Q) Bubble Point Method :- Multicomponent multistage distillation:-

F = 1000 kmol/h containing :-

0.6 methanol (normal boiling point 65°C)

0.2 ethanol (normal boiling point 98°C)

0.2 propanol (normal boiling point 97°C)

Ans.) At bottom tray,

400 + A1 = A2

~~At tray 3,~~

At distillate tray,

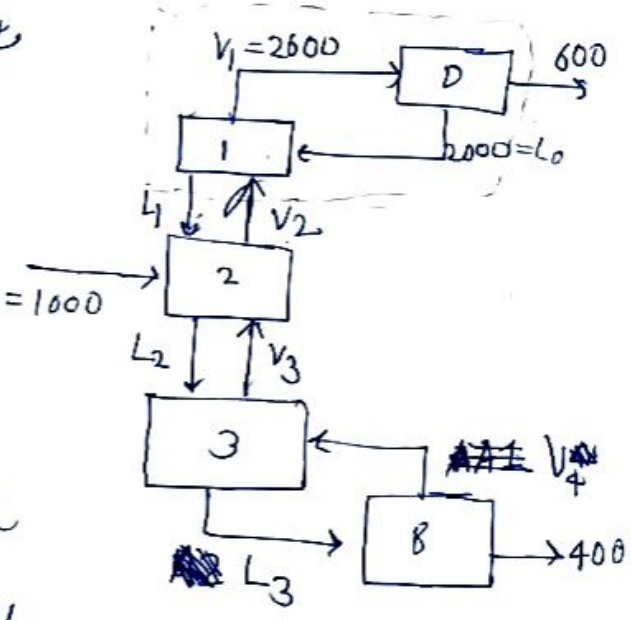
$V_1 = D + R$

Given,

~~R~~ = 2000 kmol/h

~~D~~ D = 600 kmol/h

So, $V_1 = 2600$ kmol/h



Assumption :- The vapour flow rate in add tray is constant.

Now, At tray 1,

$V_1 + L_1 = V_2 + R$

~~$L_1 + 600 = V_2$~~

$\Rightarrow \therefore L_1 = 2000$

At tray 2,

$F + L_1 + V_3 = L_2 + V_2$

$\Rightarrow L_2 = 3000$

At tray 3,

$L_3 - 400 = V_4$

Now, V_4 is also the vapour flow rate.

Column pressure = 1 atm

Temperature of distillation column = 100°C

Stage j	T_j	V_j
1	65	2600
2	81.5	2600
3	98	2600

Where,

V_j is calculated and T_j is guess value based of boiling point of methanol and ethanol.

Now,

~~K values~~ $K = P_i^S / P$ where, P_i^S (vapour pressure) is based on Clausius – Clapeyron equation :–

$$P_S = \exp\left(C_1 + \frac{C_2}{T} + C_3 \ln T + C_4 T^5\right)$$

K_{ij}	1	2	3
Methanol	1.034	3.317	3.212
Ethanol	0.585	2.095	2.024
Propanol	0.307	1.226	1.181

Construct TDM ($i = 1$) :–

Sir

~~$L_3 = 2600 - 400$~~

$= 2200$

For methanol ⇒

$$A_j = L_{j-1} = V_j + \sum_{m=1}^{j-1} (F_m - U_m - W_m)$$

$A_1 \Rightarrow$ ~~$= L_0$~~ Does not exist in matrix

$A_2 = L_1$

$= 2000$

$A_3 = L_2 = 3000$

$$B_{1j} = -[(V_j + W_j) K_{ij} + L_j + U_j]$$

$B_1 = -[(V_1) K_{11} + L_1 - U_1]$

$= -[2600 \times 1.034 + 2000 - 600]$

$= -4088.4$

$B_2 = -[V_2 K_{12} + F_2 + L_2 - U_1]$

$= -11024.2$

$B_3 = -[V_3 K_{13} + L_3 - U_1]$

$= -10751.2$

$C_{ij} = V_{j+1} K_{ij+1}$

$C_1 = V_2 K_{12} = 8624.2$ C_3 = Does not exist

$C_2 = V_3 K_{13} = 8351.2$

Applying Thomas Algorithm, For methanol:—

$$\begin{bmatrix} -4088.4 & 8624.2 & 0 \\ 2000 & -11024.2 & 8351.2 \\ 0 & 3000 & -10751.2 \end{bmatrix} \begin{bmatrix} x_{11} \\ x_{12} \\ x_{13} \end{bmatrix} = \begin{bmatrix} 0 \\ -z_{1F}F \\ 0 \end{bmatrix}$$

