McCabe-Thiele Method:

Also plate to plate Solution

This method is based on:

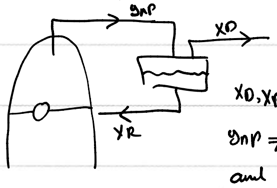
① Assumption of constant molal overflow (CMO), which results in straight line operating lines on molal basis.

② Constant column pressure [sets equilibrium data] This makes it possible to use a y-x diagram for a graphical solution.

Operating lines:

for partial condensation

(one stage equilibrium stage outside the column)



$x_D, x_R \Rightarrow$ equilibrium

$y_{NP} \neq x_D, x_r$

and not in the equilibrium

(Material Balance)

Enriching Section.

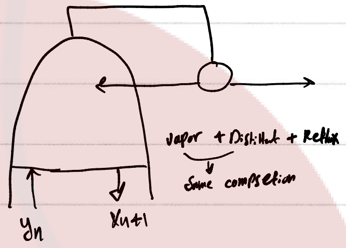
for stage n

$$y_{n-1} = \frac{L}{V} x_n + \frac{D}{V} \cdot x_D.$$

$$V = D(R+1)$$

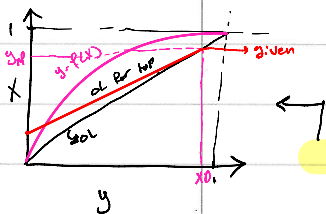
$$y_{n-1} = \frac{L}{D(R+1)} \cdot x_n + \frac{D}{D(R+1)} \cdot x_D.$$

$$\boxed{y_n = \frac{R}{R+1} \cdot x_{n+1} + \frac{1}{R+1} \cdot x_D}$$



vapor + Distillate + Reflux
↓
Same composition

if we have total condenser!!

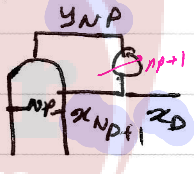


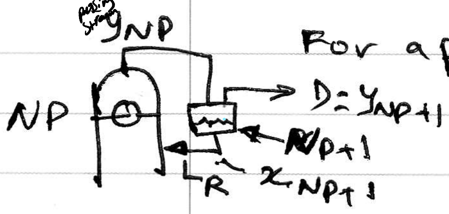
This line intersects the 45° line at $y_n = x_{n+1} = x_D$.

by this value we'll draw the operating line

↳ إذا تعطينا عن حاد الخط بقدر اطلع ال

For a total condenser: $y_{NP} = x_{NP+1} = x_D$





For a partial condenser: $y_{NP} \neq x_{NP+1} \neq x_D$ $\Big\}$ $x_D = y_{NP+1}$

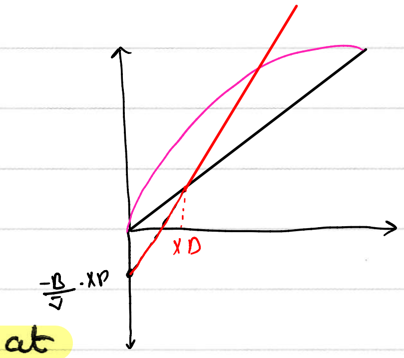
$x_{NP+1} = f(x_D) = f(y_{NP+1})$

$$\boxed{y_{NP} = \frac{L}{V} \cdot x_{NP+1} + \frac{D}{V} \cdot x_D}$$

$$y = \frac{R}{R+1} x + \frac{X_D}{R+1}$$

$$y = \frac{\bar{L}}{\bar{V}} x - \frac{X_B . B}{\bar{V}}$$

Exhausting Section:



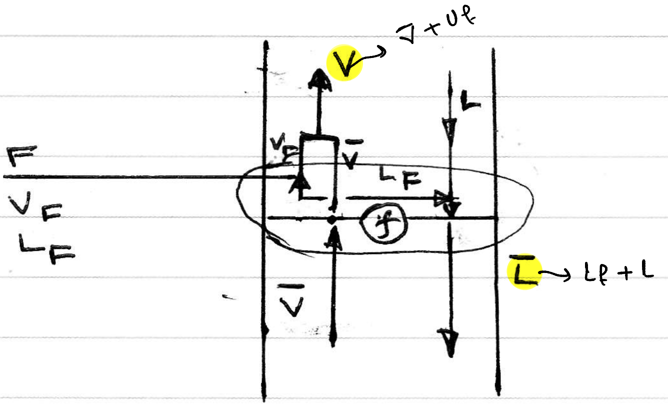
$$\boxed{y_m = \frac{\bar{L}}{\bar{V}} . x_{m+1} - \frac{B}{\bar{V}} . x_B}$$

This line intersects the 45° line at

$$y_m = x_{m+1} = x_B .$$
↳ or Xw

Note: For a saturated liquid feed the two operating lines intersect at x_f .

