Distillation Column Design

Assignment 3

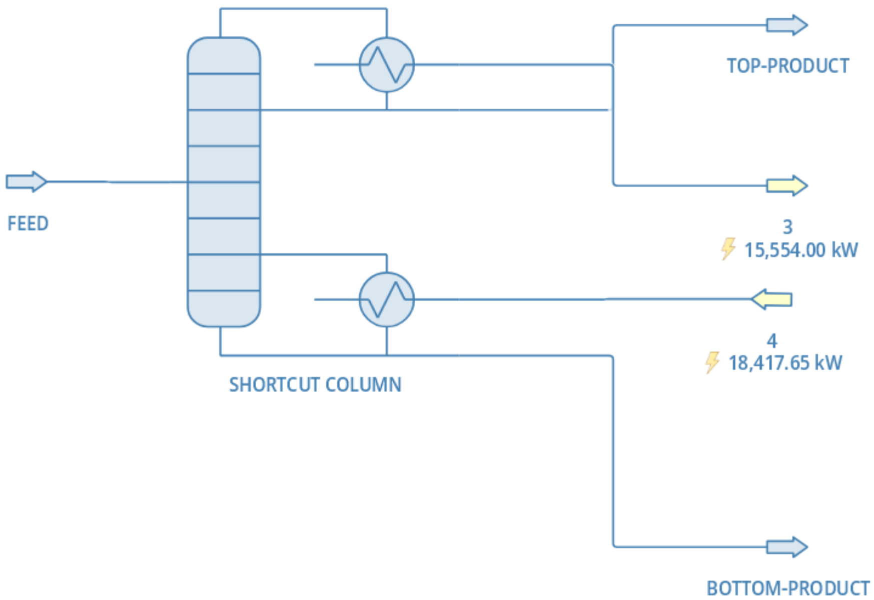
Saren Ajmera(200883) & Sushmita(201027)

System: Ethanol and Water

1. Using DWSIM instead of Python/MATLAB for simulating a distillation column & verifying the results of the Python/MATLAB code through the software.

Considering non-ideal solution.

Flowsheet using Shortcut column



By performing the simulations on DWSIM software using Shortcut Column , the results matched with MATLAB code results which proves the accuracy of the code and method.

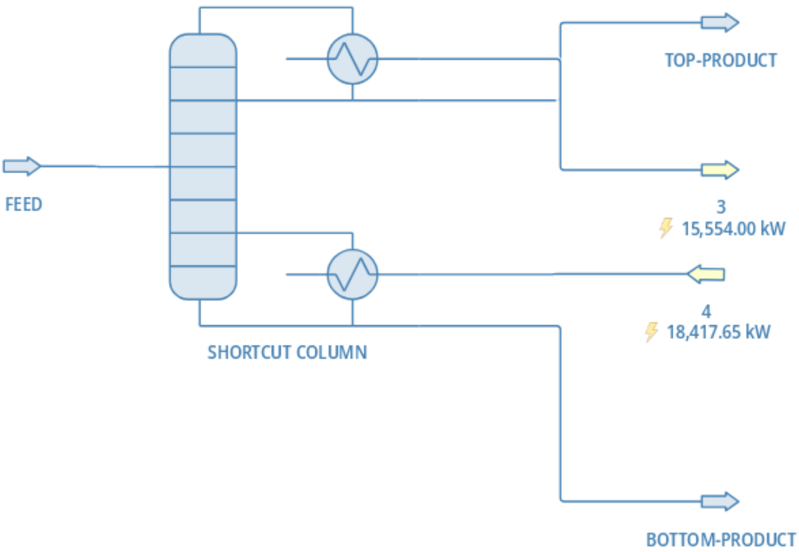
DWSIM RESULTS	MATLAB CODE RESULTS

Results

Property	Value	Units
Minimum Reflux Ratio	1.93179	
Minimum Number of Stages	9.22109	
Actual Number of Stages	19.699	
Optimal Feed Stage	5.57856	
Stripping Liquid	560.135	mol/s
Rectify Liquid	282.357	mol/s
Stripping Vapor	400.015	mol/s
Rectify Vapor	400.006	mol/s
Condenser Duty	15554	kW
Reboiler Duty	18417.6	kW

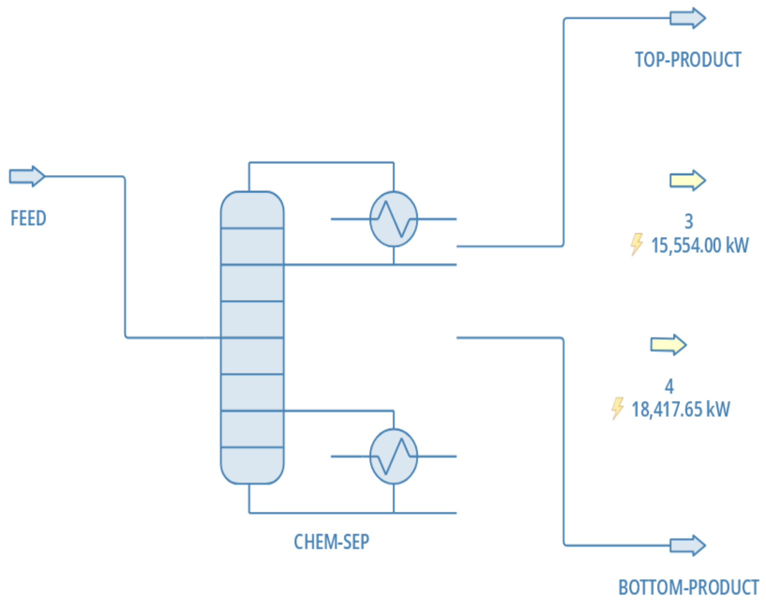
```
Actual Number Of Stages(Trays) :
    18

Minimum Number Of Stages(Trays) :
     8

Minimum Reflux Ratio :
1.974
```

Results



Master Property Table			
Object	TOP-PRODUCT	BOTTOM-PRODUCT	
Molar Flow	117.649	160.12	mol/s
Molar Fraction (Mixture) / Ethanol	0.989922	0.14	
Molar Fraction (Mixture) / Water	0.01	0.860057	

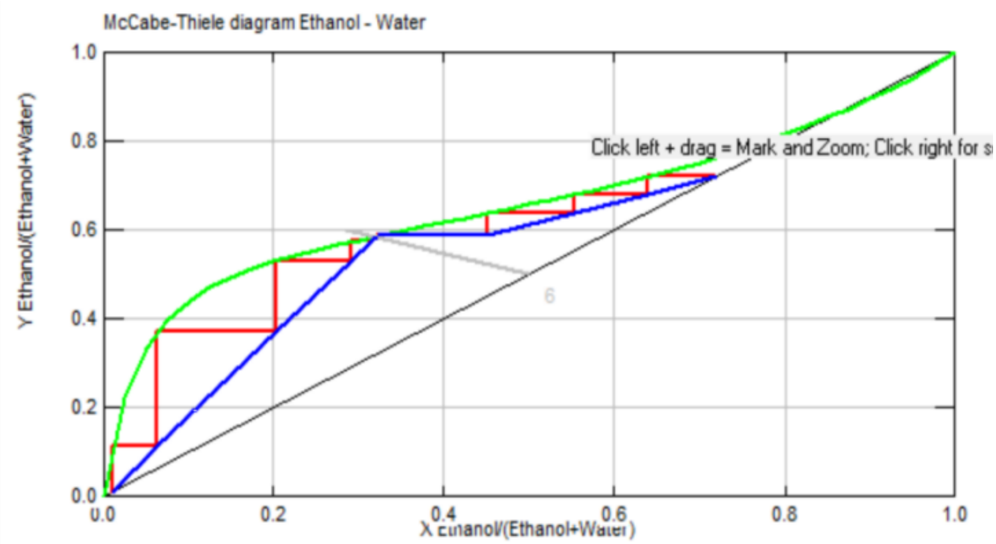
By putting the same parameters in Chem-Sep column as obtained from Shortcut column simulation we achieve separation of Ethanol and Water with Ethanol being obtained as a top product and water as the bottom product



