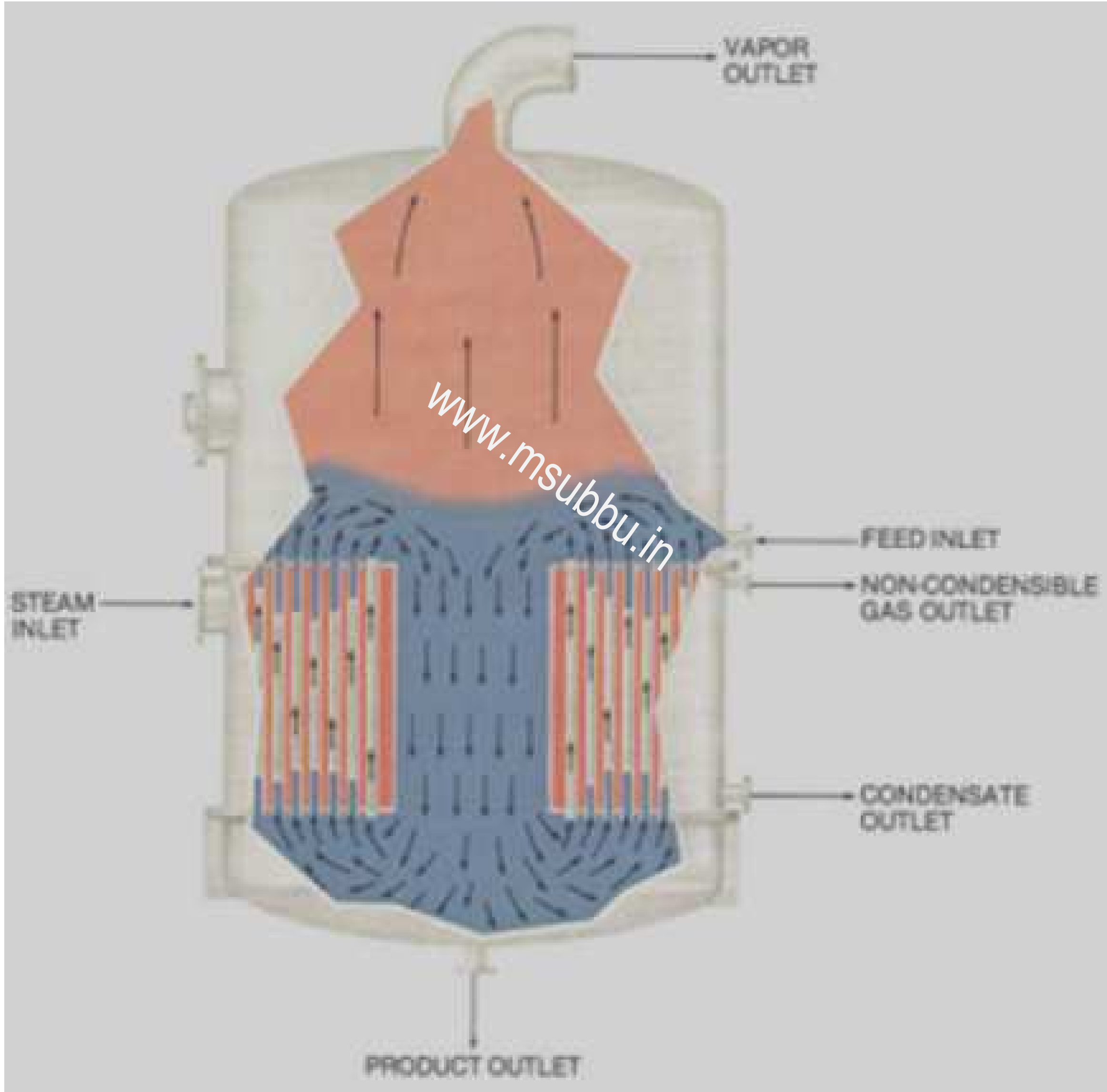
Vertical tube evaporator: (A) Tube sheets; (B) Downtake; (C) Condensate outlet; (D) Non-condensed gas outlet; (E) Liquor inlet; (F) Thick liquor outlet.

Standard Evaporator

- Cross sectional area of central downtake: 75 – 150% of the total cross sectional flow area of tubes

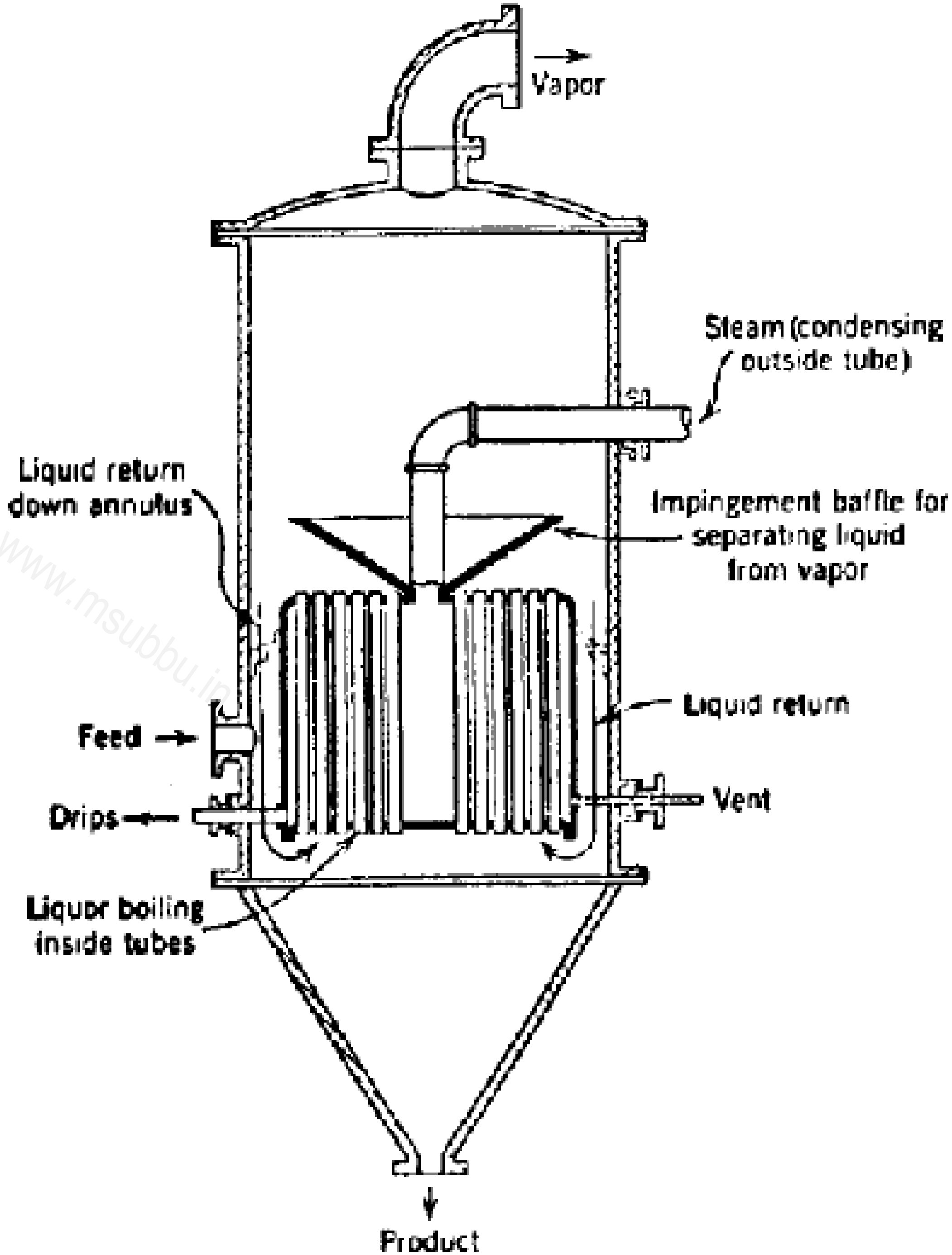
- Tubes: 1 to 4 inch dia; 3 to 5 ft long
  - Std: 2 inch dia, 5 ft long