Feed line (q - line)



Overall Balance :-

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

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

Ⓐ $\bar{L} = L + qF$

q : fraction of feed which is liq.
↳ $\frac{L}{F}$ or $(1-\psi)$

Ⓑ $\bar{V} = V - \overset{\psi}{(1-q)} F$

Stripping $y = \frac{\bar{L}}{\bar{V}} . x - \frac{B}{\bar{V}} . x_B$

Enriching $- \left(y = \frac{L}{V} x + \frac{D}{V} . x_D \right)$

حطينا هيك وجمعناهم
لأنه في حل بينهم
(نقطة تقاطع)

$$(\bar{V} - V) y = (\bar{L} - L) . x - (B x_B + D x_D)$$

Ⓑ → $(\bar{V} - V) = (q - 1) . F$

Ⓐ → $(\bar{L} - L) = \boxed{q} F$

$$\frac{\bar{L} - L}{F}$$

$$B x_B + D x_D = z_F \cdot F$$

$$y = \frac{q}{q-1} x - \frac{z_f}{q-1}$$

substitute:

$$(q-1)\cancel{F} y = q\cancel{F} x - \cancel{F} z_F$$

$$\boxed{y = \frac{q}{q-1} \cdot x - \frac{z_F}{(q-1)}}$$

q-line equation.

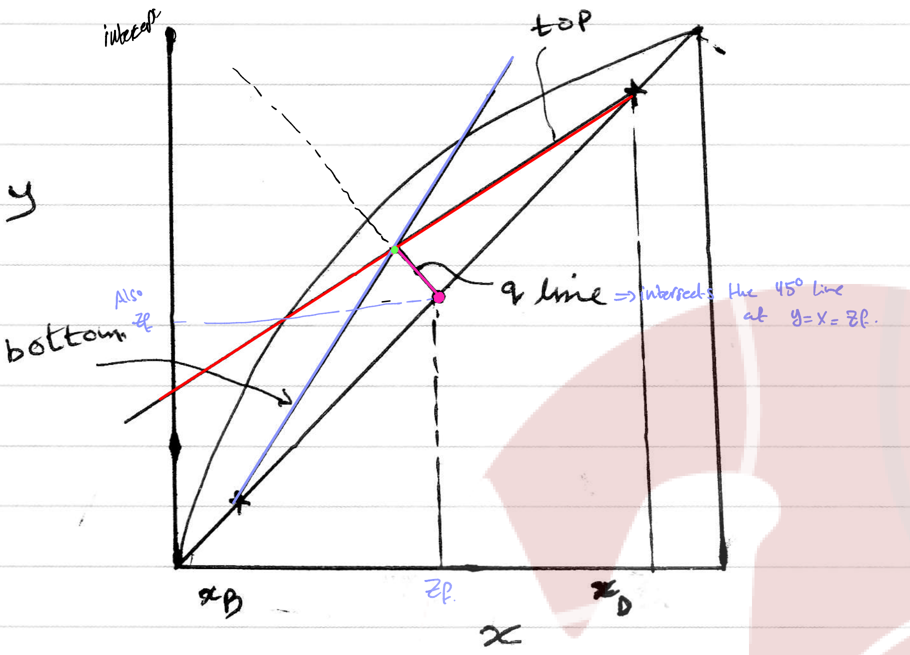
لما يتحرك خطابه Bottom، Top
بتغير شو بصير معهم النقطةa ان بتغير مكانها.

This line is the locus of the points of intersection of stripping and enriching operating lines

Slope $= \frac{q}{q-1}$ intercept $= -\frac{z_F}{q-1}$

↳ positive quantity
$q-1$ → $-ve$
with another $-ve$
+ve

and passes through $y = x = z_F$



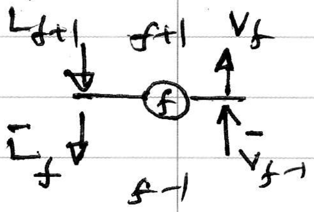
Thermal Condition of feed: → type of the feed (sat'd —)

From MB $(\bar V - V) = (\bar L - L) - F$

Enthalpy: $F h_F + L_{f+1} h_{L_{f+1}} + \bar V_{f-1} h_{\bar V, f-1} = V_f h_{V,f} + L_f h_{L_f}$

من فوق الSection.