Master Property Table		
Object	TOP-PRODUCT	BOTTOM-PRODUCT
Molar Fraction (Mixture) / Ethanol	0.800848	0.199152
Molar Fraction (Mixture) / Water	0.199152	0.800848

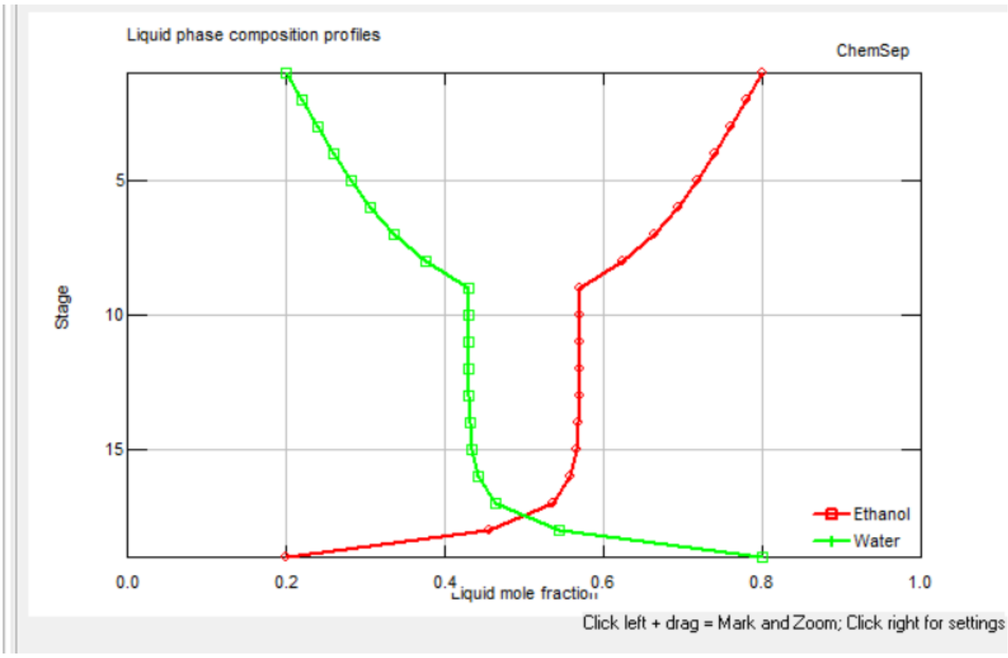
Chem-sep Column Design

McCabe Thiele Diagram



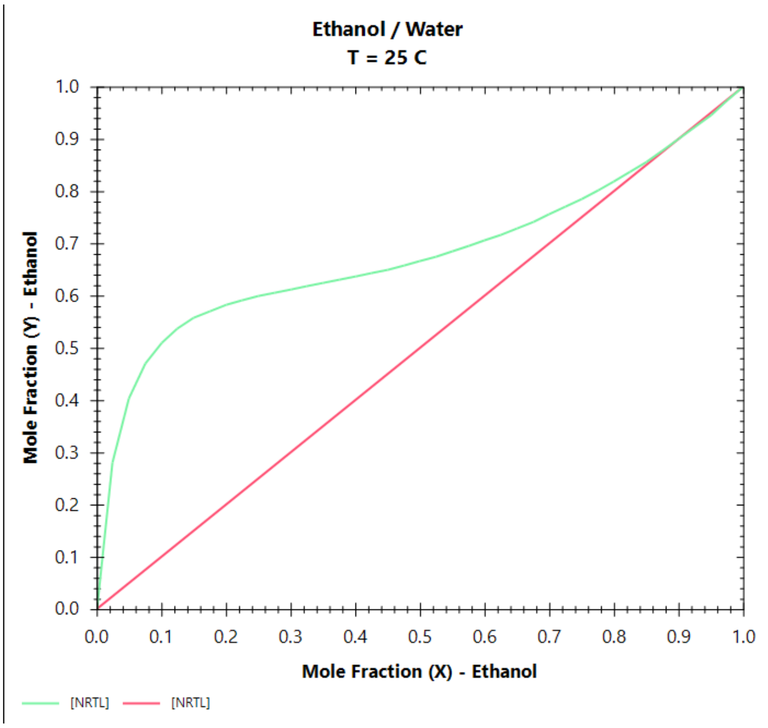
Stream Results

Stream	Feed1	Top	Bottom
Stage	9	1	19
Pressure (N/m2)	101325	101325	101325
Vapour fraction (-)	0.000000	0.000000	0.000000
Temperature (K)	298.150	351.591	356.231
Total molar flow (kmol/s)	0.277778	0.138889	0.138889
Total mass flow (kg/s)	8.90042	5.62239	3.27803
Vapour std.vol.flow (m3/s)			
Liquid std.vol.flow (m3/s)	0.0105510	0.00694045	0.00361059
Mole flows (kmol/s)			
Ethanol	0.138889	0.111229	0.0276600
Water	0.138889	0.0276600	0.111229
Mole fractions (-)			
Ethanol	0.500000	0.800848	0.199152
Water	0.500000	0.199152	0.800848
Mass flows (kg/s)			
Ethanol	6.39834	5.12410	1.27424
Water	2.50209	0.498295	2.00379
Mass fractions (-)			
Ethanol	0.718880	0.911373	0.388722
Water	0.281120	0.0886269	0.611278
Combined feed and product f			
Total molar	1.00000	0.500000	0.500000
Total mass	1.00000	0.631699	0.368301

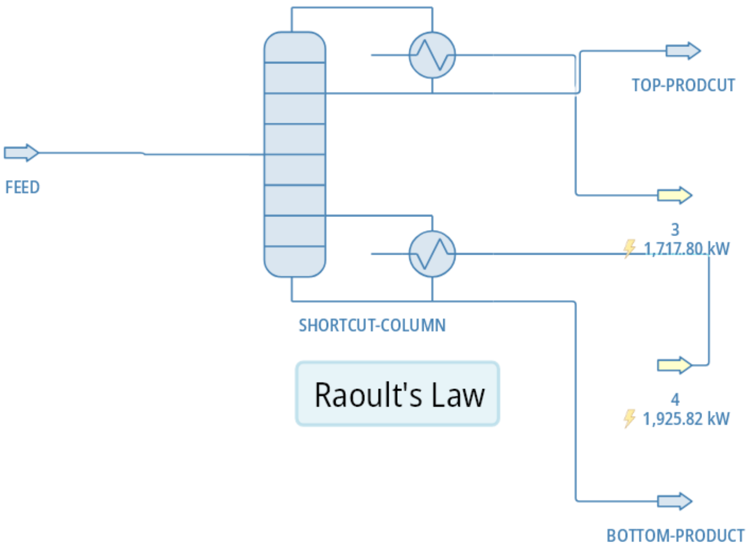


Composition of Ethanol & Water at each stage in Chem-Sep Column

T_{xy} Plot of Ethanol and Water



CONSIDERING IDEAL SOLUTION AND RAOLUT'S LAW



Shortcut Column Design

Results

Master Property Table			
Object	TOP-PRODCUT	BOTTOM-PRODUCT	
Molar Fraction (Mixture) / Ethanol	0.989982	0.15	
Molar Fraction (Mixture) / Water	0.01	0.850013	

By performing the simulations on DWSIM software using Shortcut Column , the results matched with MATLAB code results which proves the accuracy of the code and method.

