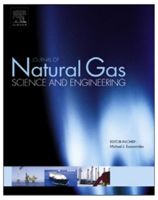
Journal of Natural Gas Science and Engineering 27 (2015) 2–17

Contents lists available at ScienceDirect

Journal of Natural Gas Science and Engineering

journal homepage: www.elsevier.com/locate/jngse



Techno-economic evaluation of a novel NGL recovery scheme with nine patented schemes for offshore applications

Jin Ho Park [a], Mohd Shariq Khan [a], Riezqa Andika [a], Mesfin Getu [b], Alireza Bahadori [c], Moonyong Lee [a, *]

[a] School of Chemical Engineering, Yeungnam University, Gyeongsan 712-749, Republic of Korea
[b] Department of Chemical & Petroleum Engineering, Curtin University of Technology, CDT 250, 98009 Miri, Sarawak, Malaysia
[c] School of Environment, Science & Engineering, Southern Cross University, Lismore 157, Australia

ARTICLE INFO

Article history:
Received 30 September 2014
Received in revised form
16 December 2014
Accepted 22 December 2014
Available online 6 January 2015

Keywords:
Natural gas liquids
Heat integration
NGL recovery process
Demethanizer
Techno-economic analysis
FLNG

ABSTRACT

A novel configuration of natural gas liquid (NGL) recovery process is proposed for offshore applications. Nine representative patented NGL recovery processes were chosen and their heat integration was modified for offshore applications. Detail techno-economic analysis of the proposed configuration was performed on these selected conventional NGL recovery processes. The results suggest that the proposed NGL configuration is most efficient among all the processes considered in terms of the operating and capital cost. The cold residue recycle and flashed vapor reflux process had the highest and lowest capital cost requirement among other processes. The excellent heat integration and sharp separation efficiency of the heavier components are the main highlights of the proposed NGL recovery process.

1. Introduction

Over the last few decades, natural gas (NG) has become the world's fastest growing fossil fuel. This growth is driven by its clean burning characteristics and high energy conversion efficiency. The predictions also suggest strong growth from 113 tcf in 2010 to 185 tcf in 2040, which is 64% growth (Energy Outlook, 2013).

Pipelines have been used to transport oil since the 1860s. On the other hand, with time the gas field locations are becoming increasingly more distant from the world market and are difficult to access. To over this problem, several solutions have been proposed, e.g., compressed natural gas (CNG), gas to liquids (GTL) and liquefied natural gas (LNG), but only LNG has found widespread use in the transport of NG from the gas field to the far markets (Mokhatab et al., 2006). Along with the development of LNG infrastructure, the gas processing technology has also evolved with time. The first major development during those times is the utilization of compression and cooling methods to separate lighter and heavier fractions of NG. Separation is necessary to maintain the dew point of the final product, and the heavier hydrocarbons (HCs), commonly referred to as natural gas liquids (NGL), yield a source of revenue and are sold in their own right. The lighter NGL fractions (ethane, propane and butane) can be sold as refinery feedstock, whereas the heavier HCs can be sold as gasoline-blending feed stock (Mokhatab et al., 2006). Initially, the compression cooling separation method, which is also called the straight refrigeration method, was used for NGL recovery. This process uses propane and typically operates at −37 °F, which that limits the NGL recovery. In addition, it is energy intensive. After this process, several modifications in the straight refrigeration method were proposed to increase the separation efficiency at low cost. The most famous modification is the turbo-expander process or as better known, the industry-standard single-stage (ISS) process. On the other hand, this process scheme also had several issues, such as low overall product recovery, narrow operational flexibility (Rahaman et al., 2004) and carbon dioxide freezing in the de-methanizer column (Lynch et al., 2002). These limitations assist in the evolution of other NGL recovery processes according to the need, and the names in chronological order of the most important of them are as follows (for details see Section 3.1–3.9):

---

* Corresponding author.
E-mail address: mynlee@yu.ac.kr (M. Lee).

http://dx.doi.org/10.1016/j.jngse.2014.12.023
1875-5100/

- Liquid Sub-cooled Process (LSP) in 1976
- Vapor Enrichment process (VEP) in 1979
- Gas sub-cooled Process (GSP) in 1981
- Cold residue-recycle (CRR) in 1989
- Split Flow Reflux (SFR) in 1989
- Recycle Split Vapor (RSV) in 1996
- Flashed Vapor Reflux (FVR) in 1996
- Enhance NGL recovery (IPSI) in 1999

Inspired the above mentioned approaches several new developments of NGL recovery process also appeared in open literature lately. Khan et al. proposed the use of dividing wall column for integrated NGL and LNG plant (Khan et al., 2014a). Long and Lee proposed the use of self-heat recuperative technology for NGL plant (Long and Lee, 2013). The complex column arrangements and design complexities in NGL process design were investigated by Yoon et al. (2013) and further proposed an optimization framework for NGL processes.