Based on assumption of CMO



$L_{f+1} = L$; $\bar{L}_f = \bar{L}$ $V_f = V$; $\bar{V}_{f-1} = \bar{V}$

$h_{V_f} = h_{\bar{V},f-1}$: $h_{L,f+1} = h_{\bar{L}f}$

$\therefore F h_F + (\bar{V}-V) h_{V_f} = (\bar{L}-L) . h_{\bar{L},f}$

Substitute for $(\bar{V}-V) = (\bar{L}-L) - F$.

$\Rightarrow \underline{F h_F} + \underline{(\bar{L}-L).h_{V_f}} - \underline{F h_{V_f}} = \underline{(\bar{L}-L).h_{\bar{L}f}}$

$\frac{\bar{L}-L}{f} = q$ → $\frac{L}{f}$

$(\bar{L}-L)(h_{V_f} - h_{\bar{L}f}) = F(h_{V_f} - h_F)$.

$$\frac{\bar{L}-L}{F} = \frac{h_{V_f} - h_F}{h_{V_f} - h_{\bar{L}f}} = q$$

Enthalpy to vaporize 1 mole of feed.

sat vap → h_{V_f} ; $h_{\bar{L}f}$ ← sat liq

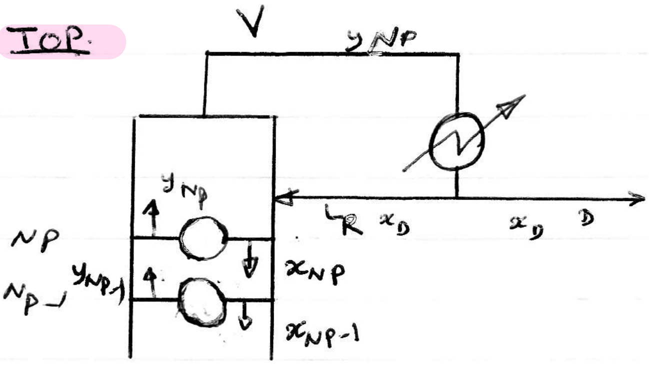
Latent heat of vaporisation.

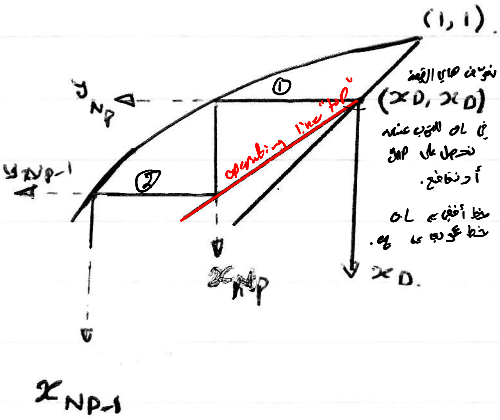
Values of q:

q	Feed Condition	Slope of q-line	
q > 1	cooled liquid	> 1	↗
q = 1	Saturated liquid	∞	|
0 < q < 1.0	vapor + liquid.	< 1	↘
q = 0	Saturated vapor	0	—
q < 0	superheated vapor	1 > slope > 0	/

Important portions in fractionation column:

TOP.

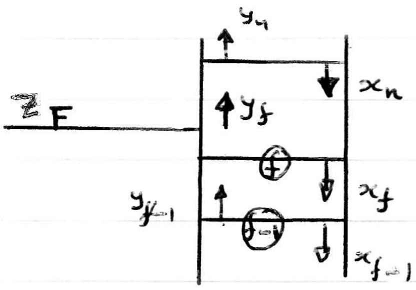


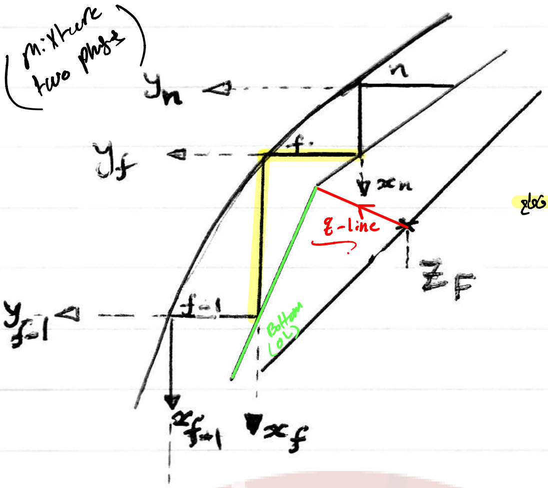


نعوّض هاي القيمة (x_D, x_D)
في OL للتوب عشان
نحصل على y_{NP}
أو نتقاطع.

خط أفقي مع OL
خط عمودي ع x.

