Pressure- Swing Distillation for separating Ternary System with Three Binary Minimum Azeotropes

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Background:

The ternary non ideal solution with three binary minimum azeotropes such as Tetrahydrofuran, ethanol and water is often found used in pharmaceutical industries, requiring separation due to environmental concern. To separate this kind of mixture simple distillation is not an apt method and often fails to give the result. The three most nonconventional distillations including pressure swing, azeotropic and extractive distillation have been developed for separation of ternary non-ideal mixtures in continuous mode. The use of entrainer in azeotropic and extractive distillation make the process highly complicated as well as expensive due to regeneration of entrainer, on the other hand pressure swing method adopt the analogy of varying pressure across the two or more column without the introduction of any entrainer. Hence the energy and capital cost depends upon on the pressure which could be reduced through the optimal design.

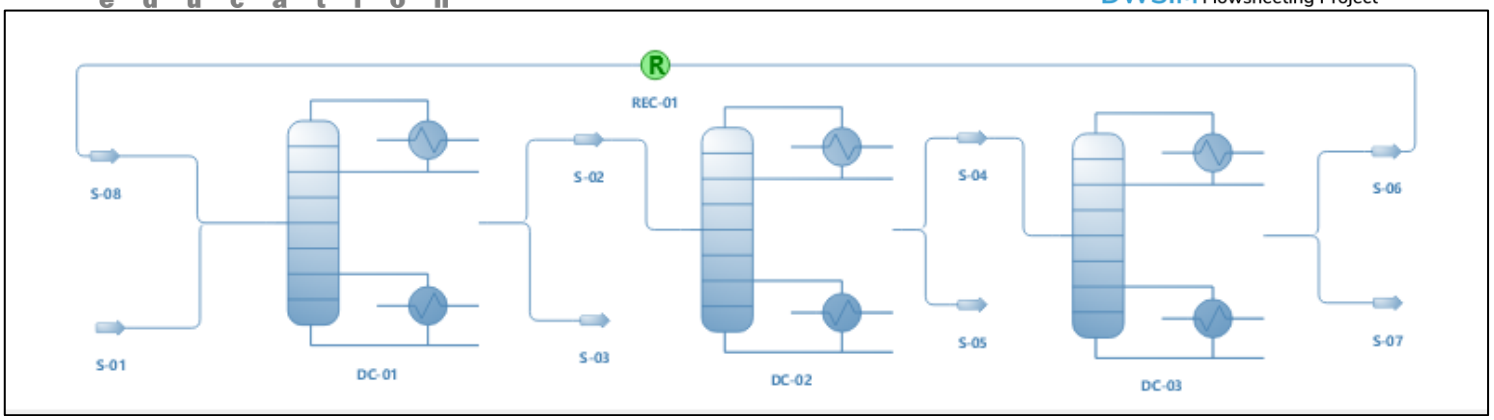
Description:

The flow sheet illustrates a triple column pressure-swing distillation process for separating a non-ideal azeotropic system with three binary minimum azeotropes. Three product of varying molar fractions are obtained at bottom streams (namely S-03, S-05 and S-07) of three different columns (DC-01, DC-02 and DC-03) under pressure varying from 1-10 bars.

The physical property package included was NRTL.

The pressure swing distillation process was performed with three columns operating at a pressure of 1.013, 7.5 and 10 bar respectively. The ternary mixture feed was fed to the first column at a 1.013 bar pressure and 25 degree Celsius having 29 theoretical trays. The feed (S-01) entered the column at 24th stage while the recycle feed (S-08) was provided at 7th stage. The composition of distillate was investigated as 0.10 mole fraction of water, 0.310 of ethanol and 0.581 of THF. The bottom product was rich in water with a composition 0.999 mole fraction of the stream(S-03). Hence water was left out as a product of first distillation column. The distillate of the first column (DC-01) act as feed for DC-02, the stream entered the column at 6th stage. The operating pressure of the column was 7.5 bars and consists of 72 theoretical trays. The composition of distillate was recorded as 0.16 mole fraction of water, 0.379 of ethanol and 0.460 of THF. The bottom stream (S-05) was rich in ethanol with a composition of 0.997 mole fraction and hence ethanol is derived out as a product of this particular stream. Further the distillate of DC-02 act as a feed stream of DC-03.The column consisted of 70 theoretical trays .The feed stream was fed at 37th stage of column at a pressure of 10 bar. The distillate composition of this column was found to be 0.170 mole fractions of water, 0.414 of ethanol and 0.414 mole fraction of THF. The bottom is rich is THF with composition of 0.995 mole fraction of stream. The distillate of DC-03 acts as a make-up feed or recycles stream of DC-01. Hence the bottom stream products are rich in water, ethanol and THF respectively. We could arrive at a result that the separation of ternary mixture had been achieved.

Flow sheet:



Optimized Flow sheet of Triple-Column Pressure Swing Distillation

Results:

Master Property Table									
Object	S-08	S-07	S-06	S-05	S-04	S-03	S-02	S-01	
Temperature	147.757	159.188	147.757	140.582	135.647	99.9569	68.3616	25	C
Pressure	10	10	10	7.5	7.5	1.01325	1.01325	1.01325	bar
Mass Flow	24339	2288.36	24339	1456.21	26627.4	591.308	28083.6	4539.65	kg/h
Molar Fraction (Vapor) / Water	0.170643	6.80549E-10	0.170643	6.80885E-09	0.15965	0.999	0.107999	0.136047	
Molar Fraction (Vapor) / Ethanol	0.414588	0.005	0.414588	0.997	0.379759	0.000999822	0.310287	0.175539	
Molar Fraction (Vapor) / Tetrahydrofuran	0.414768	0.995	0.414768	0.003	0.460591	1.77888E-07	0.581714	0.688414	

Reference:

Design and control of pressure-swing distillation for separating ternary systems with three binary minimum azeotropes--Ao Yang,Weifeng Shen,Shun'an Wei,Lichun Dong,Jie Li,Vincent Gerbaud, https://doi.org/10.1002/aic.16526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