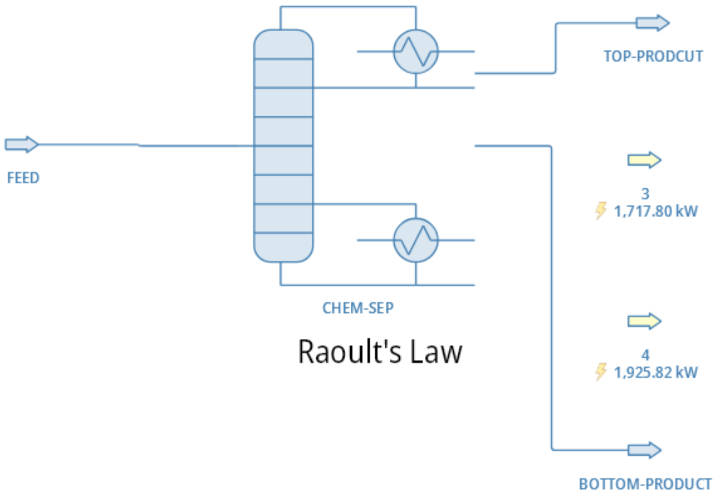
<table>
<tr><th>DWSIM Results</th><th>MATLAB Results</th></tr>
<tr><td>
Results
<table>
<tr><th>Property</th><th>Value</th><th>Units</th></tr>
<tr><td>Minimum Reflux Ratio</td><td>1.2932</td><td></td></tr>
<tr><td>Minimum Number of Stages</td><td>5.26458</td><td></td></tr>
<tr><td>Actual Number of Stages</td><td>8.6824</td><td></td></tr>
<tr><td>Optimal Feed Stage</td><td>2.78069</td><td></td></tr>
<tr><td>Stripping Liquid</td><td>1894.42</td><td>kmol/h</td></tr>
<tr><td>Rectify Liquid</td><td>894.42</td><td>kmol/h</td></tr>
<tr><td>Stripping Vapor</td><td>1267.11</td><td>kmol/h</td></tr>
<tr><td>Rectify Vapor</td><td>1267.1</td><td>kmol/h</td></tr>
<tr><td>Condenser Duty</td><td>13710.9</td><td>kW</td></tr>
</table>
Bottom product (Material Stream) | Feed (Material Stream) | 4 (Shortcut Colum
</td><td>
Actual Number Of Stages(Trays) :
7

Minimum Number Of Stages(Trays) :
5

Minimum Reflux Ratio :
1.271
</td></tr>
</table>

By putting the same parameters in Chem-Sep column as obtained from Shortcut column simulation we achieve separation of Ethanol and

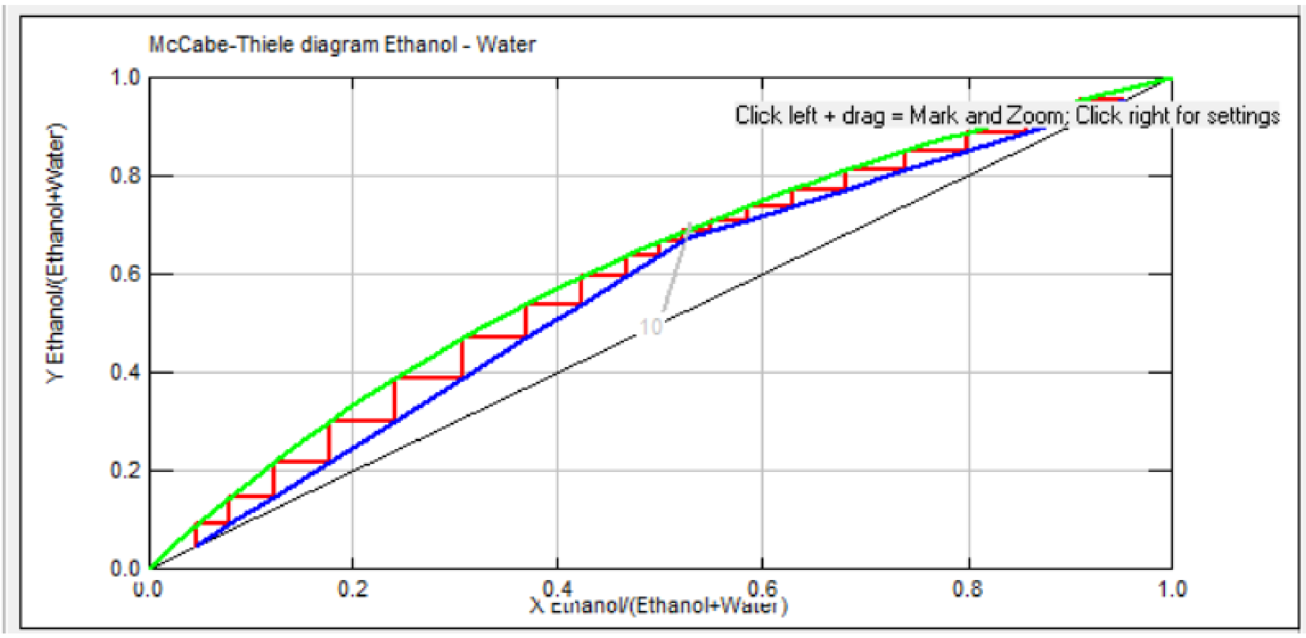
Water with Ethanol(95%) being obtained as a top product and water as the bottom product(5%)



Master Property Table		
Object	TOP-PRODCUT	BOTTOM-PRODUCT
Molar Fraction (Mixture) / Ethanol	0.952402	0.047598
Molar Fraction (Mixture) / Water	0.047598	0.952402

