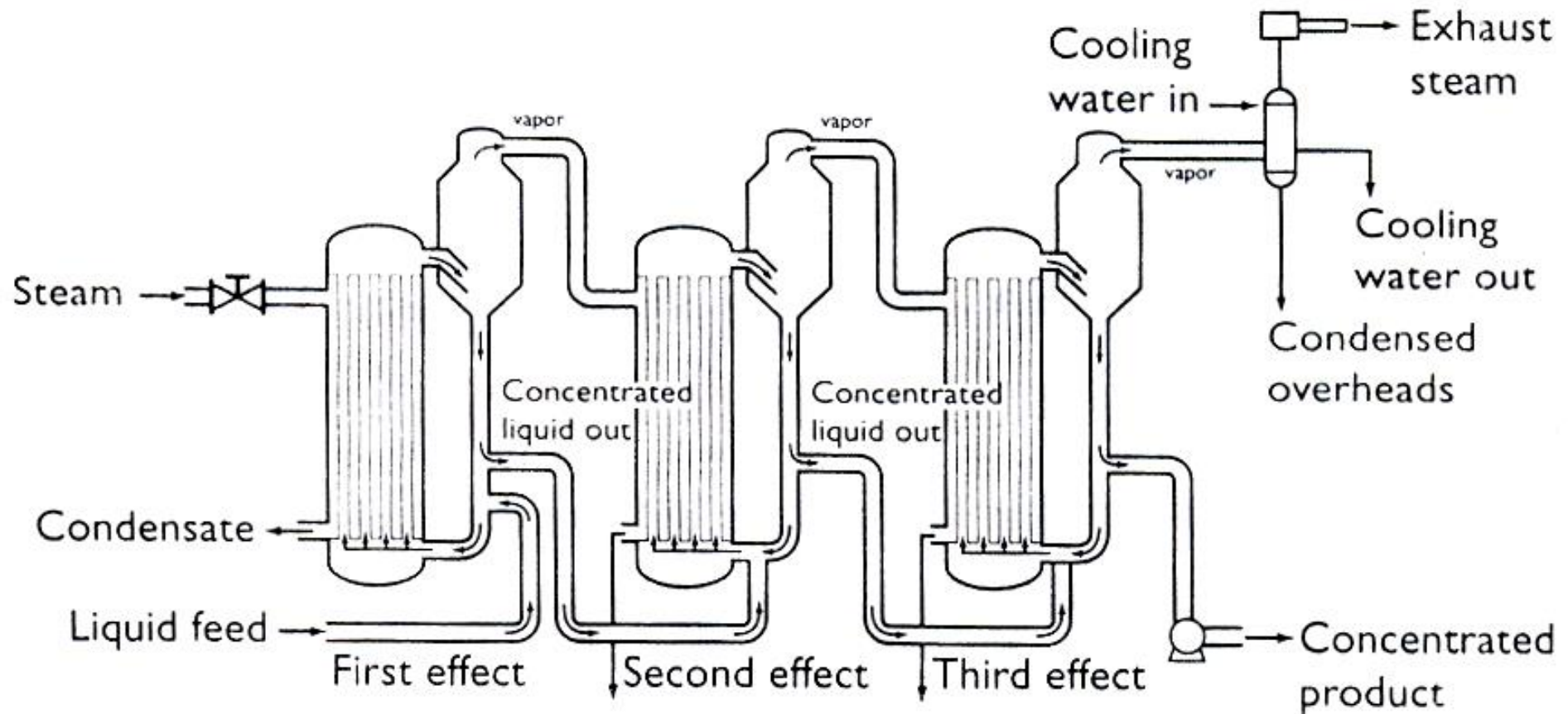
