

LIQUID-LIQUID EQUILIBRIUM FOR THE DESIGN OF EXTRACTION COLUMN

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ABSTRACT

Liquid-Liquid Extraction is a mass transfer operation in which a liquid solution (the feed) is contacted with an immiscible or nearly immiscible liquid (solvent) that exhibits preferential affinity or selectivity towards one or more of the components in the feed. The construction of the tie –line on the binodal curve to determine the number of theoretical stages, has to be made graphically using the relevant correlations. This requires experimental determination of the mutual solubility and tie-line data. Treybal even prior to Hand and other workers introduced a method of construction without using tie-lines data of binodal curves to determine the number of theoretical stages. This method is investigated and proved to be correct, rapid and does not require experimental determination of tie-line data. Treybal method is used in the present work and proved to be accurate and easy to apply. The number of stages is determined using this method and all other design parameters of a sieve tray extraction column are obtained. A complete design by hand calculation procedure is realized and Outlined. The number of theoretical stages is calculated using ASPEN PLUS SOFT WARE.

Keywords: Liquid-Liquid Extraction. The tie –line. binodal curves.

INTRODUCTION

Liquid-liquid extraction is important as it provides prospects for substantial energy saving when compared with distillation, when a minor but high density constituent of the feed mixture is to be recovered ^[1]. Liquid-liquid extraction is an operation that affects the transfer of a solute between two immiscible or partially miscible liquids. The two liquids are called the feed and extraction solvent. In simple words, this is the process of the removal of the solute, say(C), from the feed, say solution (A) , by the extraction solvent (S).The solvent containing the solute(C), after the extraction process is completed, is known as the extract and the solution(A) from which the solute (C) has been removed is called raffinate ^[2].

The Ternary Phase Diagram

Ternary phase diagrams act as map for liquid extraction applications. Ternary phase diagrams are unique in that they show all three components of a reaction system on one plot. Triangular diagrams are extensively used in the chemical literature to graphically describe the concentrations in ternary systems. It is the property of an equilateral triangle that the sum of the perpendicular distances from any point within the triangle to the three sides equals the altitude of the triangle. We can, therefore, let the altitude represent 100% composition and the distances to the three sides the percentages or fractions of the three components. Each apex of the triangle represents a pure component, as marked. The perpendicular distance from any point such as K to the base AS represents the percentage of C in the mixture at K, the distance to the base AC the percentage of S, and that to the base CS the percentage of A. Thus the composition at point K in Figure is 40% A, 20% S, and 40%

C. Any point on a side of the triangle represents a binary mixture. Point D, for example, is a binary mixture containing 80% A and 20% S. All points on the line DC represent mixtures containing the same ratio of A to S and can be considered as mixtures originally at D to which C has been added.

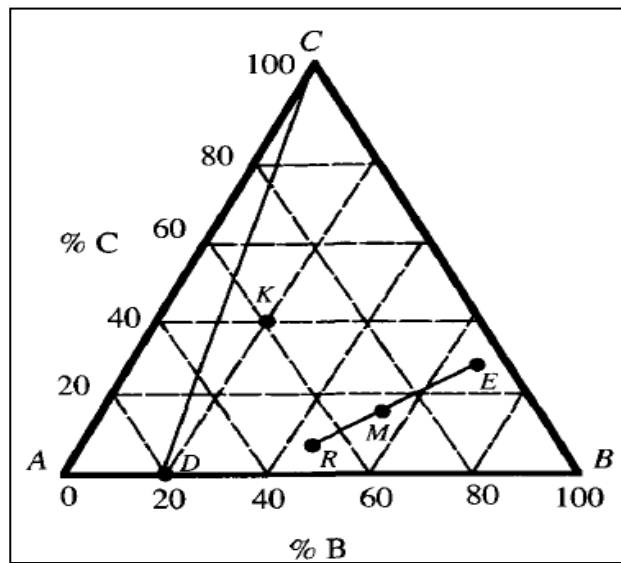


Figure 1: Equilateral-triangular diagram

Extractor design

The task in the design of extractor for liquid-liquid extraction process is the determination of the number of stages needed to achieve the separation required. Counter-current flow is the most efficient method and the most commonly used^[3]. A countercurrent cascade allows for more complete removal of the solute, and the solvent is reused so less is needed. Figure 2 is a schematic diagram of a countercurrent extraction cascade. Extract and raffinate streams flow from stage to stage in countercurrent fashion and yield two final products, raffinate R_N and extract E_1 . For a given degree of separation, this type of operation requires fewer stages for a given amount of solvent, or less solvent for a fixed number of stages, than those required for the crosscurrent extraction method described above.

In the usual design problem, the extraction column temperature and pressure, the flow rates and compositions of streams F and S and the desired composition (or percent removal) of solute in the raffinate product are specified. The designer must determine the number of equilibrium stages needed and the flow rate and composition of the outlet extract stream^[4].

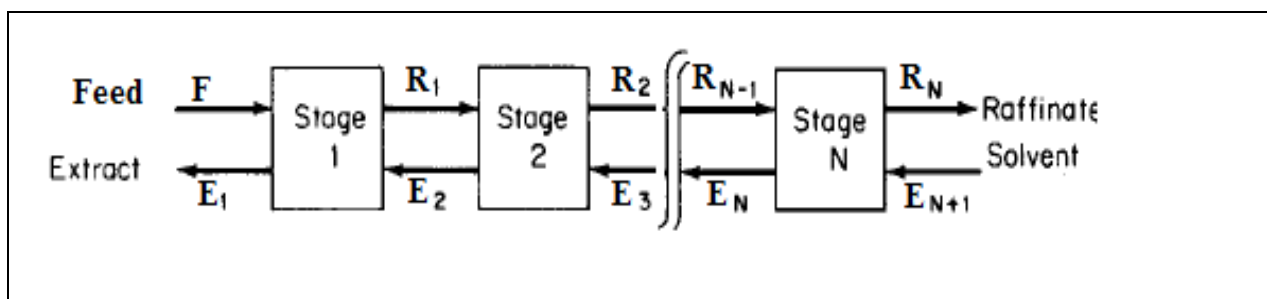


Figure 2: multi stage extraction with counter current flow

Design of extraction tower:

Table 1: Equilibrium data of ternary system: Water (A) - Acetic acid (C) - Isopropyl ether (S) at 293K and 1 atm.