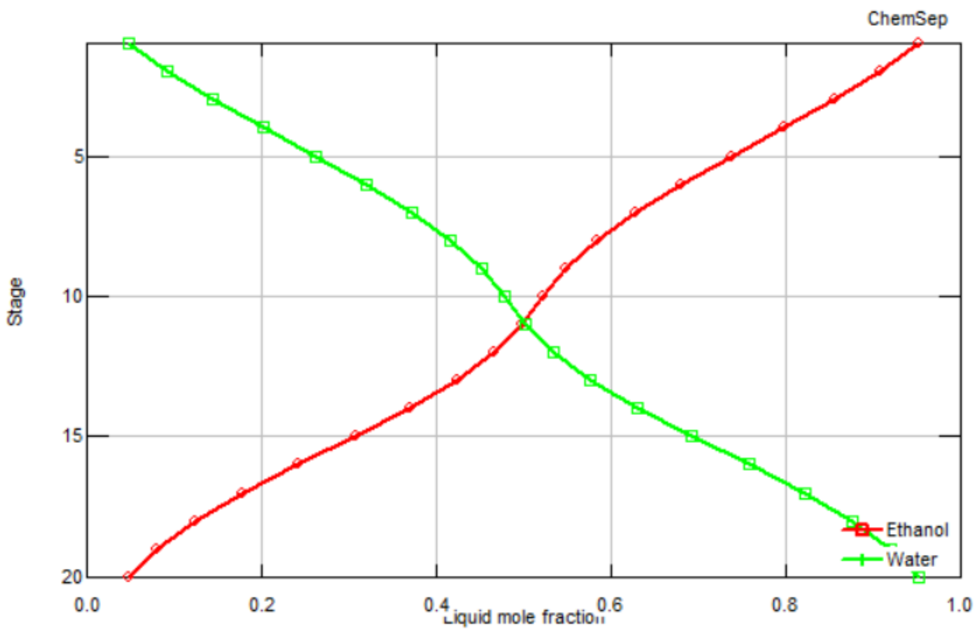
Chem-sep Column Design

McCabe Thiele Diagram



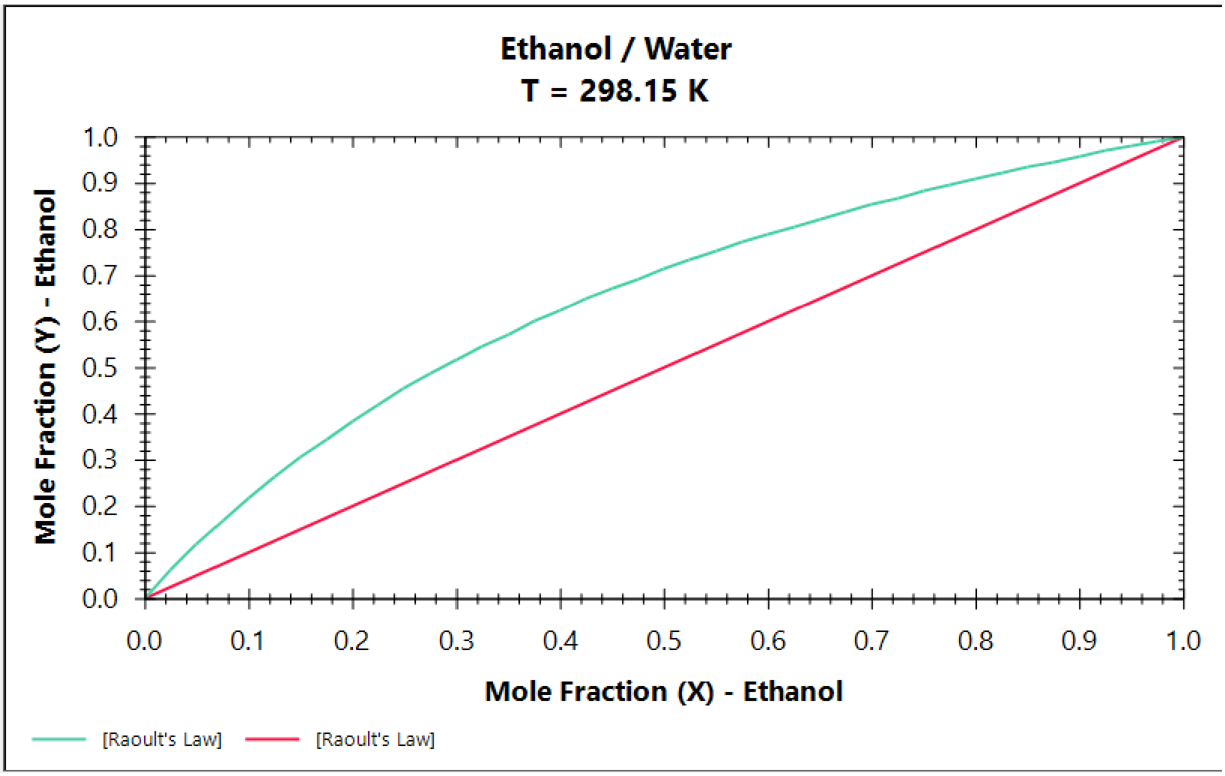
Stream Results

Stream	Feed1	Top	Bottom
Stage	10	1	20
Pressure (N/m2)	101325	101325	101325
Vapour fraction (-)	0.000000	0.000000	0.000000
Temperature (K)	298.150	351.784	369.323
Total molar flow (kmol/s)	0.0312092	0.0156046	0.0156046
Total mass flow (kg/s)	0.999989	0.698036	0.301953
Vapour std.vol.flow (m3/s)			
Liquid std.vol.flow (m3/s)	0.00118544	8.7401E-04	3.1142E-04
Mole flows (kmol/s)			
Ethanol	0.0156046	0.0148618	7.4274E-04
Water	0.0156046	7.4274E-04	0.0148618
Mole fractions (-)			
Ethanol	0.500000	0.952402	0.0475980
Water	0.500000	0.0475980	0.952402
Mass flows (kg/s)			
Ethanol	0.718872	0.684655	0.0342168
Water	0.281117	0.0133806	0.267736
Mass fractions (-)			
Ethanol	0.718880	0.980831	0.113318
Water	0.281120	0.0191689	0.886681
Combined feed and product f			
Total molar	1.00000	0.500000	0.500000
Total mass	1.00000	0.698044	0.301956



Composition of Ethanol & Water at each stage in Chem-Sep Column

T_{xy} plot of Ethanol and Water



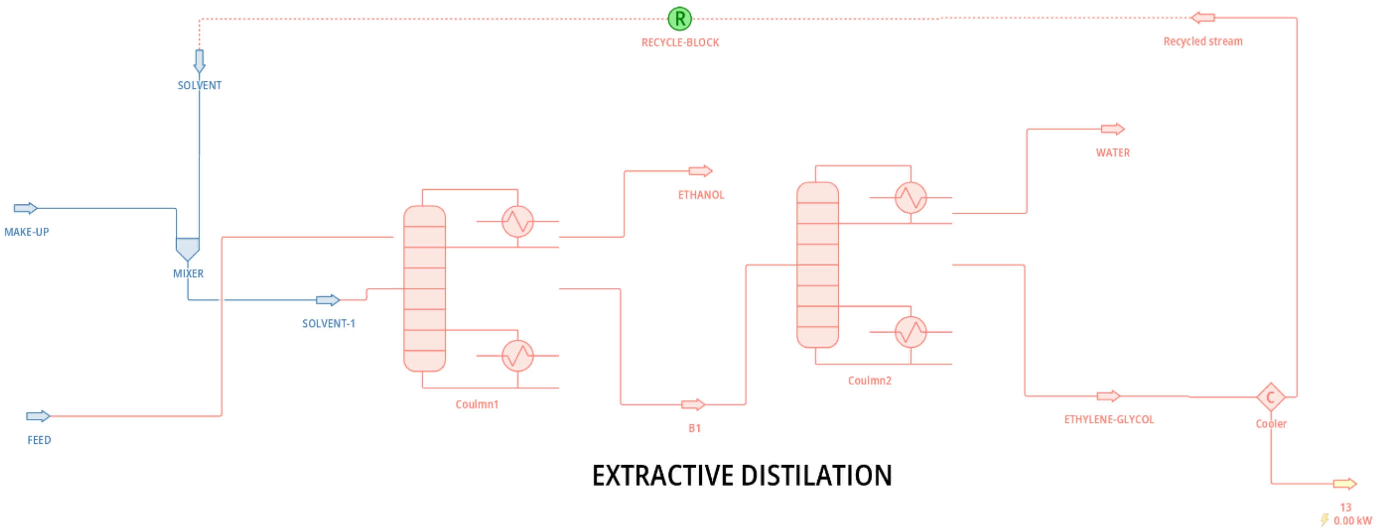
2. Separation of Azeotropic mixture by Extractive Distillation using DWSIM.

Extractive Distillation

Extractive distillation separates a binary mixture by adding a third component. The third component is less volatile and doesn't evaporate during distillation. Or, raise the boiling point.

Two components with comparable boiling points cannot be separated by distillation. Both will evaporate at identical temperatures (poor resolution).

Azeotropes aren't generated during extractive distillation. The component mixture's solvent is low-volatility. Separation solvent. The volatile component is easily vaporised during distillation. The remaining solvent and component (in the binary mixture). Since the solvent and second component don't form an azeotrope, they can be separated easily.