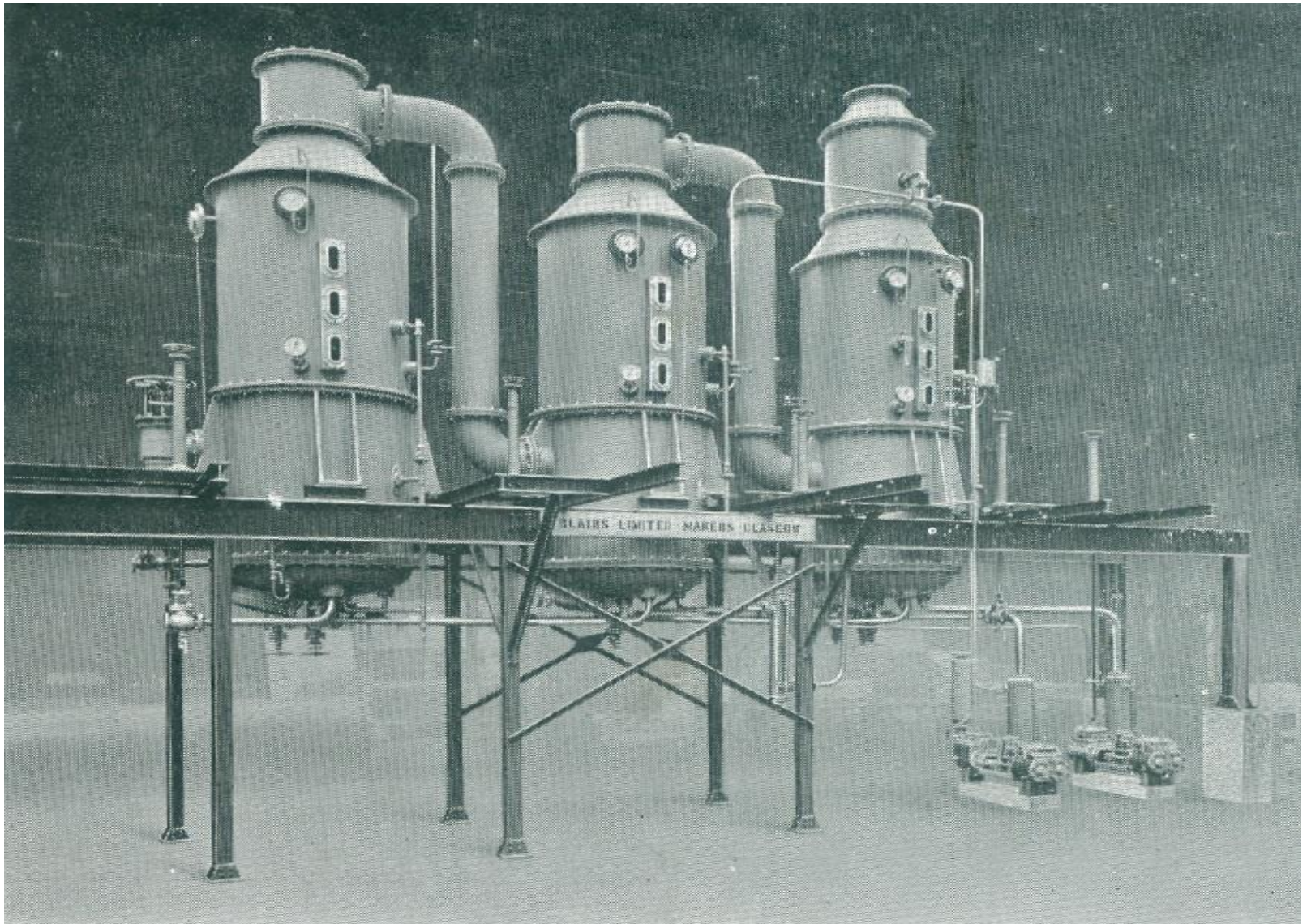