Water-rich phase			Solvent-rich phase		
X_{AA}	X_{CA}	X_{SA}	X_{AS}	X_{CS}	X_{SS}
0.981	0.007	0.012	0.005	0.002	0.993
0.971	0.014	0.015	0.007	0.004	0.989
0.955	0.029	0.016	0.008	0.008	0.984
0.917	0.064	0.019	0.010	0.019	0.971
0.844	0.133	0.023	0.019	0.048	0.933
0.711	0.255	0.034	0.039	0.114	0.847
0.589	0.367	0.044	0.069	0.216	0.715
0.451	0.443	0.106	0.108	0.311	0.581
0.371	0.464	0.165	0.154	0.362	0.487

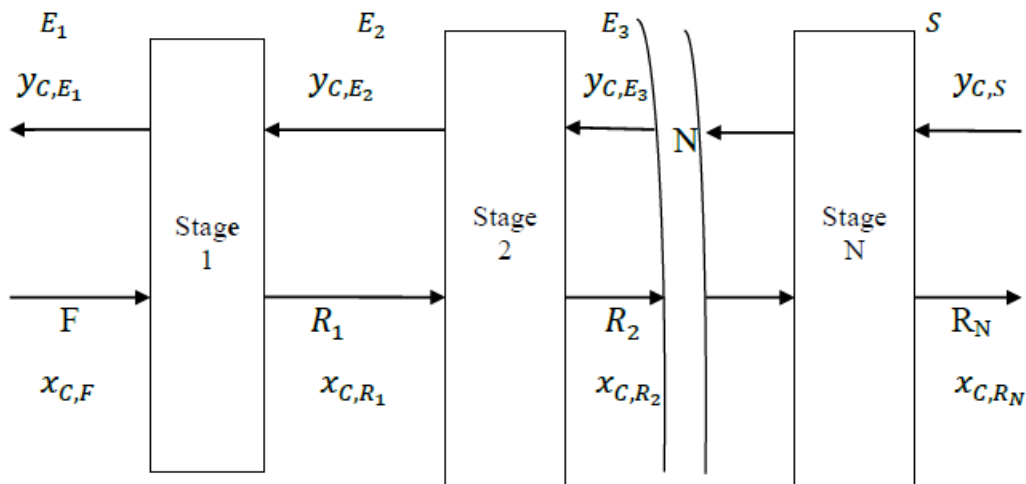
RESULTS AND DISCUSSION

Figure 3: Schematic diagram of Countercurrent multistage extraction

A total material balance around the entire plant is:

$$F + S = E_1 + R_N = M \quad (1)$$

$F = \left(\frac{\text{mass}}{\text{time}}\right)$ contains substances water (A) and acetic acid (C) = 8000kg/h

$S = \left(\frac{\text{mass}}{\text{time}}\right)$ of solvent Isopropyl ether (S) = 20000kg/h

E_1 = Final extract

R_N = Final raffinate

M = amount of mixing point

$$M = F + S$$

(2)

$$M = 8000 + 20000 = 28000 \text{ kg /h}$$

Point M can be located on line FS

A material balance for acetic acid (C):

$$Fx_{C,F} + Sy_{C,S} = E_1y_{C,E_1} + R_Nx_{C,R_N} = Mx_{C,M} \quad (3)$$

$x_{C,F}$ = Weight fraction of acetic acid (C) in Feed = 0.3

$y_{C,S}$ = Weight fraction of acetic acid (C) in Solvent = 0

(The solvent is pure isopropylether (S)).

y_{C,E_1} = Weight fraction of acetic acid (C) in Extract.

x_{C,R_N} = Weight fraction of acetic acid (C) in Raffinate = 0.02

$x_{C,M}$ = Weight fraction of acetic acid (C) in M

Determination of the mixing point (M) of composition ($x_{C,M}$):

$$x_{C,M} = \frac{Fx_{C,F} + Sy_{C,S}}{M} \quad (4)$$

$$x_{C,M} = \frac{8000 \times 0.3 + 20000 \times 0}{28000} = 0.0857$$

The mixing point (M) composition = 0.0857

The mixing point (M) falls on: a straight line connecting ($x_{C,F} = 0.3$) and ($y_{C,S} = 0$)

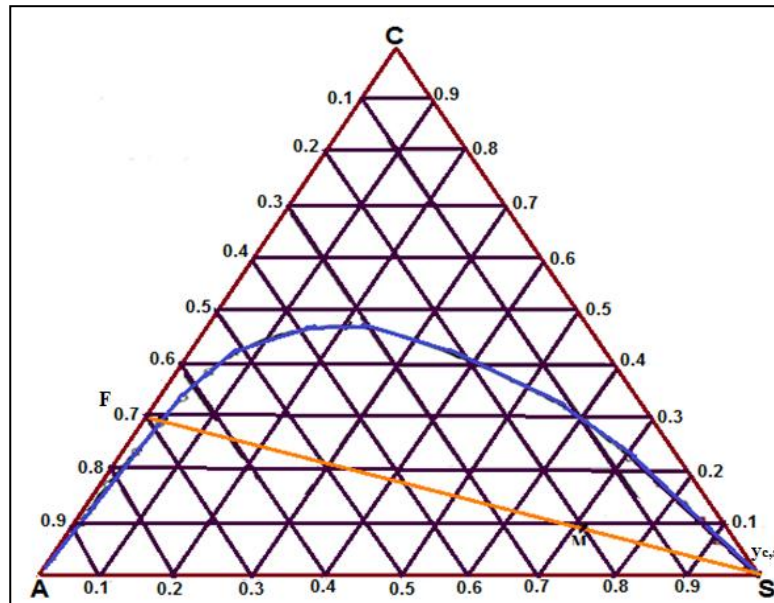


Figure 4: The location of the mixing point (M)

Determination of the extract (E) composition (y_{C,E_1}):

The extract (E) composition (y_{C,E_1}) is determined by drawing a straight line from ($x_{C,R_N} = 0.02$) through ($x_{C,M} = 0.0857$) until the line intersects the extract line at the final extract composition.

