

## Improvement of Energy Efficiency in NGL Recovery Process Using Double Prefractionator Arrangement and Double Dividing Wall Column

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### 1. Introduction

The uses and processing of natural gas (NG) are still evolving since their early twentieth century origins in the United States. Although its primary use is as a fuel, NG is also a source of hydrocarbons for petrochemical feed stocks and a major source of elemental sulfur, an important industrial chemical [1]. Its clean burning and ability to meet stringent environment requirements ensure demand for natural gas [2]. Recovery of natural gas liquids (NGL) has become increasingly economically attractive as a number of its components are often isolated and sold separately. Consequently, numerous methods exist to increase NGL recovery from a feed gas, with potential enhancements involving integrated processes [2-3].

Distillation is the primary separation process used in industrial chemical processing. While it has many advantages, a drawback is its large energy requirement, which can significantly influence overall plant profitability [4]. Increasing energy costs deter energy consumption as do tighter environmental regulations regarding fossil fuel use, leading to research into new and more efficient separation methods [5-6].

Ternary separations typically involve either direct or indirect sequences with two conventional columns. Although the control and operation of conventional columns are simple, their use is inefficient in terms of energy due to the mixing entropy by irreversible split [7]. Therefore, various methods have been developed to improve the energy efficiency of such distillation systems. Many studies confirm that the Fully Thermally Coupled Distillation System (FTCDS) or the Petlyuk column can reduce energy consumption [8-13]. The Petlyuk column allows reversible splits, with no part of the separation being performed twice, which gives superior separation energy efficiency over other column configurations [14].

Instead of having an external prefractionator, the prefractionator can be incorporated into a single shell arrangement by installing an internal wall, which divides the column into the prefractionator and the main section. This dividing wall column (DWC) is conceptually similar to the Petlyuk column, given their thermodynamically equivalent arrangements, and is expected to give a similar energy saving [15]. However, the dividing wall column requires less capital expenditure and space. Its single shell feature, single reboiler and condenser can typically reduce capital expenditure by 30% compared with conventional two column sequences.

This work aims to improve the performance of the depropanizing, debutanizing and deisobutanizing fractionation steps of NGL processing. Furthermore, inter-reboiling of the bottom section of the 2<sup>nd</sup> DWC was also studied to improve the performance of the DDWC.

### 2. Existing process

Liquid hydrocarbons recovered from NGL are typically separated into relatively pure ethane (C<sub>2</sub>), propane (C<sub>3</sub>), isobutane (iC<sub>4</sub>), normal butane (nC<sub>4</sub>), and gasoline products (C<sub>5+</sub>). This is conventionally done by distilling C<sub>2</sub>, C<sub>3</sub> and C<sub>4</sub> from gasoline in sequence and then distilling iC<sub>4</sub> from nC<sub>4</sub>. Because of the large energy consumption, there are numerous configurations and methods known to increase NGL recovery from a feed gas. The difference of operating pressures

complicates columns' integration and directly affects energy consumptions and the use of refrigeration. The high-pressure demethanizer and deethanizer columns should not be integrated with other the columns (depropanizer, debutanizer and deisobutanizer).

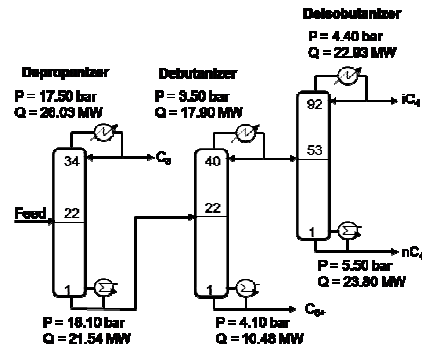


Figure 1. Simplified flow sheet illustrating the separation train of three conventional columns.