# Evaporation of food

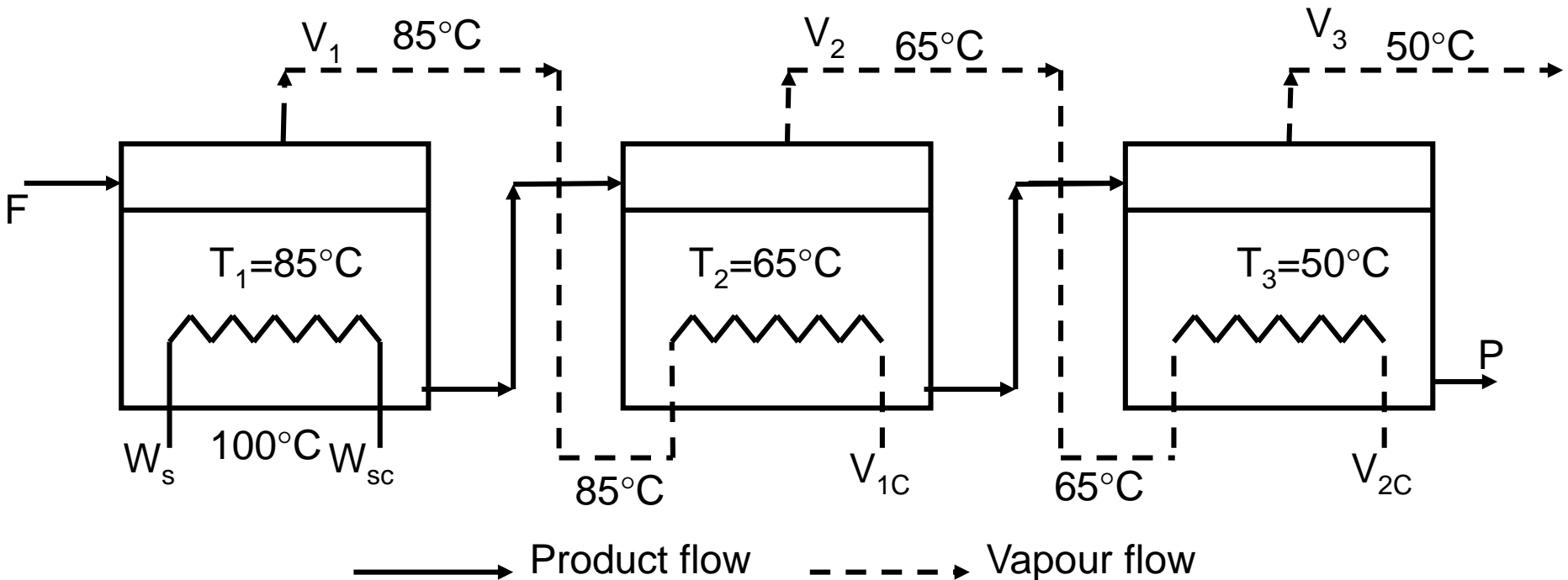
# Multiple effect evaporator



# Multiple effect evaporator



# Multiple effect evaporator



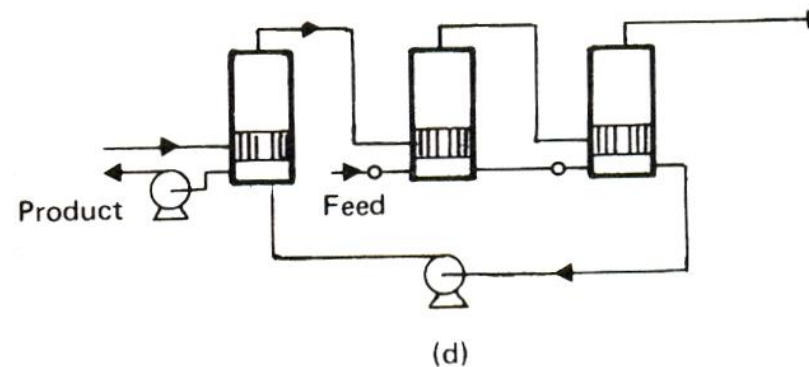
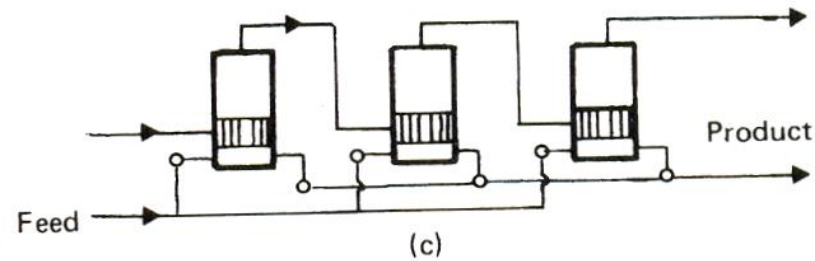
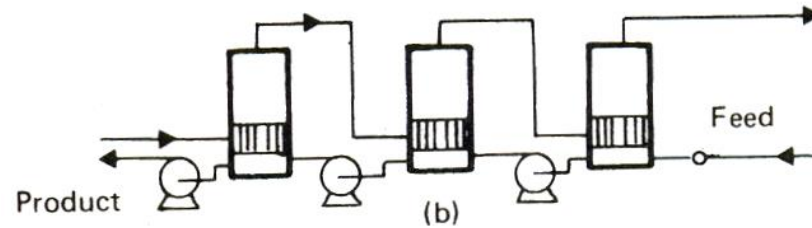
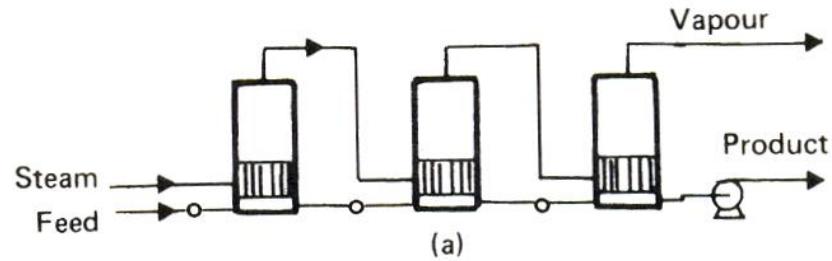
**Steam (vapour) and product flow in a multiple effect evaporator**

**Calculate the steam economy of the above system ?**

Temperature	100°C	85°C	65°C	50°C
Latent heat of evaporation, kJkg <sup>-1</sup>	2257	2296	2346	2382

