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Designing De-isopentanizer Columns of Isomerization Units to Increase the Octane Number of Gasoline

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1. ABSTRACT

In this research, the De-isopentanizer tower of the three selected units was designed and redesigned, aiming to examine the octane number of the effluent from the De-isopentanizer tower, the isopentane recovery rate, and improve the processes of the selected units. The octane number of the tower top products in the reference unit and unit 3 are 91.5 and 91.28, respectively. The recovery rate of isopentane in the reference unit is 95.96%, and in unit 3 is 92.68%. Unit 2 has an octane number and recovery of 85 and 75.24%, respectively, which is the lowest among all. By carrying out the retrofit in Units 2 and 3, a new process was achieved. A cost analysis of the De-isopentanizer towers designed for units 2 and 3 and the simulated tower for the reference unit showed that the fixed, operating, utility, and total costs of the reference unit were higher than others.

Keywords: Isopentane, Isomerization, Gasoline, Retrofit, Octane Number.

2. INTRODUCTION

The isomerization process is vital for producing high-octane gasoline in light naphtha isomerization units, and it is crucial to study the design and retrofitting of isomerization units to optimize performance and achieve maximum energy recovery. The De-isopentanizer (DIP) distillation column is a key component of the process that separates isopentane from the feed. The DIP column is important for its application and high energy consumption in the process. Research shows that companies like Axens are primarily focused on optimizing isomerization processes. Axens developed a process that includes a DIP column, which aids in increasing the octane number of products by separating isopentane. This process, called Ipsorb, can achieve a Research Octane Number (RON) of 89-90 [2].

Another study conducted in Alexandria, Egypt, showed that adding separation equipment before and after the reactor could lead to greater economic savings. Researchers found that installing both a De-isohexanizer (DIH) and DIP tower was the most profitable retrofit, resulting in a product octane number up to 86.5 [3].

The objective of this research is to redesign and design new DIP columns to reduce energy consumption and costs while improving gasoline quality. The study suggests a retrofit plan that involves adding DIP columns to units 2 and 3 to examine the isopentane recovery rate and the octane number of the overhead steam. The fixed, operation, and total costs of the simulated and designed columns were analyzed using Aspen Process Economic Analyzer software.

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3. MATERIALS AND METHODS

This research aims to process design and redesign of De-isopentimizer (DIP) columns for three selected isomerization units. The primary objective is to reduce energy consumption and operating costs while improving the quality of the produced gasoline. The process involves preheating a light naphtha feedstock and feeding it into the DIP column to separate isopentane.

The research methodology involves a series of steps to design and optimize De-isopentimizer (DIP) columns. First, a light naphtha feedstock is preheated in a heat exchanger and fed into the DIP column. The purpose of this column is to separate isopentane from feed. The simulation is carried out using Aspen HYSYS software, utilizing the Component Splitter to determine pressure. The Peng-Robinson equation of state was used for predicting thermodynamic properties. The design of the column proceeded in two stages: a shortcut design using the Fenske-Underwood-Gilliland (FUG) method to estimate the number of theoretical trays and reflux ratio, followed by a rigorous tray-by-tray design to finalize the number of trays and feed location. Finally, the RON of the top product, which was obtained from Equation 1, was calculated to assess quality [4].

$$RON = X_{NP} \cdot (RON)_{NP} + X_{IP} \cdot (RON)_{IP} + X_N \cdot (RON)_N + X_A \cdot (RON)_A \quad (1)$$

Where X_{NP} , X_{IP} , X_N , and X_A are the volume fractions of normal paraffin, isoparaffin, cycloalkane, and aromatics, respectively.

Furthermore, the economic analysis was performed using Aspen Process Economic Analyzer to evaluate capital and operating costs.

4. RESULTS AND DISCUSSION

4.1. Column pressure Determination

The optimum operating pressure for each DIP column was determined using Aspen HYSYS software. The top and bottom pressures of the reference unit were set to 0.1 and 0.8 bar-g, respectively. For unit 2, the top and bottom pressures were 0.05 and 0.75 bar-g, respectively.

