Separation of refinery light ends

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Background & Description:

This study presents the simulation and optimization of a refinery light ends separation process using Aspen HYSYS, a commercial process simulation software. The goal of this work was to recover individual hydrocarbon components—propane, i-butane, n-butane, i-pentane, and n-pentane—from a mixed natural gas liquids (NGL) stream through multi-stage distillation. These components are essential for petrochemical processes and LPG blending, and their effective separation enhances both operational efficiency and product value.

The feed mixture, derived from a natural gas treatment system, primarily contains C2–C5 hydrocarbons in the following molar proportions:

Ethane 0.005 / Propane : 0.3320 / I-Butane : 0.3583 / N-Butane : 0.1543 / I-Pentane : 0.103 / N-Pentane : 0.0518

A total of **four distillation columns** were implemented in series to achieve near-complete separation of each component. The simulations focused on optimizing column pressures, feed stage locations, and reflux ratios to ensure purity targets were met for each product stream.

The separation train consists of the following columns:

1. **Depropanizer:** Operated at 17 atm, this column separates propane as a top product with 99.85% purity. i-Butane is the heavy key. A high reflux ratio of 15 was used to achieve the purity target.
2. **Debutanizer:** Operated at 7.1 atm, this column recovers i-Butane and n-Butane overhead, separating them from heavier pentanes.
3. **Deisobutanizer:** Operated at 6.6 atm, this column splits i-Butane from n-Butane, targeting 98% purity of each in their respective product streams.
4. **C5 Splitter:** A final column separating i-Pentane and n-Pentane, designed to achieve near-pure streams of each (≥99%).

The thermodynamic model used throughout was Peng–Robinson, which is well-suited for hydrocarbon systems under moderate to high pressures.

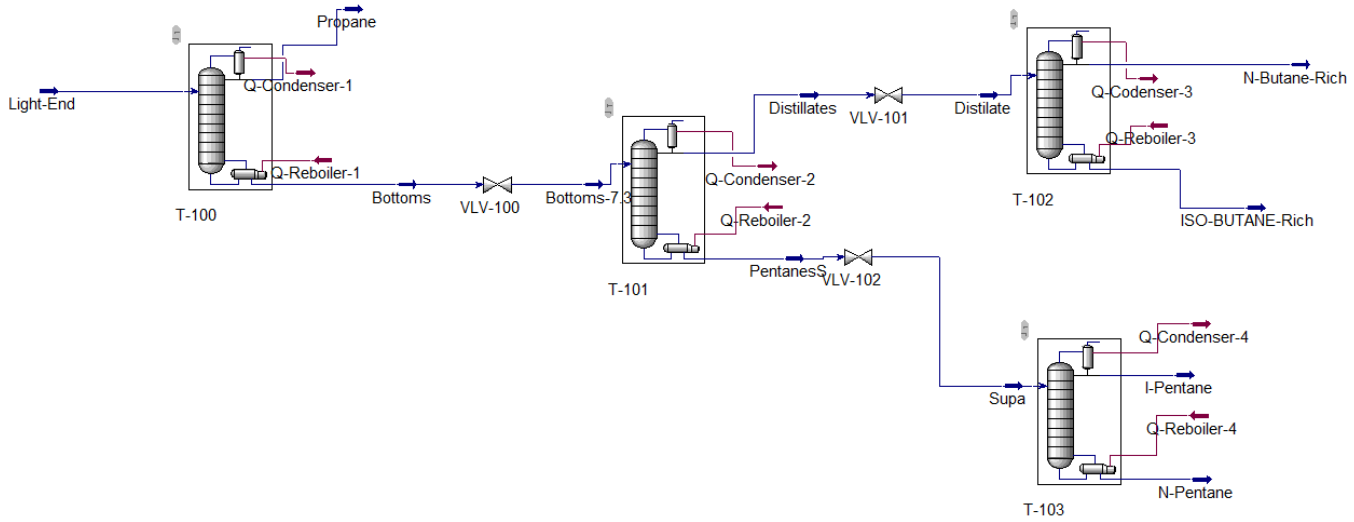
All target purities were achieved by carefully adjusting reflux ratios, feed stage locations, and column pressures. The final flowsheet demonstrates the feasibility of this approach for real refinery systems, balancing energy usage with product quality.

Discussion and Conclusion :

Despite the complexity of the multistage separation, Aspen HYSYS handled convergence well using shortcut and RadFrac columns in sequence. Initial simulations were validated using shortcut distillation with light/heavy key logic, followed by rigorous column simulations to finalize heat duties and tray arrangements. Special attention was given to the Depropanizer, which required a significant reflux ratio (RR = 15) due to the close volatility of propane and i-butane.

This simulation demonstrates a successful application of Aspen HYSYS for the design and optimization of a refinery light ends separation process, recovering pure C3–C5 components through distillation. The methodology confirms the viability of using multi-stage fractionation under optimized conditions and provides a basis for further dynamic simulation and control structure design.

Flowsheet



Results:

Master Property Tableau								
Object	**Light-End**	**Propane**	**Bottoms**	**Distillates**	***N-Pentane***	***I-Pentane***	**I-Butane Rich**	**N-Butane Rich**
T (K)	**378**	**323.1**	**340.7**	**328.9**	***383.9***	***369.9***	**340**	**322.6**
P (Atm)	**17.4**	**17.00**	**7.3**	**7.1**	***7.4***	***6.6***	**7.4**	**6.6**
Molar Flow (kgmole/h)	**1.203e04**	**4002**	**8031**	**6169**	***621.3***	***1241***	**1770**	**4399**
Mole Fract (Ethane)	**0.0005**	**0.0015**	**0**	**0**	***0***	***0***	**0**	**0**
Mole Fract (I-Butane)	**0.3583**	**0.0001**	**0.5368**	**0.6988**	***0***	***0.0002***	**0**	**0.9800**
Mole Fract (I-Pentane)	**0.1030**	**0**	**0.1543**	**0.0008**	***0***	***0.9950***	**0.0027**	**0**
Mole Fract (N-Butane)	**0.1543**	**0**	**0.2312**	**0.3004**	***0***	***0.0030***	**0.9971**	**0.0200**
Mole Fract (N-Pentane)	**0.0518**	**0**	**0.0777**	**0**	***1***	***0.0018***	**0.0002**	**0**
Mole Fract (Propane)	**0.3320**	**0.9984**	**0**	**0**	***0***	***0***	**0**	**0**

Nb : Insignificant quantities (<0) of components in the product streams can be considered negligible, effectively approximating them to zero without impacting the overall process results or conclusions (see flowsheet).

References: Luyben, W. L. (2013). Use of Mass or Molar Reflux-to-Feed Ratios In Distillation Single-End Control Structures. Industrial & Engineering Chemistry Research, 52, 15883–15895. https://doi.org/10.1021/ie401855f