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Process Simulation and Evaluation of Ethane Recovery Process using Aspen-HYSYS

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In this work, the process of ethane recovery plant was simulated for the purpose of Front End Engineering Design. The main objective is to carry out a series of simulation using Aspen HYSYS to compare recovery of ethane from Joule Thomson (JT) Valve, Turbo-Expander and Twister Technology. Twister technology offers high efficiency, more ethane recovery and lower temperature than JT valve and turbo-expander process. It lies somewhere between isenthalpic and isentropic process due to its mechanical configuration. Three processes were compared in terms of recovery of ethane. To conduct the simulations, a real gas plant composition and design data were utilized to perform the study for comparison among chosen technologies which are available for ethane recovery. The same parameters were used for the comparisons. Effect of operating conditions including pressure, temperature, and flow rate as well as carbon dioxide on the recovery of ethane was examined.

1. Introduction

Natural gas (NG) has been used as fuel for over 150 y and has gained importance as energy source recently (Rezakazemi et al., 2018). Although there are some difficulties associated with NG such as storage and transportation, the importance of natural gas has been increased in the last 25 y (Azizi et al., 2017). Nowadays, NG is an indispensable source of fuel worldwide and provides 22 % of world total energy (Rezakazemi et al., 2017). However, investigations for alternative fuel sources have been increasing due to growing energy demands (Fazaeli et al., 2015).

Natural gas is composed of organic and inorganic compounds with alkanes being the most abundant along with impurities such as carbon dioxide (CO₂), hydrogen sulfide (H₂S), mercaptans and some traces of carbonyl sulphide (COS) (Bhran et al., 2016). NG primarily consists of methane. Composition vary from 70 to 90 % depending upon the reservoir (Jin and Lim, 2018). Removal of acid gases such as CO₂ and H₂S is very crucial due to environmental and health reasons (Rezakazemi et al., 2011). Natural gas extraction process also leads to the recovery of other by-products (Kherbeck and Chebbi, 2015), i.e. Natural Gas Liquids (NGLs), which bring significant value-added products (Estupiñan Perez et al., 2016). NGL are valuable components in natural gas and these are basically hydrocarbons having the same chemical composition and with a variety of applications. These liquids are a major liquid product that do not further fractionate in demethanizer bottom. The process of removing natural gas liquid is called NGL recovery. Selling value for NGLs are higher, because they have a number of applications. NGL refers to heavier hydrocarbon such as ethane, propane, butane and natural gasoline (propane) (Chebbi et al., 2010). The heating value of NGL enhances 600 times because of phase change from gas to liquid natural gas (Li et al., 2017).

Currently, there are two main processes being used for ethane recovery from natural gas, i.e. Joule Thomson (JT) valve and turbo expanders. Recently, a new process has been developed, i.e. Twister for ethane recovery which offers great operational advantages. Twister is low temperature separation device also known as supersonic technology for replacing existing technologies such as JT and Turbo expanders (Esmaili, 2016). However, there is a definite need to compare the efficiency and performance of these three methods in ethane recovery. The purpose of this study is to simulate the recovery of ethane process by well-known process applied

throughout industries, i.e. JT valve and turbo expanders along with the newly introduced technology Twister. This paper aims to compare Twister technology for excessive recovery of ethane from natural gas with previously known process. Hence, a real gas plant composition and design data was utilized to perform the study for comparison between chosen technologies available for ethane recovery. Aspen HYSYS was utilized for simulation and optimization of process.

2. Process Simulation

2.1 Fluid package

Process simulation is model-based representation of chemical, physical and other technical processes and unit operations (Marjani et al., 2012). Process simulation was carried out to detect abnormal behaviors such as hydrate formation due to temperature pressure drop, flashing of liquid across control/drain valves, condensation of vapors due to cooling, the time-inventory behavior of inventory stream during depressurization, fall in temperature below hydrocarbon or water dew point etc.

The simulation was performed in Aspen HYSYS which contains 30 different thermodynamic models. Phase equilibrium behavior and energy level of pure compound/mixture system is usually represented by thermodynamic models.