Flowsheet showing Extractive Distialltion of Ethanol and Water

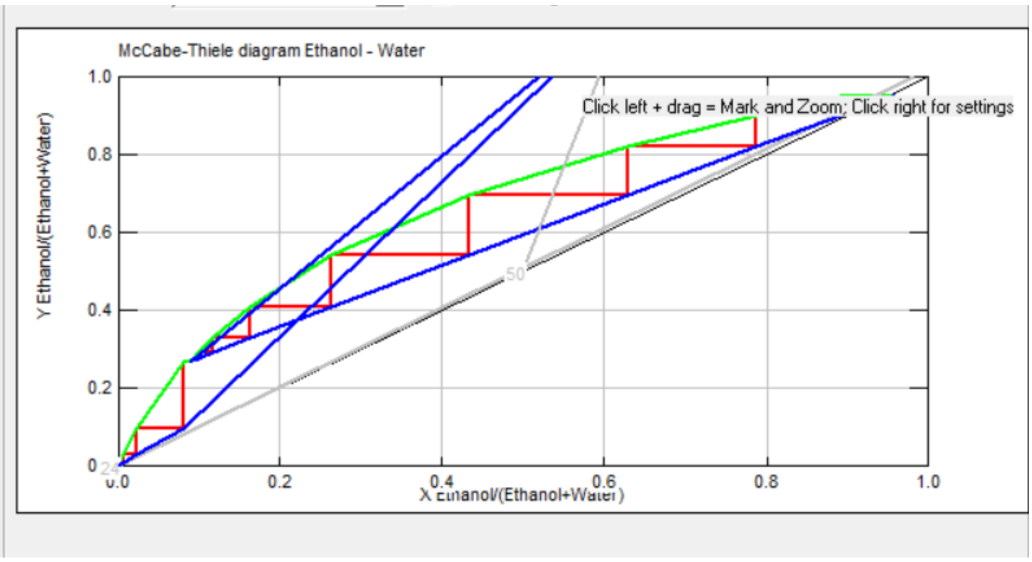
Stream Results (Coulmn1)

Tables | Graphs | McCabe-Thiele | Rating

Select table: Streams

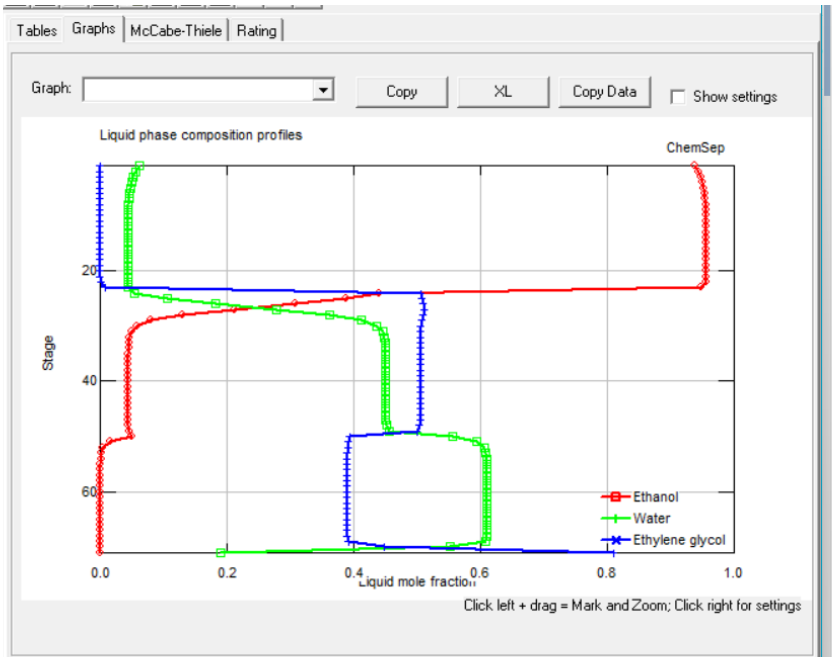
XL Edit Copy Font Print

Stream	Feed2	Feed1	Top	Bottom
Stage	24	50	1	71
Pressure (N/m2)	101325	101325	101325	101325
Vapour fraction (-)	0.000000	0.000000	0.000000	0.000000
Temperature (K)	260.150	298.150	351.176	412.293
Enthalpy (J/kmol)	-7.047E+07	-4.324E+07	-3.549E+07	-4.582E+07
Entropy (J/kmol/K)	-156584	-114706	-98879.1	-84988.6
Total molar flow (kmol/s)	0.0556392	0.0277778	0.0148113	0.0686056
Total mass flow (kg/s)	3.45341	0.890042	0.656451	3.68700
Vapour std.vol.flow (m3/s)				
Liquid std.vol.flow (m3/s)	0.00311084	0.00105510	8.2091E-04	0.00334503
Mole flows (kmol/s)				
Ethanol	0.000000	0.0138889	0.0138889	1.0296E-15
Water	0.000000	0.0138889	9.2242E-04	0.0129665
Ethylene glycol	0.0556392	0.000000	1.7407E-22	0.0556392
Mole fractions (-)				
Ethanol	0.000000	0.500000	0.937722	1.5007E-14
Water	0.000000	0.500000	0.0622784	0.189000
Ethylene glycol	1.00000	0.000000	1.1752E-20	0.811000
Mass flows (kg/s)				
Ethanol	0.000000	0.639833	0.639833	4.7432E-14
Water	0.000000	0.250208	0.0166175	0.233591
Ethylene glycol	3.45341	0.000000	1.0804E-20	3.45341
Mass fractions (-)				
Ethanol	0.000000	0.718880	0.974686	1.2864E-14