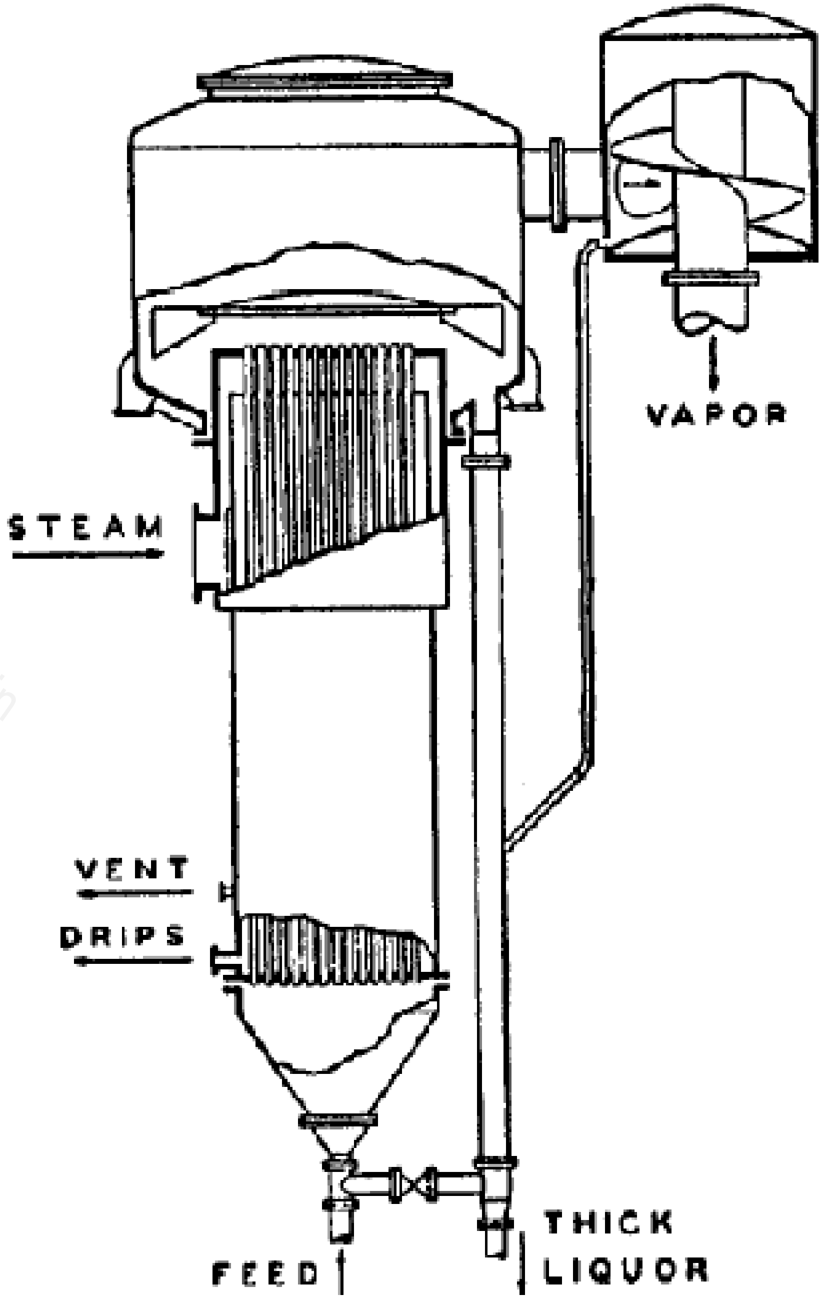

VAPOR OUTLET
FEED INLET
NON-CONDENSIBLE GAS OUTLET
STEAM INLET
CONDENSATE OUTLET
PRODUCT OUTLET

Basket Type Evaporator

