الجامعة التكنولوجية

قسم الهندسة الكيمياوية

المرحلة الثالثة

انتقال كتلة

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Similarly, for pairs (2-5), (4-5) and (6-3) and using Fensk's equation:-

$$\left.\begin{array}{l} D.x_{2D} = 67.766 \\ W.x_{2W} = 0.234 \end{array}\right\} \quad \left.\begin{array}{l} D.x_{4D} = 98.74 \\ W.x_{4W} = 201.26 \end{array}\right\} \quad \begin{array}{l} D.x_{6D} = 3.2 * 10^{-5} \\ W.x_{6W} = 110 \end{array}$$

Now $D = \sum D\,x_{iD} \Rightarrow \boxed{D = 372.325 \text{ kmol/hr}}$

$W = 1000 - 372.325$

$\boxed{W = 627.67 \text{ kmol/hr}}$

Component	α_{is}	z_i	$D.x_{iD}$	$W.x_{iW}$	x_{iD}	x_{iW}
1	3.15	0.032	31.969	0.0305	0.086	4.86×10^{-5}
2	2.75	0.068	67.767	0.234	0.182	$3.73 * 10^{-4}$
3	2.35	0.17	167.45	2.55	0.449	$4.06 * 10^{-3}$
4	1.4	0.3	98.74	201.26	0.266	0.3206
5	1.0	0.32	6.4	313.6	0.0172	0.4996
6	0.75	0.11	$3.44 * 10^{-4}$	110.0	$9.2 * 10^{-8}$	0.175
		1.0	372.325	627.67	0.999	0.999

$\sum D.x_{iD} + W.x_{iW} \simeq F$

$999.995 \simeq 1000$ kmol/hr

The Underwood - Equation for Min. Reflux

In a column for distill^n. of a binary mixture with min^m. reflux, the pinch point occurs at the feed tray if the solution is ideal or nearly ideal.
For multicomponent system, the pinch point appears at the feed tray if all the components are distributed between the top and the bottom products.
However, if one or more of the non-keys appear in only one of the products, separate pinch points in the rectifying and stripping sections may occur

- For rectifying section :-

$$V_{min} = \sum \frac{\alpha_i \cdot D \cdot x_{iD}}{\alpha_i - \phi} \quad , \quad \phi = \frac{L_{min}}{V_{min} \cdot K_{HK}}$$

ϕ ⇝ underwood constant

- For stripping section :-

$$\bar{V}_{min} = \sum \frac{\alpha_i * W \cdot x_{iw}}{\alpha_i - \bar{\phi}} \quad , \quad \bar{\phi} = \frac{\bar{L}_{min}}{\bar{V}_{min} * K_{HK}}$$

To find (ϕ) in order to find V_{min}, then we can use Underwood eq. for multicomponent

$$\boxed{1 - q = \sum \frac{\alpha_i z_i}{\alpha_i - \phi}} \text{ ---- } (*) \text{ Underwood - eq.}$$

where (q) fraction liquid in feed, depends on the inlet feed condition.

The min^m. liquid flow rate can be found where

$$\boxed{L_{min} = V_{min} - D}$$

Then (R_{min}) can be calculated as :-

$$\boxed{R_{min} = \frac{L_{min}}{D}} \quad \underline{\underline{or}} \quad \boxed{R_{min} = \frac{V_{min}}{D} - 1}$$

In solving (underwood) equation to find values for (ϕ), the following cases deserve attention :-

<u>Case ①</u> :-

The non-keys are either too light or too heavy to distribute, all (LNK) go to the top, all the (HNK) go to the bottom, (No intermediate key), then :-

$\alpha_{HK} < \phi < \alpha_{LK}$, then find V_{min} and

finally find total $(D) = \sum D \cdot x_{iD}$

Case ② :-

Distribution of the intermediate key between (LK) and (H.K).

This case can be solved by taking the two roots of eq. (*) and find (V_{min}) for each roots, and by equating (V_{min}) for each root, the value of ($D \cdot x_{iD}$) can be found.

Ex. (3) :- (The min. reflux ratio)

A saturated liquid feed at 100 kmol/hr containing 35% benzen (1), 35 mol% toluene (2) and 30% ethyl benzene (3), is to be fractionated to recover 97% of benzene at the top and 95% of the toluene in the bottom product. The total pressure atmospheric, and reflux retured is at bubble point. Determine :-

1- Min. No. of trays using fenske equation.

2- Min. Reflux ratio using Underwood equation.

