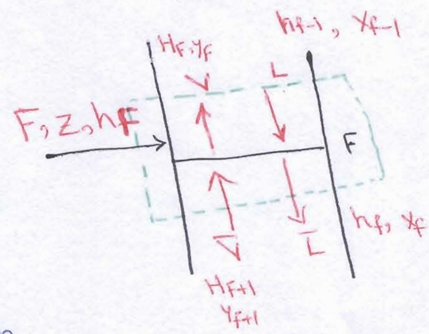
* Feed line equation (q-line)

* The phase and temperature of the feed obviously affect the vapor & liquid flow rates in the column.

* If the feed is liquid $\Rightarrow \bar{L} > L$

* If the feed is vapor $\Rightarrow V > \bar{V}$



$$F + \bar{V} + L = \bar{L} + V \qquad (1)$$

$$F h_F + \bar{V} H_{f+1} + L h_{f-1} = \bar{L} h_f + V H_f \qquad (2)$$

If we assume CMO, neither the vapor enthalpies nor the liquid enthalpies vary much from stage to stage.

$$\therefore F h_F + (\bar{V} - V) H \simeq (\bar{L} - L) h \qquad (3)$$

from (1)

$$\bar{V} - V = \bar{L} - L - F$$

$$\therefore F h_F + (\bar{L} - L) H - F H \simeq (\bar{L} - L) h$$

$$\therefore (\bar{L} - L)(H - h) \simeq F (H - h_F)$$

$$\boxed{q = \frac{\bar{L} - L}{F} \simeq \frac{H - h_F}{H - h}} \qquad (4)$$

$$q = \frac{\text{liquid flow rate below feed stage} - \text{liquid flow rate above feed stage}}{\text{feed rate}}$$

$$\boxed{\bar{L} = L + qF} \qquad (5)$$

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Whenever CMO is valid, at the feed plate we switch from one mass balance to the other.

(From top operating equation to bottom operating equation)

$\therefore$ at feed plate, we want to find the point of intersection.

At the top of the column

$$V = L + D \quad (6)$$

$$yV = Lx + Dx_D \quad (7)$$

$$\therefore y(L+D) = Lx + Dx_D \quad (8)$$

$$L(y-x) = D(x_D - y) \quad (9)$$

At the bottom of the column

$$\bar{L} = \bar{V} + B \quad (10)$$

$$\bar{L}x = \bar{V}y + Bx_B \quad (11)$$

$$\bar{L}x = (\bar{L} - B)y + Bx_B \quad (12)$$

$$\bar{L}(x-y) = B(x_B - y) \quad (13)$$

From equation 5

$$\bar{L} = L + qF$$

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$$\therefore (L+qF)(x-y) = B(x_B - y) \quad (14)$$

$$L(x-y) = B(x_B - y) - qF(x-y) \quad (15)$$

$$\therefore L(y-x) = B(y-x_B) - qF(y-x) \quad (16)$$

$\therefore$ equation 9 = equation 17

$$D(x_D - y) = B(y - x_B) - qF(y-x) \quad (17)$$

$$D(x_D - y) - B(y - x_B) = qF(x-y) \quad (18)$$

$$(Dx_D + Bx_B) - (B+D)y = qF(x-y) \quad (19)$$

From the overall Column balance

$$F = B + D \quad (20)$$

$$Fz_f = Bx_B + Dx_D \quad (21)$$

$\therefore$ From 19, 20, 21

$$Fz_f - Fy = qF(x-y) \quad (22)$$

$$\therefore z_f - y = q(x-y) \quad (23)$$

$$-y + qy = qx - z_f \quad (24)$$

$$y(q-1) = qx - z_f \quad (25)$$

$$\boxed{y = \left(\frac{q}{q-1}\right)x - \frac{z_f}{q-1} \quad (26)}$$

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For the Feed

$$F = L_F + V_F \Longrightarrow V_F = F - L_F$$

$$\frac{L_F}{V_F} = \frac{L_F}{F-L_F} = \frac{\overset{\to q}{L_F/F}}{1-L_F/F} = \frac{q}{1-q}$$

$$\frac{F}{V_F} = \frac{F}{F-L_F} = \frac{1}{1-L_F/F} = \frac{1}{1-q} = \frac{-1}{q-1}$$

$\therefore$ equation 26 can be written as

$$\boxed{y = \left(\frac{L_F}{V_F}\right)x - \frac{F}{V_F} z_F} \qquad (27)$$

also

$$\boxed{y = -\frac{1-f}{f}x + \frac{1}{f} z_f}$$

where $f = \frac{V_F}{F}$

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