Much of the world's gas reserves are in offshore fields, but onshore LNG processing is generally favored. A traditional onshore plant for offshore gas reserves normally includes an offshore platform for dehydration and compression, large pipelines to shore, an onshore liquefaction plant, and a harbor to accommodate purpose-built LNG carriers. Virtually no serious improvements in offshore technology have occurred since the late nineties. The maturity and advancement of offshore technology (for oil recovery), coupled with favorable market conditions, have resulted in the evolution of floating liquefied natural gas (FLNG) units or LNG floating production storage and offloading (FPSO) units. Since its inception, the prospects for the floating LNG industry have improved.

On the other hand, most of the abovementioned NGL recovery processes have been made considering the operation of onshore plants, and cannot be applied directly to FLNG or offshore applications. Therefore, there is a strong need for general guidelines to choose the most relevant NGL recovery process from the available schemes for any offshore/onshore NGL recovery project. The second need is a novel NGL recovery scheme that can satisfy the criteria and requirements of FLNG or offshore applications. This study aimed to achieve the following three objectives:

i) Modification of the representative NGL recovery processes for offshore applications;
ii) Development of a novel NGL recovery process that can satisfy the FLNG criteria; and
iii) Fair comparative study and evaluation of these NGL recovery processes.

Table 1
Simulation basis and feed conditions.

Components	Feed composition (mol. %)
C_1	88.98%
C_2	5.99%
C_3	2.43%
iC4	0.47%
C4	0.70%
iC5	0.23%
C5	0.20%
C6	0.10%
C7	0.09%
C8	0.04%
C9	0.01%
C10+	0.01%
N_2	0.74%
CO_2	0.00%
H_2O	0.00%
Feed condition	
Pressure (bar)	60.7
Temperature (°C)	29.45
Mass flow rate (ton/h)	472.44 @AT
Thermodynamic property package	Peng–Robinson

2. Main modeling assumptions and feed conditions

Table 1 lists the feed conditions, composition and the thermodynamic property package used for the calculation area. The feed gas, which is relatively rich in heavier components (ethane, propane and higher), was used in the simulation of all the NGL recovery processes considered and the feed conditions remained the same.

2.1. Product specifications and column design conditions

The unified column conditions, product specifications and design constraints were used to compare the NGL recovery schemes considered in this study. Fig. 1 shows a conventional NGL recovery scheme excluding the de-methanizer section. The main product of the de-methanizer column is ethane, which can be liquefied after exchanging heat with a cold mixed refrigerant (CMR). Propane refrigeration is also employed sometimes. The main product of the de-propanizer, i.e., propane, can be liquefied by exchanging heat with a warm mixed refrigerant (WMR), whereas the top is cooled using cooling water. Similarly, cooling water with low pressure steam is the only utility required in the debutanizer. Table 2 lists the simulation condition used for each column (feed location, operating pressure, number of trays). Owing to heat integration, the de-methanizer accepts three different feeds (two are pumped around and are abbreviated as PA1″ and PA2″ in Table 2), in which the main NG feed enters at tray location 15. Table 3 lists the specifications of the products obtained in all NGL extraction configurations for de-methanizer, de-ethanizer, de-propanizer, and de-butanizer. The impurities (nitrogen, sulfur etc.) must be monitored from the impurity removal plant and it has been assumed that the product satisfies the given specifications.

3. Commercially available NGL recovery processes

This section presents the chronological discussion of the major developments that have taken place in NGL recovery processes. The first noted development in NGL technologies occurred in 1970 as Turbo-expander or ISS technology, which is the major leap for the gas processing industry. The problem of operational flexibility and CO_2 freezing in the ISS process paves the way for the evolution of several other useful NGL recovery schemes. Initially, the development of NGL extraction technologies focuses mainly on improving the de-methanizer reflux stream where the GSP (Campbell and Wilkonson, 1981), the CRR (Rambo et al., 1992) and the RSV (Campbell et al., 1996) correspond to these configurations. On the other hand, with time, the developmental efforts in NGL extraction focused on the bottom of the de-methanizer column that the IPSI-1 (Lee et al., 2001) and IPSI-2 (Lee et al., 2007) correspond to. The enhanced reflux streams of the FVR (Vijayaraghavan and Ostaszewski, 1996), the LSP (Campbell et al., 1976), the SFR (Campbell et al., 1989) and the VEP (Campbell and Wilkonson, 1979) utilize successive flashing and splitting of a high pressure feed to generate several lean cold streams that act as a reflux to the de-methanizer column besides providing additional cooling to the feed gas that reduces the overall external energy requirement.

The abovementioned NGL recovery schemes were modified and optimized by adopting the intensified heat integration for offshore applications. The original schemes for these patented processes are