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RESEARCH ARTICLE

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SELECTION AND SIZING OF PACKING MATERIAL FOR DEBUTANIZER COLUMN TO ACHIEVE MAXIMUM TARGET RECOVERY

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ABSTRACT

: Hydrocarbon feed mixture containing light components with a known composition is fed to a debutanizer column to recover 98% of N-Butane overhead and 95% of Iso-Pentane from the column base for the given feed conditions. The main objective of this work is to simulate a debutanizer column with packings to find the appropriate packing material and its size for the column. Design of optimized column height, diameter, HETP, energy flow, condenser and reboiler duty with the best suited Fluid packages like Non-random two liquids (NRTL), Peng Robinson (PR), Wilson is done to achieve complete target recovery using Aspen HYSYS.

Key words: Debutanizer column, packing, Fluid package, HETP, NRTL

INTRODUCTION

Distillation column is considered one of the most common unit operations in the chemical industry. However, its complex behaviour and highly un-predictive nature, has made it as a unit operation which is complicated and difficult to handle by engineers [1]. Packed columns are used in distillation applications where the separation is based on relative volatility of components present. They are also used in distillation applications where the separation is particularly difficult due to close boiling components. The debutanizer column is an important part of several process units of the oil refinery [2]. The total energy consumption of an average unit, the separation steps accounts for about 70%, and of the separation consumption, the distillation method accounts for about 95% [3]. They are also used to remove contaminants from a gas stream (absorption). However, packed columns can also be used to remove volatile components from a liquid stream by contacting it with an inert gas (stripping).The purpose of a packed bed is typically to improve contact between two phases in a chemical or similar process. Packed beds can be used in a chemical reactor, a distillation process, or a scrubber, but packed beds have also been used to store heat in chemical plants. Packed bed can also be used in chemical reaction. They are tubular and are filled with solid catalyst particles, most often used to catalyze gas reactions. The main objective is to simulate the debutanizer column [1] for the feed conditions given in (Table 1) to achieve maximum target recovery of 98% of N-Butane in the overhead and 95% of Iso-Pentane from the column base. It has been variously estimated that the capital investment in separation equipment is 40-50% of the total for a conventional fluid processing unit. Initially the simulation is carried out with ASPEN PLUS process simulator for the given feed conditions to obtain the required results like column height, diameter, HETP, energy flow, condenser and reboiler duty [4] using three different thermodynamic property methods like Non-random two liquids (NRTL), Peng Robinson (PR) and Wilson. By comparing all the three thermodynamic property methods [5] best set of results were selected and utilized for further simulation in HYSYS where the tray sizing is done for the entire section with different type and size of packings [6].

Packing Material Characteristics:

As a rule of thumb there are certain conditions which a column design must satisfy. They are [7, 8]

1. $\left(\frac{\text{Column Diameter}}{\text{Packing material diameter}}\right)$ must be in the range of 8 to 12.
2. Permissible pressure drop per unit length of column must be between 0.2 to 0.65 KPa.
3. The ratio of height to diameter of the column must be less than 20 to 30.
4. Density of the tower (self-weight)
5. Corrosiveness of the fluid.

A good design must satisfy all these above conditions

Materials and Methods:

Rigorous simulations are usually performed using commercial process simulators such as ASPENPLUS and HYSYS by Aspen Technology, Inc. (http://www.as-pentech.com/). They have a huge list of component library, thermodynamic property methods and unit operation models which facilities the quick simulation of wide variety of equipments which are used in chemical process industries and petroleum industrial sectors [8]. Our main focus is to simulate a packed column debutanizer. The given feed conditions are insufficient to fulfill the need. In order to acquire the entire input information for accurate simulation of packed column. It was decided to simulate the debutanizer as tray column in shortcut method (DSTWU) and then in rigorous fractionation (RADFRAC) to know the exact results like column height, diameter, HETP, energy flow, condenser and reboiler duty which will serve as the input for solving packed column in HYSYS[10]. The simulation work is carried out in three steps and they are explained [11].

RESULTS AND DISCUSSION

DSTWU Model: DSTWU Model is a shortcut distillation unit in ASPEN PLUS which is used to find the approximate values for number of theoretical stages, reflux ratio, feed stage, feed conditions, light key and heavy key fractions which are the required inputs to simulate the model. The operating conditions for the condenser and reboiler are considered to be same as the feed conditions with zero column pressure drop. Selection of thermodynamic property method for the given feed mixture is done with the help of property methods decision diagram shown in Figure 1.Peng Robinson Equation of State (PREOS) was selected and the simulation was carried out.