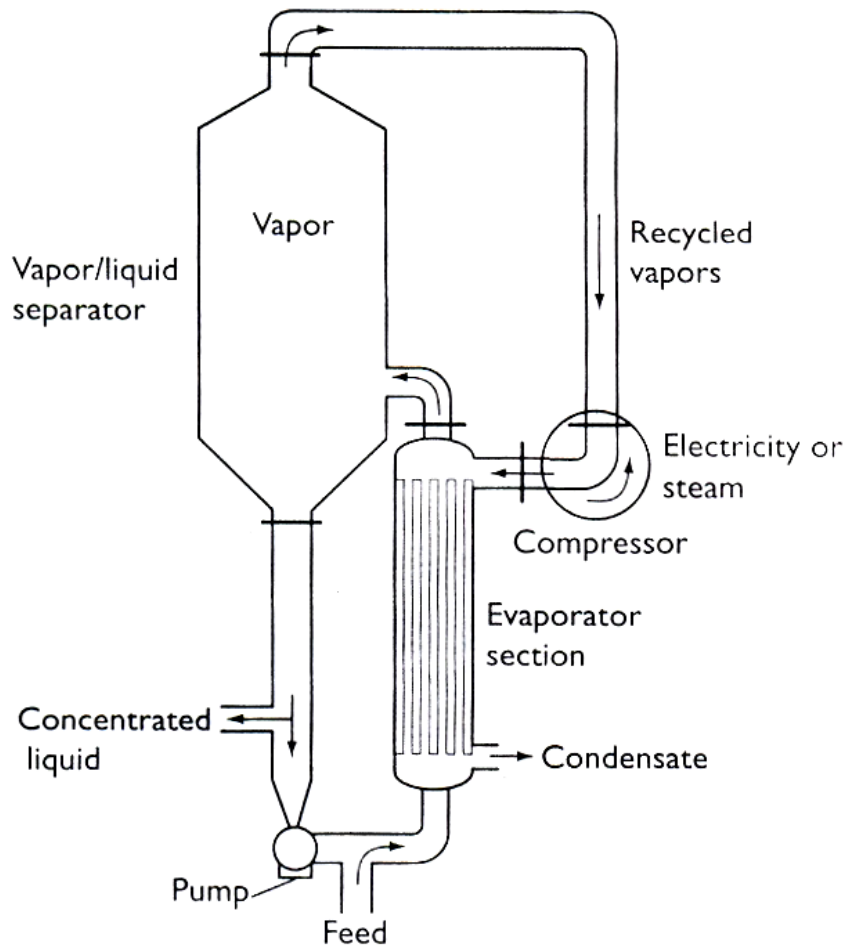


# Multiple effect evaporator

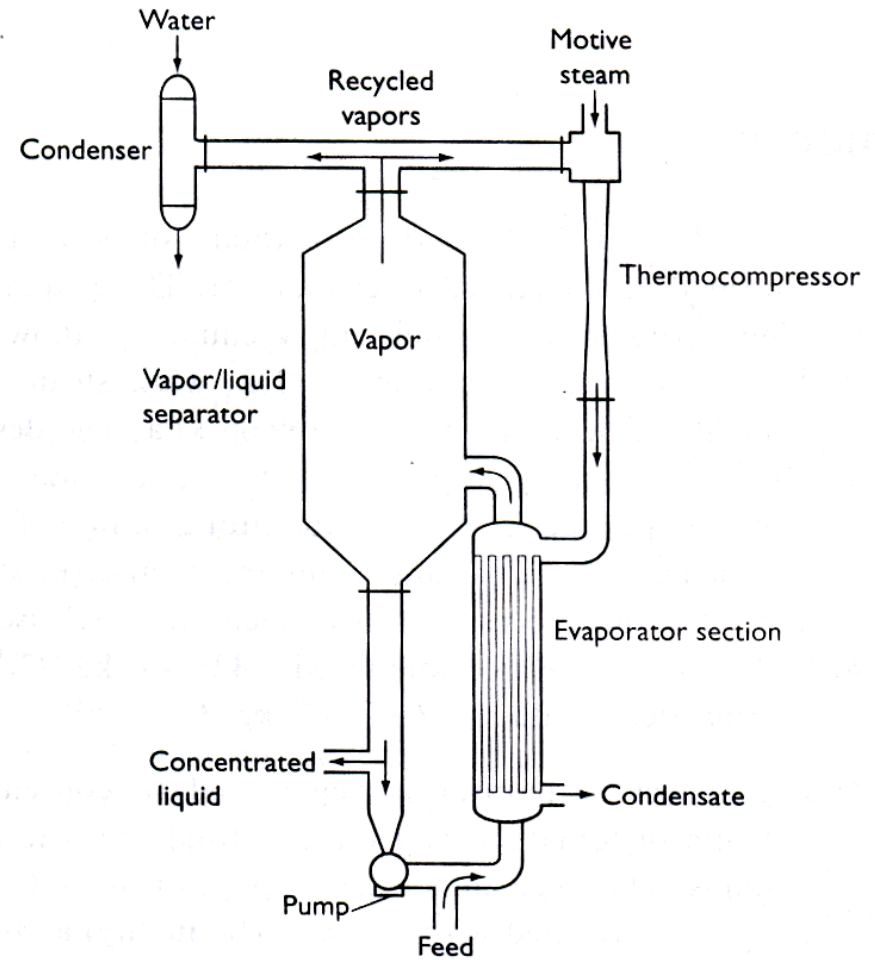


**Different flow arrangements in a multiple effect evaporation system**

# Vapour recompression



**Mechanical vapour recompression**



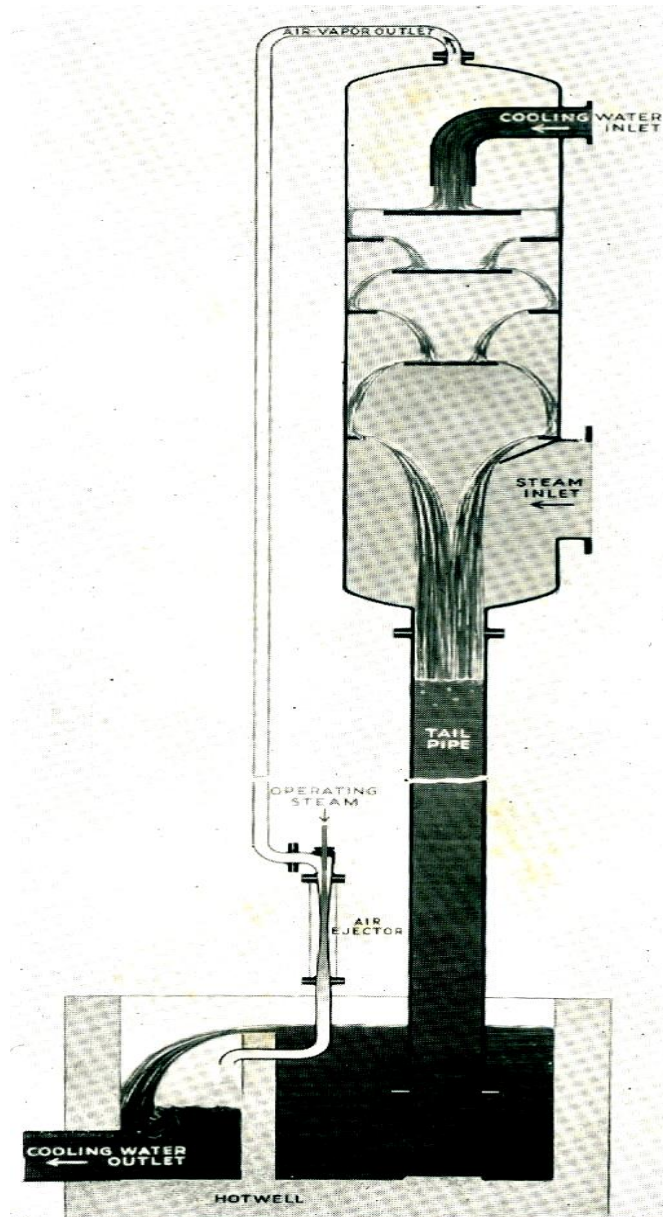
**Thermal vapour recompression**

Pre-heating of the feed also improves steam economy

**How to release the vapour from the last effect to the atmosphere without affecting the vacuum inside evaporators?**

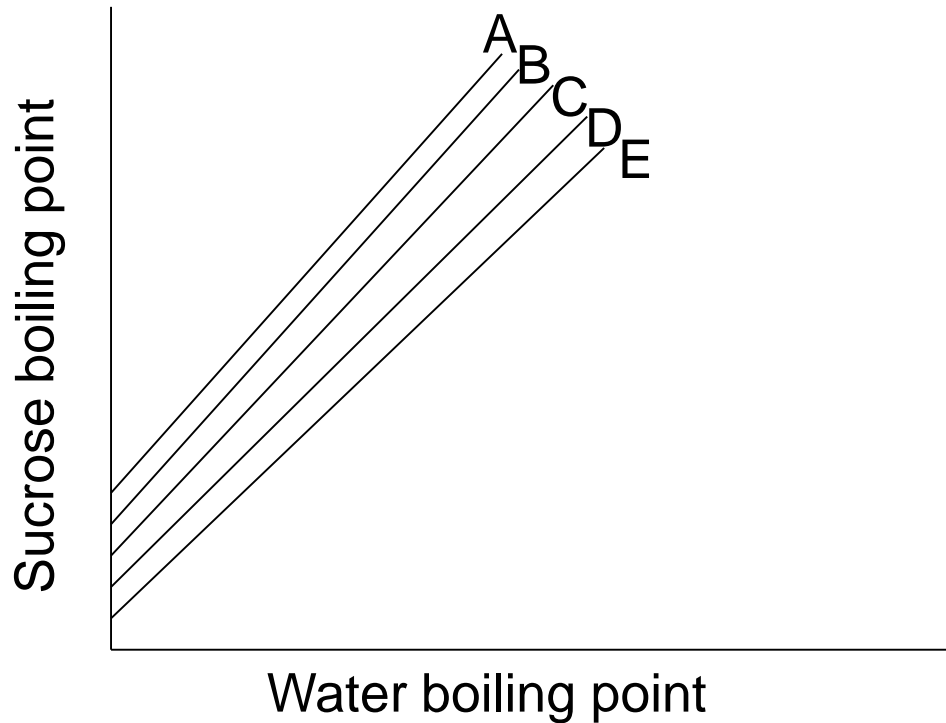


# Barometric leg



# Boiling point rise

## A. Duhring Plot



**Duhring plot for sucrose for various sucrose concentrations per 100 g of water: line A: 1000g, line B: 800 g, line C: 600g, line D: 400g, line E: 200g**

# Boiling point rise

## B. Empirical equations

$$-\ln(X_w) = \frac{\lambda'}{R} \left( \frac{1}{T} - \frac{1}{T_b} \right)$$

Where

$X_w$  is the mole fraction of solvent,

$\lambda'$  is molal latent heat,

$R$  is Universal gas constant (8.31434 kJ/kg-mole-°K),

$T$  and  $T_b$  are boiling point of pure water and solution under consideration respectively.

