Journal of Natural Gas Science and Engineering 29 (2016) 264–274

Contents lists available at ScienceDirect

Journal of Natural Gas Science and Engineering

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

A novel absorption process for small-scale natural gas dew point control and dehydration

Marcelo Díaz Rincón [a, b], Carlos Jiménez-Junca [a, *], Carlos Roa Duarte [c]

[a] Faculty of Engineering, Universidad de la Sabana, Campus Puente el Común, Km. 7 Autopista Norte de Bogotá, Chía 250001, Colombia
[b] Vicepresidencia Técnica de Producción, Ecopetrol, Cr 13 No. 36–24, Bogotá 110311, Colombia
[c] Colombian Petroleum Institute-ICP, Ecopetrol, Vía Pie de Cuesta Km. 7, Piedecuesta 681011, Colombia

ARTICLE INFO

Article history:
Received 5 November 2015
Received in revised form
6 January 2016
Accepted 9 January 2016
Available online 12 January 2016

Keywords:
Natural gas
Absorption
Process simulation
Dew point control
Triethylene glycol
Lean oil

ABSTRACT

Heavy hydrocarbon removal is one of the processes found in natural gas processing plants for reducing heating value and hydrocarbon dew point to sales gas quality. Conventional technologies include Joule–Thomson expansion, turboexpansion, mechanical refrigeration, membrane separation and supersonic centrifugal separation. In this paper, a novel absorption process system is presented for dew point control of natural gas streams associated to crude oil production. The system is based on simultaneous absorption of heavy hydrocarbons and water from natural gas using a mixture of TEG and lean oil. This alternative technology has an equipment count, investment and operating cost, and energy consumption lower than commercial technologies available nowadays. Natural gas processes are modelled and simulated within Aspen Plus® simulator with a common set of operating criteria and adjusted thermodynamic interaction parameters for the absorption process, based on experimental data. An energy balance and economic assessment for each process option are developed considering investment and operating cost and profitability analysis. Results indicate an increase in hydrocarbon absorption efficiency with increase in lean oil concentration; 46% of pentane plus components can be removed with a 20% of lean oil. Energy consumption is up to 52% lower than other process schemes, while capital cost and operating cost are also 40% and 25% lower. Process description, operating conditions, equipment requirements, recovery efficiency and limitations for the new absorption process are presented.

1. Introduction

Natural gas associated to crude oil production usually requires treatment for conditioning to sales gas specifications or fuel gas quality. Typically, those specifications include water content, hydrocarbon dew point, heating value, carbon dioxide and hydrogen sulphide (Galatro and Marin, 2014; Ghiasi et al., 2014; Rufford et al., 2012). Processes required to meet sales gas specifications usually include compression, dehydration, sweetening (removal of H_2S and CO_2) and hydrocarbon dew point control. These are performed in different sequential stages that involve several unit operations, equipment, instrumentation, piping, etc. Fig. 1 shows a typical block flow diagram for a gas treatment plant.

Dehydration processes include glycol absorption (Netusil and Ditl, 2011), polymer membranes (Scholes et al., 2012), composite membranes (Lin et al., 2012), molecular sieves (Farag et al., 2011), and isenthalpic gas cooling with controlled hydrate formation (Parks and Amin, 2012). Glycol absorption is the dehydration method used in the majority of existing natural gas treatments plants (Bahadori and Vuthaluru, 2009; Twu et al., 2005).

Triethylene glycol (TEG) is the most commonly used solvent for natural gas dehydration since it has high hygroscopic, low solubility in natural gas and low vapour pressure (Bahadori et al., 2008). Monoethylene (MEG) and diethylene glycol (MEG) can also be used for dehydration applications (Derawi et al., 2003) but are seldom considered for dehydration due to difficulty to reach water content specification for pipeline. Moreover, evaporation loss and thermal degradation in the regeneration system are normally lower for TEG.

TEG absorbs more light hydrocarbons and acid gases than EG and DEG (Bahadori and Zeidani, 2006; Bahadori et al., 2008) and is considered an undesired effect in existing plants because liquid hydrocarbon promotes foaming tendency in absorber columns and clogging of equipment that operates at high temperature in the regeneration system (Manning and Thompson, 1991). However,

* Corresponding author.
E-mail address: carlosjj@unisabana.edu.co (C. Jiménez-Junca).

