Ponchon Savarit Method for Binary Distillation

Graphical Multistage Calculations:

Features:

- Stage to stage calculations
- No need to make CMO assumption (∴ any set of consistent units can be used)
- Hxy diagrams must be available
- VLE data must be available
- Limited to binary systems

VLE data + Hxy diagram —> graphical solution of material and energy balances

Working Equations:

Top Section:

Material balance:

$$y_{n-1}.V_{n-1} = x_n.L_n + D.x_D$$

Eliminate D: $V_{n-1} = L_n + D$

$$\frac{L_n}{V_{n-1}} = \frac{x_D - y_{n-1}}{x_D - x_n}$$

Enthalpy Balance:

$$V_{n-1}.h_{V,n-1} = L_n.h_{L,n} + D.Q' \quad ; \quad Q' = h_D + \frac{Q_C}{D}$$

This represents the mixing line on an Hxy diagram OR $V_{n-1} - L_n = \Delta D.$

It also represents a family of straight lines passing through points V_{n-1}, L_n and a common point ΔD. The coordinates of these points are obtained as follows:

Eliminate D from enthalpy balance:

$$\frac{L_n}{V_{n-1}} = \frac{Q' - h_{V,n-1}}{Q' - h_{L,n}} = \frac{x_D - y_{n-1}}{x_D - x_n}$$

This is a straight line equation passing through points:

V_{n-1}	$(y_{n-1}\ ,\ h_{V,n-1})$
L_n	$(x_n\ ,\ h_{L,n})$
ΔD	$(x_D\ ,\ Q')$

Stream Ratios:

$$\frac{L_n}{V_{n-1}} = \frac{\overline{\Delta D, V_{n-1}}}{\overline{\Delta D, L_n}} \qquad \frac{L_n}{D} = \frac{\overline{\Delta D, V_{n-1}}}{\overline{L_n, V_{n-1}}} \qquad \frac{V_{n-1}}{D} = \frac{\overline{\Delta D, L_n}}{\overline{V_{n-1}, L_n}}$$

Location of ΔD point:

Knowing the reflux ratio $\frac{L_R}{D} = R = \frac{\overline{\Delta D, V_{Np}}}{\overline{L_R, V_{Np}}}$

Point ΔD can be located very easily (specially for reflux at bbpt)

Total Condenser:

We need R and h_{L_R} since $h_{V_{Np}}$ is fixed on saturated vapour line.

Partial condenser:

Saturated vapour is withdrawn and point D is on saturated vapour line.

Bottom Section:

Material balance:

$$y_m \bar{V}_m = x_{m+1}\,\bar{L}_{m+1} \; - \; x_B\, B$$

$$B = \bar{L}_{m+1} - \bar{V}_m$$

Eliminate B

$$\frac{\bar{L}_{m+1}}{\bar{V}_m} = \frac{y_m - x_B}{x_{m+1} - x_B}$$

Enthalpy Balance:

$$h_{\bar{V}_m}\;\bar{V}_m = h_{\bar{L}_{m+1}}\;\bar{L}_{m+1} - \; h_B B + \; Q_B$$

$$h_{\bar{V}_m}\;\bar{V}_m = h_{\bar{L}_{m+1}}\;\bar{L}_{m+1} - \; B Q_B^{"}$$

$$Q_B^{"} = \quad h_B - \frac{Q_B}{B}$$

Eliminate B from enthalpy balance: $B = \bar{L}_{m+1} - \bar{V}_m$

$$h_{\bar{V}_m}\;\bar{V}_m = h_{\bar{L}_{m+1}}\;\bar{L}_{m+1} - \; (\bar{L}_{m+1} - \bar{V}_m)\; Q_B^{"}$$

$$\frac{\bar{L}_{m+1}}{\bar{V}_m} = \frac{h_{\bar{V}_m} - Q_B^{"}}{h_{\bar{L}_{m+1}} - Q_B^{"}} = \frac{y_m - x_B}{x_{m+1} - x_B}$$

This represents another family of straight lines passing through points:

$\bar{V}_m$	$(y_m\,, h_{\bar{V}_m})$
$\bar{L}_{m+1}$	$(x_{m+1}\,,\; h_{\bar{L}_{m+1}})$
ΔW	$(x_B\;\;,\; Q^{"})$

Overall Balances:

Total: $F = D + B$

Component balance: $Z_F F = D x_D + B x_B$

Enthalpy balance: $F h_F + Q_B = D h_D + B h_B + Q_C$

Substitute for F and rearrange:

$$\frac{D}{B} = \frac{h_F - Q''}{Q' - h_F} = \frac{Z_F - x_B}{x_D - Z_F}$$

This is a straight line passing through points:

F	(z_F, h_F)
ΔD	(x_D, Q')
ΔW	(x_B, Q'')

Feed location and number of trays:

Feed location:

- In the process of solving material and energy balances, each tie line represents an equilibrium stage
- The optimum feed stage location is where an equilibrium tie line crosses the line $\overline{\Delta D F \Delta W}$
- The change of difference point is made at this stage

Number of stages:

- Starting at the top of the column and using the ΔD difference point, the construction of operating lines and equilibrium tie lines is continued until the feed stage
- A change of difference point is made at the feed stage.
- Construction of equilibrium stages is continued until a tie line crosses the vertical at x_B
- The number of stages including the reboiler (partial) is equal to the number of tie lines.

Limiting conditions

Minimum Number of plates (Total Reflux)

$$\left\{\begin{matrix} D = 0 \rightarrow Point \quad \Delta D \quad at \quad \infty \\ R = \infty \rightarrow Point \quad \Delta W \; at \; -\infty \end{matrix}\right\}$$ Operating lines are parallel and vertical

Minimum Reflux ratio:

This condition is obtained when ΔD and ΔW are located in such a way so that $\overline{\Delta D F \Delta W}$ and a tie line coincide