# Boiling point rise

$$\Delta T_b = 0.51 \text{ m}$$

Where  $\Delta T_b$  is the boiling point rise of solution with molality 'm' above the boiling point of pure water at the given absolute pressure.

# Boiling point rise

The pressure at the bottom of liquid pool is higher than the abs.pr. of vapour, and this difference also tend to increase the boiling pt of liquid.

## **Factors affecting the rate of heat transfer**

- Temperature diff. between the steam and boiling liquid
- Deposits on heat transfer surfaces (fouling)
- Boundary films

## **Factors affecting economy of operation**

- Loss of concentrate (Foaming and entrainment)
- Energy expenditure

## **Other factors affecting evaporation process**

- Solubility limit of food material: crystallization (when the product is taken out and cooled crystallization occurs).
- Temperature sensitivity of material
- Pressure and temperature



# Factors affecting the selection of an evaporator

Operating capacity (how much water to be evaporated per hour)

Degree of concentration required (as % of dry solids in the product)

Frequent changes in the product or capacity

Heat sensitivity of the product in relation to the residence time and temperature of evaporation

Requirement of volatile recovery facilities

Ease of cleaning

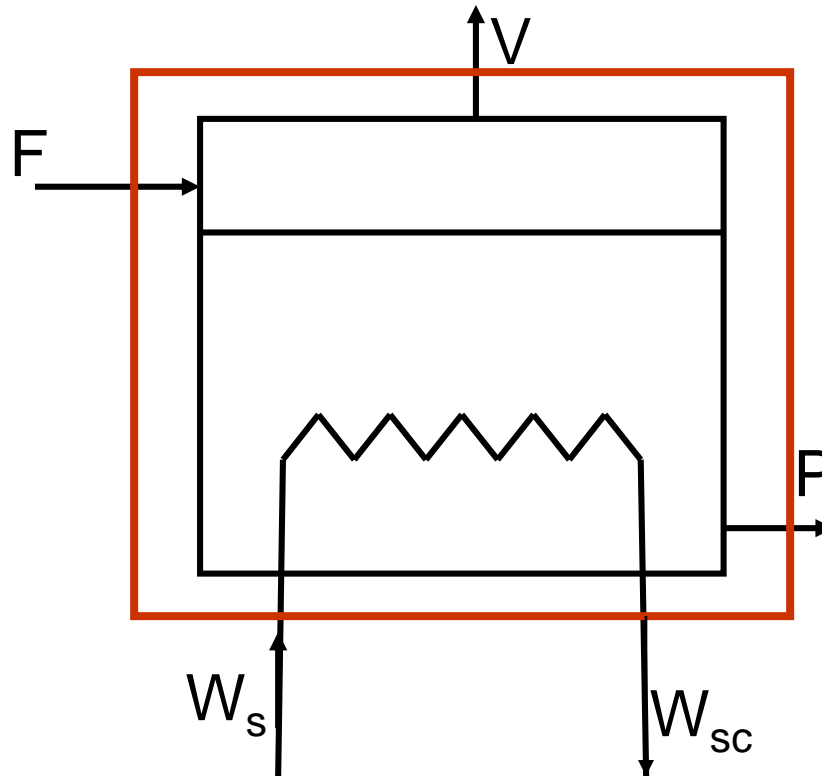
Reliability and simplicity of operation

Size of evaporator in relation to its capacity

Capital and operating costs in relation to capacity and product quality.

# Mass and energy balance in an evaporator

# Mass and energy balance in an evaporator



$$F = P + V$$

$$F.X_f = P.X_p + V.X_v$$

$$F.X_f = P.X_p$$

$$V = F - P = F - F\left(\frac{X_f}{X_p}\right) = F\left(1 - \frac{X_f}{X_p}\right)$$

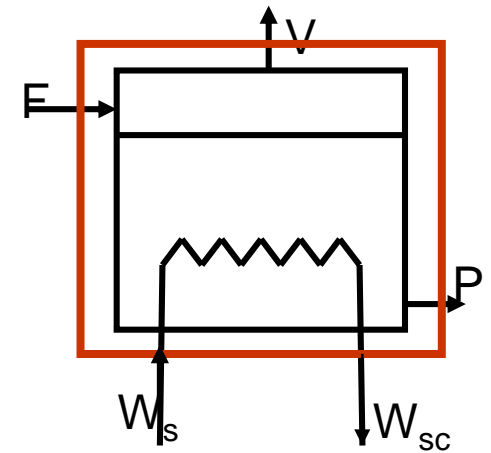
$$F.H_f + W_s.H_s = V.H_v + P.H_p + W_s.H_{sc}$$

