Mass Transfer Operations

Midterm exam Model Answer

2016-2017

Question (I):

1. **Corrections**
   a. In **simple batch (differential)** distillation, as vaporization of liquid proceeds, the vaporized product becomes leaner in the **MVC**.
   b. The slope of q- line = infinity if the distillation tower feed is at its **bubble** point. Or the slope of q- line = **zero** if the distillation tower feed is at its dew point.
   c. When a feed enters a distillation column at its bubble point, the liquid flow rate in the stripping section increases while the vapor flow rate in the rectifying section **remains constant.**
   d. When a feed to distillation tower is a **subcooled liquid**, the flow of liquid in the stripping section increases and the vapor flow in the rectifying section decreases.
   e. In **partial** condensation, a portion of the overhead vapor is liquefied and returned to the column as reflux while the other portion leaves as a vapor distillate.
   f. The value of the internal reflux ratio is greatly affected by the ratio between the amounts of the **operating** phases leaving the tray.
   g. Multiphase mixtures, such as particles suspended in a solution can be separated easily by **mechanical means.**

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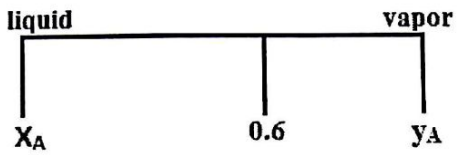
2. **What are the main disadvantages of using mass separating agents?**
   a. Need makeup
   b. Needs regeneration step
   c. Complicated design
   d. Possible contamination of the product

3. **A mixture of A and B containing 60% A by mole was partially vaporized by heating to 97°C. The fraction vaporized of the mixture was found to be 0.3. If the vapor/liquid ratio is 0.45, what is the composition of the liquid phase?**



$$\frac{0.6 - x_A}{y_A - x_A} = 0.3$$

$$\frac{0.6 - x_A}{y_A - 0.6} = 0.45$$

Solve the two equations simultaneously to get the unknowns.

Question (II):

1. **With the aid of neat sketch, compare between kettle-type reboiler and vertical thermosyphon reboiler?**

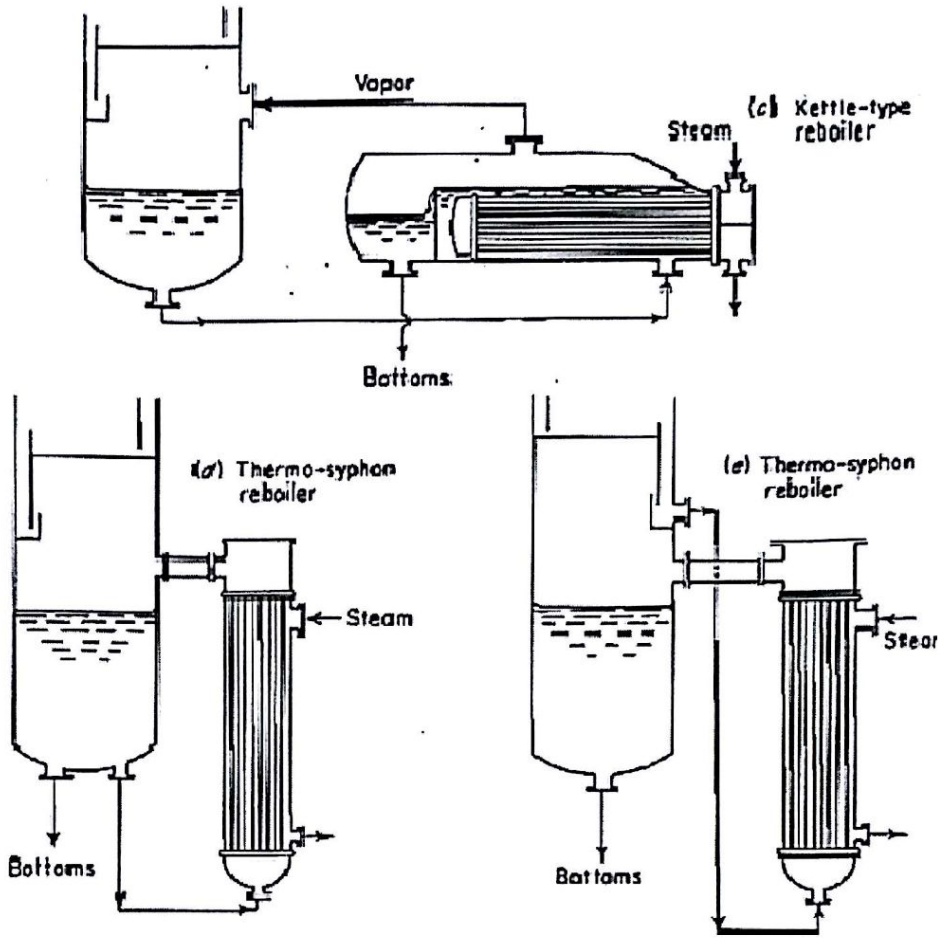
Thermosyphon Reboiler

Thermosyphon reboiler operates based on static head of the liquid available at the stripping column bottom. Normally heating medium is passed through tube side due to pressure drop limitation in shell side. Horizontal thermosyphon reboilers are mostly used in Refinery and petrochemical plants. Vertical thermosyphon reboilers with tube side vaporization are adopted by chemical plants.

Kettle Type Reboiler

Kettle type reboilers are employed where vaporization rate is high. This type provides large diameter shell for vapor for accommodating vapors. Here also heating fluid is passed through tube side.

Kettle- Type Reboiler	Thermosyphon Reboiler
Advantages: • Most reliable in terms of operation • High vaporization percentage and good vapor quality • Easy cleaning and mentainance • Low circulation rates • Contain vapor disengaging space	**Advantages:** • Cheapest reboiler installation in terms of capital and operating cost • Permits simple, compact piping arrangement • Provides excellent thermal performance Low residence time Not easily fouled
Disadvantages: • Long residence time • Not good for high pressure boiling • Easily fouled • Lower heat flux and heat transfer rate • Expensive installation cost	**Disadvantages:** • Not suitable for viscous or solid bearing fluids • More heat transfer area required for vacuum operation • Not specified for pressure below 0.3 bar • Column base must be elevated to provide the hydrostatic head required for the thermosyphon effect. This increases the cost of the column supporting structure.



2. **A continuous fractionating column is designed to separate 2.5 kg/s of mixture of 60% toluene and 40% benzene. The overhead contains 97% benzene and the bottom product contains 98% toluene by mass. A reflux ratio of 3.5 kmol reflux/ 1 kmol of product is used, and the molar latent heat of benzene and toluene may be taken as 30 MJ/kmol. The boiling point of the mixture is 370.5 K.**
   Calculate:
   i. **The mass flow rates of the products.**
   ii. **The number of theoretical plates**
   iii. **Position of the feed tray, if the feed is liquid at 295K (Specific heat capacity 1.84 kJ/kg.K)**
   iv. **The minimum reflux ratio.**

Solution

إجابة إسترشادية

$D = 1\,kg/s \; and \; B = 1.5\;\; kg/s$

$(x_D, x_D) = (0.974, 0.974)$

$(x_F, x_F) = (0.44, 0.44)$

$x_B = 0.024$

$q = 1.4 \qquad and \qquad \theta = 74°$

$$\frac{x_D}{R_{D_{min}} + 1} = 0.44 \qquad and \qquad R_{D_{min}} = 1.21$$