The depropanizer, possessing 34 theoretical trays, is operated at 17.50 bar as commercial propane can be condensed with cooling water at this pressure, as seen in Figure 1. The debutanizer and deisobutanizer columns, with 40 and 92 trays, respectively, are operated at 3.50 and 4.40 bar, respectively [16-17]. The final distillation of  $iC_4$  from  $nC_4$  is energy and capital intensive because these compounds' small relative volatility [18]. The Peng-Robinson equation of state that supports the widest range of operating conditions and the greatest variety of systems was used to predict the vapor-liquid equilibria of these simulations [19]. The base case simulation shows that the energy consumptions of the depropanizer, debutanizer and deisobutanizer are 21.54, 10.48 and 23.80 MW, respectively.

### 3. Proposed arrangements

#### 3.1. Integration by the Double Prefractionator Arrangement (DPA)

The integration of debutanizer and deisobutanizer using the prefractionator arrangement has been reported elsewhere [17]. Figure 2 illustrates the double prefractionator arrangement. In the first prefractionator arrangement, the 2<sup>nd</sup> column is considered the main fractionator as well as the prefractionator in the second arrangement. Simulation of this arrangement was performed with respect to the flow of the distillate and reflux streams of the 1<sup>st</sup> and 2<sup>nd</sup> columns, side tray location and the feed tray location in each column, to minimize the size of the column and total energy consumption.

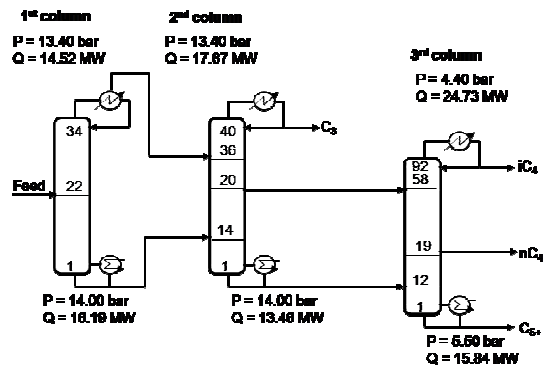


Figure 2. Simplified flow sheet illustrating the DPA system.

The energy savings of this arrangement were 18.50% compared with the conventional column sequence. Note that the side draw stream from the debutanizer in the DPA is vaporous.

### 3.2. Integration by Double Dividing Wall Column (DDWC)

In this sequence (Figure 3), energy saving relies on the first column splitting the components well. The sequence contains two dividing wall columns. The first column isolates  $C_3$  from the mixture, and also partly splits the remaining components. The second dividing wall column completes the separation.

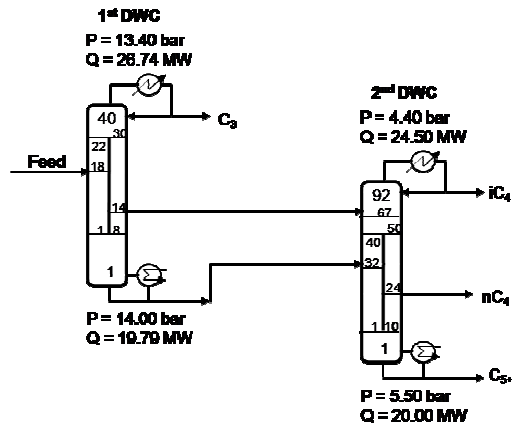


Figure 3. Simplified flow sheet illustrating the DDWC system.

Simulation based on the equilibrium-stage model was performed for this arrangement with respect to the flow of  $iC_4$  in the side stream and in the first dividing wall column, as well as the feed and side tray locations in the two new dividing wall columns to minimize the size and total energy consumption of the system. The DDWC arrangement showed a 28.74% improvement in energy consumption compared with the conventional column sequence. Compared with using three conventional columns of diameters 4.9, 3.6 and 4.5 m, using two DWC of 5.2 and 4.9 m diameter could reduce capital costs.

