Energy Saving for Close Boiling Mixtures

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***Abstract:*-Separation of close boiling mixture requires a huge amount of energy. Nearly 40-60% of the total energy used in the chemical industry is used for the separation of product by distillation. To reduce energy consumption and improve the thermal efficiency of distillation various improved technologies have been suggested. Mechanical vapour recompression heat pumps (MVRHPs) can recycle the energy of the vapour and thus can be used in reducing the energy requirements of fractionating close boiling mixtures. Three different distillation schemes, namely, conventional distillation, top MVRHP distillation, and bottom-flashing MVRHP distillation, were simulated for the separation of the close boiling mixture of n-butane and iso-butane using Aspen Hysys to determine the economically best option.**

The research results indicate that, compared to conventional distillation, the energy savings for bottom-flashing MVRHP distillation and top MVRHP distillation can reach 7.92% and 72.92%, respectively.

***Keywords*—energy saving, close boiling mixture,MVRHP, BFHP & Hysys.**

I. INTRODUCTION

Conventional distillation system used in the petroleum and chemical industries for the separation of fluid mixtures is highly energy intensive. Among energy-saving technologies, mechanical vapor recompression heat pumps (MVRHPs) are the most efficient technique for minimizing energy consumption, especially for vapor-involving systems.

Various techniques, such as heat integration, heat pumps, thermal couplings and others have been employed to achieve energy reductions. Nowadays different types of assisted heat pump distillation systems exist and have found practical applications in the industries. The most commonly used are the absorption heat pump (AHP) and mechanical heat pump (MHP). The MHP is categorized into three types, the vapor recompression heat pump (VRHP), bottom flash heat pump (BFHP) and closed cycle heat pump (CCHP). Among the aforementioned types, the VRHP has gained more recognition due to its outstanding performance. This technology pressurizes vapor of a low grade heat to a higher grade by using mechanical power and then the pressurized vapor provides a heating effect when condensing benefits.

II. PROCESS DESIGN & OBJECTIVE

The main aim of our work is to simulate close boiling mixture distillation process and find out suitable energy saving options for a given separation task. Here we have chosen a close boiling system with 100 kmol/hr of an equimolar binary mixture of i-butane/n-butane. The mole fraction of i-butane in the top product was specified as 0.9, and the mole fraction of n-butane in bottom product was specified as 0.9. The boiling point of n-butane and iso-butane are respectively 273^0C and 261^0C. To determine the best alternative to the conventional distillation we have simulated the conventional distillation column, distillation column with top vapor recompression heat pump and bottom flashing heat pump case.

Energy requirement of the conventional process will be compared with the distillation column with the top vapour recompression heat pump case and Distillation column with bottom flashing heat pump case to find out the best suitable technology for energy saving. We are using HYSYS model version 2004.2 under licence from Aspentech.

III. LITERATURE SURVEY

Quadri [1] optimised the design of a propylene/propane system using single and double stage vapour recompression systems, and,whenAnnakou and Mizley [2] studied the same system, they found that when using either a single or double stage vapour recompression system, the annual costs could be reduced by 37%. Ferre et al [3] applied a direct vapour recompression heat pump to an ethylbenzene/xylene separation and to an ethylbenzene/styrene separation; both cases reduced energy consumption. An absorption heat pump was described by Davidson and Campagne [4] as an absorption refrigeration system redesigned for use at temperatures entirely above ambient. With this kind of heat pump, Tufano [5] estimated that a 40% energy saving could be reached.

Technology	**Condition of separation task**	**Performance information**	**Application**	**References**
VC, MVR, Bottom Flashing column integration	C4 splitters, P=5 bar, ΔTb=10K. Feed upgrade from 19%-99.1% I butane.	MVR allows higher energy & cost savings (50% lower TAC) than column integrated schemes.VC savings are similar to MVR with higher energy costs. 36% energy savings from column integration	Case study	[6]
MVR, AHP	n-Butane/i-butane separation. ΔTb=10 K at P 10 kPa	MVR yields 33% energy savings and 9% less TAC. AHP incorrectly implemented. Both compared to conventional distillation.	Case study	[7]
HIDiC, MVR	Propane-propylene separation.	MVR Industrial implementation gives COP =7.4 and 37% TAC. HIDiC case study yields COP =10 and 25% TAC savings against MVR with ΔTb =10.9 K.	Case study/in dustrial Implem entation	[8,9]