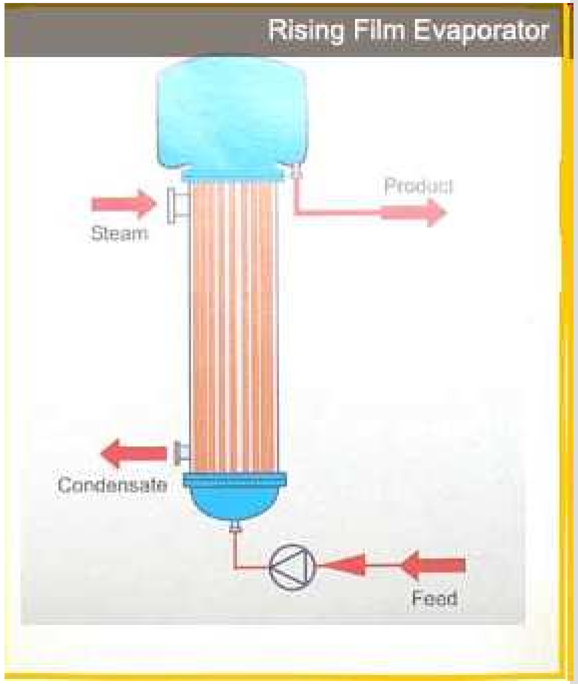
Annular downtake



Long Tube Vertical Evaporator



Rising film Evaporator



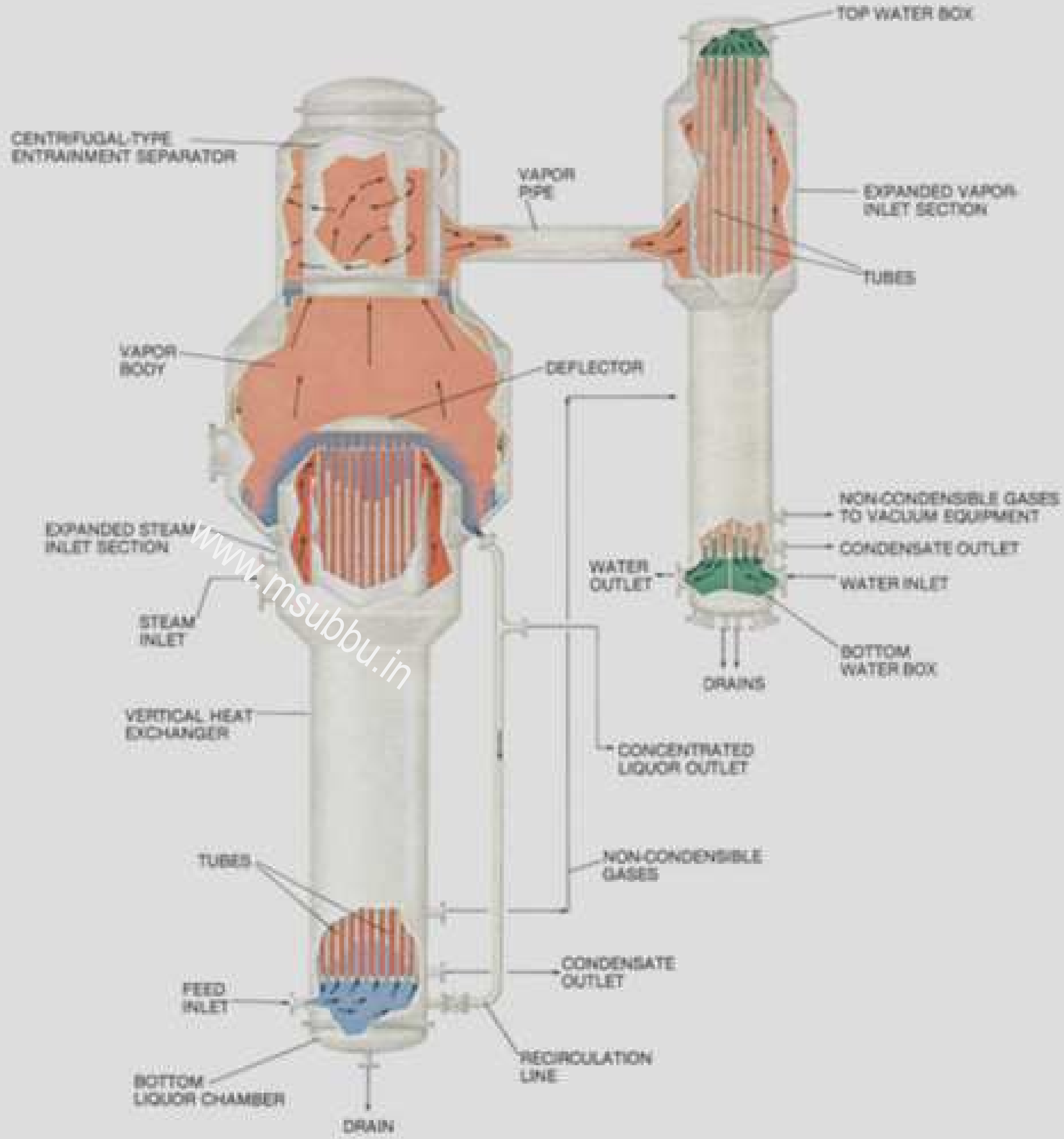
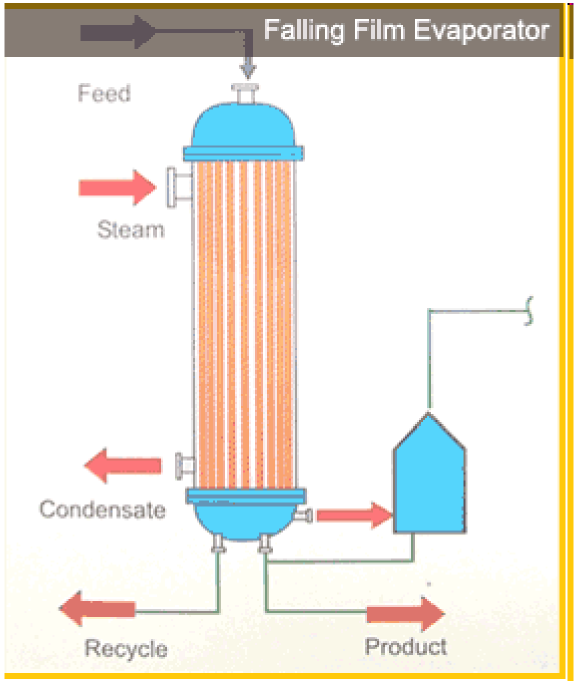


