McCabe & Thiele Method (Read from R.E. Treybal)

- McCabe & Thiele method assumes that for each section (enriching & stripping sections), straight operating lines can be used.

- Less rigorous, as detailed enthalpy data is not used. Nevertheless, this method works for most cases.

- Main assumption of McCabe & Thiele method: "Equimolar overflow & vaporization". That is, the molar flow rates of liquid & vapor streams don't change along the column for each section.

  Therefore for enriching section: $\begin{cases} L_1 = L_2 = \cdots = L_N = L & \text{(mole/time)} \\ G_1 = G_2 = \cdots = G_N = G \end{cases}$

  for stripping section: $\bar{L}_m = \bar{L}_{m+1} = \cdots = \bar{L}_{N_p} = \bar{L}$ & $\bar{G}_m = \bar{G}_{m+1} = \cdots = \bar{G}$

  Note: The molar flow rates are constant for stripping & enriching sections. However, the mass flow rates can vary because the → average molecular mass (of liquid & gas streams) can vary along the column.

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Background: For enriching section, we have

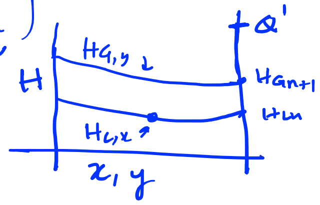
$$G_{n+1} H_{G_{n+1}} = L_n H_{L_n} + Q_c + D H_D \quad \text{(from previous lecture)}$$

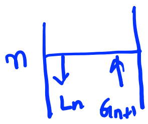
$$\Rightarrow G_{n+1} H_{G_{n+1}} - L_n H_{L_n} = D\left(H_D + \frac{Q_c}{D}\right) = DQ' \qquad \left[Q' = H_D + \frac{Q_c}{D}\right]$$

Combine previous equation with species balance

$$\Rightarrow \frac{L_n}{G_{n+1}} = \frac{Q' - H_{G_{n+1}}}{Q' - H_{L_n}} = \left(1 - \frac{H_{G_{n+1}} - H_{L_n}}{\underline{Q' - H_{L_n}}}\right)$$

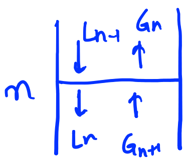
$Q' >> H_{L_n}$



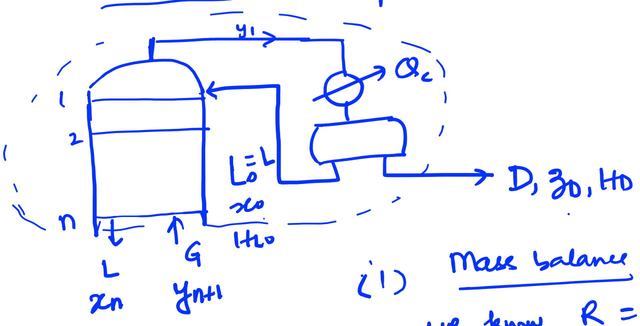


$H_{G_{n+1}} - H_{L_n}$ = This term also doesn't change much if the component form ideal solution, heat of solution is negligible, $H_{G,y}$ & $H_{L,x}$ don't vary much with change in composition, heat losses are negligible.

Physical Significance: When L_{n+1} & G_{n+1} come into contact, they undergo equimolar counterdiffusion. Therefore, their molar flow rates do not change.

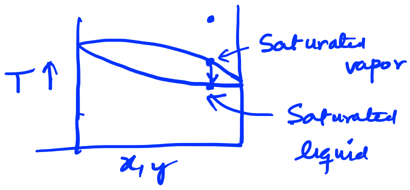


Let us obtain operating lines for the enriching section:



Assumption: Complete condensation of vapor to saturated liquid

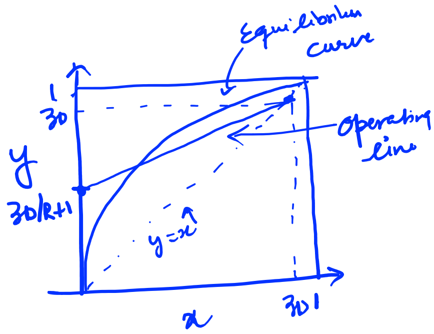
i.e. $y_1 = z_D = x_0$



(i) Mass balance: $G = L + D$

we know, $R = L/D \Rightarrow \boxed{G = (1+R)\,D}$

Reflux ratio



$x = x_A$

$y = y_A$

(ii) Species balance: $G y_{n+1} = L x_n + D z_D$

↳ Applying on the lighter component (volatile component)

$$y_{n+1} = \frac{L}{G} x_n + \frac{D}{G} z_D \leftarrow \text{operating line}$$

Using $R = L/D$

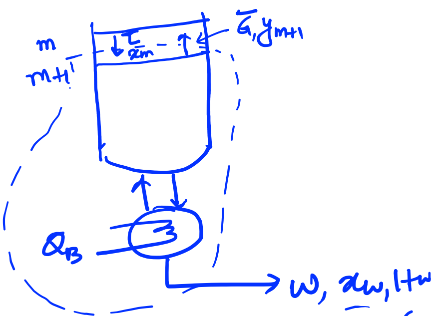
$$\Rightarrow y_{n+1} = \left(\frac{R}{R+1}\right) x_n + \left(\frac{z_D}{R+1}\right) \leftarrow \text{operating line for enriching section}$$

x_D

@ $x_n = z_D \Rightarrow y_{n+1} = z_D$

@ $x_n = 0 \Rightarrow y_{n+1} = \frac{z_D}{R+1}$ (Intercept on the y-axis)

For the stripping section:

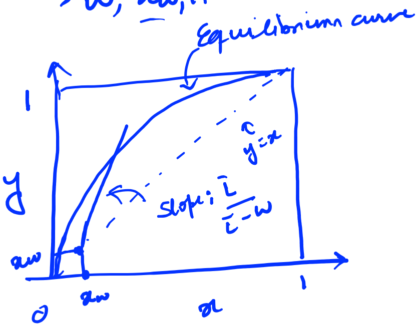


- Mass balance: $\bar{L} = \bar{G} + W$ — (i)
- Species balance: $\bar{L} x_m = \bar{G} y_{m+1} + W x_W$ — (ii)

(i) & (ii) $\Rightarrow$ $\boxed{y_{m+1} = \frac{\bar{L}}{\bar{G}} x_m - \frac{W}{\bar{G}} x_W}$ ← operating line

$$\text{or: } y_{m+1} = \left(\frac{\bar{L}}{\bar{L} - W}\right) x_m - \left(\frac{W}{\bar{L} - W}\right) x_W$$

← operating line



@ $x_m = x_W \Rightarrow y_{m+1} = x_W$

Draw a line of slope $\frac{\bar{L}}{\bar{L}-W}$ passing from (x_W, x_W). This is the operating line for the stripping section.