The equation of states are used to model single or multi-phase systems and measure thermodynamic features such as enthalpy, density, phase balances etc. It is important to determine the proper equation of state. Peng Robinson equation of state is generally recommended property package for oil/gas and petrochemical applications, and is ideal for vapor-liquid equilibrium (VLE) calculations and solves single, two- and three-phase systems efficiently.

2.2 Process optimization of tower

Peng Robinson equation of state was applied at constant pressure to determine bubble point and dew point of feed. For ethane separation, all parameters are supposed constant. Feed temperature was altered from bubble point temperature to real gas temperature and molar ratio of ethane and methane was observed in top and bottom of demethanizer tower. It is pointless to optimize process condition in order to achieve higher recovery level if it's not economically justified. Process efficiency usually declines and operating or capital cost rises when a higher recovery level is expected which is due to requirement of more energy.

HYSYS built-in optimizer was used throughout this study for optimization. Once the simulation is completed and converged, the optimizer is used to evaluate operating conditions which maximize recovery of ethane. Objective parameters and constraints are defined in the spreadsheet of the optimizer for optimization purposes. This helps achieve maximum recovery as well as reduced utilities and power consumption. For this project, the followings items were assumed:

- Primary variable: Temperature and Pressure of stream exiting JT/Turbo-Expander and Twister
- Objective function: Ethane Recovery
- Constraint: Feed Pressure/Temperature /Flow, Demethanizer Pressure

By manipulating the defined primary variables, it calculated optimum condition by iteration of giving the formula to improve recovery and minimization of chiller duty and compression power for each simulation case.

2.3 Conceptual design basis for simulations

The objective of setting up the Ethane Recovery Plant is to treat the raw gas containing sour gases to meet the pipeline gas quality specifications. The gas treatment shall contain the system for removal of acid gases as well as effect of utilizing Turbo Expander, JT valve and Twister technology for comparison. To meet this objective, the simulations should be fortified with Gas Treatment Unit, Dehydration Unit, Turbo Expander, JT Valve, Twister.

3. Results and discussions

3.1 Process simulation

The flowsheet generated in Aspen HYSYS is shown in Figure 1. Remarkable ethane recovery was seen in this process. Comparison between Turbo-expander and Joule-Thompson valve efficiency for this case is discussed in the next section.

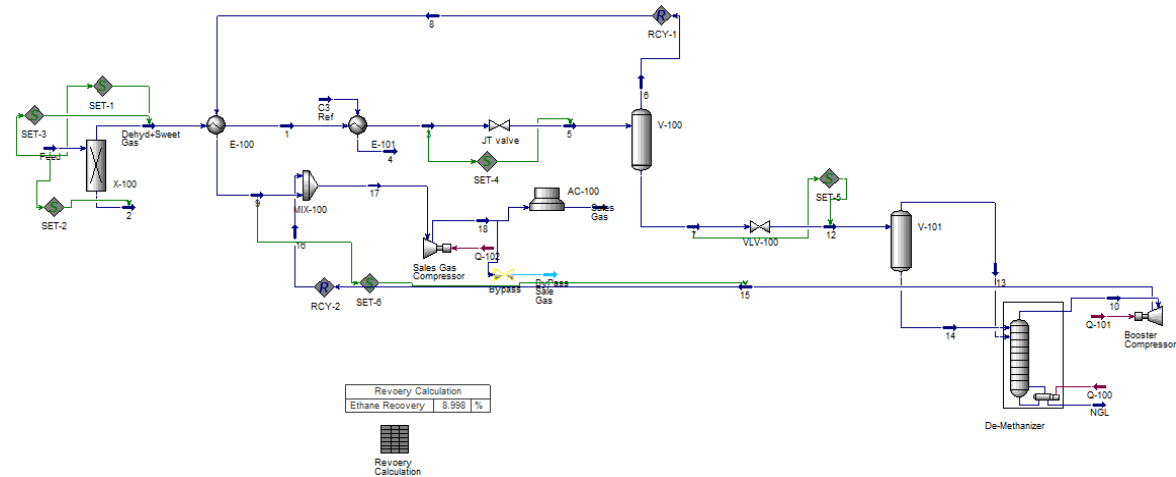


Figure 1: Process Flow Diagram for Front End Design of Ethane Production Process in Aspen HYSYS.

