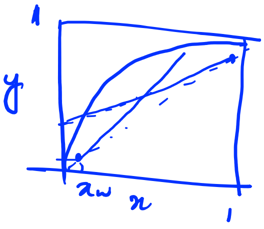
McCabe - Thiele Method Continue..

Recap: For the enriching section, we have:

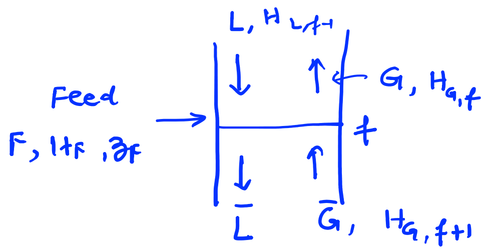
$$y_{n+1} = \frac{R}{R+1} x_n + \frac{x_D}{R+1} \quad ; \quad (x_D, x_D)$$



Similarly, for the stripping section, we have:

$$y_{m+1} = \frac{\bar{L}}{\bar{L}-W} x_m - \frac{\bar{W}}{\bar{L}-W} x_w \quad ; \quad (x_w, x_w)$$

Introduction of feed:



Feed: May be a single phase or two phase mixture

$$F : \begin{cases} L_F, \ x_F, \ H_{L,F} \\ G_F, \ y_F, \ H_{G,F} \end{cases}$$

Mass balance on the figure drawn above: $F + L + \bar{G} = \bar{L} + G$ — (i)

Energy balance: $F H_F + L H_{L,f-1} + \bar{G} H_{G,f+1} = \bar{L} H_{L,f} + G H_{G,f}$ — (ii)

Since the temperature & composition change over a tray can be assumed to be small:

$$\Rightarrow \quad H_{G,f} \simeq H_{G,f+1} = H_G$$

$$\& \quad H_{L,f-1} \simeq H_{L,f} = H_L$$

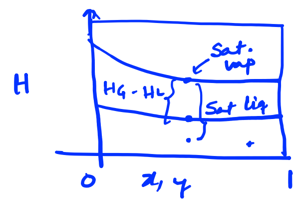
The previous equation can be written as:

$$(\bar{L} - L) H_L = (\bar{G} - G) H_G + F H_F \quad -(3)$$

(1) & (3) $\Rightarrow$ $\dfrac{\bar{L} - L}{F} = \dfrac{H_G - H_F}{H_G - H_L} = q$ (~~Quality of the feed~~)

↳ Amount of liquid in the feed.

q - for different feeds:



Case 1: Liquid below bubble point ; $q > 1$

Case 2: Saturated liquid : $q = 1$

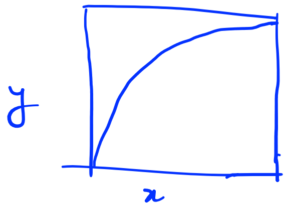
Case 3: Saturated vapor : $q = 0$

Case 4: Superheated vapor
$H_F > H_G \Rightarrow q < 0$

Case 5: Mixture of vapor & liquid
$H_L < H_F < H_G \Rightarrow 0 < q < 1$

Feed line: From the previous discussion, we know

$$\frac{\bar{L}-L}{F} = q \Rightarrow (\bar{L}-L) = qF$$

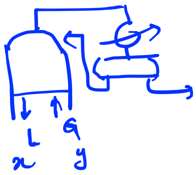


Similarly: $(\bar{G}-G) = F(q-1)$

From mass / species balance on enriching & stripping section, we have

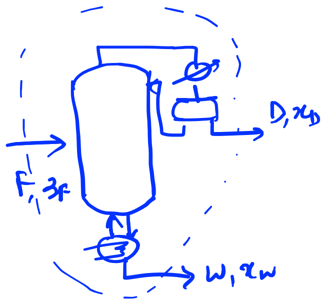
$$yG = Lx + Dx_D \quad -(i)$$
$$y\bar{G} = \bar{L}x - Wx_W \quad -(ii)$$

[x, y are the point of intersecⁿ of the two operating lines]



Subtract the above equations:

$$(ii) - (i) \Rightarrow y(\bar{G}-G) = x(\bar{L}-L) - (Wx_W + Dx_D)$$



From overall species balance:

$$Fz_F = Dx_D + Wx_W$$

$$\Rightarrow \quad x(\bar{L}-L) - Fz_F = y(\bar{G}-G)$$

$$\Rightarrow \quad y(q-1)F = xqF - Fz_F$$

$$\Rightarrow \quad \boxed{y = \frac{q}{q-1}x - \frac{z_F}{q-1}}$$

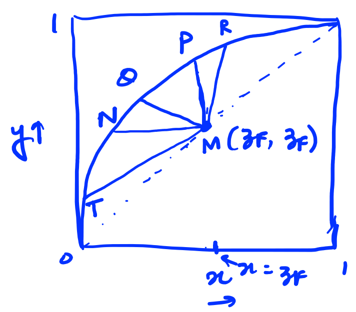
← Feed line: Equation of straight line of slope $\frac{q}{q-1}$ & passing from $x = y = z_F$

$$x = z_F \Rightarrow y = z_F$$

Feed line for different types of feed: (See Table 9.1 of RE Treybal)

(i) Liquid below bubble point : $q > 1 \Rightarrow \frac{q}{q-1} > 1$ [line MR]

(ii) Saturated liquid: $q = 1 \Rightarrow \frac{q}{q-1} \rightarrow \infty$ [line MP]



(iii) Saturated vapor : $q = 0 \Rightarrow \frac{q}{q-1} = 0$ [line MN]

(iv) Superheated vapor ; $q < 0 \Rightarrow 0 < \frac{q}{q-1} < 1$ [line MT]

(v) Mixture of liquid & vapor : $1 > q > 0 \Rightarrow \frac{q}{q-1} = \frac{L_F}{L_F - F}$ [line MO]