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Supersonic separation in onshore natural gas dew point plant

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ABSTRACT

Conditioning of natural gas (NG) for sales mainly involves meeting water- and hydrocarbon-dew points (WDP and HCDP, respectively) while assuring high heating value (HHV) specifications achievable through minimal extraction of C_{5+} components (NGL). This paper compares technically and economically a supersonic separator technology – Twister®, which can promote simultaneously WDP, HCDP and enhanced NGL extraction – to a conventional gas treating technology, consisting of an onshore natural gas dew pointing plant with TEG Dehydration unit coupled to a Joule-Thomson/Low Temperature Separation unit (TEG + JT/LTS). In Twister® technology, water and hydrocarbon dew pointing normally requires pressure drop, which results in more NGL recovery than necessary to meet the established product specifications. An economic scenario was evaluated with NG and crude oil prices of US$ 4.22/GJ and US$ 50/bbl, respectively. The economic performance of each process alternative is evaluated in terms of the net present value (NPV) after 20 years of operation, with an assumed discounted rate of 10%. Twister® based process outperformed conventional TEG + JT/LTS process as the additional revenue from the increased NGL production compensates for the lower revenue from the NG sale resulting from decreased flow rate and lower NG HHV.

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1. Introduction

Processing of natural gas is the largest industrial gas separation application. The U.S. consumption of natural gas is higher than 22 trillion scf/year (0.62 trillion m^3/a), and the total worldwide consumption surpasses 95 trillion scf/year. This consumption drives a worldwide market for new natural gas separation equipment of more than $5 billion per year (Baker and Lokhandwala, 2008). Natural gas contains many contaminants, water being the most common undesirable component. Most natural gases will be nearly water-saturated at the temperature and pressure of production. Dehydration of natural gas is hence a critical step of the natural gas conditioning process as it reduces the potential for corrosion, hydrate formation and freezing in the pipeline. Water is also removed to meet a water dew point requirement of sales specifications, normally ranging from 32.8 to 117 kg/10^6sm^3 (Gandhidasan et al., 2001).

A conventional method for dehydration in the natural gas industry is the use of a liquid desiccant contactor-regeneration process. In this process, the wet gas is contacted with a lean solvent (containing only a small amount of water). The water in the gas is absorbed by the lean solvent, producing a rich solvent stream and a dry gas (Carrol, 2009). The solvent is regenerated in a second column and is then returned to the first column for water removal from feed gas. Glycols have proved to be the most effective liquid desiccants in current use since they have high hygroscopy, low vapor pressure, high boiling points and low solubility in natural gas (Gandhidasan et al., 2001). TEG has gained nearly universal acceptance as the most cost effective of the glycols due to superior dew point depression, operating cost, and operation reliability. However, there are several operating problems with glycol dehydrators. Suspended foreign matter may contaminate glycol solutions and overheating of the solutions may produce decomposition products. Foaming of solution may also occur with resultant carry-over of liquid. Last, there are environmental issues associated to fugitive emissions and efforts for reducing these emissions are being sought (Gandhidasan et al., 2001).

Besides water contamination, natural gas contains liquids that should be commonly removed to meet hydrocarbon dew point specification. In most instances, natural gas liquids (NGLs) have higher values as separate products, and cryogenic processing, although a costly alternative is the preferred technology for this purpose. It is worth noting that hydrocarbon dew point in natural

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gas is operationally important and HCDP is a quality parameter for gas sale (Herring, 2010). An undesirable result of extracting NGL is a lower heating value of the gas product which can reduce its market value. HCDP specification usually is met through Low Temperature Separation (LTS).

In this work, an alternative technology – the Twister® Supersonic Separator – is evaluated and compared to a conventional TEG + JT/LTS technology. Twister® can achieve both water- and hydrocarbon dew pointing in one unit. The supersonic separation equipment has thermodynamics similar to a turbo expander, combining cyclone gas/liquid separation, and re-compression in a compact, tubular device (Brouwer and Epsom, 2003). According to Brouwer and Epsom (Brouwer and Epsom, 2003), whereas turbo-expander transforms pressure drop into shaft power, Twister® achieves a similar pressure drop by converting pressure to kinetic energy. Table 1 displays the advantages and disadvantages of Twister® and TEG + JT/LTS for achieving HCDP.

2. Process simulation

To assess the technical feasibility of TEG + JT/LTS and Twister® gas processing alternatives, material and energy balances were performed using process simulator UniSim® Design (Honeywell). Equipment sizing was conducted according to Campbell (Campbell, 2004). Capital and operational expenditures (CAPEX and OPEX), revenue and cash flow were evaluated according to Turton et al. (2009). The composition and flow rate of the gas to be treated in the present study is reported in Table 2, in a water free base. The gas was taken as saturated in water at process inlet conditions. As process design premises, it was assumed specifications of WDP of −45 °C@1 atm and HCDP of 0 °C@45 bar, which are consistent with the Brazilian market regulations.