3.2 Comparisons of technologies for ethane recovery (Joule/Turbo-expander/Twister)

For the sake of study, the simulations were conducted for three scenarios of feed gas flowrates 16.35, 22.89, and 32.70 m³/s. Pressure ranges were 6.205×10⁶, 7,584,233, and 9,652,660 Pa. Temperature ranges are falling between the assumed site data. Selected temperatures are as follows: 0 °C (Winter Case), 40 °C (Operating Case), 60 °C (Summer Case). Each case is simulated to different flowrates and pressure in order to evaluate and compare the performance of three selected technologies against each other on the basis of recovery of ethane from these methodologies.

3.3 Comparison of JT valve and Turbo-expander efficiencies by using Ethane Production Plant Scheme

One of the obvious options for optimization is that whether it is possible to use the turbo-expander in place of JT valve, which can improve the power recovery by making process as energy efficient. Table 1 indicates the power comparisons between JT and Turbo-expander methods.

Table 1: Power Consumption for JT valve and turbo Expander.

Description	Pressure (Pa)		Temperature (°C)		Exporter Gas Compressor Power (J/s)
	P _{in}	P _{out}	T _{in}	T _{out}	
JT Valve	6.343×10 ⁶	2031885	45.55	-78.78	2510025.9
Turbo Expander	6.343×10 ⁶	2031885	45.55	-89.83	2008915.6

Chilled gas from Turbo-Expander Knock-Out Drum is directed to the Turbo-Expander where the gas expands as it flows across the turbine blades and cools near the isentropic gas expansion process. Since the expansion is near isentropic, expander outlet temperature is significantly lower than that is achieved by JT valve. The Joule Thomson process is a constant enthalpy expansion, whilst the turbo expander process is a near constant entropy expansion. The Turbo Expander can recover useful work from the gas expansion process if a re-compressor is required. Turbo-expander energy can be utilized in running the re-compressor so that more power recovery can be done.

The simulation was made in order to study the effect of temperature, pressure, and flow of three different technologies available for ethane recovery. The data are presented in Tables 2 - 4. The ethane recovery of the process using the turbo-expander is higher than 90 % during both summer and winter. The simulation results also showed that the recovery of the process for flow sheet containing JT Valve is about 10 % while Twister simulation showed a 75 - 85 % recovery.

Table 2: Assessment Table for JT Valve.

Parameter s	Winter			Operating			Summer		
Pressure (Pa)	6.205x10 ⁶	7,584,233	9,652,660	6.205x10 ⁶	7,584,233	9,652,660	6.205x10 ⁶	7,584,233	9,652,660
Flow (m ³ /s)	16.35	16.35	16.35	16.35	16.35	16.35	16.35	16.35	16.35
	22.89	22.89	22.89	22.89	22.89	22.89	22.89	22.89	22.89
	32.70	32.70	32.70	32.70	32.70	32.70	32.70	32.70	32.70
Recovery %	8.998	11.24	11.67	8.998	11.24	11.67	8.998	11.24	11.67

Table 3: Assessment Table for Turbo-expander.

Parameter s	Winter			Operating			Summer		
Pressure (Pa)	6.205x10 ⁶	7,584,233	9,652,660	6.205x10 ⁶	7,584,233	9,652,660	6.205x10 ⁶	7,584,233	9,652,660
Flow (m ³ /s)	16.35	16.35	16.35	16.35	16.35	16.35	16.35	16.35	16.35
	22.89	22.89	22.89	22.89	22.89	22.89	22.89	22.89	22.89
	32.70	32.70	32.70	32.70	32.70	32.70	32.70	32.70	32.70
Recovery %	91.4	90.95	90.66	91.5	91.2	91.04	91.56	91.39	91.04

Table 4: Assessment Table for Twister.