IV. HYSYS SIMULATION OF THE DISTILLATION COLUMN SYSTEMS

A. Distillation Column with Conventional Case

The flow diagram of the conventional scheme is shown in **Fig. 1.** To compare the advantages of introducing a heat pump system into a conventional distillation column, 100 kmol/hr of an equimolar binary mixture of i-butane/n-butane was fed to the column. The inlet stream was supplied as a saturated liquid at 710 kPa pressure; the mole fraction of i-butane in the top product was specified as 0.9, and the mole fraction of n-butane in bottom product was specified as 0.9 The column for this system was initially set up using the short-cut column design facility to obtain an initial estimate for the number of trays required and the reflux ratio needed in the column. The column was then simulated with the rigorous column facility which converged successfully.

To determine optimal conditions, the top column pressure was varied between 500 and 1000 kPa, while maintaining the ratio *R/Rmin*at 1.3. The lower pressure limit was 500 kPa because smaller values would significantly increase costs due to the requirement to use a refrigerant fluid, instead of air, for the coolers. In all simulations column pressure drop was kept constant at 20 kPa. For a top product pressure of 700 kPa and a ratio *R/Rmin*of 1.3, top column temperature is 52.24 ºC and bottom column temperature is 63.65 ºC. In this case, 33 theoretical stages are needed to reach the required separation. Table 1 shows how the number of theoretical stages varies with *R/Rmin*and with column pressure.

In all simulations in this paper the feed is supplied at the same condition, and the product streams are required as saturated liquids at 700 kPa. Cooling is provided by air-cooled heat exchangers.

Table 1: Optimal TheoreticalStages And Feed Stages For Different Column Pressures R/Rmin= 1.3

Top Pressure (kPa)	Theoretical Stages	Feed Stage
500/520	30	15
600/620	32	16
700/720	33	17
800/820	34	17
900/920	35	18
1000/1020	36	19

Table II: Conditions of the main streams of the conventional distillation process with column top pressure equal to 700 kPa and R/Rmin ratio =1.3.

Stream	Temperature (ºC)	Pressure (kPa)
Top product outlet stream	52.24	700
Bottom product outlet stream	63.65	720

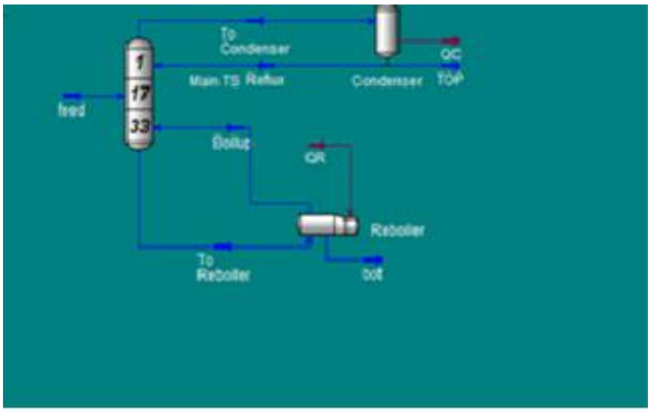

Fig.1.Hysys flow diagram for conventional case

B. Distillation Column with Top Vapour Re-compression Heat Pump

Figure 2 shows the flow diagram of the top vapour recompression scheme. The top vapour was compressed with compressor K-100 to raise its temperature and promoting its energy content to be more usable. The pressure of the compressed vapour was increased from 700 kPa to 1540 kPa and the temperature was increased from 52.6 ºC to 88.5 ºC. The latent heat of the top vapour is used to boil up the bottom column outlet stream in the heat exchanger E-100. The compressor outlet stream is condensed and cooled to 68.4 ºC, while the bottom column outlet stream is partially boiled.

Top column outlet stream is further cooled in the Air cooler AC-100 to 52.3 ºC before being recycled to the column. This stream is then divided in two in TEE-100. One outlet stream is the final top product and the other one is recycled back to the column. After E-100 heat exchanger, the bottom column outlet stream is divided in V-100 flash drum. . The vapour outlet stream is recycled back to the column, and the liquid outlet is the final bottom product stream. As in the case of conventional distillation, the top column pressure was varied between 500 and 1000 kPa, while maintaining the ratio *R/Rmin*at 1.3. In the same way, the ratio *R/Rmin*was varied between 1.1 and 1.5 while keeping top column pressure at 700 kPa. Note that 'direct' heat exchange between the top and bottom streams is more thermodynamically efficient than via a separate heat pump fluid. Table 3 shows stream temperatures and pressure for the case when the top column pressure is 700 kPa, and *R/Rmin*is 1.3.