$$F.C_f.T_f + W_s.\lambda = V.h_v + P.C_p.T_p$$

$$W_s.\lambda = V.h_v + P.C_p.T_p - F.C_f.T_f$$

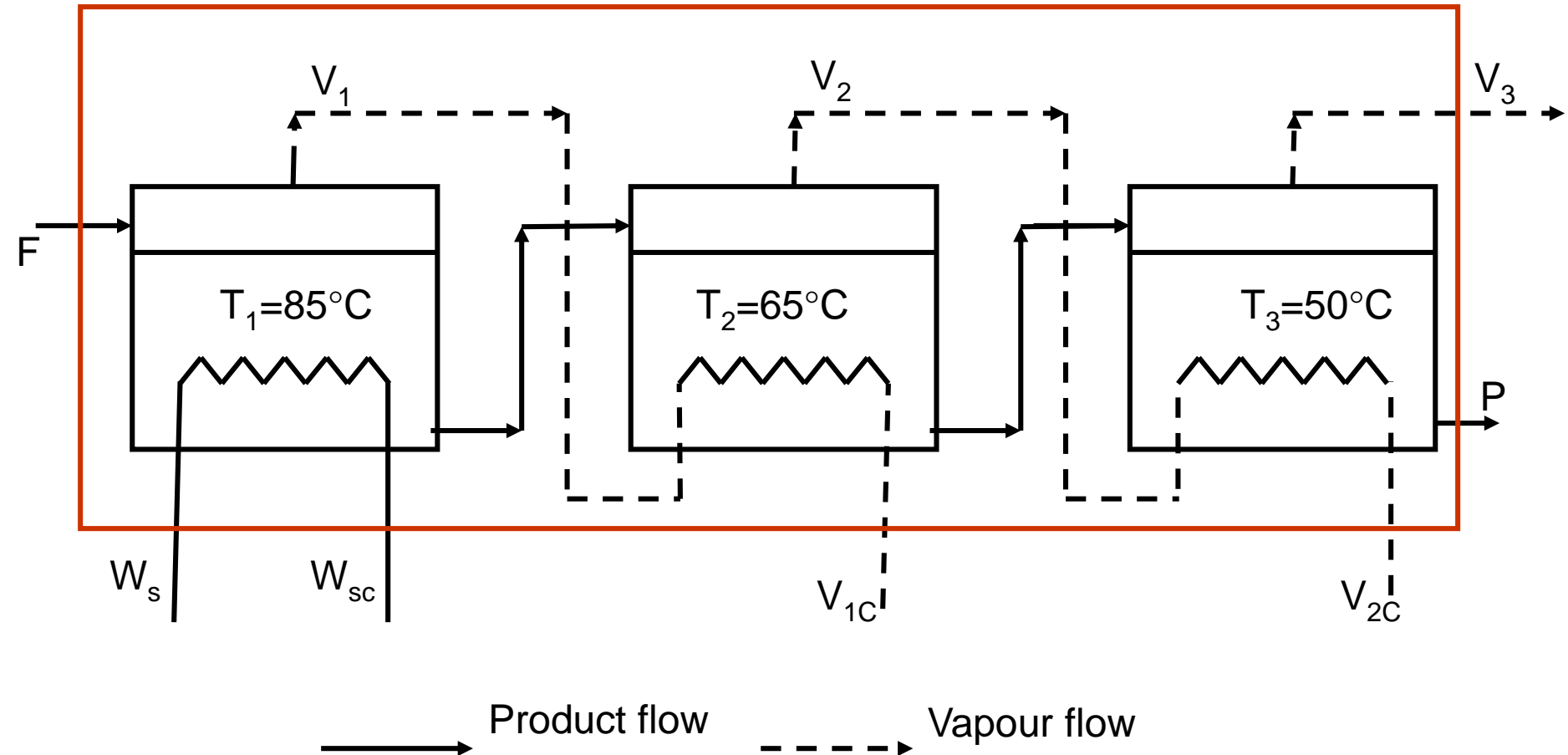
$$W_s\lambda = F\left(\frac{X_f}{X_p}\right)C_pT_p + F\left(1 - \frac{X_f}{X_p}\right)H_v - F C_f T_f$$