4.2. Column Design

It is assumed that all three columns require 90 actual trays so that the results can be compared. The condenser and reboiler temperatures were higher for Unit 2 compared to the reference unit. According to Table 1, the reference unit had a higher condenser and reboiler heat duty compared to the other two units.

Table 1. Comparison of the simulation results for units 2 and 3 with the reference unit

	Isopentane Recovery (%)	Bottom Product Molar Flow (kgmole/h)	Overhead Product Molar Flow (kgmole/h)	Reboiler Heat Duty (MW)	Condenser Heat Duty (MW)	Reboiler Temp. (°C)	Condenser Temp. (°C)
Unit 1	95.96	1114	485.25	21.51	25.28	105.9	66.4
Unit 2	75.24	1317	154.4	13.61	11.07	115.2	71.65
Unit 3	92.68	610	102.9	11.92	9.252	116.7	67.43

4.3. Isopentane Recovery and Octane Number

Based on the data presented in Table 1, the reference unit had the highest isopentane recovery at 95.96%, followed by unit 3 at 92.68%. Unit 2 had the lowest recovery rate at 75.24%, possibly due to a lower percentage of isopentane in its feed stream. The octane numbers for the top product were 91.5, 91.28, and 85 for the reference unit, unit 3, and unit 2, respectively. Unit 2 lower octane is because of the lower mole fraction of isopentane (a branched-chain compound) and a higher mole fraction of normal pentane in its overhead product.

4.4. Cost Analysis

The operating, utility, and total costs for the DIP column are the highest for the reference unit since the surface area of the condenser and reboiler is the highest, resulting in higher fixed costs and the greatest utility consumption.

4.5. Process Design Perspective

The study performed retrofits on units 2 and 3 a DIP column was added (Figure 1). For unit 2, the process was converted to a DIP-Penex-DIH process, which is expected to yield an octane number up to 7 units and have a better efficiency. For unit 3, the addition of a DIP column was found to help increase equilibrium reactions, leading to a high-octane product.

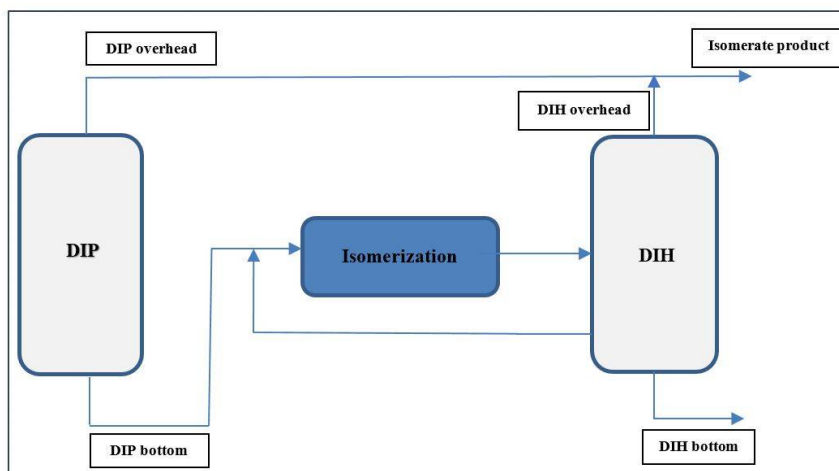


Figure 1. Design of DIP tower for unit 2 and conversion of Penex process to DIP-Penex process-DIH [5].

5. CONCLUSION

This study was conducted with the aim of investigating the quality and energy of the output stream from the DIP column. Unit 2 has the lowest octane number and isopentane recovery. The results of economic analysis of the DIP columns showed that the reference unit had higher fixed, operating, utility, and total costs compared to the other two units. A new process was developed. It is recommended to study the effect of reducing the reflux stream on the energy consumption and costs of units 2 and 3 for future work.

6. REFERENCES

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