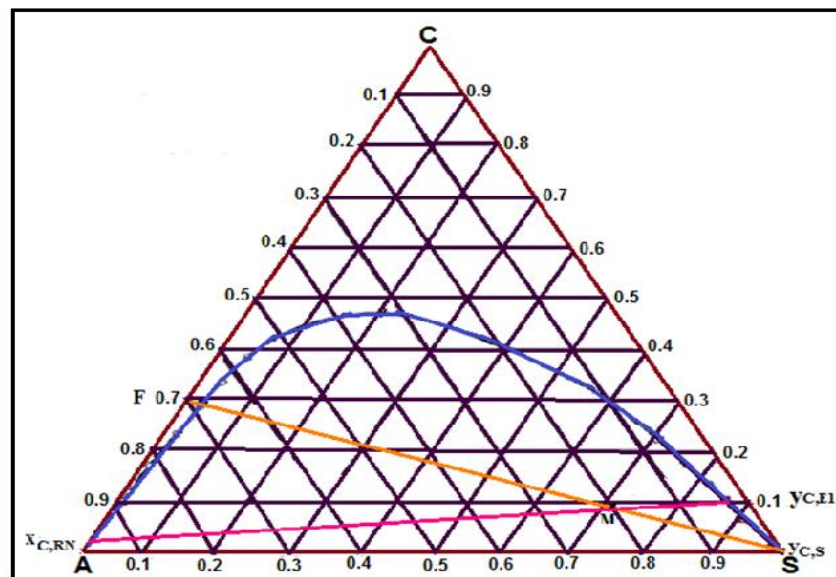


Figure 5: The location of the extract (E) composition (y_{C,E_1})

Determination the difference point Δ_R :

- The difference point is then found at the intersection of two lines:
- One line connects the feed ($x_{C,F} = 0.3$) and extract composition ($y_{C,E_1} = 0.1$)
 - The other line connects the raffinate ($x_{C,R_N} = 0.02$) and solvent composition ($y_{C,S} = 0$)

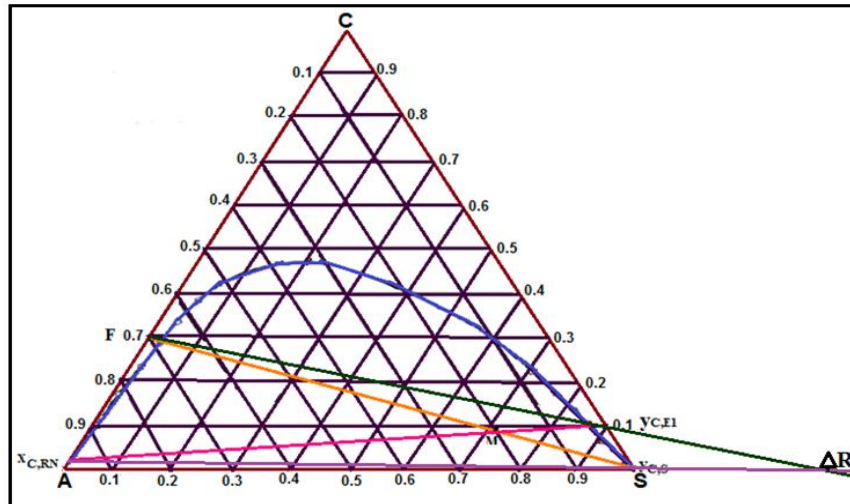


Figure 6: The location of the difference point Δ_R

The graphical Construction

After location of points F, S, M, E_1, R_N and ΔR , a few lines are drawn at random from point ΔR to intersect the two branches of the solubility curves. Tie-line from E_1 provides R_1 . Since extract and raffinate from the first stage are in equilibrium. A line from ΔR through R_1 when extended provides E_2 , a tie-line from E_2 provides R_2 . A tie-line from E_3 provides R_3 , a tie-line from E_4 provides

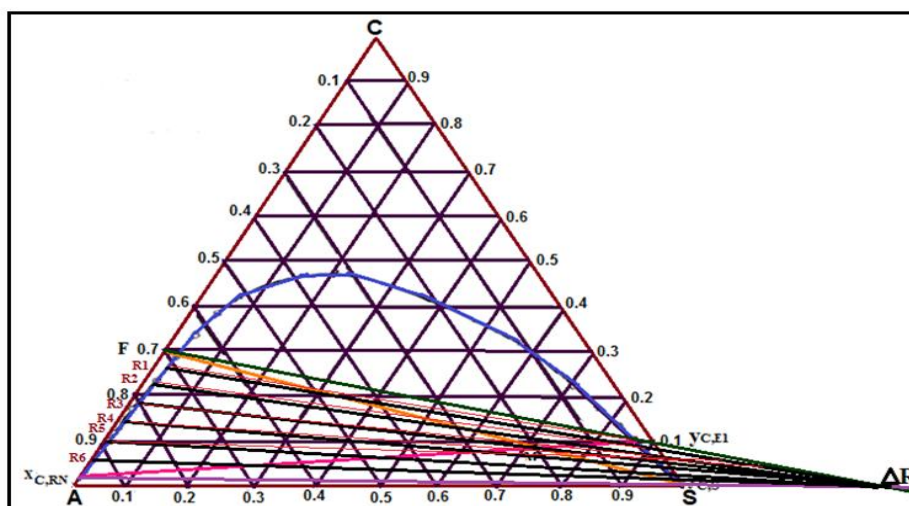


Figure 7: The left –triangular graphical

R_4 , atie-line from E_5 provides R_5 , atie-line from E_6 provides R_6 , atie-line from E_7 provides $R_N = 0.02$. The lowest possible value of $x_{C,RN}$ is given by the water-rich end of the tie-line which pass through S. A few lines are drawn at random from point ΔR to intersect the two branches of the solubility curves.