The average relative volatilities with respect to comp. (2) are :-

$$\alpha_{12} = 2.4 \quad , \text{ and } \quad \alpha_{32} = 0.48$$

Sol. :- $f_{1D} = 0.97$, $f_{2W} = 0.95$ then

$$1- \; N_{min} = \frac{\log\left[\frac{f_{1D} * f_{2W}}{(1-f_{1D})(1-f_{2W})}\right]}{\log \alpha_{AB} \leftarrow \alpha_{12}}$$

$$N_{min} = \frac{\log\left[(0.97 * 0.95)/(1-0.97)(1-0.95)\right]}{\log 2.4} = \boxed{7.33}$$

To calculate the fraction of comp (3) removed at the bottom, then :-

$$N_{min} = \frac{\log\left[f_{1D} * f_{3W} / (1-f_{1D})(1-f_{3W})\right]}{\log \alpha_{13}} = 7.33$$

$$7.33 = \frac{\log\left[0.97 * f_{3W} / (1-0.97)(1-f_{3W})\right]}{\log(\alpha_{12}/\alpha_{32})}$$

$$\boxed{\therefore f_{3W} = 0.9997}$$

2- To calculate (R_{min})

Since most of the comp.(3) goes to the bottoms ($f_{3W} = 0.999$), then we assume that it does not distribute. then case (1) will be considered.

$$1 - q = \frac{\alpha_1 Z_1}{\alpha_1 - \phi} + \frac{\alpha_2 Z_2}{\alpha_2 - \phi} + \frac{\alpha_3 Z_3}{\alpha_3 - \phi}$$

∵ Saturated liquid, then $q = 1$

$$0 = \frac{(2.4)(0.35)}{2.4 - \phi} + \frac{(1)(0.35)}{1 - \phi} + \frac{(0.48)(0.3)}{0.48 - \phi}$$

$\boxed{\phi_1 = 1.465}$, $\phi_2 = 0.589$

∵ comp.(3) does not go to distillate $\Rightarrow \alpha_{LK} > \phi > \phi_{HK}$

∴ $\boxed{\phi = 1.465}$

Now:- $D.x_{1D} = 0.97 * F * Z_1$

$= 0.97 * 100 * 0.35$

$\boxed{D.x_{1D} = 33.95}$

$W.x_{2W} = 0.95 * F * Z_2$

$= 0.95 * 100 * 0.35$

$\boxed{W.x_{2W} = 33.25}$

$D.x_{2D} = F.Z_2 - W.x_2W$

$= 100 * 0.35 - 33.25$

$\boxed{D.x_{2D} = 1.75}$

$\boxed{D.x_{3D} = 0}$

$$D_{total} = 33.95 + 1.75 + \text{Zero}$$
$$D = 35.7 \text{ Kmol/hr}$$

$$V_{min} = \frac{\alpha_1 D \cdot x_{1D}}{\alpha_1 - \phi} + \frac{\alpha_2 \cdot D x_{2D}}{\alpha_2 - \phi} + \cancel{\frac{\alpha_3 D x_{3D}}{\alpha_3 - \phi}} \rightarrow 0$$

$$V_{min} = \frac{(2.4)(33.95)}{(2.4) - (1.465)} + \frac{(1)(1.75)}{(1) - (1.465)} + 0 = \boxed{83.4}$$

$$V_{min} = D(R_{min} + 1) \qquad \underline{\text{or}} \qquad R_{min} = \frac{L_{min}}{D}$$
$$83.4 = 35.7(R_{min} + 1) \qquad\qquad = \frac{V_{min} - D}{D}$$
$$\boxed{R_{min} = 1.336} \qquad\qquad = \frac{83.4 - 35.7}{35.7}$$
$$\boxed{R_{min} = 1.336}$$

Now if we try to solve the examph using case (2)
$D \cdot x_{1D} = 33.95$, $D \cdot x_{2D} = 1.75$ but $D \cdot x_{3D} \neq 0$

for $\phi = 1.465$
$$V_{min} = \frac{(2.4)(33.95)}{2.4 - 1.465} + \frac{(1)(1.75)}{1 - 1.465} + \frac{(0.48)(D \cdot x_{3D})}{0.48 - 1.465} \quad \text{--- (1)}$$
for $\phi = 0.589$

$$V_{min} = \frac{(2.4)(33.95)}{2.4 - 0.589} + \frac{(1)(1.75)}{1 - 0.589} + \frac{(0.48)(D \cdot x_{3D})}{0.48 - 0.589} \quad \text{--- (2)}$$

Solving (1) and (2) yield a negative value for $D \cdot x_{3D}$ which insure that case (1) is more suitable, for calculating R_{min}.

Ex.(4) :- (Distribution of the intermediat Key)

A saturated liquid feed flowing at 100 Kmol/hr containing 38 mol% benzene(1), 17 mol% toluene(2) and 45 mol% Cumene (3) is to be seperated to recover 99.7% benzene in the distillate and 99.9% of the cumene in the bottom. Calculate the minimum reflux ratio and the distribution of the intermediate key.