McCabe-Thiele Diagram

Composition of Ethanol,Ethylene Glycol & Water at each stage in Chem-Sep Column

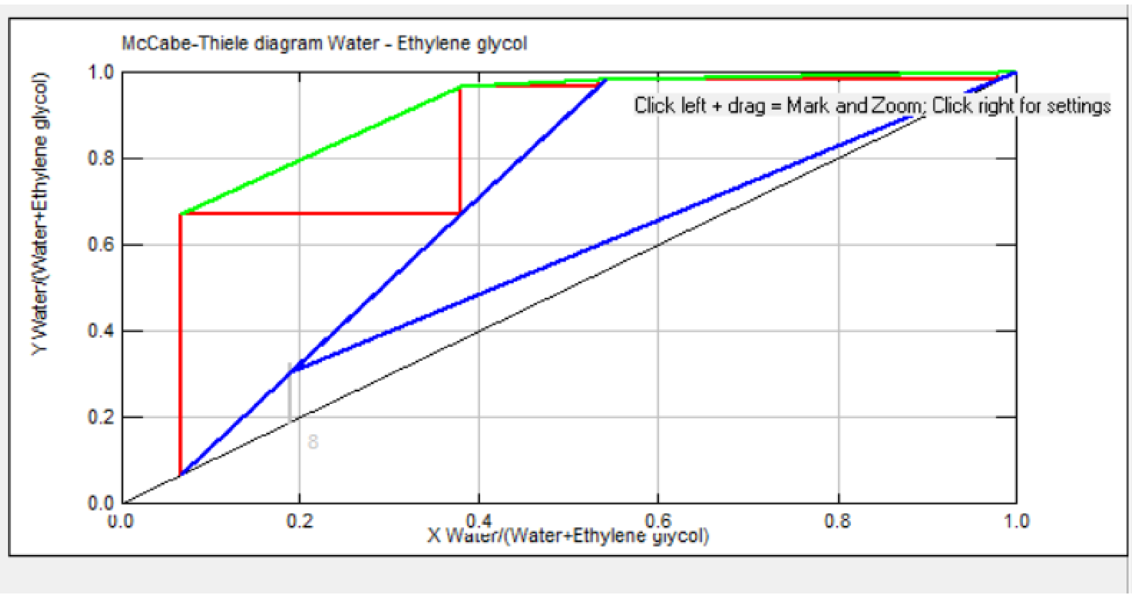


Column2

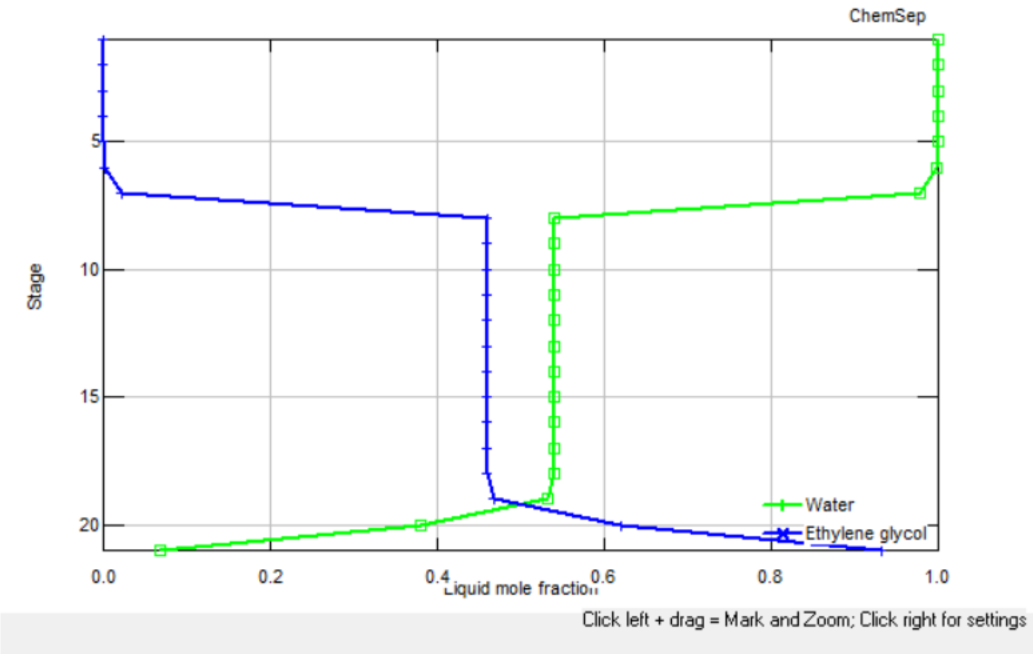
Stream Results

Stream	Feed1	Top	Bottom
Stage	8	1	21
Pressure (N/m2)	101325	101325	101325
Vapour fraction (-)	0.000000	0.000000	0.000000
Temperature (K)	412.293	372.936	438.920
Total molar flow (kmol/s)	0.0686057	0.00896770	0.0596380
Total mass flow (kg/s)	3.68701	0.161553	3.52545
Vapour std.vol.flow (m3/s)			
Liquid std.vol.flow (m3/s)	0.00334503	1.6196E-04	0.00318307
Mole flows (kmol/s)			
Ethanol	1.6956E-15	1.6956E-15	6.0173E-24
Water	0.0129665	0.00896770	0.00399880
Ethylene glycol	0.0556392	3.2345E-12	0.0556392
Mole fractions (-)			
Ethanol	2.4715E-14	1.8908E-13	1.0089E-22
Water	0.189000	1.00000	0.0670512
Ethylene glycol	0.811000	3.6069E-10	0.932949
Mass flows (kg/s)			
Ethanol	7.8115E-14	7.8115E-14	2.7720E-22
Water	0.233591	0.161553	0.0720384
Ethylene glycol	3.45342	2.0076E-10	3.45341
Mass fractions (-)			
Ethanol	2.1186E-14	4.8352E-13	7.8630E-23
Water	0.0633552	1.00000	0.0204338
Ethylene glycol	0.936645	1.2427E-09	0.979566

McCabe Thiele Diagram



Composition Of Ethylene Glycol and water



3.Separation by Pressure Swing Distillation using Dwsim.

Pressure Swing Distillation

Process and chemical industries use pressure swing distillation to extract azeotropes. Azeotropes are liquid mixes that do not separate when boiling, meaning the gas and liquid phases are identical.

Principle Of Pressure Swing Distillation

At constant pressure, azeotrope mixes may contain more than one azeotropy point, but this is uncommon.

When pressure fluctuates, the azeotropy point moves. At different pressures, the same liquid combination forms a distinct azeotrope.

Since pressure can vary the relative volatility of a liquid combination, many azeotropes lose their azeotropy when the pressure is raised to a specific degree. A distillation column can separate the azeotropic system.

Advantages of Pressure Swing Distillation

No more material is needed, therefore cost, availability, and usage issues are eliminated.

Continuous operations save energy because heat integration optimises heat transport.

Smaller columns reduce early investment costs.

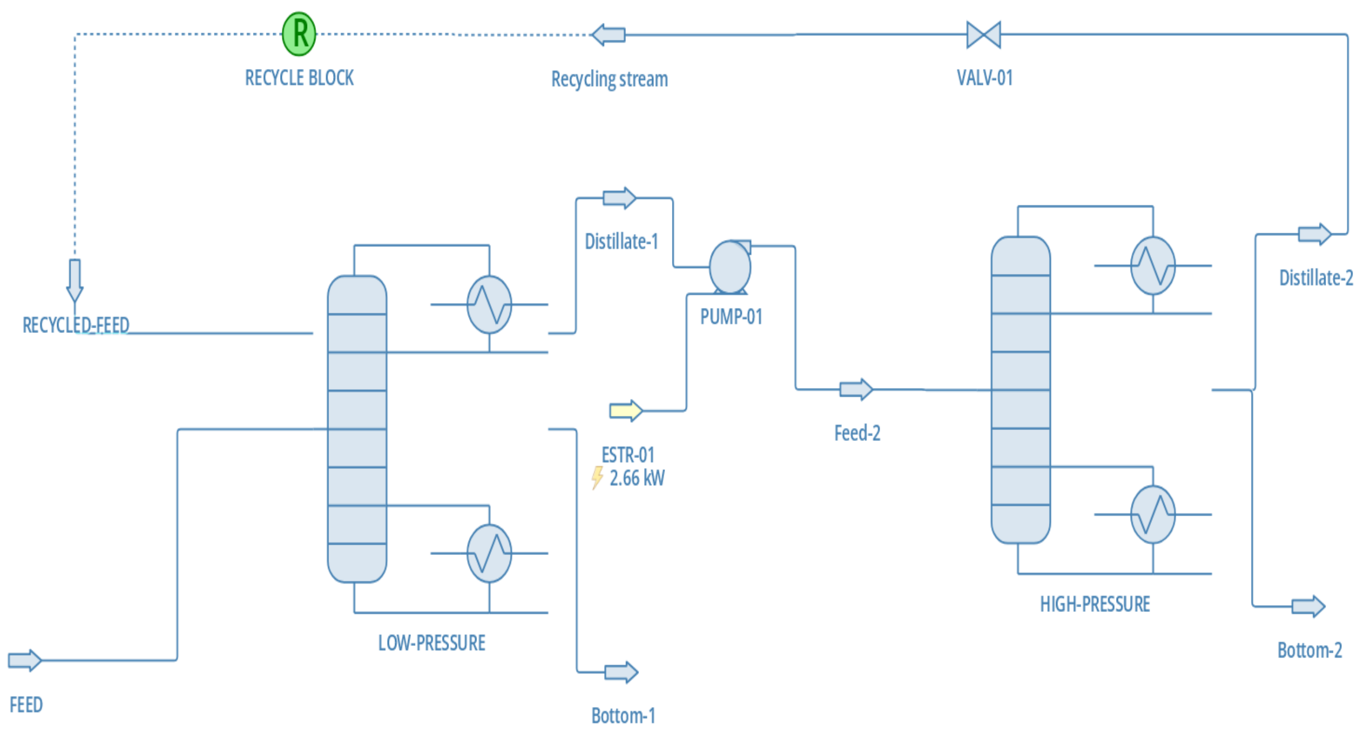
Disadvantages of Pressure Swing Distillation

Balance and azeotropic data are needed to construct the system.