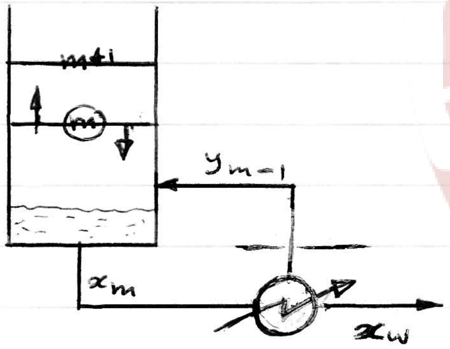
Feed.

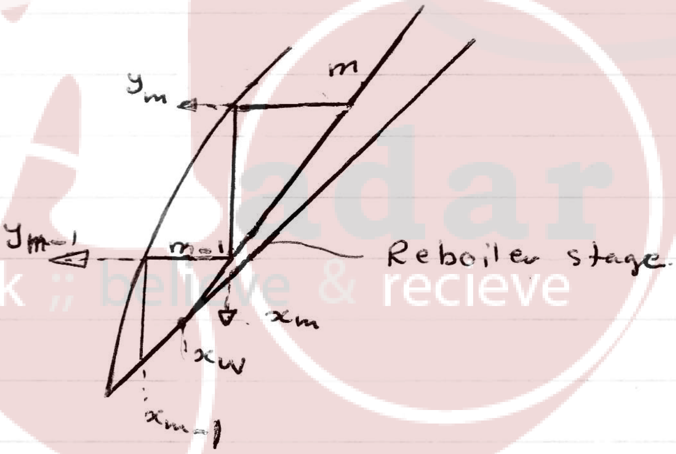


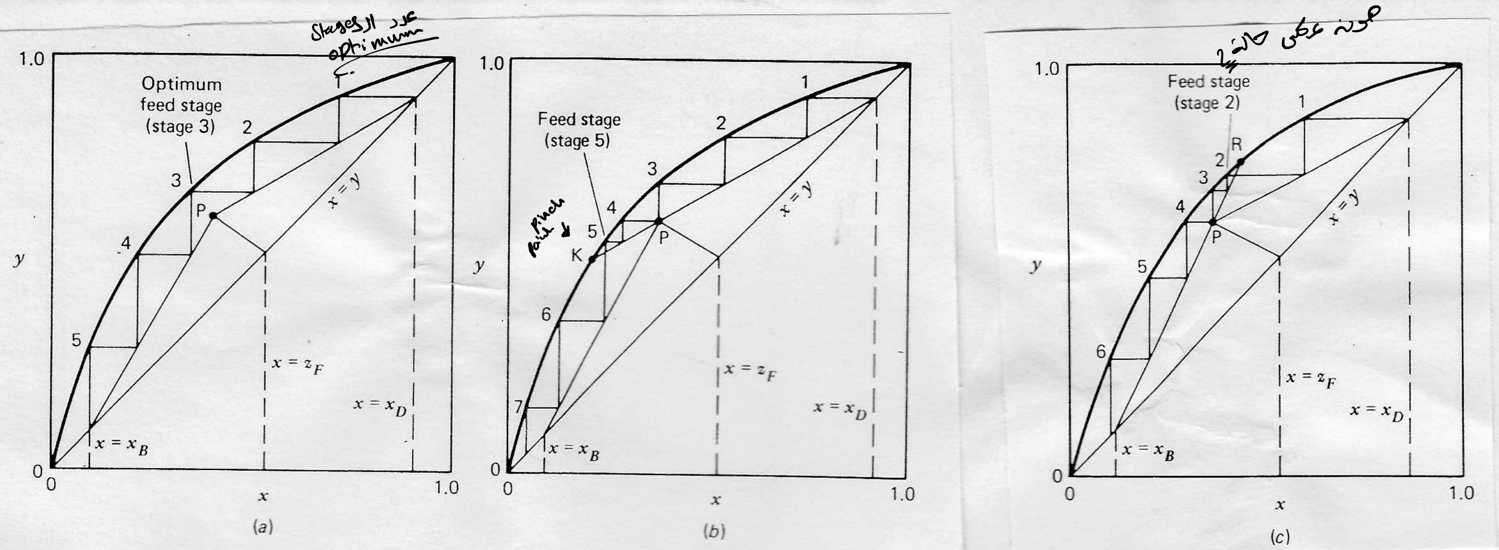


لما نوصل عند q لاين
صرنا دغري بنغير وبناخذ
OL ال (Bottom)

Reboiler and bottom stage:







جهاي الاحداثات وبين تنقطع الـ operating Line!