$\alpha_{12} = 2.28$, $\alpha_{22} = 1$, $\alpha_{32} = 0.22$

Sol.

F = 100 Kmol/hr at bubblepoint

$Z_1 = 0.38$, $Z_2 = 0.17$, $Z_3 = 0.55$

99.7% of comp. (1) as distillate $\Rightarrow$

$$D x_{1D} = 0.997 * F * Z_1$$
$$= 0.997 * 100 * 0.38$$

$$\therefore \boxed{D.x_{1D} = 37.886}$$

99.9% of comp. (3) as waste $\Rightarrow$

$$D x_{3D} = (1 - 0.999) * F * Z_3$$
$$= 1 * 10^{-3} * 100 * 0.55$$

$$\therefore \boxed{D.x_{3D} = 0.055}$$

$$1 - q = \sum \frac{\alpha_i Z_i}{\alpha_i - \phi} \qquad \because q = 1$$

$$0 = \frac{(2.28)(0.38)}{2.28 - \phi} + \frac{(1)(0.17)}{1 - \phi} + \frac{(0.22)(0.45)}{0.22 - \phi}$$

$\phi_1 = 1.233 \quad , \phi_2 = 0.358$

∴ Toluene will distribute between Top and bottom, then case (2) must be applied:

V_{min} for ϕ_1:

$$V_{min} = \frac{(2.28)(37.88)}{2.28 - 1.233} + \frac{(1)(D \cdot x_{2D})}{1 - 1.233} + \frac{(0.22)(0.055)}{0.22 - 1.233}$$

V_{min} for ϕ_2:

$$V_{min} = \frac{(2.28)(37.88)}{(2.28) - (0.358)} + \frac{(1)(D \cdot x_{2D})}{1 - 0.358} + \frac{(0.22)(0.055)}{0.22 - 0.358}$$

$\therefore D \cdot x_{2D} = 6.4337 \implies V_{min} = 54.877$

$$\boxed{\therefore D_T = 44.375 \text{ Kmol/hr}}$$

$$\boxed{\therefore R_{min} = 0.237}$$

Gilliland Correlation For the Number of Trays

Gilliland made a tray-by-tray calculation to determine the number of ideal stages (N) (included Reboiler) required to seperate a multicomponent mixture by correlating (N) total by N_{min} and R_{min}, R.

$$\boxed{X = \frac{R - R_{min}}{R+1}}$$

$$\boxed{Y = 1 - \exp\left[\left(\frac{1+54.4X}{11+117.2X}\right)\left(\frac{X-1}{X^{0.5}}\right)\right]}$$

$$\boxed{Y = \frac{N - N_{min}}{N+1}}$$

Also feed stage location could be expressed as :-

$$\boxed{\frac{N_R}{N_s} = \left[\left(\frac{Z_{HK}}{Z_{LK}}\right)\left(\frac{x_{LK.W}}{x_{H.K.D}}\right)^2 \frac{W}{D}\right]^{0.206}}$$

$$\boxed{N_{Total} = N_R + N_s}$$

N_R = no. of trays in the Rectifying section.

N_s = " " " " " stripping section

Ex. (5) :-

A Feed mixture containing 35% benzene, 35% toluene and 30% Cumene (all mol %), is to be fractionated at a rate of 100 kmol/hr to recover 98% of benzene in the distillate and 98.5% of the toluene in the bottom product. The feed is saturated vapour and the reflux at bubble point. Calculate:-

1- N_{min}.

2- R_{min}.

3- The number of ideal stages if a reflux ratio 1.3 times the R_{min} is used. Specify feed stage.

Given:-

$P_{total} = 1$ atm.

$$\left.\begin{array}{ll} \text{top}: & 2.55 \\ \text{bott.}: & 2.25 \end{array}\right\} \alpha_{AB} \qquad \left.\begin{array}{l} 0.254 \\ 0.311 \end{array}\right\} \alpha_{CB}$$

Sol. :-

$$f_{AD} = 0.98 \quad , \quad f_{BW} = 0.985$$

$$F = 100 \quad , \quad Z_A = 0.35 \quad , \quad Z_B = 0.35 \quad , \quad Z_C = 0.3$$

$$q = 0 \quad (\text{sat. vap.})$$

$$D \cdot x_{AD} = 0.98 * 100 * 0.35$$

$$\boxed{D \cdot x_{AD} = 34.3} \Longrightarrow \boxed{W \cdot x_{AW} = 0.7 \text{ kmol}}$$

$$W \cdot x_{BW} = 0.985 * 100 * 0.35$$

$$\boxed{W \cdot x_{BW} = 34.47} \Longrightarrow \boxed{D \cdot x_{BD} = 0.53 \text{ kmol}}$$

