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A novel process configuration for hydrocarbon recovery process with auto–refrigeration system

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ABSTRACT

A new process for recovery of natural gas liquids from a treated feed gas is introduced and analyzed. This process applies demethanizer and deethanizer columns in order to produce pure methane and ethane as main products. The needed refrigeration is supplied by a self-refrigeration system. The results show that the self-refrigeration compression power is 38.57% less than the external propane refrigeration cycle. Ethane and propane plus recoveries are greater than 90% and 95% respectively. Energy and exergy analysis of the process is done and results show that the towers and expansion valves have the highest irreversibility while irreversibility of the heat exchangers are acceptable.

1. Introduction

The NGL (Natural Gas Liquids) is the term commonly used for separating the hydrocarbon liquids from natural gas especially ethane and heavier hydrocarbons. NGL recovery is not only required for the control of natural gas hydrocarbon dew point, but it is also a source of income (Bai et al.). In a gas refinery after purification units, hydrocarbon recovery unit is a basic unit. Due to the high demand of ethane for petrochemical feed and also as fluid mixing for increase the oil recovery process, many new NGL plants are under construction around the world. Increase in energy resources cost and economic difficulties have caused cryogenic natural gas liquid recovery plants to be more vital and important (Mehrpooya et al., 2010a). Methods used for the production and recycling of the hydrocarbon liquids until the twentieth century included of dense and cold gas feed for sustainable production (Gas Processors Suppliers Association, 2004). Refrigeration and separation of the feed is used as a most conventional and efficient method in advanced hydrocarbon recovery units. Refrigeration of the feed gas can be done by mechanical refrigeration, absorption refrigeration and expansion through a Joule-Thomson valve, or a combination of these procedures. In order to achieve lower process temperatures, mixed refrigerants systems and turbo expander are developing. Process configuration and operating condition are important parameters which influence the performance of the process. Exergy analysis is a powerful tool for finding the efficiency of a process and its components based on the concept of second law of thermodynamics. Also the results of the analysis disclose the irreversibility of the components. In the NGL plants the sweet treated natural gas is cooled by demethanizer top outlet and its side draws in the multi heat exchangers. The cold liquid stream to the column act as top reflux and improves recovery of heavier hydrocarbon components (Farzaneh and Abbasgholi, 2011). Propane refrigeration cycles are known as the most conventional and suitable refrigeration systems for supplying the required refrigeration in hydrocarbon recovery units. Nonetheless a high portion of the required power in the process is related to the refrigeration cycle compressors. So self-refrigeration idea is introduced in order to decrease the required power in the process. This technology uses a side stream from the demethanizer bottom. This stream is vaporized and provides a portion of the required refrigeration for inlet gas cooling while another portion should be supplied by external refrigeration system. The flashed vapor generated from the auto-refrigeration cycle is compressed and recycled to the bottom of the column where it serves as stripping gas. This innovation not

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Nomenclature

G	Gibbs free energy (kJ/kgmol)
I	Irreversibility (kW)
e	Exergy (kJ/kgmol)
Ex	Exergy (kJ)
T	Temperature (°C)
P	Pressure (bar)
S	Entropy (kJ/kgmol °C)
h	Enthalpy (kJ/kgmol)
x	Component mole fraction
ṁ	Flow rate (kgmol/hr)
Q	Heat duty (kW)
W	Work transfer rate (kW)
N	Exergy loss number
m	Number of cold streams
n	Number of hot streams
Greek letters	
η	Exergy efficiency
γ	Activity coefficient
Δ	Gradient
Subscripts	
i	Inlet
i	Component
o	Outlet
REV	Reversible
sh	Shaft
a	Air
c	Cold
h	Hot
Superscripts	
ΔP	Pressure component
ΔT	Thermal component
°	Standard condition
ph	Physical
ch	Chemical
mix	Mixture
E	Excess property
Abbreviations	
NGL	Natural gas liquids
J–T	Joule–Thomson valve
COP	Coefficient of performance
E	heat exchanger
MSHX	Multi stream heat exchanger
C	Compressor
P	Pump
V	Expansion valve
D	Flash drum
AC	Air cooler
MIX	Mixer