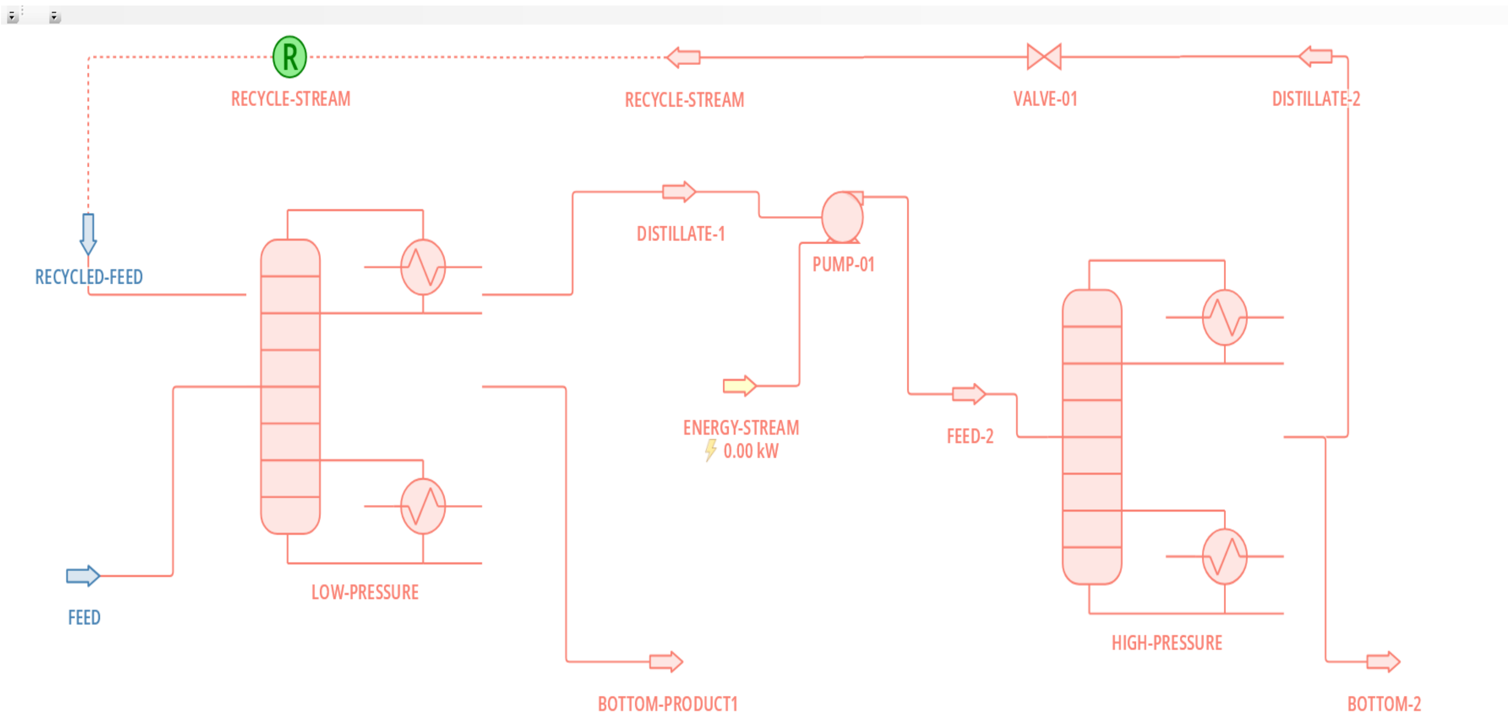
System design requires extensive control and automation.

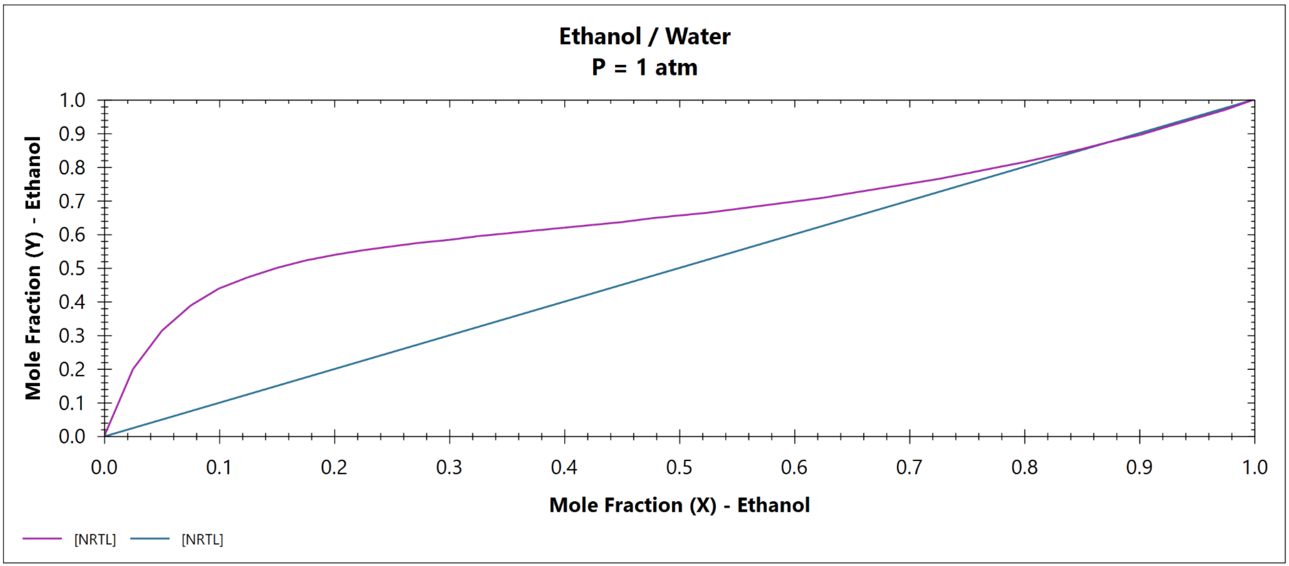
If the azeotropes are low boiling, the product may be contaminated with high boiling components.