$D_{total} = 34.3 + 0.53 + 0$

$\boxed{D_T = 34.83 \text{ Kmol}} \Rightarrow \boxed{W = 65.17 \text{ Kmol}}$

$\therefore x_{A.D} = 0.985$ $\qquad x_{A.W} = 0.0107$

ⓐ $$N_{min} = \frac{\text{Log}\left[\frac{f_{AD} * f_{BW}}{(1-f_{AD})(1-f_{BW})}\right]}{\text{Log}\, \alpha_{AB}|_{avg.}}$$

(α_{AB}) at top differ than (α_{AB}) at bottom, then

$$\alpha_{AB}|_{avg.} = \left(\alpha_{AB}|_{top} \cdot \alpha_{AB}|_{Bot}\right)^{0.5}$$

$$= (2.55 * 2.25)^{0.5} \Rightarrow \alpha_{AB}|_{avg.} = 2.4$$

$$\alpha_{CB}|_{avg.} = (0.254 * 0.311)^{0.5} \Rightarrow \alpha_{CB}|_{avg.} = 0.281$$

$$N_{min} = \frac{\text{Log}\left[\frac{0.98 * 0.985}{(1-0.98)(1-0.985)}\right]}{\text{Log}\,(2.4)} = \underline{\underline{9.2}}$$

Ideal trays + the reboiler = $\boxed{9.2}$

(Now we can check for comp.(c) by calculating its fraction in the distillate by using N_{min})!

(b) R_{min}.

To calculate (R_{min}) We must first find (ϕ)

$$1-q = 1-0 = \frac{(0.35)(2.4)}{2.4-\phi} + \frac{(0.35)(1.0)}{(1.0)-\phi} + \frac{(0.3)(0.28)}{(0.28-\phi)}$$

$\boxed{\phi = 1.44}$ (because (HNK) is non-distributing)

$$V_{min} = \frac{(2.4)(34.3)}{2.4-1.44} + \frac{(1.0)(0.53)}{1.0-1.44} + 0$$

$$\boxed{V_{min} = 84.54 \text{ Kmol}}$$

$$L_{min} = V_{min} - D \Rightarrow 84.54 - 34.83$$

$$\boxed{L_{min} = 49.71 \text{ Kmol}}$$

$$R_{min} = \frac{L_{min}}{D} = \frac{49.71}{34.83} \Longrightarrow \boxed{R_{min} = 1.43}$$

(c) To find No. of trays.

$$R_{act.} = 1.3\, R_{min}$$

$$R = 1.3 * 1.43 \Longrightarrow \boxed{R = 1.86}$$

$$X = \frac{R - R_{min}}{R+1} = \frac{1.86 - 1.43}{1.86+1}$$

$$\boxed{X = 0.1503}$$

$$Y = 1 - \exp\left[\frac{1+(54.4)(0.1503)}{11+(117.2)(0.1503)}\left(\frac{0.1503-1}{(0.1503)^{0.5}}\right)\right]$$

$$\boxed{Y = 0.505}$$

$$Y = \frac{N - N_{min}}{N+1} = 0.505 = \frac{N - 9.2}{N+1}$$

$$\boxed{N = 19.6}$$

To find feed plate location:-

$$\frac{N_R}{N_s} = \left[\left(\frac{Z_{HK}}{Z_{LK}}\right)\left(\frac{x_{LK.W}}{x_{H.K.D}}\right)^2\left(\frac{W}{D}\right)\right]^{0.206}$$

$$= \left[\left(\frac{0.35}{0.35}\right)\left(\frac{0.0107}{0.015}\right)^2\left(\frac{65.17}{34.83}\right)\right]^{0.206}$$