Fig. 5. Swenson LTV Rising-Film Evaporator with Vertical-Tube Surface Condenser

Falling film Evaporator



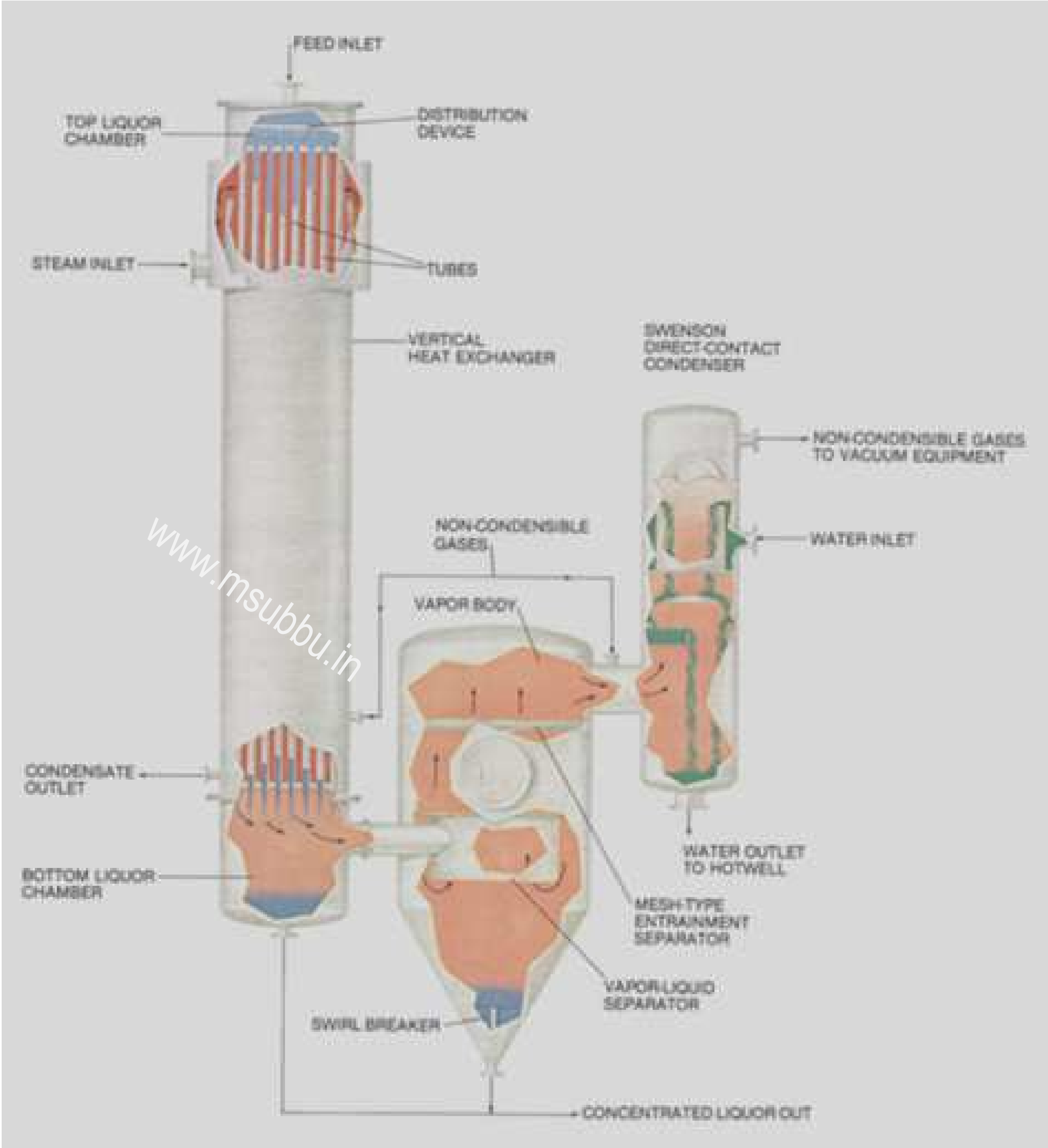
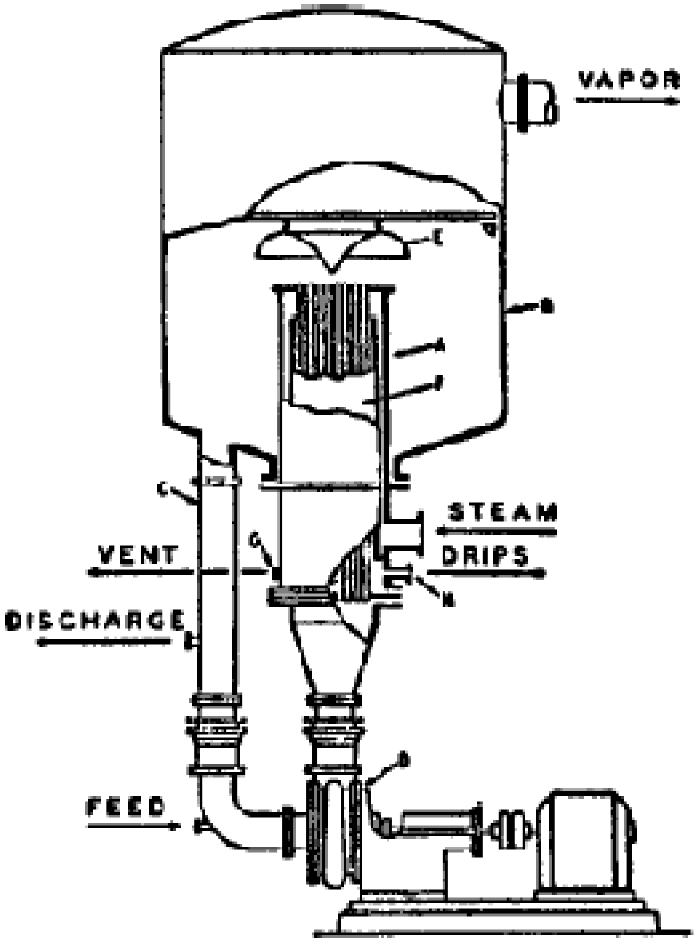
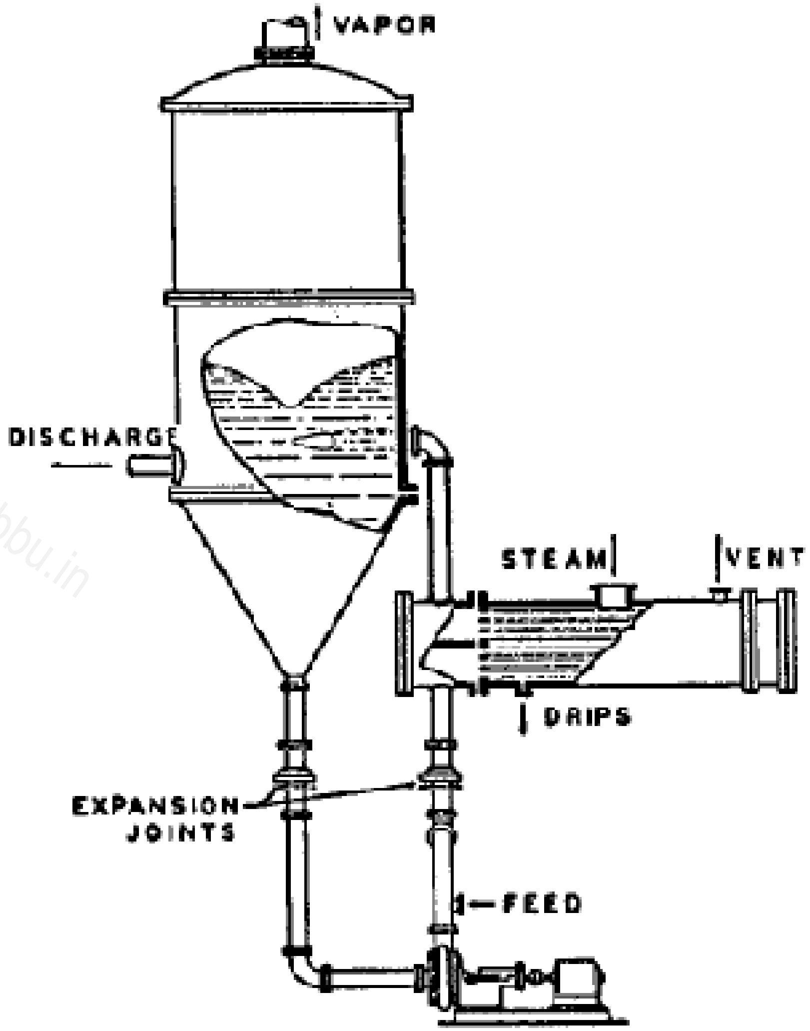