$$H_v = H_v^* + \phi, \text{ where } \phi \text{ is the boiling point rise}$$



$$W_s.\lambda = q = U.A.\Delta T$$

# Selection of the system and boundary in an evaporator for mass and energy balance



## In a triple effect evaporator

$$Q_1 = U_1 \cdot A_1 \cdot \Delta T_1, \Delta T_1 = (T_s - T_1)$$

$$Q_2 = U_2 \cdot A_2 \cdot \Delta T_2, \Delta T_2 = (T_1 - T_2)$$

$$Q_3 = U_3 \cdot A_3 \cdot \Delta T_3, \Delta T_3 = (T_2 - T_3)$$

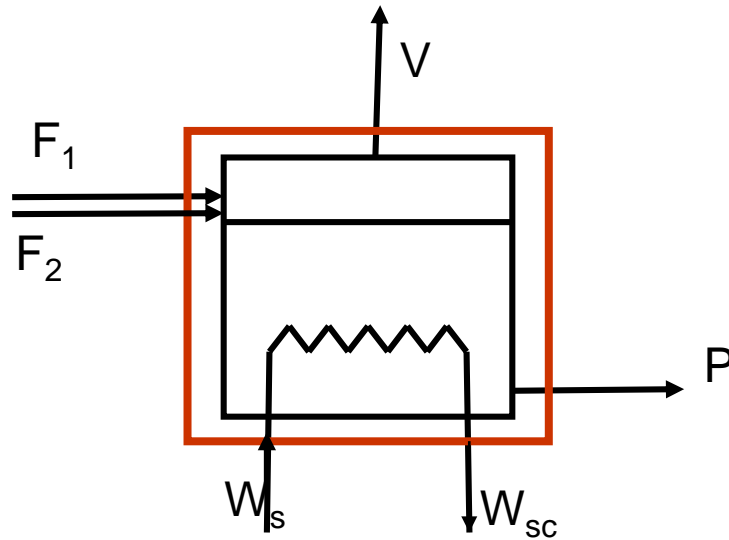
Now,  $W_s \cdot \lambda = Q_1 = Q_2 = Q_3$  (assuming no boiling point rise)

$$\frac{\Delta T_i}{\sum \Delta T} = \frac{1/U_i}{1/U_1 + 1/U_2 + 1/U_3}$$



## PROBLEMS

In the manufacture of jam, the crushed fruit is mixed with sufficient sugar to give a mixture of 45 parts of fruit to 55 parts of sugar. The mixture is then evaporated until the soluble solids are 67%. What yield of jam is expected from a fruit which has 14% soluble solids.



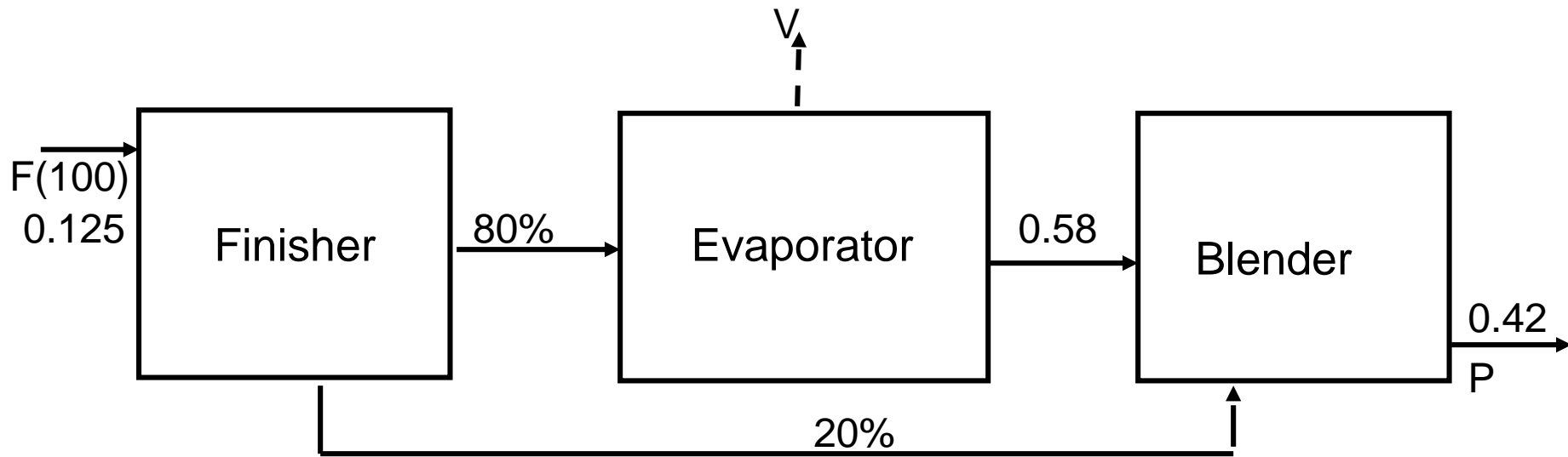
## PROBLEMS

If orange juice is as such evaporated at high temperature, it results in a flat flavour from the loss of volatile constituents during evaporation. A process was used earlier to overcome the problem by concentrating the extracted juice to 58% solids in vacuum evaporators and blending the concentrate with unconcentrated juice to a final product with 42% solids.

The process first involves passing of fresh extract containing 12.5% solids through juice finishers in which a pulpy juice and a strained juice are separated (other streams which are leaving are negligible). 80% by weight of the feed to the finishers passes to the vacuum evaporators. The 20% of the feed not passing to the evaporators, i.e. the pulpy juice, is then fed directly to a blender. In the blender the pulpy juice is used to dilute the concentrated juice (58% solids) coming from the evaporator to the desired final strength of 42% solids.

Calculate:

- A) The weight of water evaporated per 100 kg of fresh extracted juice fed to the system
- B) Concentration of solids in each stream leaving the finisher.
- C) The weight ratio of conc. and unconc. juice in the final product.



Calculate:

- A) The weight of water evaporated per 100 kg of fresh extracted juice fed to the system
- B) Concentration of solids in each stream leaving the finisher.
- C) The weight ratio of concentrated and unconcentrated juice in the final product.

**Thank you**