RADFRAC Model:

RADFRAC Model is a rigorous fractionation model in ASPEN PLUS shown in Figure 2 which will produce accurate results. The results of DSTWU Model was utilized to simulate RADFRAC Column and the specifications are given in Figure 3. The simulation is repeated for reflux ratio of 2 and 2.8 for PREOS and also for other thermodynamic property methods NRTL and Wilson. Comparison of results was shown in Table 2, 3. From these results it was concluded that the best fitted thermodynamic property package is PREOS. At these conditions the Recovery was 98.47% for n-Butane and 99.65% for i-Pentane which was more than targeted.

Distillation column model in ASPEN HYSYS:

Direct packed column distillation unit is not available in HYSYS. Initially tray column was utilized and the entire tray section is converted to packing by tray sizing. The Process Flow Diagram with entire column information acquired from RADFRAC model is shown in Figure 4. The column converges when DOF is 0. Select tray sizing and click Add Utility to include the entire tray section which has to be replaced by the packing material and it is shown in Figure 5. Based on the characteristics of packing material, the choices were made and the result comparisons were shown in Table 4. The Process Flow Diagram with output stream information is shown in Figure 6.

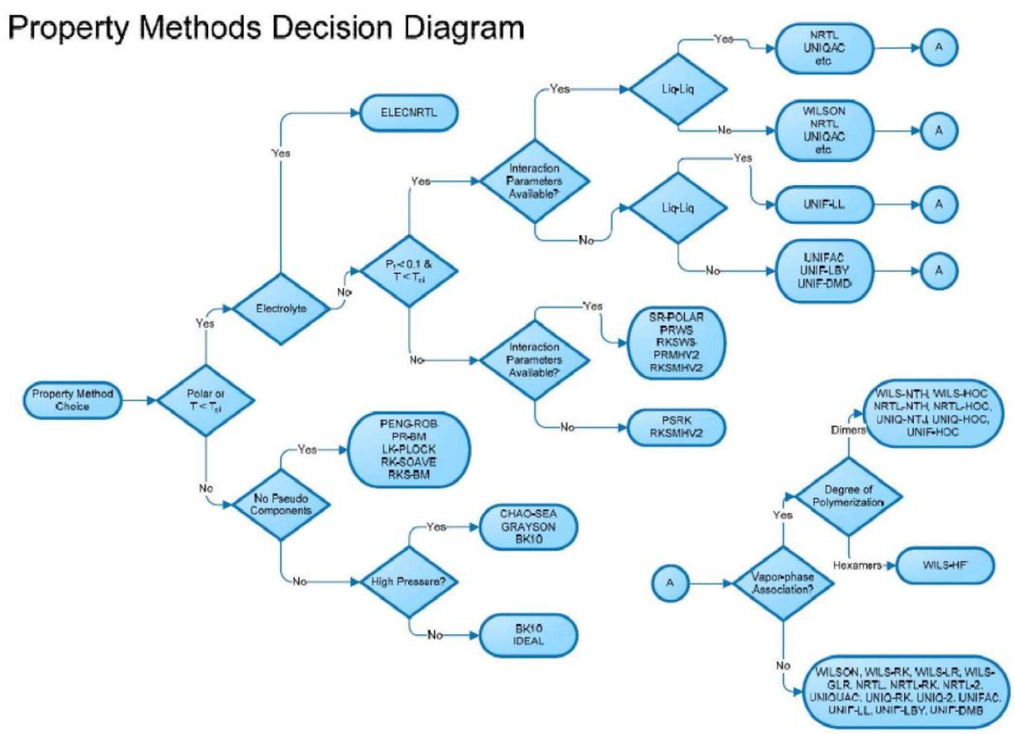

Figure 1. Property methods decision diagram

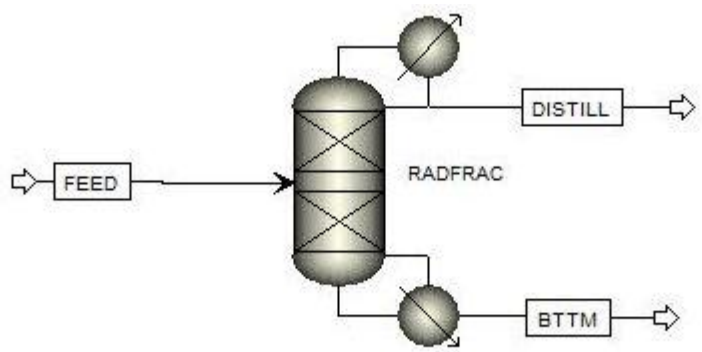

Figure 2. RADFRAC Model

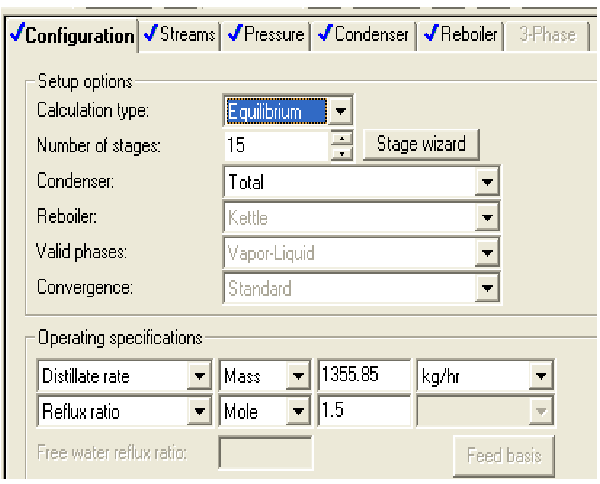

Figure 3. Operating specifications

Table 2 Comparison of property methods

Method	Reflux Ratio	Number of Actual stages	Condensor energy (MM kcal/hr)	Reboiler energy (MM kcal/hr)
NRTL	1.5	12	0.2962	0.1805
	2	11	0.3561	0.2403
	2.8	11	0.4519	0.3362
Peng Robinson	1.5	15	0.2952	0.1740
	2	14	0.3549	0.2337
	2.8	13	0.4503	0.3290
Wilson	1.5	12	0.2931	0.1804
	2	11	0.3561	0.2431
	2.8	11	0.4519	0.3361

Table 3 Comparison of reflux ratio for PR equation

Reflux Ratio	Number of stages	n-Butane % of recovery	i-Pentane % of recovery
1.5	15	98.19	99.17
2	14	98.47	99.65
2.8	13	98.4	99.44