Fig. 7. Swenson LTV Falling-Film Evaporator

Forced Circulation Evaporators

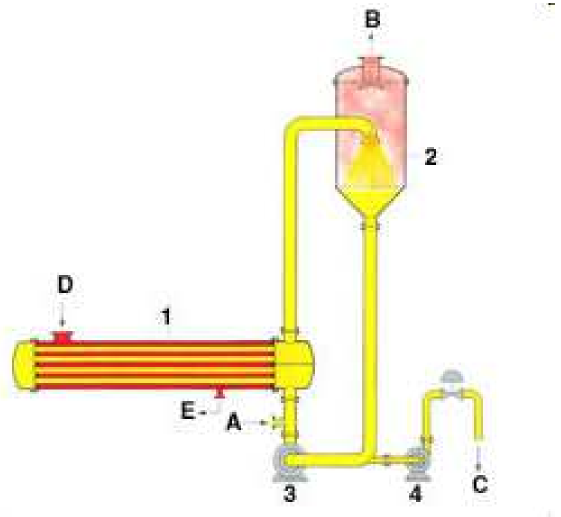


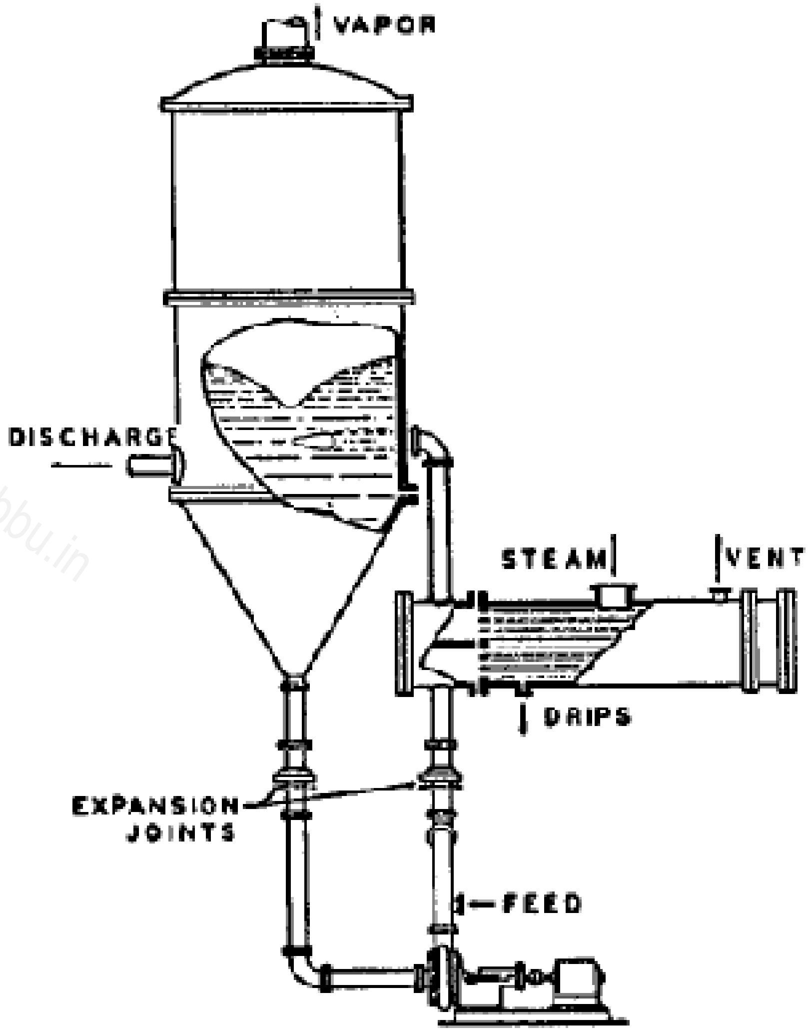
a) With internal heating element



b) With external heating element

Forced-Circulation Evaporator with external heating element





A: Product
B: Vapor
C: Concentrate
D: Heating System
E: Condensate
1) Heat Exchanger
2) Flash Vessel (Separator)
3) Circulation Pump
4) Concentrate Pump

Evaporator - Applications

Long Tube Vertical Evaporators

- (Rising, Falling films)
- Acid Sulfite Liquor
- Ammonium Nitrate
- Calcium Chloride
- Caustic Soda
- Coffee Extract
- Gelatin
- Glue
- Kraft Liquor
- Magnesium Chloride
- Pectin
- Phosphoric Acid (Bright Dip)
- Pickle Liquor
- Sodium Aluminate
- Sodium Nitrate
- Sodium Sulfate
- Soybean Oil
- Sugars
- Sulfuric Acid
- Syrups
- Tomato Juice
- Urea

Forced-Circulation Evaporators:

Ammonium Sulfate
Calcium Chloride
Caprolactum
Caustic Potash
Citric Acid
Magnesium Chloride
Mono-Sodium Glutamate
Sodium Carbonate Monohydrate
Sodium Chloride
Sodium Dichromate
Sodium Sulfate
Super-Phosphoric Acid
Urea
Wet Process Phosphoric Acid