only reduces or eliminates the need for external refrigeration, but also decreases the temperature profile in the column. Several NGL recovery processes were investigated in order to optimize and improve the process performance (Mehrpooya et al., 2006a, 2006b; Panjeshahi and Tahouni, 2008; Mak, 2010). A new configuration which uses an open-closed refrigeration system was proposed in (Mehrpooya et al., 2010a). In this configuration hydrocarbon recovery can be reached to 90%. In (Chen et al., 1999) an open cycle self-refrigeration considering economy of NGL recovery processes was presented. Propane refrigeration cycle was replaced by an internal refrigeration system in a new NGL recovery process (Lee et al., 2007). In this process ethane can be recovered up to 90.1%. Mak et al. (Corporation and Mak, 2004) demonstrated an NGL recovery plant that operates with a cooled low pressure feed gas. In their configuration maximum achievable C_2 recovery was 85%. Farzaneh and Abbasgholi (2011) shows that the process performance with a self-refrigeration system is better than the propane refrigeration cycle. Also there are several studies on the NGL processes and energy and exergy analysis of their refrigeration systems (Tozer and James, 1998; Nikolaidis and Probert, 1998; Ahmet et al., 2008; Khaliq and Kumar, 2008; Bhattacharyya et al., 2007; Zhang and Lior, 2007; Qiang et al., 2005; Mehrpooya et al., 2009, 2011). Exergy analysis of a multistage propane refrigeration cycle used in a hydrocarbon recovery plant was done (Tirandazi et al., 2011). An industrial refrigeration cycle in an NGL recovery plant was investigated by the exergy method (Mehrpooya et al., 2006a). Their results showed that the condensation and evaporation sections have the highest irreversibility. In (Mehrpooya et al., 2011) exergy analysis of a multistage cascade low temperature refrigeration system used in an olefin plant was presented. Exergy analysis of a new cycle which produced power and cooling simultaneously was studied (Vidal et al., 2006). A complete exergy analysis of a cascade refrigeration cycle employed for natural gas liquefaction was reported (Kano, 2002).

In this study a novel process configuration for recovery of ethane, propane and heavier hydrocarbons is proposed. An open-closed self-refrigeration system supplies the required refrigeration. The process performance is compared with a similar process configuration with external refrigeration system. At the end the process is investigated by exergy analysis method.

2. Process description

Fig. 1 illustrates the process and its self-refrigeration system. Treated sweet feed gas enters the process through the inlet gas stream at 27.7 °C and 62 bar. This stream is cooled in MSHX-1 multi-stream heat exchanger up to −34 °C. The Output stream from MSHX-1 enters D-1 for separation of condensed liquid. A portion of the separated liquid is sent to the middle of demethanizer column to enhance separation. Before entering the column its temperature is decreased to about −53 °C by a J–T valve. Another portion, stream 3, after entering MSHX-2 and cooling is expanded through the expansion valve and follows to the demethanizer. The outlet vapor stream 2 from the D-1 drum is splited into two parts (streams 2&6). Stream 2 which is about 63% is sent to EX-1 turbine before entering the demethanizer. The remaining part, stream 6, is cooled to −90 °C in MSHX-1.

Operating pressure of the demethanizer is approximately 24 bar. Demethanizer column has five side streams which provide a part of the require refrigeration. Streams 14 and 16 enter the MSHX-2 at −61 and −41 C and return at −42, −40 °C respectively. Liquid side draws, streams 18 and 20, enter the MSHX-1 at −8.8 and 9 °C and return at −3 and 39 °C respectively.

Residue gas 7, outlet stream from top of the demethanizer follows to the MSHX-2 exchanger and supplies a portion of the required refrigeration for condensing or sub-cooling the stream 6