The concentration $x_{C,OP}$ and $y_{C,OP}$ corresponding to these are given in Table 2

Table 2: Operating curve Data

$y_{C,OP}$	$y_{C,S} = 0$	0.01	0.02	0.04	0.06	0.08	$y_{C,E_1} = 0.10$
$x_{C,OP}$	$x_{C,RN} = 0.02$	0.055	0.090	0.150	0.205	0.250	$x_{C,F} = 0.30$

The concentration $x = \frac{x_{CA}}{x_{AA}}$ and $y = \frac{x_{CS}}{x_{SS}}$ corresponding to these are given in Table: 3.

$$x = \frac{x_{CA}}{x_{AA}} \quad . \quad x = \frac{0.007}{0.981} = 0.007$$

In same way, the other points were determined.

$$y = \frac{x_{CS}}{x_{SS}} \quad . \quad y = \frac{0.002}{0.993} = 0.002$$

In same way, the other points were determined.

Table 4: Equilibrium curve Data

$y = \frac{x_{CS}}{x_{SS}}$	0.002	0.004	0.008	0.019	0.051	0.134	0.302	0.535	0.743
$x = \frac{x_{CA}}{x_{AA}}$	0.007	0.014	0.030	0.069	0.157	0.358	0.623	0.982	0.25

The concentration $x_{C,OP}$ and $y_{C,OP}$ and plotted on x and y coordinates as shown in Figure 7 to generate an operating curve. Tie-line data provide the equilibrium curve curve x versus y and the theoretical stages are stepped off in the resulting McCabe-Thiele diagram A total of 7 equilibrium

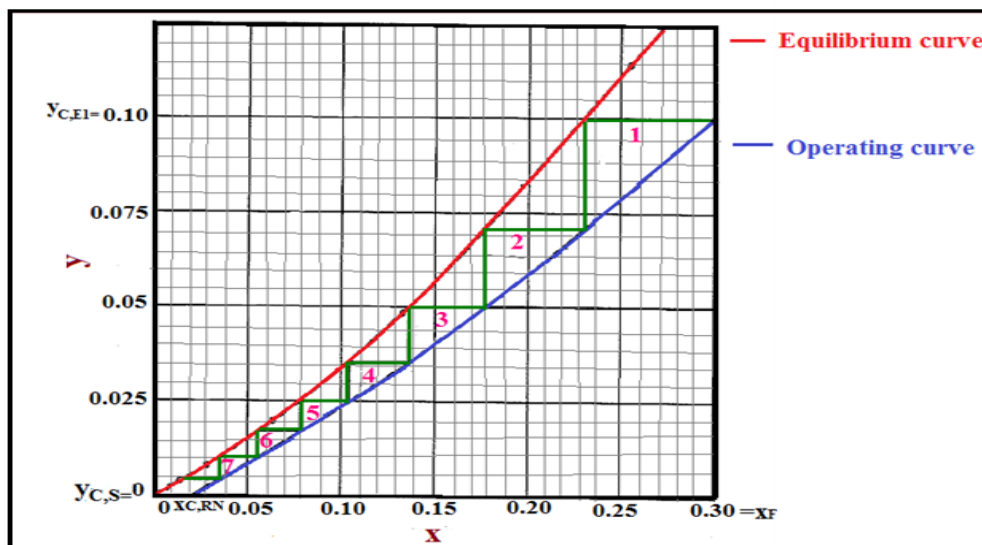


Figure 8: Construction of the equilibrium, operating curves, and step off of the number of theoretical stages

Table 5: Extract and Raffinate Concentration Profiles

stage	1	2	3	4	5	6	7
y_{C,E_i}	0.070	0.0048	0.033	0.022	0.013	0.007	0.001
x_{C,R_i}	0.227	0.173	0.13	0.097	0.07	0.05	0.02

Determine the extract (E_i) and raffinate (R_i) Flow rate:

From Equation (1):

$$E_1 = M - R_N \quad (5)$$

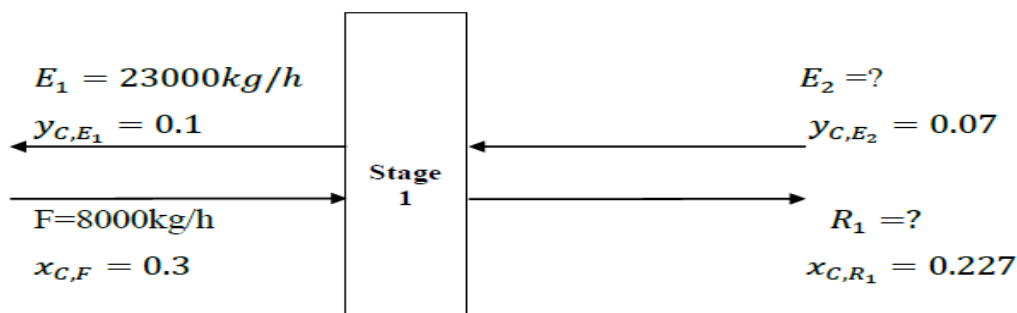
Equation (5) and (3) gives:

$$F x_{C,F} + S y_{C,S} = (M - R_N) y_{C,E_1} + R_N x_{C,R_N} \quad (6)$$

$$R_N = \frac{F x_{C,F} + S y_{C,S} - M y_{C,E_1}}{x_{C,R_N} - y_{C,E_1}} \quad (7)$$

$$R_N = \frac{8000 \times 0.3 + 20000 \times 0 - 28000}{0.02 - 0.1} = 5000 \text{ kg/h}$$

$$E_1 = 28000 - 5000 = 23000 \text{ kg/h}$$

Stage-wise of determination of the number of theoretical stages:**Stage (1):**

A total material balance:

$$F + E_2 = R_1 + E_1 \quad (8)$$

Acetic acid balance:

$$F x_{C,F} + E_2 y_{C,E_2} = R_1 x_{C,R_1} + E_1 y_{C,E_1} \quad (9)$$

From equation (8):

$$R_1 = F + E_2 - E_1 \quad (10)$$

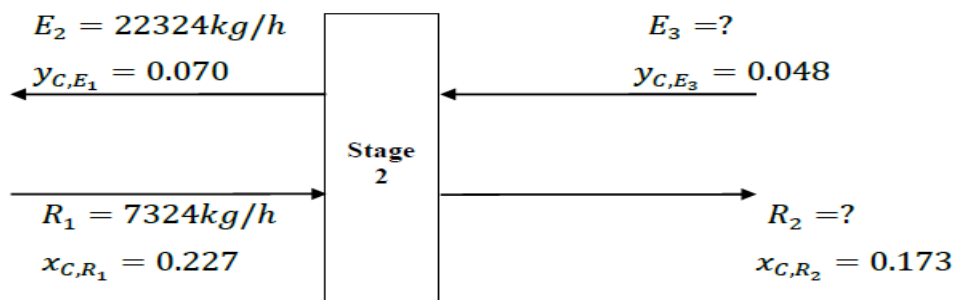
equation (9) and equation (10) gives:

$$E_2 = \frac{F(x_{C,F} - x_{C,R_1}) + E_1(x_{C,R_1} - y_{C,E_1})}{(x_{C,R_1} - y_{C,E_2})} \quad (11)$$

$$E_2 = \frac{8000(0.3 - 0.227) + 23000(0.227 - 0.1)}{(0.227 - 0.07)} = 22324 \text{ kg/h}$$

$$R_1 = 8000 + 22324 - 23000 = 7324 \text{ kg/h}$$

Stage (2):



A total material balance:

$$R_1 + E_3 = R_2 + E_2 \quad (12)$$

Acetic acid balance:

$$R_1 x_{C,R_1} + E_3 y_{C,E_3} = R_2 x_{C,R_2} + E_2 y_{C,E_2} \quad (13)$$

From equation (12):

$$R_2 = R_1 + E_3 - E_2 \quad (14)$$

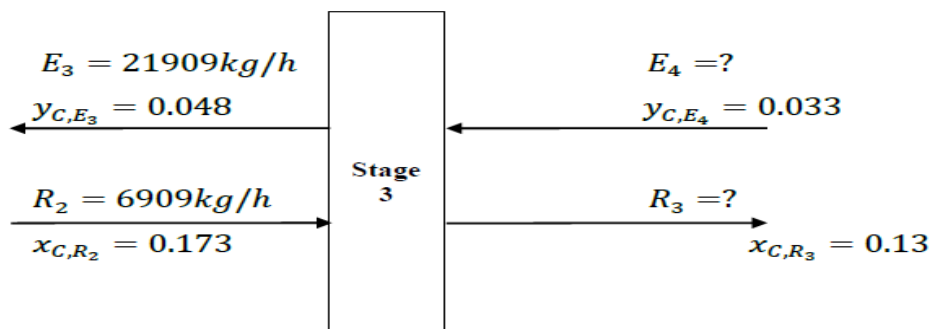
Equation (13) and equation (14) gives:

$$E_3 = \frac{R_1(x_{C,R_1} - x_{C,R_2}) + E_2(x_{C,R_2} - y_{C,E_2})}{(x_{C,R_2} - y_{C,E_3})} \quad (15)$$

$$E_3 = \frac{7324(0.227 - 0.173) + 22324(0.173 - 0.070)}{(0.173 - 0.05)} = 21909 \text{ kg/h}$$

$$R_2 = 7324 + 21909 - 22324 = 6909 \text{ kg/h}$$

Stage (3):



A total material balance:

$$R_2 + E_4 = R_3 + E_3 \quad (16)$$

Acetic acid balance:

$$R_2 x_{C,R_2} + E_4 y_{C,E_4} = R_3 x_{C,R_3} + E_3 y_{C,E_3} \quad (17)$$

From equation (16):

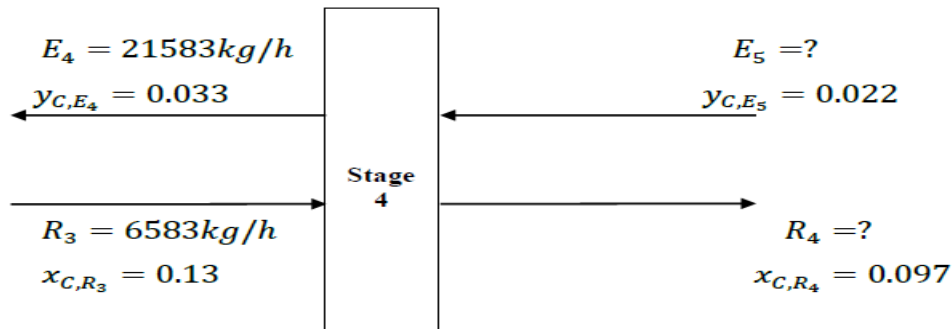
$$R_3 = R_2 + E_4 - E_3 \quad (18)$$

Equation (16) and equation (17) gives:

$$E_4 = \frac{R_2(x_{C,R_2} - x_{C,R_3}) + E_3(x_{C,R_3} - y_{C,E_3})}{(x_{C,R_3} - y_{C,E_4})} \quad (19)$$

$$E_4 = \frac{6909(0.173 - 0.13) + 21909(0.13 - 0.048)}{(0.13 - 0.033)} = 21583 \text{ kg/h}$$

$$R_3 = 6909 + 21583 - 21909 = 6583 \text{ kg/h}$$

Stage (4):