Parameter s	Winter			Operating			Summer		
Pressure (Pa)	6.205x10 ⁶	7,584,233	9,652,660	6.205x10 ⁶	7,584,233	9,652,660	6.205x10 ⁶	7,584,233	9,652,660
Flow (m ³ /s)	16.35	16.35	16.35	16.35	16.35	16.35	16.35	16.35	16.35
	22.89	22.89	22.89	22.89	22.89	22.89	22.89	22.89	22.89
	32.70	32.70	32.70	32.70	32.70	32.70	32.70	32.70	32.70
Recovery %	73.6	83.18	27.41	73.6	84.3	35.1	83.84	80.93	49.3

3.4 Pressure Variation

For further optimization of the facility, it is observed that there is a possibility of operating the gas plant at higher pressure since wellhead flowing pressure is much higher. It is understood that the facility is operated at the lower pressure since there is a possibility of hydrates formation at the downstream of JT valve. Gas hydrate is an ice-like crystalline solid formed from a mixture of water and natural gas, usually methane. Hydrates once formed are extremely difficult to break and can choke piping. In order to utilize the available upstream flowing pressure, the possibility of increasing the choke valve downstream pressure is evaluated. After carrying out simulation runs for various cases, it is confirmed that as facility pressure is increased, the difference between the actual temperature and hydrate formation temperature decreases raising the possibility of the hydrate formation.

This increased pressure is also responsible for the high recovery of NGL products yet in the case of JT valve it increases power consumption, however, Turbo-Expander has an advantage to recompression that saves additional power (Figure 2).

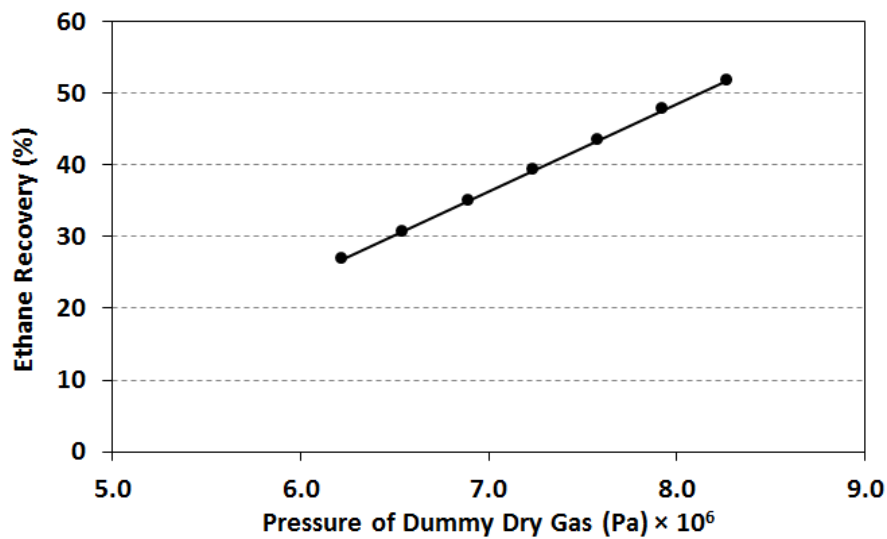


Figure 2: Feed Pressure Vs. Ethane Recovery - Turbo Expander Case.

3.5 Effect of Feed Pressure on Refrigeration Load and Compression Power

The effect of feed pressure was also studied (Figure 3). Utilizing JT technique, the pressure is decreased by a valve so compressor load would be higher than Turbo expander and Twister Technology due to the conversion of utilizable work by expansion is transferred to the attached compressor which reduces the sales gas compressor load to a certain extent. Figure 3 shows the concurrency with the above statements.