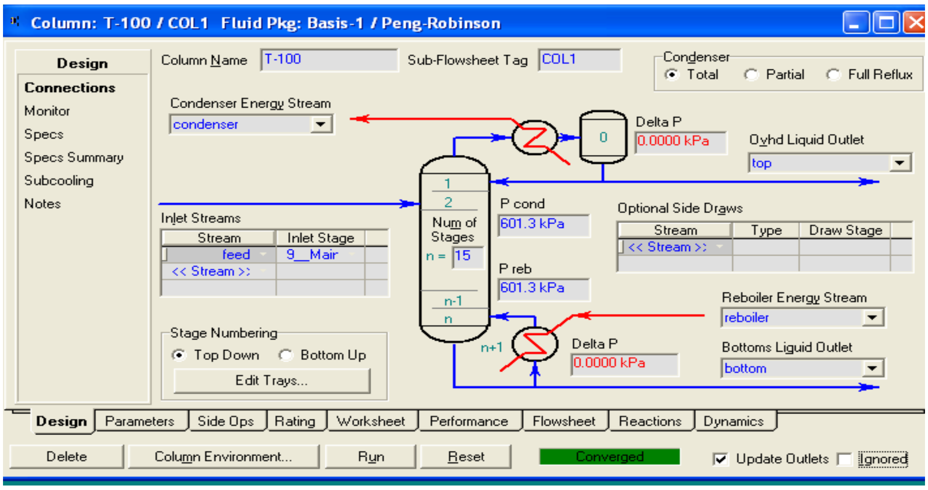

Figure 4: Distillation column information

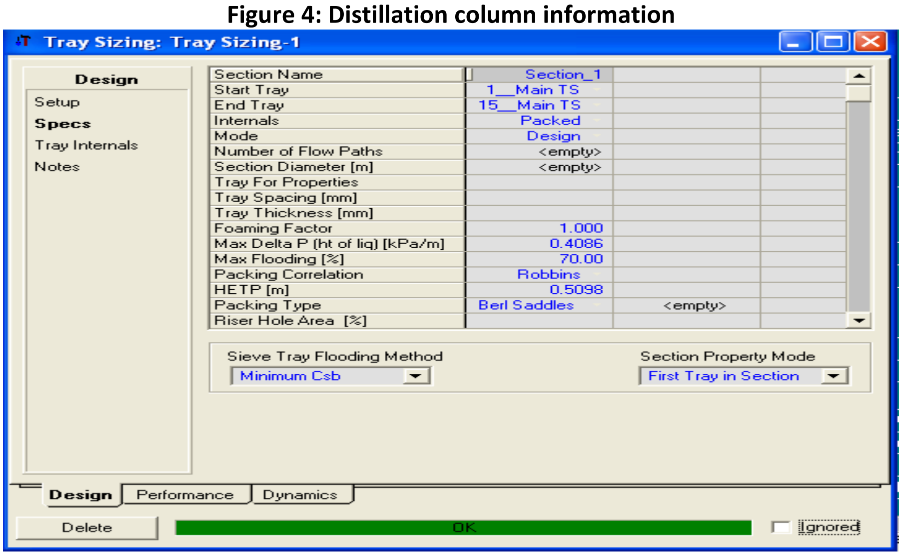

Figure 5: Tray sizing

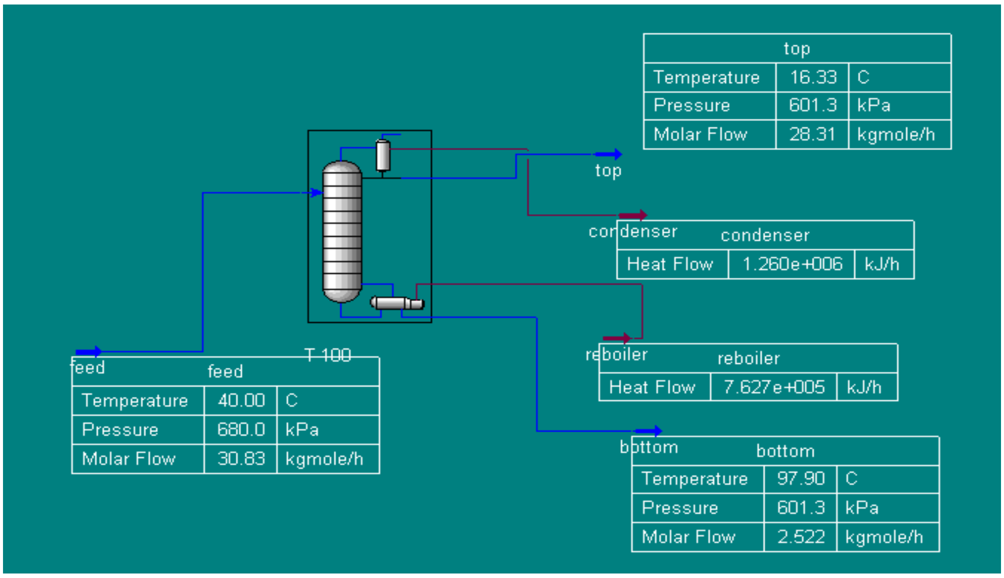

Figure 6: Output material and energy stream results

Table 4 Comparison of various packing materials in ASPEN HYSYS

Packing Type	Size (inch)	HETP (m)	Column Diameter(m)	Height (m)	Pressure Drop (KPa per unit length)
Berl Saddle (ceramic)	0.25	0.5098	1.067	7.467	0.4580
	0.5	0.4608	0.7620	6.913	0.6155
	0.75	0.4310	0.6096	6.465	1.777
Dixon	0.25	0.4608	0.7620	6.913	0.7178
	0.625	0.4608	0.7620	6.913	0.5841
Pall ring(metal)	0.625	0.4310	0.6096	6.495	0.4161
Pall ring(plastic)	0.625	0.4310	0.6096	6.465	0.4829
Intalox Saddles (Ceramic)	0.375	0.4608	0.7620	6.913	0.7265
	0.5	0.4608	0.7620	6.913	0.4227
	0.75	0.4310	0.6096	6.465	1.621
Raschig ring (ceramic)	1.25	0.4310	0.6096	6.465	1.515
	1.5	0.4310	0.6096	6.465	0.4161
Raschig ring (carbon)	1.25	0.7721	4.267	8.5	0.4736
	1.5	0.4310	0.6096	6.465	1.515
Raschigring (metal)	0.75	0.4310	0.6096	6.495	1.591

Conclusion

Based on the comparison of simulated results in ASPEN HYSYS the recommended conditions to attain the target recovery is as follows: Reflux ratio -1.5, Number of theoretical stages-15, Packing (Raschig ring (ceramic))-1.5 inch. The column should be of height-6.465 m and Diameter-0.6096 m. Maximum allowable pressure drop per unit length is found to be 0.4161 (KPa per unit length), HETP-0.4310 m.

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