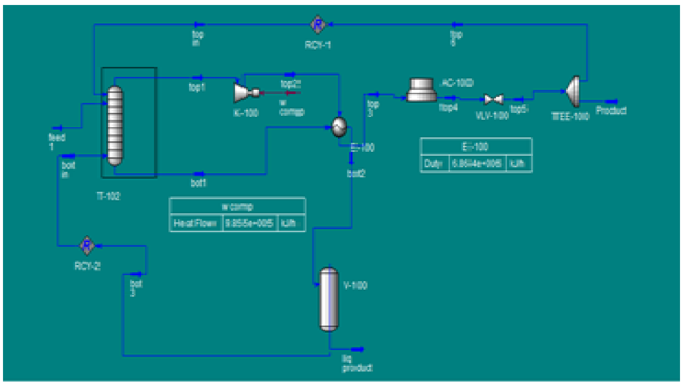

Fig.2 Hysys process flow diagram for the vapour recompression heat pump

Table III: Conditions of the main streams of the top vapour recompression heat pump case with top vapour pressure equal to 700 kPa and R/Rmin ratio equal to 1.3

Stream	Temperature (ºC)	Pressure (kPa)
Top column outlet stream	52.64	700
Bottom column outlet stream	63.41	720
Compressor outlet stream	88.49	1540
Top Product outlet stream	52.32	700
Bottom product outlet stream	63.71	720

C. Distillation Column With Bottom Flashing Heat Pump

Fig.3. shows the flow diagram of the bottom flashing scheme.The outlet from the column bottom is expanded in VLV-100 valve to decrease its temperature and allow heat exchange with the top stream in E-100. the pressure is decreased from 720 kPa to 360 kPa and the temperature of this stream is decreased from 63.5 ºC to 37.0 ºC In the Heat exchanger E-100 boil up the bottom column outlet stream and condense the top column outlet stream. The bottom stream is recompressed in K-100 compressor. Hence its temperature is increased to 63.9 ºC, and it must be slightly air-cooled before being recycled to the column (AC-100 block). As in the case of conventional distillation, the top column pressure was varied between 500 and 1000 kPa, while maintaining the ratio *R/Rmin*at 1.3.

Table IV: Conditions of the main streams of the bottom flashing heat pump case with top column top pressure equal to 700 kPa and R/Rmin equal to 1.3

Stream	Temperature (ºC)	Pressure (kPa)
Top column outlet stream	52.60	700
Bottom column outlet stream	63.51	720
Valve outlet stream	37.03	360
Top product outlet stream	52.29	700
Bottom product outlet stream	63.83	720

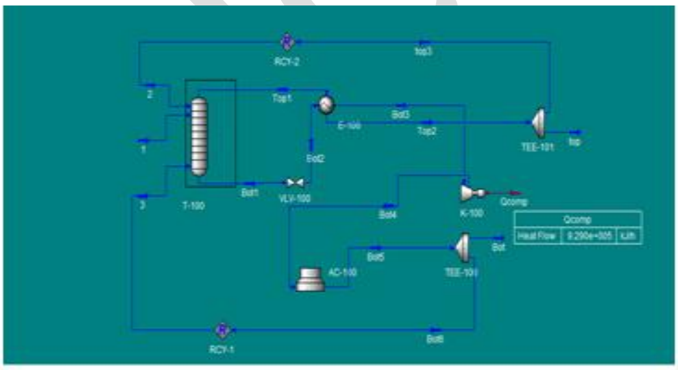

Fig 3. Hysys flow diagram for bottom flashing heat pump

IV. CONCLUSION

We have studied the simulation of three different distillation alternatives for separating an n-butane/ iso-butane mixture; including conventional distillation, top MVRHP distillation, and bottom-flashing heat pump distillation. Using the simulation result we will recalculate the energy savings and total annual cost. From the hysys flow diagram we can see that substantial energy savings can be achieved by using MVRHPs for separating close-boiling mixtures. Obviously, the top MVRHP distillation scheme provides advantages in terms of higher energy savings.

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