http://dx.doi.org/10.1016/j.jngse.2016.01.016
1875-5100/

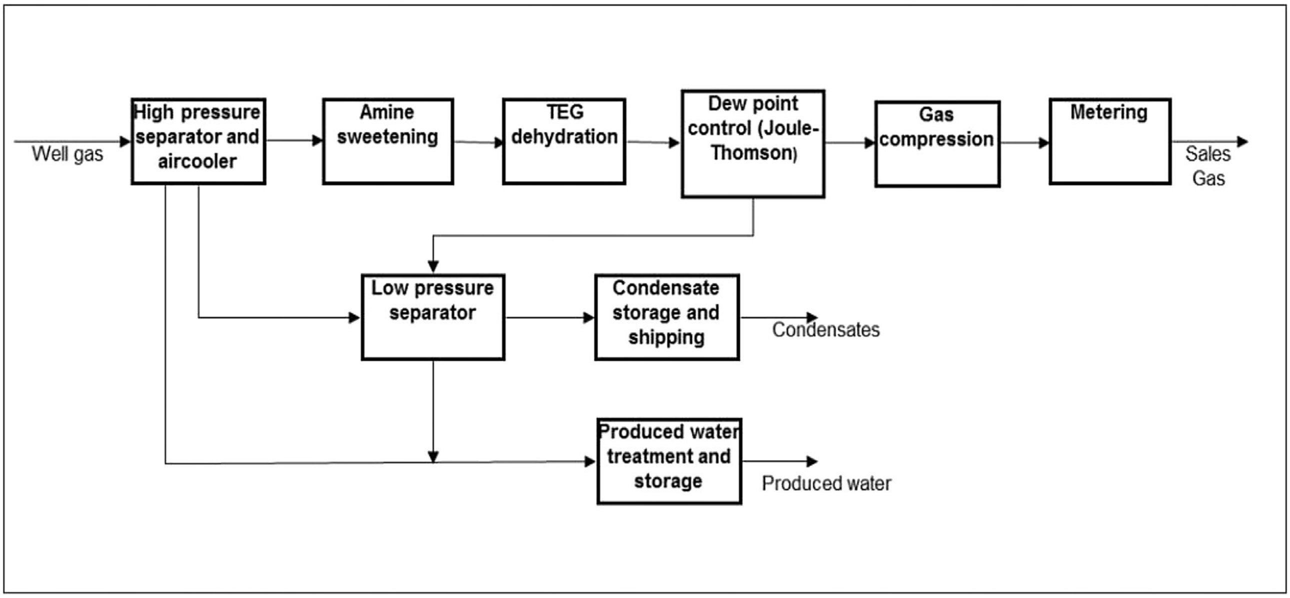

Fig. 1. Block diagram for a typical natural gas processing plant.

operation experience in existing plants shows that absorption level is not sufficient to reduce the heavy hydrocarbon content to sales gas quality. Investigations have been performed for equilibria of glycols with water (Twu et al., 2005), light alcane hydrocarbons (Derawi et al., 2003; Bahadori et al., 2008; Ng et al., 1993; Al-Saifi et al., 2008), aromatic hydrocarbons usually present in natural gas (Moshfeghian and Hubbard, 2012; Ng et al., 1993), and acid gases such as CO2 and H2S (Afzal et al., 2012). Even potassium formeate as an additive to enhance water absorption efficiency on TEG has been studied (Isa et al., 2013). However, absorption of heavy hydrocarbons in TEG was not correlated in aforementioned researches.

Dew point control is usually included in a gas processing plant to produce a natural gas within specifications or maximize hydrocarbon liquid recovery (Mehrpooya et al., 2015) depending on the production objective. Desired degree of recovery determines process technology, its complexity and investment and operating costs. Conventional methods for dew point control of natural gas include mechanical refrigeration, isenthalpic expansion (Joule–Thomson effect), turboexpansion, lean oil absorption, solid bed adsorption, membrane separation and supersonic centrifugal separation (Mokhatab, 2012). All these treatment process have high energy consumption and investment and operating costs, and several investigations have been conducted to reduce them with variations on process configuration and conditions (Fissore and Sokeipirim, 2011; Getu et al., 2013; He and Ju, 2014; Machado et al., 2012; Mehrpooya et al., 2010; Shin et al., 2015; Vatani et al., 2013); capital investment for a new natural gas processing plant is mainly influenced by the gas compression and dew-point control equipment. Then, natural gas industry is always aiming to simpler process configurations and lower energy requirements and costs (Khorsand and Maleki, 2012). Investment and operating costs are usually paid back with the revenue associated to sales gas and stabilized hydrocarbon condensates that are obtained from the treatment process, usually named natural gas liquids or NGL (Mehrpooya et al., 2015; Shin et al., 2015). However, heavy crude oil fields have low associated gas production and treatment for pipeline or fuel gas is not economically feasible. Also, the NGL production depends on heavy hydrocarbon content of gas to be processed (Getu et al., 2012). Hence, in some cases recovery of NGL is economical only for rich natural gases with a high content of heavy hydrocarbons.

Lean oil absorption process has been commercially used for hydrocarbon dew point control for natural gas treatment. Lean oil is usually a mixture of hydrocarbons with high molecular weight with affinity to absorption of heavy hydrocarbons that are present in natural gas (Campbell, 2004). Lean oils usually have a molecular weight 100–200 g/mol to reduce losses in heating operations in regeneration systems (Gas Processors Suppliers Association, 2004), can absorb at ambient temperature and high pressure (Mokhatab, 2012) and have an initial boiling point usually higher than 150 °C. Such conditions are similar to gas dehydration process with TEG. Then, when using a mixture of TEG-lean oil, simultaneous removal of water and heavy hydrocarbons from natural gas stream in a single absorption column is expected, with a subsequent reduction in capital and operating costs.

In this paper, simultaneous dehydration and dew point control of natural gas using a mixture of TEG and lean oil is presented as an alternative technology with an equipment count, investment and operating cost, and energy consumption lower than existing technologies. This process can achieve both water and hydrocarbon dew point specifications in one unit. Operating conditions, equipment requirements, recovery efficiency and limitations for the conventional technologies are compared with this novel absorption process. A process description of this new process is included.

2. Materials and methods

2.1. Pilot experimental tests

Experimental tests for evaluation of absorption efficiency of TEG-lean oil absorbent were conducted with a pilot scale unit. The unit was installed at an oil field where gas from crude oil production was available. Fig. 2 shows flow diagram and process conditions during experiments. Main equipment characteristics of the pilot scale unit are as follows:

- Absorption column: packed type, carbon steel, design pressure 100.3 bar, 4.9 m height, 16.8 cm diameter.