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Techno-economic analysis of potential natural gas liquid (NGL) recovery processes under variations of feed compositions

Mesfin Getu[a], *Shuhaimi Mahadzir*[b], *Nguyen Van Duc Long*[c], *Moonyong Lee*[c,*]

[a] *Department of Chemical Engineering, Curtin University of Technology, CDT 250, 98009 Miri, Sarawak, Malaysia*
[b] *Department of Chemical Engineering, Universiti Teknologi PETRONAS, Bandar Seri Iskandar, 31750 Tronoh, Perak, Malaysia*
[c] *School of Chemical Engineering, Yeungnam University, 214-1 Dae-dong, Gyeongsan, Gyeongbuk 712-749, Republic of Korea*

ABSTRACT

This paper presents the different process schemes used for known NGL recovery methods with respect to their economic performance. The original turbo-expander (ISS) was considered as base case plant. The GSP, CRR and RSV process schemes focus on improvement at the top of the demethanizer column. The IPSI-1 and IPSI-2 schemes focus on the bottom of the demethanizer column. All the process schemes were initially built using Aspen HYSYS with a common set of operating criteria. Numerous simulation runs were made by taking various typical feed compositions classified as lean and rich. The economic assessment for each process scheme was later made by considering the capital cost, operating cost and profitability analysis. Results showed that the IPSI-1 process scheme gives the best economic performance with lowest TAC and payback time compared to the other process schemes. On the other hand, the RSV process gives higher TAC and payback time compared to others.

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1. Introduction

Technology trends in gas processing industries have emerged since early 1900s. During those times, heavier hydrocarbons from natural gas streams are removed by compression and cooling methods. A number of changes have been made after that to improve the process efficiency that contributes to the incentive for high recovery of the desired products from the plant, such as refrigerated oil-absorption (Lee et al., 1999). However, a major leap in gas processing industries was the introduction of a turbo-expander design, which is also known as an Industry-Standard Single-stage (ISS) process scheme. This process scheme has certain limitations in terms of operational flexibility and overall recovery performance (Rahaman et al., 2004). The carbon dioxide freezing problem in the demethanizer column was another issue associated with the turbo-expander process scheme (Lynch et al., 2002). Due to these and many other factors, a number of various process scheme options have been evolved and are available in public domain. Among these, only few of them are licensed under the U.S. Patent. The most known ones are those which are developed by Ortloff and IPSI Companies. The gas sub-cooled (GSP), cold residue (CRR) and Recycle vapor-split (RSV) are all owned by Orloff Company. The enhanced NGL recovery processes (IPSI-1 and IPSI-2) belong to IPSI Company.

The GSP process scheme was developed by Campbell and Wilkinson (1981) as an improvement to the ISS process scheme. This process scheme uses a split-vapor feed as a reflux to the rectification section of the demethanizer column. Accordingly, the portion of the feed gas is first condensed and sub-cooled before it is flashed and introduced as a top liquid feed reflux to the demethanizer column. The cold liquid reflux liquid will condense and absorb ethane and propane rising up through the column and thereby allow higher recovery. The other advantage of the cold reflux liquid stream is that it can significantly reduce the risk of carbon dioxide solid

* Corresponding author.
E-mail address: mynlee@yu.ac.kr (M. Lee).
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formation. This is done by warming up the temperature of the cold separator, which in turn enhance the temperature inside the column to minimize the carbon dioxide freezing problem. By using this process scheme, more than 95% ethane can be recovered (Rahaman et al., 2004).

The CRR process scheme was introduced in the original design of GSP by Campbell et al. (1989) to improve ethane recovery efficiency. In this process scheme, an additional compressor has been incorporated to boost a portion of the cold tower overhead. The portion of the overhead stream is then condensed and sub-cooled by split-vapor feed, flashed to column pressure and fed as reflux at the top of the demethanizer column. The reflux stream in the CRR process scheme improves the rectifying section by allowing a clean separation to recover high ethane or propane compared to the GSP process scheme. As a result, ethane or propane recovery in excess of 99 percent can be produced using this scheme (Wilkinson and Hudson, 1992). Even if the CRR process scheme gives a higher ethane or propane recovery with smaller recycle flow and less compression requirement, the capital cost for the newly added cryogenic compressor may be expensive.

