Heat Integration Of Alcoholic Distillation Columns With Different Configurations

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Background:

Bioethanol is a biofuel produced from the carbohydrate content of plants. First-generation bioethanol is sugar and starch based and needs food plants as raw material, but second-generation is produced from lignocellulosic vegetable biomass, therefore eliminating the competition of food and fuel production for raw materials. Bioethanol is produced from the beer by multiple distillation steps. The composition of beer containing 3.49 mass% ethanol , 96.48% water and 0.03% organic pollutants.

Process description:

Bioethanol is produced from beer which is contain 14 different components (3.49 Mass % ethanol , 96.48% water and 0.03% organic pollutants). The bioethanol distillation plant consists of three distillation columns in series with increasing pressure.

The first one is the Beer Stripper (Column 1) , which removes the majority of the beer's water content and the enzymes. It is operated without reflux and in vacuum (0.242 bar) to prevent the desaturation of the recovered enzymes. It's distillate (D1) which is out around 50 deg.C goes to preheater where outlet temperature of preheater is at 85 deg.C which is fed to the atmospheric Aldehyde Column (Column 2)Where value of reflux ratio is taken as 12.5, whose distillate (D2) contains good quantity of aldehydes. The bottom product (F3) which is at around 90 deg.C is fed into the Rectification Column (Column 3) ,Where value of reflux ratio is taken as 12.3, which is operated at moderate pressure. It's distillate (D3) contain mostly ethanol and the bottom product is pure water. The pressure drop of the columns were taken as 0.05 bar (Column 1) and 0.1 bar (Column 2 and 3) respectively. The vapour-liquid equilibrium condition were describe by the NRTL model.

As for the original system , in case of heat integration of two columns the condenser of Column-3 is coupled with the reboiler of Column-1. By doing this external heating demand is reduced . With this single coupling the heating energy demand of the process is reduced by 35-40%.

Flowsheet:

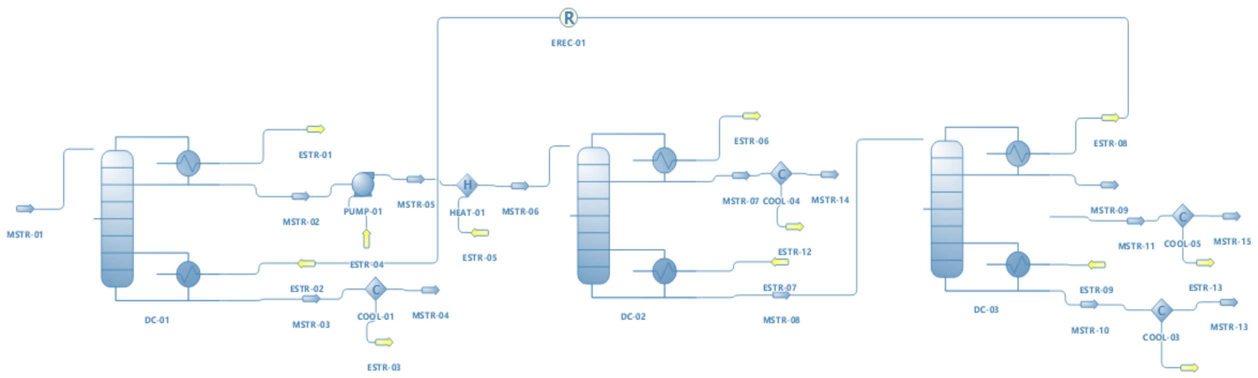

Figure 1: Heat integration of two columns (HI-B)

Results:

HI-B Flowsheet

Object	DC-03	DC-02	DC-01		Object	MSTR-09	MSTR-03	MSTR-02	MSTR-01	
Condenser Pressure	2.929	1.024	0.242	bar	Temperature	106.658	68.4811	50.8035	20	C
Reboiler Pressure	3.335	1.17706	0.292303	bar	Pressure	2.88414	0.298	0.195742	1.033	kgf/cm2
Condenser Pressure Drop	0.101949	0.101949	0.0509746	kgf/cm2	Mass Flow	341.318	6599.7	1263.2	7862.9	kg/h
Reflux Ratio	12.3	12.5	0.000713982		Molar Flow	4984.74	210975	34361.7	245336	m3/d @ BR
Distillate Molar Flow	8.63428	0.105061	59.5192	kmol/h	Volumetric Flow	0.457994	6.74811	1.32317	7.91625	m3/h
Condenser Duty	1162.29	14.7274	748.885	kW	Mass Flow (Mixture) / Ethanol	269.799	7.80E-06	272.163	272.162	kg/h
Reboiler Duty	-1225.26	-22.7659	-1271.94	kW	Mass Flow (Mixture) / Water	33.2698	6577.76	947.631	7525.39	kg/h
Number of Stages	40	30	18							

Conclusion and Recommendation:

- A flowsheet for production of ethanol from beer component was built with the product purity of greater than 95% with the open-source simulation software tool DWSIM.
- With the help of heat integration of two columns where condenser of column 3 is coupled with the reboiler of column 1 (HI-B) decrease the heating energy demand of the process by 35-40% as compare to original plant or basic flowsheet.
- It is also conclude that increase of the saving can be obtained only by increasing the complexity of the system in terms of good decrement in the total Operating cost at an expanse of slight increment of the fixed cost

Reference:

Hegely, L., & Lang, P. (2020). Reduction of the energy demand of a second-generation bioethanol plant by heat integration and vapour recompression between different columns. *Energy*, *208*, 118443.