Journal of Natural Gas Science and Engineering 37 (2017) 327–340

Contents lists available at ScienceDirect

Journal of Natural Gas Science and Engineering

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

Technical and economic evaluations of the triethylene glycol regeneration processes in natural gas dehydration plants

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ARTICLE INFO

Article history:
Received 12 August 2016
Received in revised form
11 October 2016
Accepted 24 November 2016
Available online 28 November 2016

Keywords:
Natural gas
Dehydration plant
TEG
Stripping gas

ABSTRACT

A conventional natural gas dehydration plant and one based on striping gas concept, which employs triethylene glycol (TEG) as the dehydrating agent, were simulated using a steady state simulator (UniSim Design). The main units were included in the flowsheets, namely: absorber, flash units, heat exchangers, regenerator, and reboiler. All simulations were performed of about 25 L TEG/kg water absorbed. The equation of state (EOS) used in the simulation is the Peng Robinson (PR). The reboiler temperature of conventional regenerator and then the hot stripping gas flowrate, have been studied for their response to changes in the regenerated TEG concentration, dew point of sale gases, TEG losses (make-up), regenerator overhead vapor flowrate, and partial pressure of water vapor. Despite the increase in plant complexity, the fixed capital investment estimation proves an insignificant costs increase of the stripping gas configuration over the benchmark. It appears that stripping gas is a more effective way to improve the regenerated TEG concentration and entire dehydration plant performance.

1. Introduction

Among all fossil fuels, natural gas is the most environmentally friendly and for this reason it is expected a rapidly growing in global importance as a primary energy source. Natural gas is also used by industry, mainly as a feedstock for downstream industry.

The natural gas must satisfy some specifications that it makes suitable for transport in specific systems. Consequently, natural gas, which in most cases contains contaminants (i.e. non-hydrocarbon gases such as water vapors, carbon dioxide, hydrogen sulfide, nitrogen, oxygen, and helium) and heavy (liquid) hydrocarbons, must be processed or treated, prior for delivery to the pipelines transport (Mokhatab et al., 2006). The treatment process includes several steps for creating pipeline-quality natural gas. The number of the steps and the type of the techniques most often depends upon the gas source. A dehydration step is needed to eliminate water that is present in various amounts dependent on upstream conditions (Carol, 2002). Water in natural gas can create serious problems during gas transportation and processing or depreciate its quality by decreasing the heating value. The most severe problem is the formation of gas hydrates that may block plug valves fittings or pipelines, compression systems, process equipment and instruments (Gong et al., 2010; Mokhatab et al., 2007). Another common problem in the oil and gas industry associated with natural gas and condensed water is the corrosion of materials, particularly when CO_2 and H_2S are presented in the gas (ObaniJesu, 2009).

The treatment for removal of the water vapors from natural gas consists basically of dehydration process which is accomplished by decreasing the dew point temperature. The most common methods of natural gas dehydration are absorption in liquid desiccant, adsorption on solid desiccant, and refrigeration (Netusil and Ditl, 2011; Rouzbahani et al., 2014).

The liquid desiccants suitable for dehydrating of the natural gas include the following substances: calcium chloride, lithium chloride, glycols, zinc chloride (Gandhidasan et al., 2001). Among of these, the glycols are the main ones used for natural gas dehydration. The commonly available glycols are monoethylene glycol (MEG), diethylene glycol (DEG), triethylene glycol (TEG) and tetraethylene glycol (TREG). Triethylene glycol is used for many decades in vapor water absorption and by far the most suitable for commercial application where dew point depressions of about 15–49 °C are required (Gas Processors and Suppliers Association, Engineering Data Book, 2012). When dew point depressions

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http://dx.doi.org/10.1016/j.jngse.2016.11.052
1875-5100/

consistently higher than about 82 °C are required, the adsorption-based processes are generally specified (Kohl and Nielsen, 1997). The most common solid desiccants used in adsorption of water vapors are molecular sieves, silica gel or alumina. Despite their higher costs, the molecular sieves are preferred as adsorbent when very lower dew points are required, such as natural gas feed streams for cryogenic hydrocarbon recovery units. The main drawback of dehydration based on adsorption technique is the capital cost, which is 2–3 times higher than that for absorption (Netusil and Ditl, 2011).

Refrigeration by external vapor recompression, as a dehydration technique, requires large pressure drop therefore; this process is recommended when high-pressure gas is available.

Dehydration by membrane permeation or supersonic processes are seldom used. Some of the disadvantages of membranes in the dehydration process, such as lower selectivity, easily fouling by gas contaminants, high costs especially for large gas flowrates applications, make the process noncompetitive (Scholes et al., 2012).