The RSV process scheme developed by Campbell et al. (1996) was another alternative process scheme for high NGL recovery. In this process scheme, a recycle stream is withdrawn from the demethanizer column overhead after it has been warmed and compressed. The compressed recycle stream is later cooled sufficiently to make it more condensed before it is supplied as a top feed to the demethanizer column. The reflux stream in the RSV process scheme is driven by the residue gas compressors and hence a separate compressor for the recycle stream is not needed. One of the advantages of the RSV process scheme is its ability to switch easily for ethane recovery and ethane rejection operation as market price changes. In addition, it can also be operated in GSP mode by disallowing the reflux flow. Compared to GSP design, both the CRR and RSV have a better CO_2 tolerance than GSP as the demethanizer column can operate at higher pressure with these process schemes (Pitman et al., 1998).

All the GSP, CRR and RSV process schemes mainly focus on improving the reflux stream to the demethanizer column. Unlike these process schemes, an enhanced NGL recovery process (IPSI-1) introduced by Yao et al. (1999) gives process enhancement at the bottom of the demethanizer column. This process scheme uses a self-refrigeration system by taking a slip-stream from the bottom of the tower as a mixed refrigerant to cool the inlet feed. As a result, it can significantly reduce the need for propane refrigeration. However, it has also certain limitations as the plant capacity increases and the feed gets richer, it may require additional refrigeration to maintain a high NGL recovery level.

The internal refrigeration for enhanced NGL recovery (IPSI-2), introduced recently by Lee et al. (2007), is another process enhancement that focuses on the bottom of the demethanizer column. This process scheme consists of an open cycle refrigerant withdrawn from the demethanizer column and a closed cycle refrigerant derived from the open cycle refrigeration system. The open-cycle loop is similar to the self-refrigeration system in the IPSI-1. The advantage of IPSI-2 process scheme over the IPSI-1 is that the closed-cycle loop can avoid the need for external refrigeration especially for very rich feeds.

Almost there is no published works in the academic area for comparing the performance of the aforementioned process schemes. However, there are few technical papers which are presented on the annual convention of gas processors association. These technical papers discuss and compare for two or three process schemes only. Moreover, the comparison is limited on the operating performance, such as operational flexibility, carbon dioxide tolerance and reduction of refrigeration, without incorporating a detailed economic study. The important factors that drive process selection in gas processing industries are capital and operating cost, process efficiency, environmental and safety regulations (Khorsand and Maleki, 2012). The selection of the optimum process scheme depends on the condition and composition of the inlet gas, cost of utilities, product specifications and relative product values (Lee et al., 1999). The condition for feed composition is very important because it mainly determines what kind of process configuration should be employed for recovering NGLs (Jibril et al., 2006). It is also considered as a basic requirement for the performance test of a particular process scheme whether it can accommodate a range of feed compositions which vary from time to time. Such variation effect has also a significant impact on the economics of NGL recovery plants (Mehrpooya et al., 2010).

In this work, various feed compositions were considered and characterized under the basic classifications of lean and rich feeds. The original turbo-expander process scheme (ISS) is taken as a base case plant. The GSP, CRR, RSV, IPSI-1 and IPSI-2 schemes were selected for this study as representative NGL recovery processes based on their commercial availability and wide application at the industry level. In addition, some of these process schemes are considered as a future forefront for the coming generation (Lee et al., 1999). HYSYS (ASPEN HYSYS, 2009) simulations were made initially for all of the process schemes by setting common operating parameters in order to compare the performance of each process scheme. Later, a detail economic analysis is made by considering the respective capital and operating costs as well as the profitability of each process schemes.

2. HYSYS process models

HYSYS process models were developed for the selected process schemes (ISS, GSP, CRR, RSV, IPSI-1 and IPSI-2). The process models were initially built based on the original operating conditions (T & P) that are labeled in the respective US Patent papers. The process description of each process scheme is presented below.

2.1. *Turbo-expander (ISS)*

The ISS turbo-expander process scheme was considered as the base case and is shown in Fig. 1. After the feed stream 1 pretreated and cleaned, it is then divided into two parts: where 40% of the feed stream goes into stream 2 and the remaining 60% into 3. Stream 2 is then cooled in heat exchanger E-100 using residue gas stream 19, which originates from the top of the demethanizer column (T-100). Stream 3 is first cooled in heat exchanger E-101 using bottom stream 23, and further cooled in E-102 by pump-around stream PA2′ from the demethanizer column (T-100).

Streams 5 and 6 are then mixed into stream 7, which later divided into two parts: where 70% going into stream 8 and the remaining 30% into stream 9. Stream 8 is cooled via E-103 by residue gas stream 17. Stream 9 is then cooled (E-104) by pump-around stream PA1′ from the side of the demethanizer column. Streams 10 and 11 are mixed before stream 12

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