$$\frac{N_R}{N_s} = 0.99 \implies \boxed{N_R = 0.99 * N_s}$$

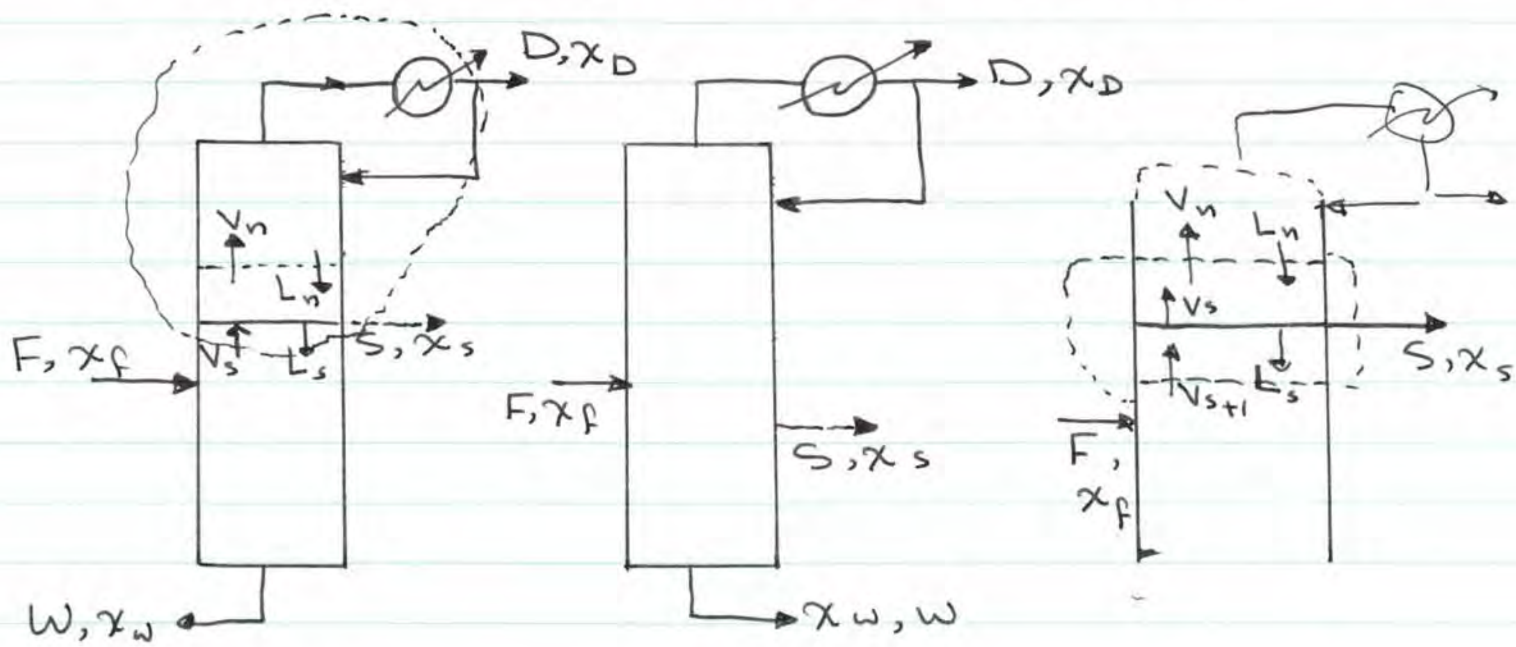
$$N_R + N_s = N_T = 19.6 \implies \boxed{N_s = 19.6 - N_R}$$

$\therefore N_R = 9.85$, $N_R = 9.5$

so feed tray is (10 th) tray from the top.

Multiple Feed and Sidestreams

Side stream is defined as any product stream other than the overhead product and the residue.



① Above feed tray ② below feed tray

The operating line for the upper section.

$$\boxed{y_n = \frac{L_n}{V_n} x_{n+1} + \frac{D \cdot x_D}{V_n}}$$

M.B. between Top and side stream.

$$V_n = V_{n+1} = V_{s+1} = V_s$$

$$\therefore V_s = L_s + S + D$$

$$V_s \cdot y_n = L_s \cdot x_{n+1} + S \cdot x_s + D \cdot x_D$$

$$\boxed{\therefore y_n = \frac{L_s}{V_s} x_{n+1} + \frac{S \cdot x_s + D \cdot x_D}{V_s}}$$ Side stream equation

Since (s) always withdrawn or removed as liq. then:-

$$L_s = L_n - S \quad \text{and} \quad V_s = V_n$$

Ex.(1) "Side stream"

A mixture of water and ethyl alcohol containing 0.16 mole fraction alcohol, is continously distilled in fractionater column to give product containing 0.77 mol. fractn. alcohol and a waste of 0.02 mol. fractn. alcohol. It is proposed to withdraw 25% of the alcohol in the entering stream as side product with 0.5 mol. fractn. alcohol. Determine the No. of theoritical plates required and side stream location if the feed is liquor at the boiling point, given that $R=2$.

Sol. :- Basis = 100 kmol feed.

As the (S.S) composition is to be (0.5) then there are (8 kmol) in that stream

$\rightarrow 100 * 0.16 * 0.25 = 0.5\,S$

O.M.B :-

$$F = D + W + S \Rightarrow 100 = D + W + 8$$

$$\boxed{\therefore D + W = 92}$$

C.M.B :-

$$100 * 0.16 = 0.77\,D + 0.02\,W + 8 * 0.5$$

$$\boxed{12 = 0.77\,D + 0.02\,W}$$

$\therefore D = 13.5$ Kmol. , $W = 78.45$ Kmol.