Supersonic gas processing systems were recently promoted in this area and both condensation and separation occurs in a simple device, i.e. supersonic nozzles. They are relatively simple to operate, cheap, environmentally friendly and significant for offshore gas applications (Karimi and Abedinzadegan Abdi, 2009; Wen et al., 2011).

In the near future, it is unlikely that membrane permeation and supersonic processes would obtain significant market share for dehydration of natural gas applications. Many researches and developments of this dehydration processes are needed to make them competitive with absorption in triethylene glycol or adsorption on solid desiccant processes which are successfully used in current practices for many years.

There are also many commercially available processes for customized dehydration systems, especially absorption in TEG. Several processes are available today, each employing different strategies to enhance glycol regeneration (Rahimpour et al., 2013b). The alternative glycol regeneration concepts available in current practice are related to the Drizo, the Coldfinger, vacuum distillation and the stripping gas processes (Rahimpour et al., 2013a). From all of these concepts, the stripping gas is the simplest and most widespread process for enhanced glycol regeneration. Stripping gas is therefore mainly used to increase the purity between 99.1 and 99.6 wt % at the regeneration temperature and slightly over atmospheric pressure. Injecting the stripping gas directly into the reboiler has the great advantage to require few additional equipments (Kohl and Nielsen, 1997).

In this paper, according to the advantages noted above, the performances of a stripping natural gas drying process which employs triethylene glycol (TEG) as the dehydrating agent are re-examined both as technological feasibility and economics, in comparison to those of a conventional drying process. The paper is sequenced as follows: Section 2 describes the drying processes and state the input data employed in our investigation. The drying processes are presented in terms of simulation flowsheets according to UniSim Design software facilities. In section 3, the calculation methods for sales gas dew point, for the total equivalent work and for economic evaluations (*i.e.,* fixed capital investment and total cost of production) are showed. In section 4, a systematic procedure in order to determine the operating conditions that maximize the regenerated TEG concentrations, is developed. The simulation results are discussed in terms of their limitations and advantages on overall technological performance of both drying processes. The economic evaluation is completing our investigation and its results support the final decision. Some concluding remarks will be given in Section 5.

2. Process description

Two process configurations are re-examined in this work: the conventional process with a simple regenerator as benchmark and the process with hot gas stripping injection in the reboiler of regenerator. In help of our investigations, a commercial simulator for chemical processes, namely UniSim Design R-380 is involved.

In the conventional drying process, the rich TEG is regenerated by reducing the pressure and increasing the temperature, before it is recycled into the absorption column. The most important drawback of the atmospheric conventional process is the lean TEG concentration of 98.8–98.9 wt% (*GPSA, 2012*; Piemonte et al., 2012). Nowadays, the simplest and most used strategy employed for enhanced glycol regeneration is the stripping gas process (*GPSA, 2012*; Kohl and Nielsen, 1997; Piemonte et al., 2012). In this paper, a small portion of the dry gas at the regeneration pressure is heated and introduced into the regenerator of reboiler. Stripping gas is used in order to decrease the partial pressure of water in the vapor phase, and thereby to obtain glycol with purities between 99.2 and up to 99.9 wt% at the regeneration temperature and near ambient pressure. However, in the stripping configuration, the process complexity will increase. These configurations are described in sections 2.1 and 2.2.

It is well known that natural gas compositions can vary widely, depending on where and from what type of reservoir the natural gas is produced (Kotarba and Nagao, 2008; Wang and Economides, 2009). Moreover, the gas composition and properties play a major role in gas processing plants. Available literature related to natural gas compositions or operating conditions in the processing plants are very limited. This is not surprising because most of technical data are confidentially. Taking into account these aspects, a specified natural gas composition is not used in this work. More than that, for general applicability of this work, a typical natural gas composition was preferred. The specifications of typical sweet natural gas are given in Table 1 (Demirbas, 2010). The pressure inlet in gas plant dehydration is based on example 20–11 from *Gas Processors Suppliers Association (GPSA) Data Book.*

2.1. Conventional drying process

Fig. 1 shows a schematic flowsheet of the conventional drying process with TEG.

As shown in Fig. 1, a typical natural gas (see Table 1) saturated with 0.001192 mol fraction water at equilibrium conditions enters to the bottom of absorber [ABS] and flows upward. The dry gas leaves the top of the absorber column. Equilibrium water content or equilibrium dew point of the dry gas is strongly dependent by lean

Table 1
Typical sweet natural gas specification.

Properties	Value
Temperature (°C)	30
Flow rate (Nm^3/day)	1,000,000
Pressure (kPa)	4100
Composition (vol%)	
Methane	94.9
Ethane	2.5
Propane	0.2
i-butane	0.003
n-butane	0.003
i-pentane	0.001
n-pentane	0.001
n-hexane	0.001
CO_2	0.7
Oxygen	0.02
Nitrogen	1.6