$$\Rightarrow \begin{bmatrix} -4088.4 & 8624.2 & 0 \\ 2000 & -11024.2 & 8351.2 \\ 0 & 3000 & -10751.2 \end{bmatrix} \begin{bmatrix} x_{11} \\ x_{12} \\ x_{13} \end{bmatrix} = \begin{bmatrix} 0 \\ -600 \\ 0 \end{bmatrix}$$

$$\Rightarrow \begin{bmatrix} -4088.4 & 8624.2 & 0 \\ 0 & -6805.3 & 8351.2 \\ 0 & 0 & -7069.7 \end{bmatrix} \begin{bmatrix} x_{11} \\ x_{12} \\ x_{13} \end{bmatrix} = \begin{bmatrix} 0 \\ -600 \\ -264.49 \end{bmatrix}$$

$x_{13} = 0.037$

$x_{12} = 0.133$

$x_{11} = 0.281$

For ethanol:—

$A_2 = 2000 \qquad A_3 = 3000$

$B_1 = -2921, \quad B_2 = -7847, \quad B_3 = -7662.4$

$C_1 = 5447, \quad C_2 = 5262.4$

Similarly by Thomas Algorithm,

$x_{13} =$ ~~0.499~~ 0.120

$x_{12} =$ ~~0.267~~ 0.267

$x_{11} =$ ~~0.750~~ 0.499

For propanal :—

$A_2 = 2000 \quad A_3 = 3000$

$B_1 = -2198.2, \quad B_2 = -5587.6, \quad B_3 = -5470.6$

$C_1 = +3187.6, \quad C_2 = +3070.6$

Similarly by Thomas Algorithm,

$x_{33} = 0.109$

$x_{32} = 0.199$

$x_{31} = 0.288$

Stage	1	2	3
Methanal	0.281	0.133	0.037
Ethanal	0.181 ~~0.499~~	0.097 ~~0.267~~	~~0.120~~ 0.038
Propanol	0.288	0.199	0.109
$3\sum_{i=1} x_i$	~~1.068~~ 0.75	~~0.599~~ 0.43	~~0.266~~ 0.18

Normalise $\overline{x_{ij}} = \dfrac{x_{ij}}{\sum_{i=1}^{3} x_{ij}}$

Stage j	1	2	3
Methanol (x_{1j})	0.263	0.222	0.140
Ethanol (x_{2j})	~~0.467~~ 0.187	~~0.446~~ 0.097	0.038 ~~0.451~~
Propanol (x_{3j})	0.269	0.332	0.409

Now,

Antoine Constant of :-

	A	B	C
Methanol	5.20	+ 1581.34	- 33.5
Eth	5.32	+ 1670.40	-40.19
n-prop	5.31	1690.86	- 51.80

Now, The verification equation using Antoine equation :-

$$10^{\left(A_M + \frac{B_M}{T+C_M}\right)}\bar{x}_{11} + 10^{\left(A_E + \frac{B_E}{T+C_E}\right)}\bar{x}_{21} + 10^{\left(A_P + \frac{B_P}{T+C_P}\right)}\bar{x}_{31} = P_T$$

So, For first iteration :- Tray 1 temp. $\Rightarrow$ 412.67K

Tray 2 temp. $\Rightarrow$ 417.83K

Tray 3 temp. $\Rightarrow$ 423.56K

Stage j	1	2	3
Methanol (x_{1j})	0.374	0.309	0.205
Ethanol (x_{2j})	0.241	0.226	0.211
Propanol (x_{3j})	0.384	0.462	0.605

So, For first iteration:—

Tray 1 temp. $\Rightarrow$ 401.92 K

Tray 2 temp. $\Rightarrow$ 406.78 K

Tray 3 temp. $\Rightarrow$ 412.14 K

Now,

$$\sum_{j=1}^{n} \frac{(T_j - T_{j,assumed})^2}{T_j}$$

$\Rightarrow$ 10.108 + 6.673 + 4.070 $\Rightarrow$ 20.851

$\Rightarrow$ Error = 20.851