2.1. *TEG + JT/LTS*

Fig. 1 shows the flowsheet used for the conventional scheme. Water absorption by TEG is used to achieve the WDP (−45 °C, 1 atm). Subsequently, HCDP (0 °C, 45 bar) is adjusted in the Joule-Thomson expansion system. The saturated feed gas enters to the bottom of the absorber and flows in countercurrent to the TEG solution to absorb water. The water lean TEG solution is fed to the top of the absorber, whilst a water rich TEG solution is recovered at the bottom. The dry gas leaving the top of the absorber has the specified water content. The column operates at 70 bar and the dry

Table 1
Comparison of natural gas HC dew point technologies (Mokhatab and Meyer, 2009).

Process	Advantages	Disadvantages
TEG + JT/LTS	- Simple and compact process - Ease in operation - Low capital cost - Low maintenance cost	- Hydrocarbon dew point control is directly related to the pressure reduction cross Joule–Thomson (JT) valve - Off-spec gas during start up - Sensitive to feed gas composition
Twister®	- Can achieve dehydration and dew point control simultaneously - Remove more hydrocarbons than JT valve for the same pressure drop - Compact module design - Ease of installation and operation - Low maintenance cost	- High compression horsepower - Limited commercial test experience and performance relies on proprietary information - Limited turndown without operator involvement

Table 2
Inlet gas flow rate and composition.

Flow rate ($MMsm^3/d$)	6.00
Component	% mol
CO_2	0.1394
C1	95.7814
C2	2.3263
C3	0.7095
iC4	0.2139
nC4	0.1808
iC5	0.1026
nC5	0.0550
nC6	0.0724
nC7	0.1232
nC8	0.0886
nC9	0.0094
N_2	0.1975

gas stream temperature is 26.4 °C. This gas is cooled down to 11.2 °C in a heat integration exchanger before entering the Joule–Thomson valve. The isenthalpic expansion drops the temperature to −3.3 °C and the heavier hydrocarbons condensate. The condensed hydrocarbon liquid is recovered in a vessel (V-102), while the gas passes through the gas-gas heat exchanger and leaves the plant at 13.7 °C and 39.5 bar. The HCDP@45 bar is −3 °C (specification: 0 °C max) and the WDP@1 atm is −54 °C (specification: −45 °C max).

The rich TEG solution that leaves the absorber contains dissolved gas, which is released through depressurization to 4 bar. The expanded stream flows into a coil that passes through the top of the TEG regenerator column and is consequently heated up to 85 °C. The solution is fed to a vessel, where the gas is separated and sent to a flare. The equilibrium calculations predict a mass flow of 2.2 kg/h for this flare gas. The rich TEG is heated in a TEG-TEG heat integration exchanger and is fed to the top of the TEG regeneration column at 140 °C. The regenerator re-boiler operates at 195 °C, and receives a stripping gas flow of 201 sm^3/h to improve the concentration of TEG in the bottom stream. As a result, the lean TEG solution has a purity of 99.3% w/w. The lean TEG coil helps to lower the top temperature to about 110 °C, avoiding massive TEG losses. The top outlet shows ca 0.4% TEG, which is equivalent to 1.93 kg/h. The high purity lean TEG is cooled down to 140 °C at the TEG-TEG exchanger and pumped to a 70 bar pressure at which it enters an auxiliary heat exchanger that uses water to cool the TEG down to 40 °C. At this temperature and pressure, the lean TEG is fed to the top of the absorber.

The plant has direct emissions as the top product of the regenerator, consisting of a mixture of water (41.77%), hydrocarbons (53.52%), CO_2 (1.92%), N_2 (2.73%) and TEG (0.06%). These values are given by UniSim® Design, based on thermodynamic equilibrium calculations (Peng Robinson EOS), but practice indicates that carry over effects can lead to TEG losses of about 1%. This more conservative value was used for OPEX and emissions calculations.

2.2. *Twister® scheme description*

Fig. 2 shows the flowsheet used for the Twister® scheme. The saturated production gas is compressed (K-100) from 70 bar to 82 bar, leading to a discharge temperature of 40 °C. The gas exchanges heat with the export gas (E-100), reaching −21 °C. Knock-out vessel V-101 separates the liquid phase that results from both compressing and cooling the gas. Saturated gas at 81 bar and −21 °C enters the Twister® tubes. At the primary outlet, the temperature reaches −34 °C and the pressure drops to 54.2 bar. At the secondary outlet, the temperature reaches −40 °C and the

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