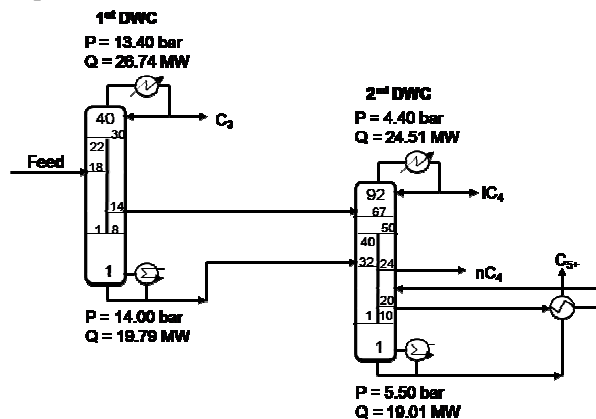


Figure 4. Simplified flow sheet illustrating the DDWC system with interboiling the bottom section of the 2<sup>nd</sup> DWC.

To minimize energy consumption, the bottom liquid product can be subcooled while inter-reboiling the bottom section of the 2<sup>nd</sup> DWC (Figure 4) [16]. This can save 0.99 MW compared with DDWC, i.e. this system reduced energy consumption by 30.50% compared with the conventional column sequence.

#### 4. Conclusions

Complex distillation sequences were studied to improve the performance of the depropanizing, debutanizing and deisobutanizing fractionation steps of NGL processing. The double prefractionator arrangement and double dividing wall column significantly reduced energy consumption compared with conventional distillation. Furthermore, the double dividing wall column, with a decreased number of smaller columns, could reduce investment costs. Further energy savings occurred by inter-reboiling the bottom section of the 2<sup>nd</sup> DWC.

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#### References

- [1] A.J. Kidnay, W.R. Parrish. *Fundamentals of Natural Gas Processing*, 1st ed., Taylor and Francis, **2006**; 1-23.
- [2] D. Elliot, W.R. Qualls, S. Huang, J.J. (Roger) Chen. In *Proceedings of AIChE Spring National Meeting*, 5th topical conference on Natural Gas Utilization (TI) Session 16c-Gas, **2005**.
- [3] J. Mak. U.S. Patent 7,051,552, **2006**.
- [4] M.A. Schultz, D.G. Stewart, J.M. Harris, S.P. Rosenblum, M.S. Shakur, D.E.O'Brien. *CEP*, **2002**, 64.
- [5] J.P. Knapp, M.F. Doherty. *AIChE J.*, **1990**; 36, 969-984.
- [6] I. Malinenand, J. Tanskanen. *Ind. Eng. Chem. Res.*, **2009**; 48, 6387-6404.
- [7] N. Asprion, G. Kaibel. *Chem. Eng. Process.*, **2010**; 49, 139-146.
- [8] A. Jiménez, N. Ramírez, A. Castro, S. Hernández. *Trans. IChemE.*, **2003**; 81 (Part A), 518-524.
- [9] N.V.D. Long, S.H. Lee, M.Y. Lee. *Chem. Eng. Process.*, **2010**; 49, 825-835.
- [10] I.J. Halvorsen, S. Skogestad. *Ind. Eng. Chem. Res.*, **2003**; 42, 605-615.
- [11] E. A. Wolff, S. Skogestad. *Ind. Eng. Chem. Res.*, **1995**; 34, 2094-2103.
- [12] I. J. Halvorsen, S. Skogestad. *J. Process Control*, **1999**; 9, 407-424.
- [13] I. J. Halvorsen, S. Skogestad. *Ind. Eng. Chem. Res.*, **2004**; 43, 3994-3999.
- [14] N. Poth, D. Brusis, J. Stichlmair. *Chem. Ing. Tech.*, **2004**; 76, 1811-1814.
- [15] K. A. Amminudin, R. Smith, D. Y. C. Thong, G. P. Towler. *Trans. IChemE.*, **2001**; 79 (Part A), 701-715.
- [16] D.B. Manley. U.S. patent 5,673,571, **1997**.
- [17] K. A. Amminudin, R. Smith. *Trans. IChemE.*, **2001**; 79, 716-724.
- [18] D. B. Manley. U.S. patent 8,806,339, **1998**.
- [19] Aspen Technology. *Aspen HYSYS Thermodynamics COM Interface*, version number V7.1, **2009**.