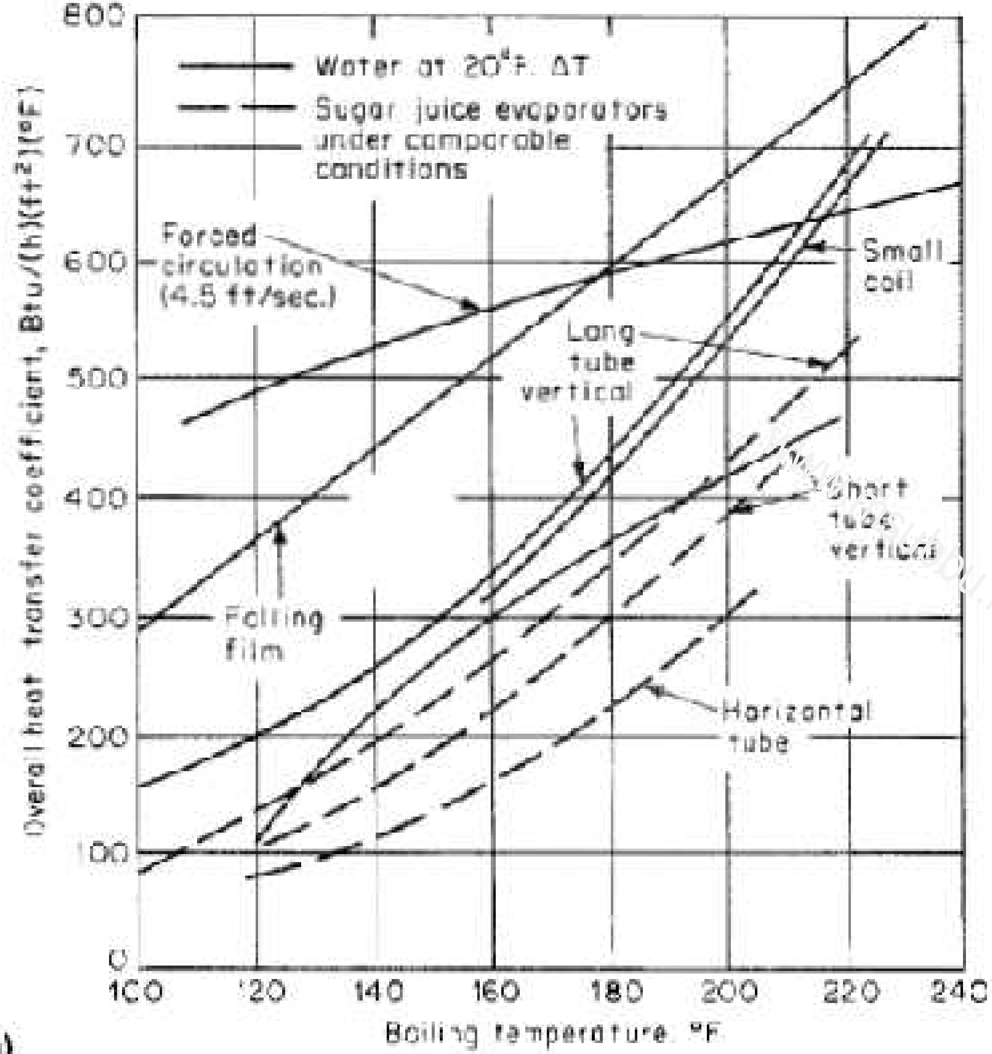
Calandria Evaporators:

The calandria evaporator can be used for many of the applications described for both forced-circulation and LTV rising-and -falling-film evaporators.

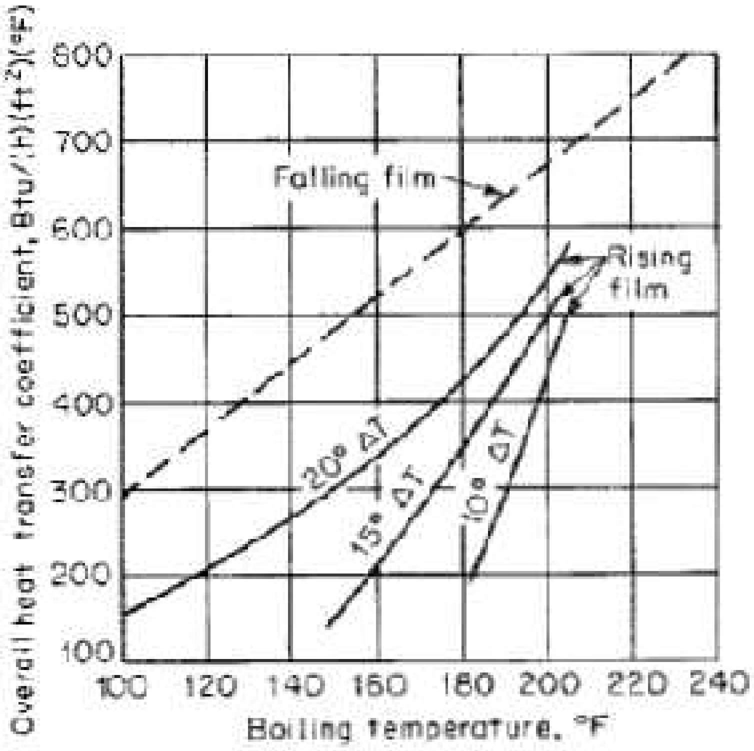
Evaporator Sizing

- Forced circulation and falling film evaporators have higher heat transfer coefficients
- With the approximate values of heat transfer coefficients, an estimate can be made of a possible configuration for a given duty (diameter, length, number of tubes)
- Heat transfer correlations can be applied to these geometrical data, and area can be recalculated

Heat Transfer Coefficient



(a)



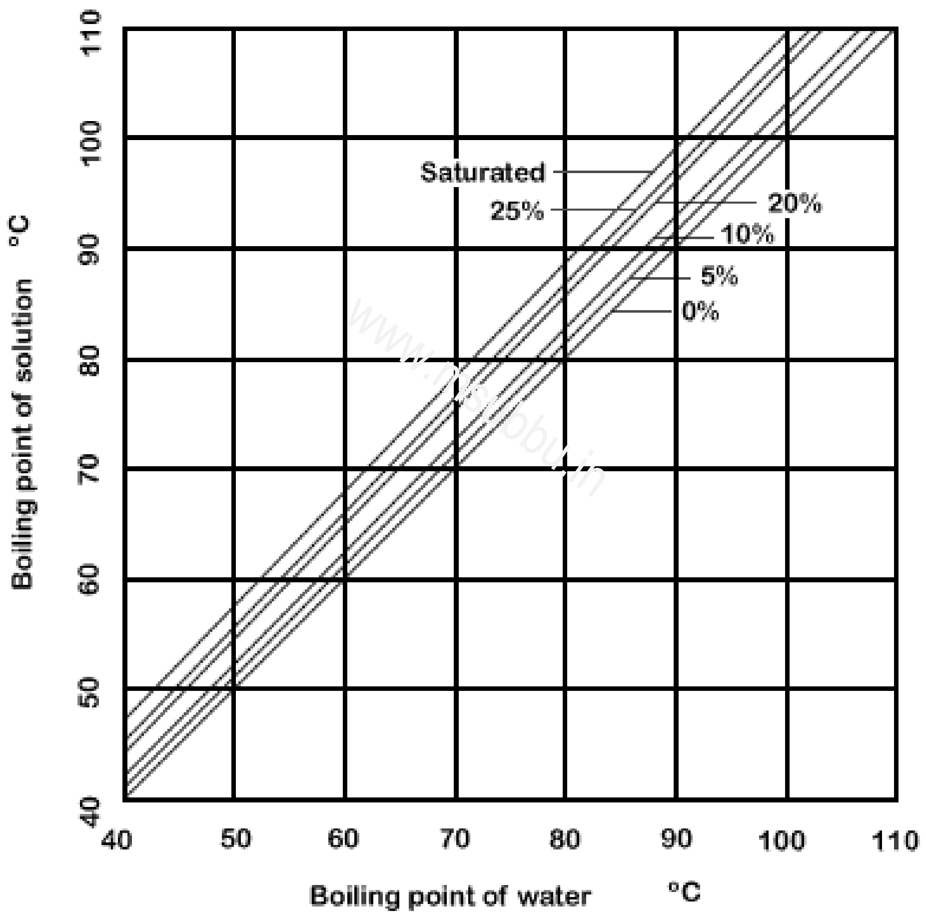
(b)

