Fundamentals of Chemical Engineering

Material Balance

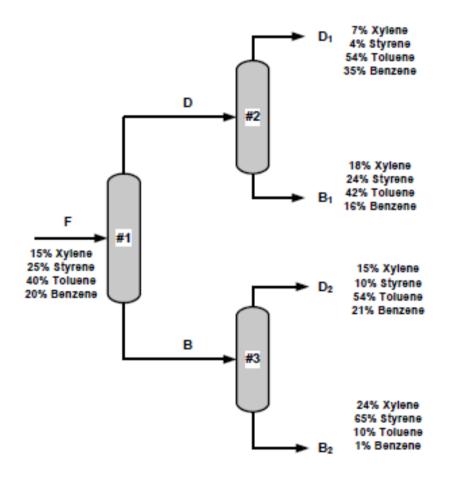
1. Non-Reactive system

Example: Separation Train

Xylene, Styrene, Toluene and Benzene are to be separated with the array of distillation columns that is shown below where F, D, B, D1, B1, D2 and B2 are the molar flow rates in mol/min. F is the feed flow rate of 70 mol/min,

a. calculate the flow rates of the top and bottom products of the second and third distillation columns,

b. calculate the molar flow rates of the four components in both streams B and D.



Part a:

Solution of such a system can be performed by solving a set of algebraic equations simultaneously, these equations are material balance equations for each component.

Material balance equations on the overall of the three columns will yield:

0.15×70=0.07×D1+0.18×B1+0.15×D2+0.24×B2 0.25×70=0.04×D1+0.24×B1+0.10×D2+0.65×B2 0.40×70=0.54×D1+0.42×B1+0.54×D2+0.10×B2 0.20×70=0.35×D1+0.16×B1+0.21×D2+0.01×B2 This can be shown in the form of a matrix:

AX=B

$$\begin{bmatrix} 0.07 & 0.18 & 0.15 & 0.24 \\ 0.04 & 0.24 & 0.10 & 0.65 \\ 0.54 & 0.42 & 0.54 & 0.10 \\ 0.35 & 0.16 & 0.21 & 0.01 \end{bmatrix} \begin{bmatrix} D_1 \\ B_1 \\ D_2 \\ B_2 \end{bmatrix} = \begin{bmatrix} 0.15 \times 70 \\ 0.25 \times 70 \\ 0.40 \times 70 \\ 0.20 \times 70 \end{bmatrix}$$

Its solution is as follows

X=A-1B

This can be solved in Microsoft excel by using the built-in function "MINVERSE" and "MMULT".

"MINVERSE" will find the inverse of matrix A while "MMULT" will multiply the inverse of matrix A and matrix B

The calculated matrix is then the solution to the above system of equations and required flow rates are calculated. i.e D1, B1, D2 and B2

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	А	В	С	D	E	F	G	H I	1. Type Miniverse(111.01) in Dy
1	Α								2. Then select cell B9:E12
2		0.07	0.18	0.15	0.24		10.5		
3		0.04	0.24	0.1	0.65		17.5		3. Press F2
4		0.54	0.42	0.54	0.1		28		3. I 1000 I L
5		0.35	0.16	0.21	0.01		14		4. And finally press ctrl+shift+enter
6									1. The many press cur (sinte (cheer
7		X=A^-1*B							This will give you the inverse of matrix
8	A A 1	2 01040	1 001774	1 002410255	6.050404		10.5		
9 10	A^-1	94.3629	-29.8306	-1.802419355 -36.68548387	41.1371	В	10.5 17.5		А
11		-66.0444			-36.2056		28		
2			9.362903		-9.99194		14		* To use the "MMULT"
13		24.0001	5.502505	0.555077415	5.55154		14		
4									1. Type '= $mmult(B9:E124,G9:G12)$ ' in
5	x	26.25							B15
6		17.5							
7		8.75							2. Select cell B15:B18
8		17.5							
9									3. Press F2
	confirm	10.5							
21									4. And finally press ctrl+shift+enter
22	В								
23									This will give the values of D1, B1, D2
	↓) .	CRE	CRE Assig	n CRE Regr	ession1	CRE Regre	ssion2	CRE Regression	and B2
REA	DY							-	
0	9 (>			x∎				

Part b :

The two streams B and D can be got from material balance equations around both towers number 2 and 3,

For tower 2: D=D1+B1

DxDX=0.07×D1+0.18×B1 DxDS=0.04×D1+0.24×B1 DxDT=0.54×D1+0.42×B1 DxDB=0.35×D1+0.16×B1

For tower 3: B=D2+B2

BxBX=0.15×D2+0.24×B2 BxBS=0.10×D2+0.65×B2 BxBT=0.54×D2+0.21×B2 BxBB=0.21×D2+0.01×B2

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	0.04	0.24	0.1	0.65		17.5			-				-							
	0.54	0,42	0.54	0.1		28														
	0.35	0.16	0.21	0.01		34														
	X=A^-1*B																			
	n-m 1 0																			
A^-1	-2.81048	1.221774	-1.802419355	6.060484	8	10.5														
	94.3629	-29.8306	-36.68548387	41.1371		17.5														
	-66.0444	20.24597	30.52822581	-36.2056		28														
	-24.5081	9.362903	8.959677419	-9.99194	1	14														
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	17.5		Xylene Styrene	1.85/3	3,15	- marinian	11.4													
	17.5		Toluene	14.175	7.35		45.2													
	Ares		Bensene	9.1875	2.8		27.4													
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