A total material balance:

$$R_3 + E_5 = R_4 + E_4 \quad (20)$$

Acetic acid balance:

$$R_3 x_{C,R_3} + E_5 y_{C,E_5} = R_4 x_{C,R_4} + E_4 y_{C,E_4} \quad (21)$$

From equation (20):

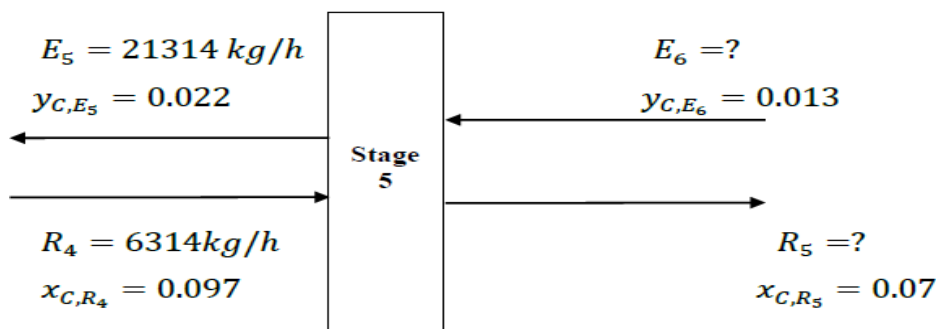
$$R_4 = R_3 + E_5 - E_4 \quad (22)$$

Equation (21) and equation (22) gives:

$$E_5 = \frac{R_3(x_{C,R_3} - x_{C,R_4}) + E_4(x_{C,R_4} - y_{C,E_4})}{(x_{C,R_4} - y_{C,E_5})} \quad (23)$$

$$E_5 = \frac{6583(0.13 - 0.097) + 21583(0.097 - 0.033)}{(0.097 - 0.022)} = 21314 \text{ kg/h}$$

$$R_4 = 6583 + 21314 - 21583 = 6314 \text{ kg/h}$$

Stage (5):

A total material balance:

$$R_4 + E_6 = R_5 + E_5 \quad (24)$$

Acetic acid balance:

$$R_4 x_{C,R_4} + E_6 y_{C,E_6} = R_5 x_{C,R_5} + E_5 y_{C,E_5} \quad (25)$$

From equation (24):

$$R_5 = R_4 + E_6 - E_5 \quad (26)$$

Equation (25) and equation (26) gives:

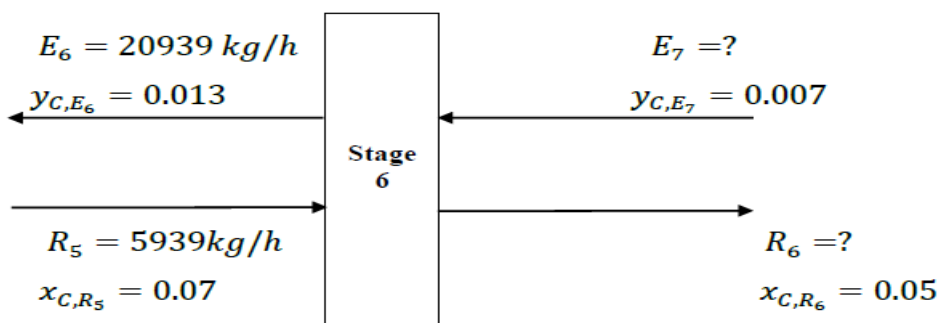
$$E_6 = \frac{R_4(x_{C,R_4} - x_{C,R_5}) + E_5(x_{C,R_5} - y_{C,E_5})}{(x_{C,R_5} - y_{C,E_6})} \quad (27)$$

$$E_6 = \frac{6314(0.097 - 0.07) + 21314(0.07 - 0.022)}{(0.07 - 0.013)} = 20939 \text{ kg/h}$$

$$R_5 = R_4 + E_6 - E_5$$

$$R_5 = 6314 + 20939 - 21314 = 5939 \text{ kg/h}$$

Stage (6):



A total material balance:

$$R_5 + E_7 = R_6 + E_6 \quad (28)$$

Acetic acid balance:

$$R_5 x_{C,R_5} + E_7 y_{C,E_7} = R_6 x_{C,R_6} + E_6 y_{C,E_6} \quad (29)$$

From equation (28):

$$R_6 = R_5 + E_7 - E_6 \quad (30)$$

Equation (29) and equation (30) gives:

$$E_7 = \frac{R_5(x_{C,R_5} - x_{C,R_6}) + E_6(x_{C,R_6} - y_{C,E_6})}{(x_{C,R_5} - y_{C,E_6})} \quad (31)$$

$$E_7 = \frac{5939(0.07 - 0.05) + 20939(0.05 - 0.013)}{(0.05 - 0.007)} = 20779 \text{ kg/h}$$

$$R_6 = R_5 + E_7 - E_6$$

$$R_6 = 5939 + 2435 - 20939 = 5779 \text{ kg/h}$$

Table 6: Flow rate profiles

Stage	1	2	3	4	5	6	7
R_i (kg/h)	7324	6909	6583	6314	5939	5779	5000
E_i (kg/h)	23000	22324	21909	21583	21314	20939	20779

Determination of the extraction asieveTower Diameter (D_T):