* In the section between the (S.S) and top of column

$$R = L_n / D \Rightarrow L_n = 27.0$$

$$V_n = L_n + D \Rightarrow V_n = 40.50$$

* For section between (S.S) and feed

$$V_s = V_n = 40.50$$
$$L_n = L_s + S \Rightarrow L_s = 19.0$$

* In the bottom

$$L_m = L_s + F \Rightarrow L_m = 119.0$$

∵ feed is sat. liq. then :-

$$V_m = L_m - W \Rightarrow V_m = 40.55$$

∵ slope always (L/V), the slope for each part can be found.

U.O.L. $\quad slope = \frac{L_n}{V_n} = \frac{27.0}{40.50} = 0.67$

نرسم من النقطة (x_d, x_d) وبالميل 0.67 حتى تقاطع q-line عند
$x_s = 0.5$ ، بعد ذلك نحسب ميل S.S.L

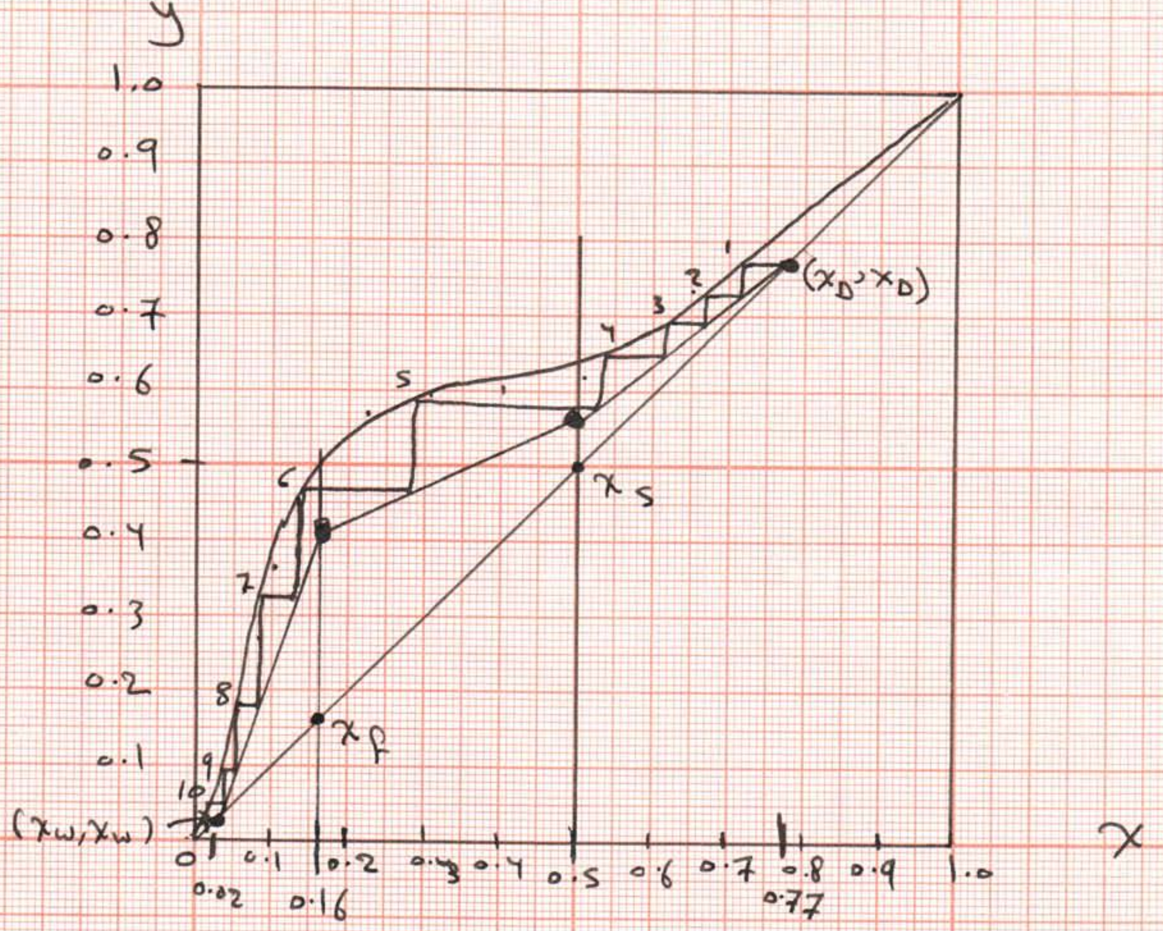
$$slope = \frac{19.0}{40.50} = 0.47$$

من نقطة تقاطع q-line مع U.O.L وبميل 0.47 نبدأ
بتوصيل خط مستقيم إلى قيمة $Z_f = 0.16$. وبعد ذلك نحسب ميل L.O.L :-