Figure 8.13. Location of feed stage (because of convenience, stages are stepped off and counted in top-down direction. (*a*) Optimum feed-stage location. (*b*) Feed-stage location below optimum stage. (*c*) Feed-stage location above optimum stage.

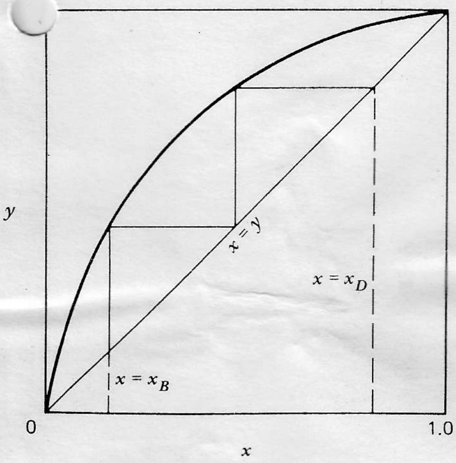


Figure 8.14. Minimum stages, total reflux.

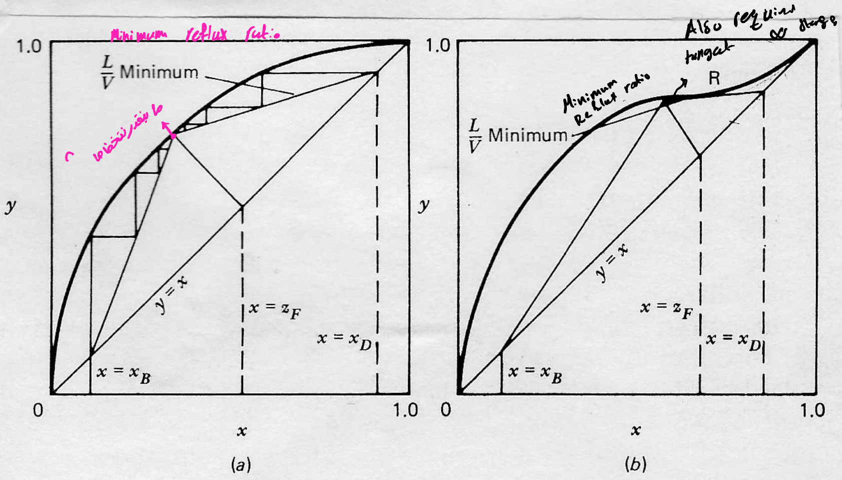
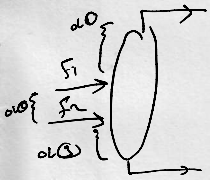
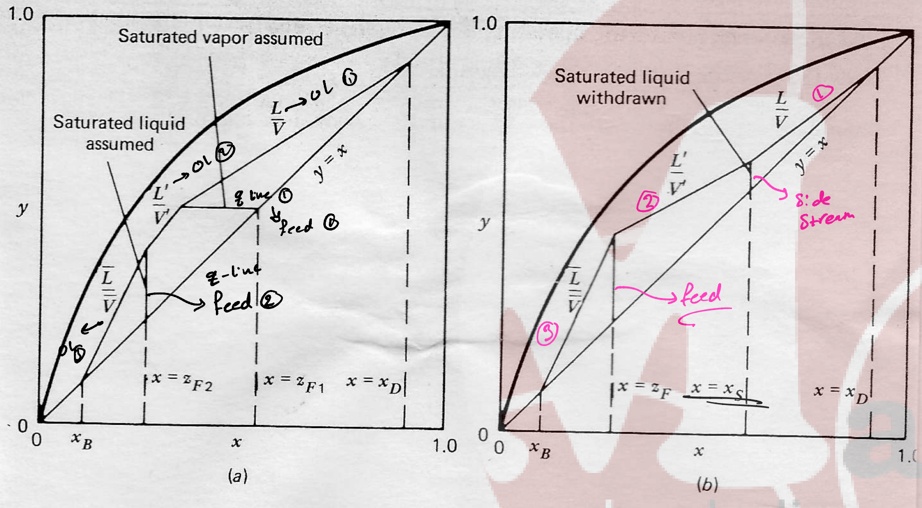


Figure 8.15. Minimum reflux ratio conditions. (*a*) Intersection of operating lines at equilibrium curve. (*b*) Operating line tangent to equilibrium curve.





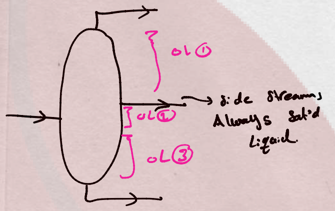


Figure 8.20. Variation of operating conditions. (*a*) Two feeds (saturated liquid and saturated vapor). (*b*) One feed, one side stream (saturated liqui