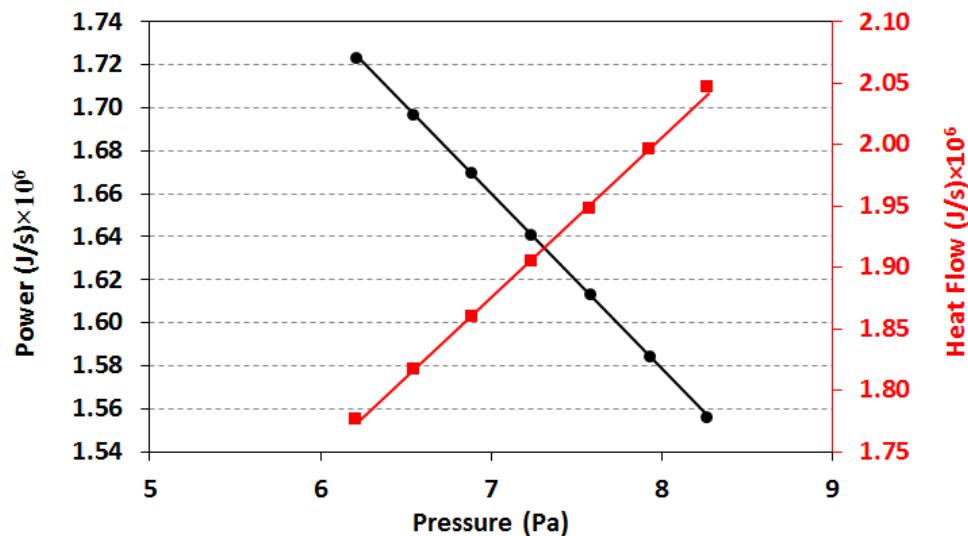


Figure 3: Feed Press Vs. Compressor and Refrigeration Load - JT case.

4. Conclusions

This article presents results of process simulation and comparison of the operating principles of a typical JT valve operation, turbo-expander and a supersonic gas separation Twister™ system as well as the analysis of the results and simulation's outcomes. A range of feed compositions, temperatures, and pressures which represent the possible ranges of feed conditions in the actual gas plants are employed in the study to produce comprehensive results. It was figured out that in overall, Twister is more efficient than turbo-expander; however, there is the indistinguishable difference between the performance of Twister and turbo-expander with the lean feed cases. In addition, whereas the feed temperature does not cause much change in the rate of NGL's recovery, the feed pressure and feed composition play more important roles. They all follow the same pattern,

the higher the feed pressure is, the higher the recovery rate is; and the richer the feed is, the higher the amount of NGL recovered is. Feed pressure plays a crucial role in gas processing acting as source for cooling the gas to low temperature. The pressure should be around 5.861×10^6 to 6.895×10^6 Pa while entering recovery section. Furthermore, Turbo-expander is economically attractive if gas flowrate is more than $1.63 \text{ m}^3/\text{s}$. Joule-Thompson expander was proved to be the least effective process for the recovery of ethane as the lighter end product of vapor separator can be cooled but can't be liquefied by JT valve. However, JT valve can be used to cool the heavier effluent streams from the separator making it easier to separate components through the distillation column after. Throughout the study, the results reflected the similarities between turbo expander and Supersonic technology like comparable efficiency till the similarities between twister and JT expanders like the response towards pressure. The results reflected the differences between the valves as well, like the trajectory in opposite directions in adiabatic efficiency vs. recovery of ethane. None of these expanders alone can achieve the desirable recovery of ethane reaching the demands with minimal wastage. The combinations are to be included in the systems to achieve the better output. It was observed that replacing the JT valve is becoming an obsolete technique to recover ethane or other NGL products as compared to Turbo-expander and Twister. It was also observed that with a higher gas pressure, dehydration quality can be achieved, the hydrate formation temperature can be reduced which in turn allows higher facility pressure with this higher pressure, there can be potential power saving of additional kW. From the simulation of ethane production plant, it was revealed that replacing the JT valve with Turbo-expander for desired gas dew pointing can provide potential power saving of $\sim 500,000 \text{ J/s}$.

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