L.O.L $\Rightarrow \quad slope = \frac{119.0}{40.55} = 2.92$

ومن نقطة $Z_f = 0.16$ وبميل 2.92 أو
من نقطة $Z_f = 0.16$ إلى قيمة $x_w = 0.02$
نوصل خط مستقيم.
وبعد ذلك نبدأ من x_D بخط أفقي ويليه عمودي كما أن نصل إلى x_w
نجد قيمة N :-

From Fig. :- $\boxed{N = 10}$


y
x
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.1
0.2
0.4
0.5
0.6
0.7
0.8
0.9
1.0
0.02
0.16
0.77
(x_w, x_w)
(x_D, x_D)
x_f
x_s
1
2
3
4
5
6
7
8
9
10

Ex. (2) :- "Two feed"

For Ethanol & N-Propanol system, Find the amounts of D & W, the actual No. of plates and the heat duties for the partial condenser & reboiler for the following data :-

$F_1 = 750$ kmol/hr sat. liquid $x_{f_1} = 0.65$ mol. fract.
$F_2 = 27900$ kg/hr Sat. vap. $x_{f_2} = 0.24$ wt. fract.
$x_D = 0.96$, $x_w = 0.04$
R = twice the minimum reflux ratio

$\lambda_{ethanol} = 38770$ J/mol.
$\lambda_{propanol} = 41784$ J/mol.
Efficiency = 70%

x :	0	0.1	0.2	0.3	0.5	0.7	0.8	0.9	1.0
y :	0	0.19	0.34	0.47	0.67	0.83	0.89	0.95	1.0

Sol. :-

$$x_{f_2} = \frac{0.24/46}{\frac{0.24}{46} + \frac{0.76}{60}} = 0.29$$

From Fig. :-

$$\frac{x_D}{R_{min}+1} = 0.4 \implies \text{Therefore} \quad R_{min} = 1.4$$

$$R = 2R_{min} \implies R = 2 * 1.4 \implies R = 2.8$$

$$\frac{x_D}{R+1} = \frac{0.96}{2.8+1} = 0.25$$

$$F_2 = \frac{27900}{0.29 * 46 + 0.71 * 60} = 498.15 \ \text{Kmol/hr}$$

$$F_1 + F_2 = D + W \Rightarrow 750 + 498.15 = 1248.15 = D + W$$

$$F_1 x_{f_1} + F_2 \cdot x_{f_2} = D \cdot x_D + W \cdot x_D$$

$$750 * 0.65 + 498.15 * 0.29 = D * 0.96 + (1248.15 - D) 0.04$$

$$\therefore D = 632.65 \ \text{Kmol/hr}$$
$$W = 615.50 \ \text{Kmol/hr}$$

$$\therefore R = \frac{L_n}{D} \Rightarrow \quad 2.8 = \frac{L_n}{632.65} \Rightarrow \boxed{L_n = 1771.42 \ \frac{\text{Kmol}}{\text{hr}}}$$

$$V_n = L_n + D = 1771.42 + 632.65 \Rightarrow \boxed{V_n = 2404.07 \ \frac{\text{Kmol}}{\text{hr}}}$$

$$\hookrightarrow V_n = V_f$$

$$\therefore V_W = V_m = V_F - F_2 = 2404.07 - 498.15 = 1906 \ \frac{\text{Kmol}}{\text{hr}}$$

For first feed

$$F_1 + V_F = L_F + D$$
$$F_1 x_{f_1} + V_f y_f = L_f \cdot x_f + D \cdot x_D$$

$$y_f = \frac{L_f}{V_f} x_f + \frac{D \cdot x_D - f_1 \cdot x_{f_1}}{V_f}$$

$$V_f = V_n = 2404.07 \ \frac{\text{kmol}}{\text{hr}}$$

$$\text{intercept} = \frac{632.65 * 0.96 - 750 * 0.65}{2404.07} = \frac{607.344 - 487.5}{2404.07}$$

$$\text{intercept} = 0.05$$

slope for the second feed :-

$$\text{slope} = \frac{L_m}{V_m} = \frac{L_f + F_2 \leftarrow \text{sat. vap.} = 0}{V_m} \Longrightarrow \frac{L_f}{V_m} \Longrightarrow$$