Flow Sheet showing Pressure Swing Distilaation



Flow Sheet showing Pressure Swing Distilaation





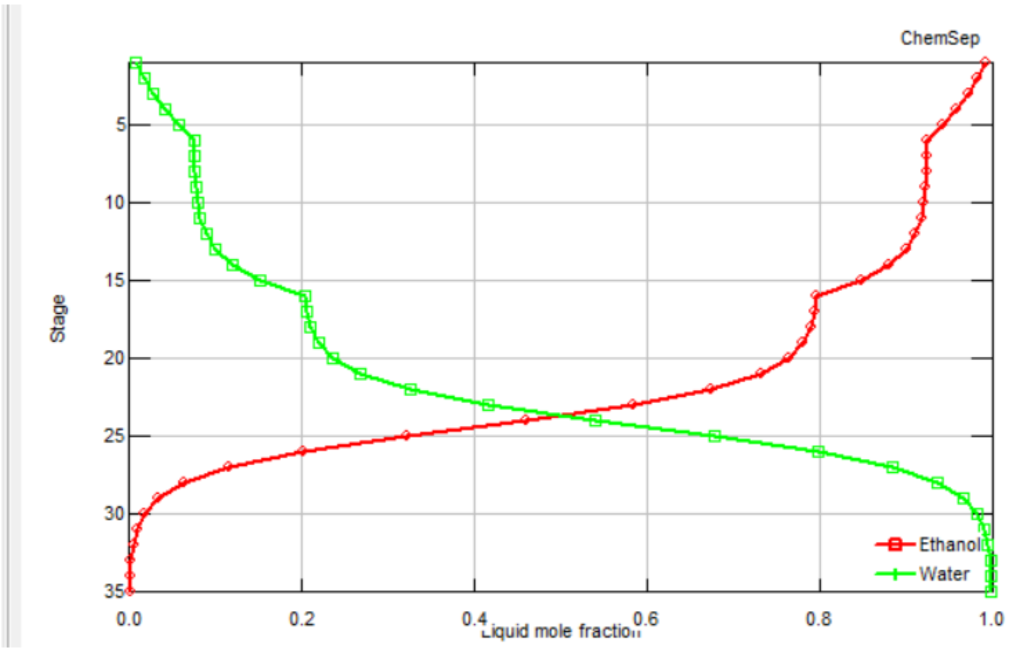
Results from Low-Pressure Column

Stream Results

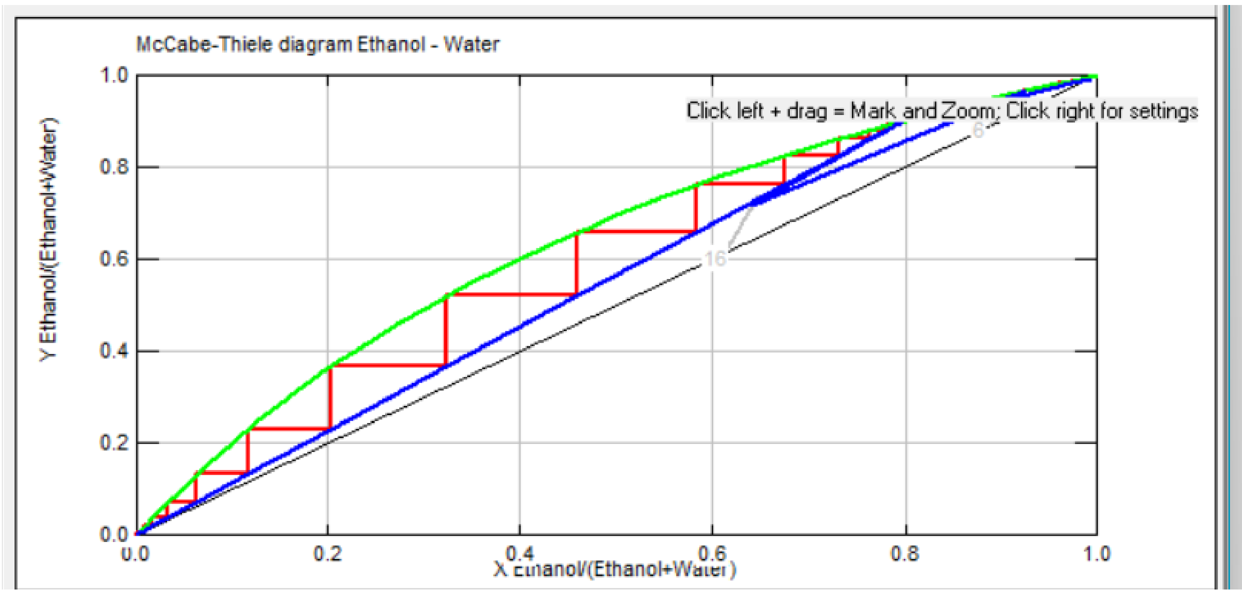
Stream	Feed1	L.Feed1	Feed2	L.Feed2	
Stage	6	6	16	16	
Pressure (N/m2)	101325	50662.5	101325	50662.5	506
Vapour fraction (-)	0.000000	0.000000	0.000000	0.000000	0.00
Temperature (K)	298.150	298.150	298.150	298.150	334.
Enthalpy (J/kmol)	-4.267E+07		-4.308E+07		-3.762
Entropy (J/kmol/K)	-120817		-115555		-10
Total molar flow (kmol/s)	0.0290815	0.0290815	0.0237226	0.0237226	0.040
Total mass flow (kg/s)	1.24999	1.24999	0.833324	0.833324	1.8
Vapour std.vol.flow (m3/s)					
Liquid std.vol.flow (m3/s)	0.00155655	0.00155655	0.00100507	0.00100507	0.0023
Mole flows (kmol/s)					
Ethanol	0.0258826	0.0258826	0.0144712	0.0144712	0.040
Water	0.00319897	0.00319897	0.00925141	0.00925141	2.9630
Mole fractions (-)					
Ethanol	0.890000	0.890000	0.610018	0.610018	0.99
Water	0.110000	0.110000	0.389982	0.389982	0.0072
Mass flows (kg/s)					
Ethanol	1.19236	1.19236	0.666660	0.666660	1.8
Water	0.0576294	0.0576294	0.166664	0.166664	0.0053
Mass fractions (-)					
Ethanol	0.953896	0.953896	0.800001	0.800001	0.99
Water	0.0461040	0.0461040	0.199999	0.199999	0.0028

Combined feed and product f

Compositions of Ethanol and Water



McCabe thiele Diagram



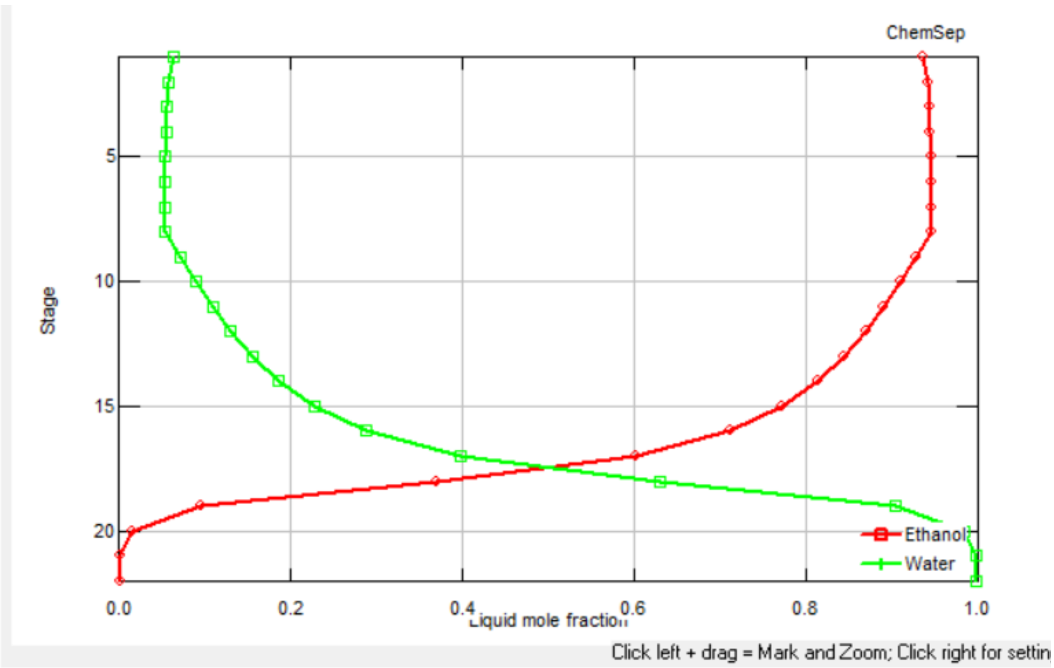
Results from High-Pressure Column

Stream Results

Stream	Feed1	L.Feed1	Top	Bottom
Stage	8	8	1	22
Pressure (N/m2)	1.1145E+06	1.1145E+06	1.1145E+06	1.1145E+06
Vapour fraction (-)	0.000000	0.000000	0.000000	0.000000
Temperature (K)	335.190	335.190	428.004	457.349
Enthalpy (J/kmol)	-3.758E+07		-2.209E+07	-3.072E+07
Entropy (J/kmol/K)	-107674		-66728.5	-87260.5
Total molar flow (kmol/s)	0.0406440	0.0406440	0.0430980	0.000000
Total mass flow (kg/s)	1.86408	1.86408	1.90842	0.000000
Vapour std.vol.flow (m3/s)				
Liquid std.vol.flow (m3/s)	*	*	*	*
Mole flows (kmol/s)				
Ethanol	0.0403477	0.0403477	0.0403526	0.000000
Water	2.9630E-04	2.9630E-04	0.00274533	0.000000
Mole fractions (-)				
Ethanol	0.992710	0.992710	0.936300	0.00200000
Water	0.00729013	0.00729013	0.0636998	0.998000
Mass flows (kg/s)				
Ethanol	1.85874	1.85874	1.85896	0.000000
Water	0.00533785	0.00533785	0.0494571	0.000000
Mass fractions (-)				
Ethanol	0.997136	0.997136	0.974085	0.00509853
Water	0.00286353	0.00286353	0.0259152	0.994901

Combined feed and product f

Composition Of Ethanol and Water



McCabe-Theile Diagram