Table 7: The Design Condition Data

Flow rate of water solution(continuous) (kg/h)	C	8000
Density of water solution(continuous) (kg/m ³)	ρ_C	1009
Volumetric rate of water solution(continuous)(m ³ /s)	q_C	0.0022
Viscosity of water solution(continuous) (kg/m.s)	μ_C	0.0031
Flow rate of Isopropyl ether solution(dispersed) (kg/h)	D	20000
Density of Isopropyl ether solution(dispersed) (kg/m ³)	ρ_D	730
Volumetric rate of Isopropyl ether solution(dispersed)(m ³ /s)	q_D	0.00761
Viscosity of Isopropyl ether solution(dispersed) (kg/m.s)	μ_D	0.0009
Interfacial tension (N/m)	σ	0.013
Conversion factor (kg.m/N.s ²)	g_c	1
Acceleration of gravity (m/s ²)	g	9.807

Columns Perforations:

The orifice diameter to jet diameter ratio $\left(\frac{d_o}{d_j}\right)$:

Set :

$$d_{o=\text{orifice diameter}}^{[3]} = 0.006m$$

$$p = \text{triangular pitch}^{[3]} \text{ on } 15mm \text{ centers} = 0.015m$$

$$\Delta\rho = \rho_C - \rho_D = 1009 - 730 = 279kg/m^3$$

$$\Delta\rho = 279kg/m^3$$

$$\frac{d_o}{d_j} = 0.485 \left[\frac{d_o}{\left(\frac{\sigma g_c}{\Delta\rho g}\right)^{0.5}} \right]^2 + 1 \quad \text{For} \quad \frac{d_o}{\left(\frac{\sigma g_c}{\Delta\rho g}\right)^{0.5}} < 0.785 \quad (32)$$

$$\frac{d_o}{d_j} = 1.51 \frac{d_o}{\left(\frac{\sigma g_c}{\Delta\rho g}\right)^{0.5}} + 0.12 \quad \text{For} \quad \frac{d_o}{\left(\frac{\sigma g_c}{\Delta\rho g}\right)^{0.5}} > 0.785 \quad (33)$$

$$\frac{d_o}{\left(\frac{\sigma g_c}{\Delta\rho g}\right)^{0.5}} = \frac{0.006}{\left(\frac{0.013 \times 1}{279 \times 9.807}\right)^{0.5}} = 2.75$$

$$2.75 > 0.785$$

$$\frac{d_o}{d_j} = 1.51 \frac{d_o}{\left(\frac{\sigma g_c}{\Delta\rho g}\right)^{0.5}} + 0.12 = 1.51 \times 2.75 + 0.12 = 4.28$$

$$\frac{d_o}{d_j} = 4.28$$

$$d_j = \frac{d_o}{4.28} = \frac{0.006}{4.28} = 1.402 \times 10^{-3}m$$

$$d_j = 1.402 \times 10^{-3}m$$

The velocity through perforations (orifice):

$$V_o = 2.69 \left(\frac{d_j}{d_o}\right)^2 \left[\frac{\sigma}{d_j(0.5137\rho_D + 0.4719\rho_C)} \right]^{0.5} \quad (34)$$

$$V_o = 2.69 \left(\frac{1.402 \times 10^{-3}}{0.006}\right)^2 \left[\frac{0.013}{1.402 \times 10^{-3}(0.5137 \times 730 + 0.4719 \times 1009)} \right]^{0.5} = 0.0153m/s$$

If the resulting velocity calculates to be less than 0.1 m/s,

$$V_o \text{ Should be set at } 0.1 \frac{m}{s} \quad V_o = 0.1m/s$$

Perforation area,:

$$A_{per} = \frac{qD}{V_o} \quad (35)$$

$$A_{per} = \frac{0.00761}{0.1} = 0.0761m^2$$

Number of perforations:

$$N_o = \frac{A_{per}}{\left(\frac{\pi(d_o)^2}{4}\right)} \quad (36)$$

$$N_o = \frac{0.0761}{\left(\frac{\pi(0.006)^2}{4}\right)} = 2691$$

plate area for perforations:

$$A_p = \frac{A_{per}}{0.907\left(\frac{d_o}{p}\right)^2} \quad (37)$$

$$A_p = \frac{0.0761}{0.907\left(\frac{0.006}{0.015}\right)^2} = 0.5244m^2$$

Downspouts:

Set: the continuous-phase velocity = the terminal velocity of dispersed- phase drop

$$V_d = V_t$$

$$d_p = 0.7m = 0.0007m$$

$$V_t = \frac{0.8364 (\Delta\rho)^{0.5742} \times (d_p)^{0.7037} \times (g)^{0.5742}}{(\rho_c)^{0.4446} \times (\sigma g_c)^{0.01873} \times (\mu_c)^{0.11087}} \quad (38)$$

$$V_t = \frac{0.8364 (279)^{0.5742} \times (0.0007)^{0.7037} \times (9.807)^{0.5742}}{(1009)^{0.4446} \times (1 \times 0.013)^{0.01873} \times (0.0031)^{0.11087}} = 0.04m/s$$

$$V_t = V_d = 0.04m/s$$

Downspout area,:

$$A_d = \frac{q_c}{V_d} \quad (39)$$

$$A_d = \frac{0.0022}{0.04} = 0.055m^2$$

Total plate area:

$$A_T = \frac{A_p + 2A_d}{0.8} \quad (40)$$

$$A_T = \frac{0.5244 + 2 \times 0.055}{0.8} = 0.793m^2$$

Tower Diameter:

$$D_T = \sqrt{\frac{4 \times A_T}{\pi}} \quad (41)$$

$$D_T = \sqrt{\frac{4 \times 0.793}{\pi}} = 1.00m$$

$$E_0 = 0.70$$

Stage Efficiency:

Tray efficiency range to 0.7^[5]

$$E_0 = 0.70$$

Number of actual stages:

N_T = The number of theoretical stages = 7

$$N_a = \frac{N_T}{E_0} \quad (42)$$

N_T = The number of theoretical stages = 7

$$N_a = \frac{N_T}{E_0} = \frac{7}{0.7} = 10$$

Tower Height:

$$H_T = (N_a - 1)C_t + \frac{N_a C_t}{10} + 0.1H_T \quad (43)$$

Set:

Z_t = the tray spacing = 0.45m

$$H_T = \frac{9 \times 0.45 + 0.45}{0.9} = 5m$$

$$H_T = 5m$$

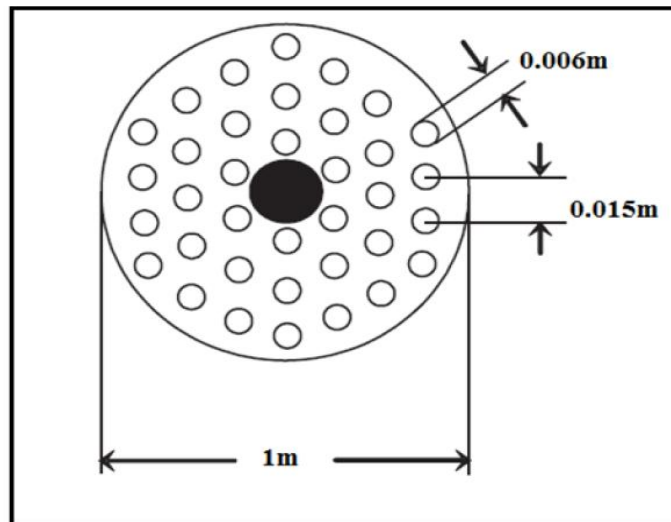


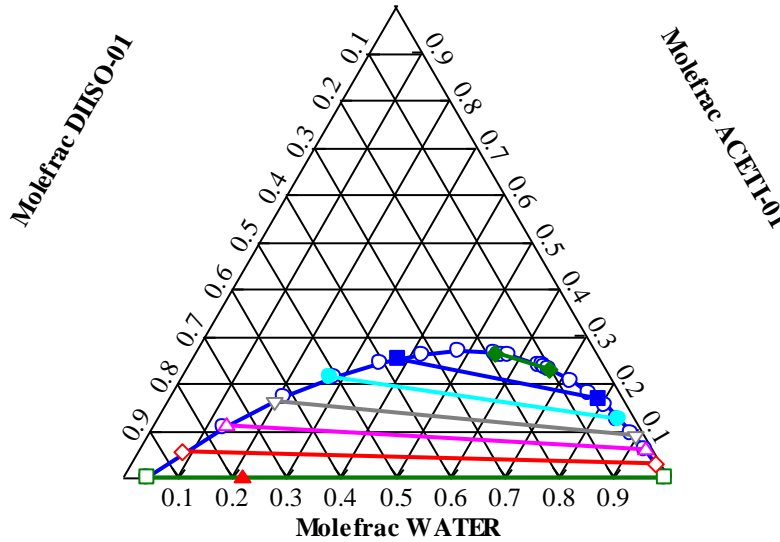
Figure 9: Single Sieve Plate.

Table 8: Summary of Design Results

Material of Construction	Stainless steel
Type of column	Sieve plate
Hole diameter	0.006 m
Hole pitch	0.015 m
Jet diameter	0.001402 m
Perforation area	0.0761m ²
Number of perforations	2691
Plate area for perforations	0.5224m ²
Downspout area	0.055m ²
Total plate area	0.793m ²
Tower diameter	1 m
Tray spacing	0.45 m
Stage efficiency	0.70
Number of theoretical stages	7
Number of actual stages	10
Tower Height	5 m

ASPEN PLUS SOFT WARE

Ternary map for WATER/ACETI-01/DIISO-01



Table(7): water (A)-acetic acid(C)-DIISO(S) equilibrium data at 293k and 1atm

NUMBER	MOLEFRAC LIQUID1 WATER	MOLEFRAC LIQUID1 ACETI-01	MOLEFRAC LIQUID1 DIISO-01	MOLEFRAC LIQUID2 WATER	MOLEFRAC LIQUID2 ACETI-01	MOLEFRAC LIQUID2 DIISO-01
1	0.9957451	0	0.0042549	0.0444524	0	0.9555476
2	0.9637425	0.0294037	0.0068537	0.0825466	0.0535267	0.8639266
3	0.9313982	0.0580782	0.0105235	0.1333218	0.1087396	0.7579385
4	0.8958089	0.0881922	0.0159989	0.1976284	0.162599	0.6397726
5	0.8529771	0.1221136	0.0249092	0.2775414	0.2117098	0.5107488
6	0.7941464	0.1639182	0.0419353	0.3797574	0.2510637	0.3691789
7	0.6674905	0.2314715	0.1010381	0.5538558	0.2621535	0.1839907

Table (4.8): Comparison between Hand calculations and ASPEN PLUS SOFTWARE

Data	Calculation	Aspen Simulation	Error%
Number of theoretical stages	7	7	0

CONCLUSION AND RECOMMENDATIONS

Conclusion

It was Treybal who introduced a random selection points on the binodal curve left to the operating point taking random compositions. These compositions are extended through the operating points to cut the binodal curve on the far right.

The composition on the intersection give data of the operating line .The equilibrium data has to be taken from mutual solubility data and plotted with the operating line plotted from the random points selected.

The numbers of theoretical stages were determined by stepping off and determined. This method was adopted and found to be accurate, easy and simple. A complete design by hand calculation procedure is realized and Outlined. The number of theoretical stages is calculated using ASPEN PLUS SOFT WARE and it is found to be in agreement with the method investigated in this paper.

Recommendations

More work is required to verify the method developed by Treybal and activated in this research. Comparison between liquid-liquid extraction in stage-wise and continuous column needs to be investigated.

Hand calculation results and that obtained through aspen plus software gives some deviation which indicates that soft ware has to be revised.

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