$$\text{slope} = \frac{F_1 + L_n}{V_m} = \frac{750 + 1771.42}{1906}$$

$$\text{slope} = 1.32$$

From Fig., the No. of plates = 14

The actual No. of plates $= \frac{14}{0.7} = 20$ trays

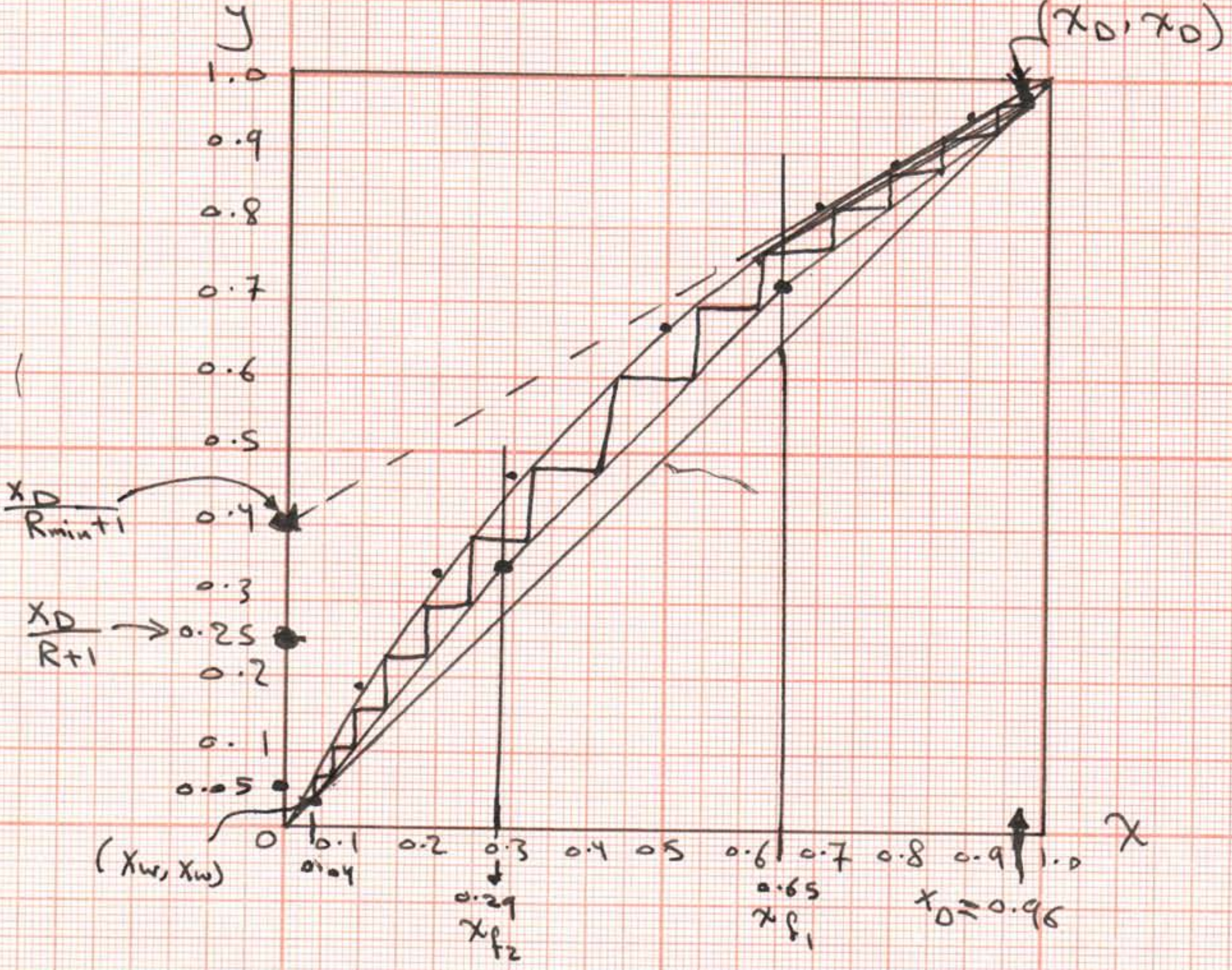
$$q_r = V_w \cdot \lambda_w$$
$$\lambda_w = \lambda_e \cdot y_{we} + \lambda_p y_p = 38770 * 0.07 + 41784 * 0.93$$
$$\lambda_w = 41573.02 \text{ kJ/kmol}$$

$$q_r = V_w \cdot \lambda_w$$
$$= 1906 * 41573.02$$
$$q_r = 7.92 * 10^7 \text{ kJ/hr} = 22000 \frac{\text{kJ}}{\text{s}} = 22000 \text{ kw}$$

$$q_D = L_n \lambda_R$$

$$\lambda_R = x_R \cdot \lambda_e + (1 - x_R)\lambda_p$$
$$= 0.92 * 38770 + 0.08 * 41784$$
$$\lambda_R = 39011.12 \text{ kJ/kmol}$$

$$q_D = 1771.42 * 39011.12$$
$$= 6.91 * 10^7 \frac{\text{kJ}}{\text{hr}} = 19195.8 \frac{\text{kJ}}{\text{s}} = 19195.8 \text{ kw}$$
$$\simeq 19 \text{ MW}$$


y
x
(xD, xD)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.25
0.2
0.1
0.05
0
xD / Rmin+1
xD / R+1
(xw, xw)
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
0.04
0.29
xf2
0.65
xf1
xD = 0.96