Walas, Chemical Process Equipment

Figure 8.18. Overall heat transfer coefficients in some types of evaporations. (a) Water and sugar juice evaporators; (b) Sea water evaporators. *[F.C. Standiford, Chem. Eng., 157–176 (9 Dec. 1963)]*.

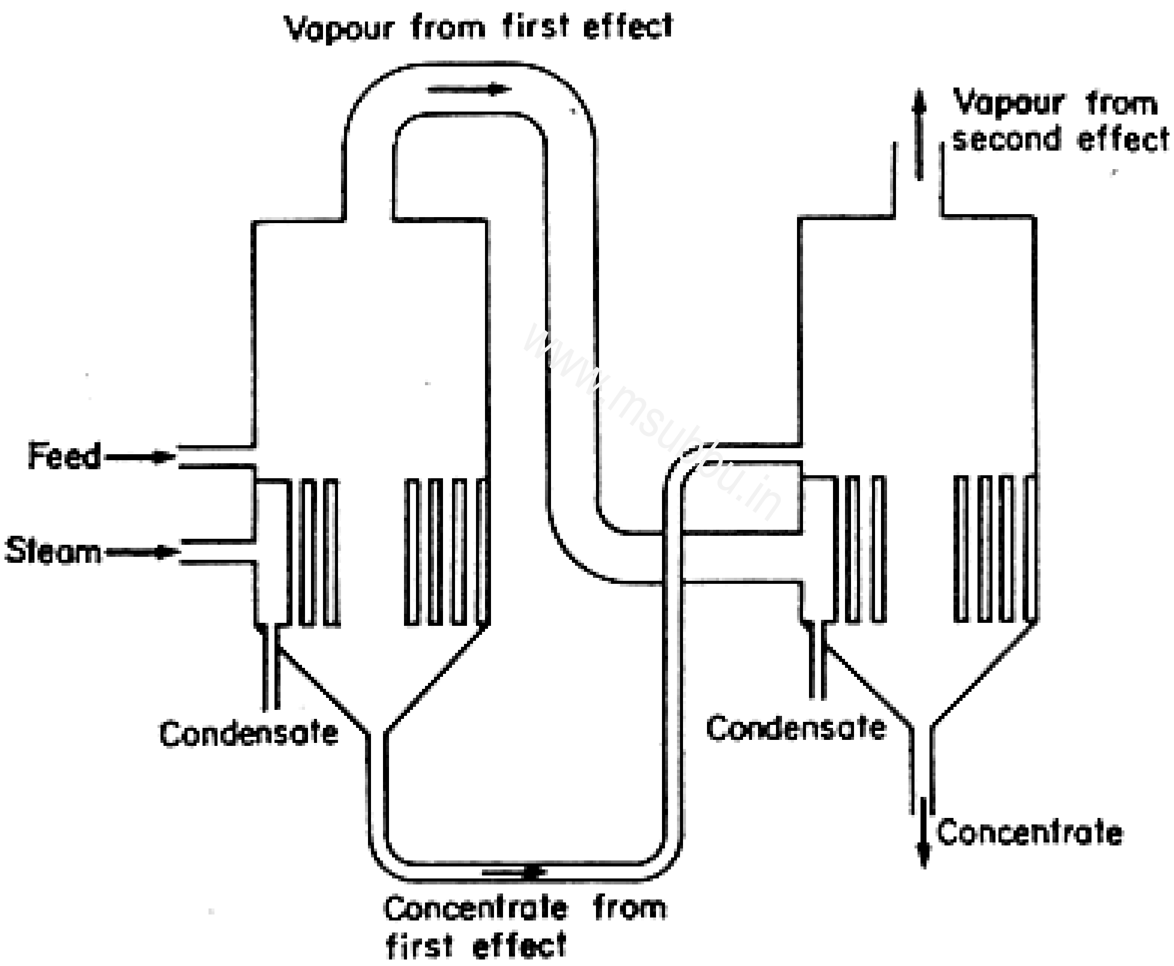
Boiling point Elevation

-

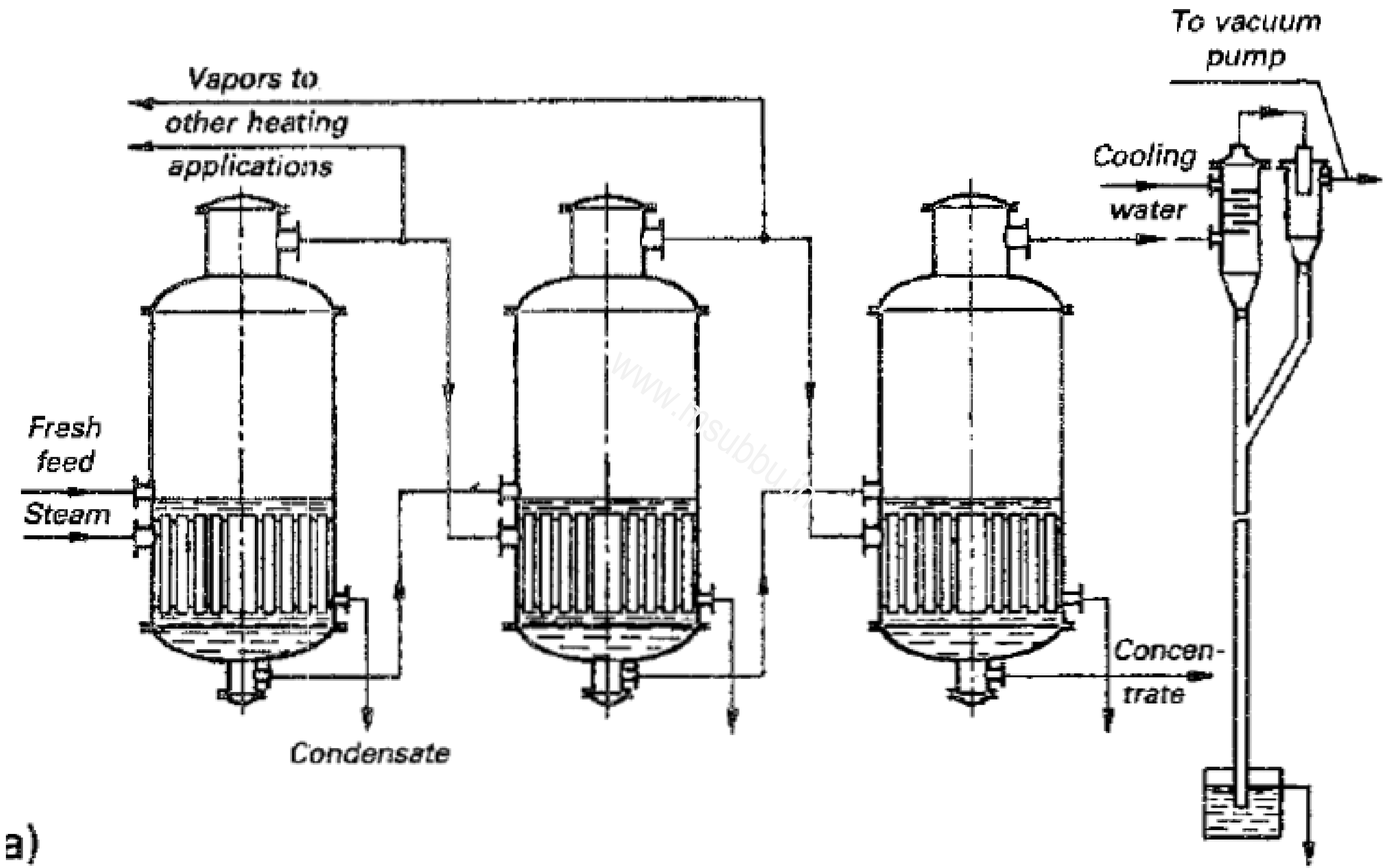


Duhring plot for boiling point of sodium chloride solutions

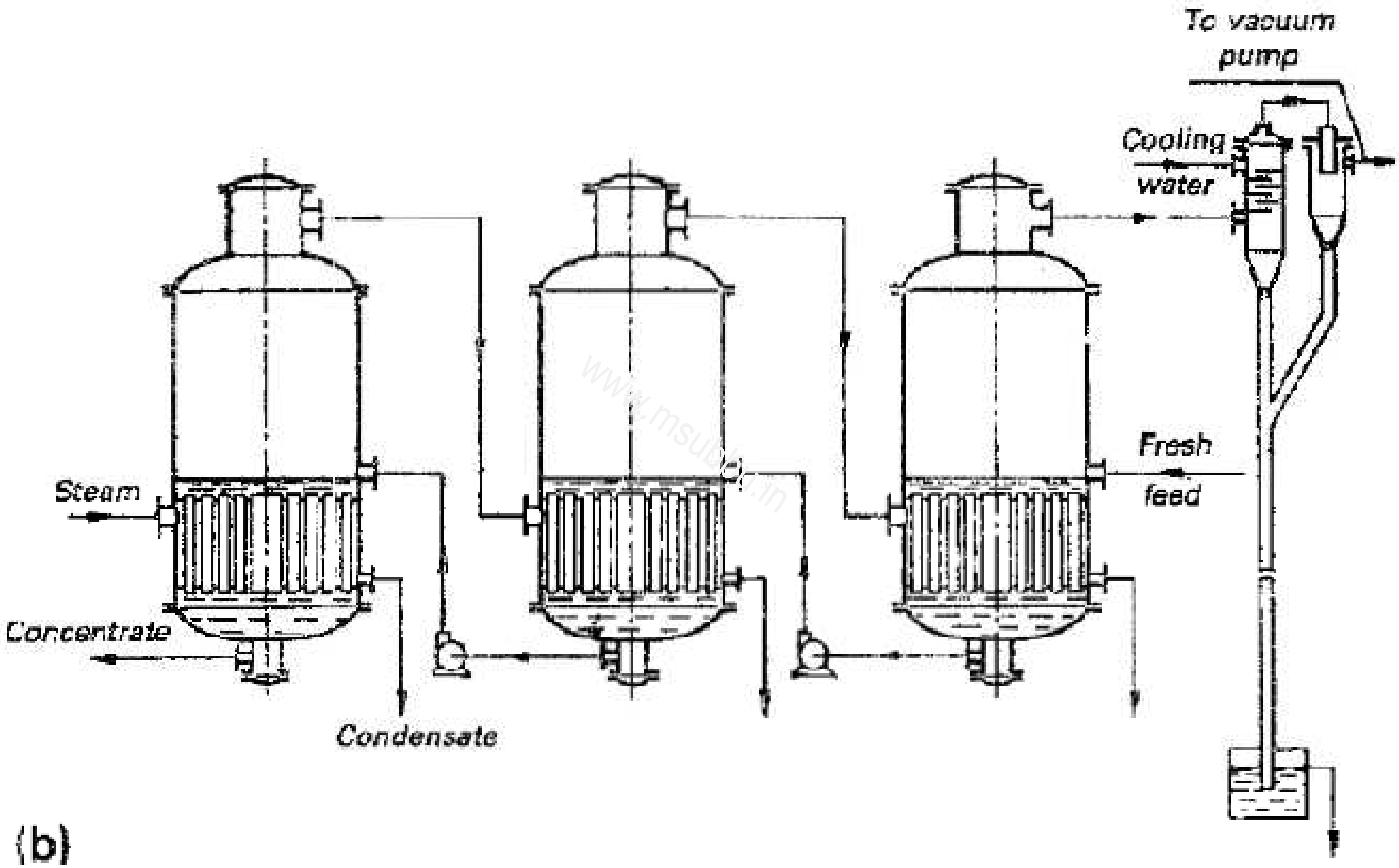
Double Effect Evaporator (Forward Feed)



Forward Feed



Backward Feed



Multiple Effect Evaporators

- To increase the steam economy

- Vapor from one effect serves as the heating medium for the next one

- The effects are always numbered in the direction of steam flow

- Designed on the basis: capacity of the effects are nearly the same, *A* – same

$$\Delta T \propto \frac{1}{U} \qquad \Delta T_1 : \Delta T_2 : \Delta T_3 = \frac{1}{U_1} : \frac{1}{U_2} : \frac{1}{U_3}$$

- Forward feed – no pumping of slurry is required

- Backward feed – concentrated slurry is heated by high pressure steam, which reduces the size of the unit

Effect of Boiling Point Elevation

- The capacity of evaporator is reduced
- The capacity of triple effect evaporator is less than one third of the three single effects