Analysis for the implementation of a system for natural gas liquids removal and recovery at the gas processing plant El Centro in Santander, Colombia

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Abstract. The present work carried out the analysis of seven natural gas liquids removal and recovery technologies, evaluating ten decision criteria to identify the technology with the highest technical and economic potential to be implemented at the gas plant “El Centro”, Colombia. The technical criteria evaluated took into account: the chemical composition of the natural gas processed; the flow, pressure and temperature of the system; the efficiency in the removal of natural gas liquids and the technology adaptability against fluctuations that may occur in the operating conditions. On the other hand, the economic criteria evaluated included the purchase of high-cost supplies and equipment, as well as space and maintenance requirements for their implementation. Based on the analysis, the triethylene glycol improved absorption process was established as the technology with the greatest potential to be implemented at the gas plant “El Centro”, Colombia, so it was evaluated in a pilot test where a reduction of 30 °F on the cricondentherm point was observed, associated to the removal of higher molecular weight hydrocarbons from the natural gas stream.

1. Introduction

In the last decades, humanity has satisfied its energy requirements through different renewable and non-renewable energy sources, especially fossil fuels [1]. Generally, this type of fuel is strongly associated with environmental pollution due to the large amount of atmospheric emissions that are generated during its extraction, processing and consumption [2]. However, natural gas is a particular fossil fuel since the level of atmospheric emissions it generates is very low and, therefore, it has become one of the main energy sources throughout the planet, supplying in recent years more than a fifth of the world energy demand [1,3].

Natural gas is composed mostly of methane, which can be used in a wide variety of industrial applications and processes [4]. In addition, in the natural gas mixture can be found higher molecular weight hydrocarbons such as ethane, propane, butane, pentane and hexane, among others, which modify the physicochemical properties of the gas [4,5]. The presence of these compounds in natural gas during the processing and transport stages can cause the appearance of the gas–liquid two-phase flow inside the pipes, which causes different types of inconveniences during the operation such as:
reduction of the commercial quality of the gas, clogging, accumulation of liquids and impurities, increased energy consumption of equipment, internal corrosion phenomena and loss of structural integrity of pipelines and processing equipment, among others [6,7].

Natural gas processing plants implement a set of technologies designed to carry out the removal of natural gas liquids, which can be recovered and sold to increase the economic profitability of the operation [8,9]. In the market, there is a wide variety of technologies that can be implemented to carry out the removal and recovery of these liquids, such as mechanical refrigeration, absorption with lean oil and absorption improved with triethylene glycol (TEG), as well as the Joule–Thomson and Turbo Expander processes [10]. In addition to this, there are currently new emerging processes such as Twister technology and molecular sieves, which seek to position themselves at industry of removal of natural gas liquids [11,12].

In the case of the department of Santander, in Colombia, the natural gas extracted from the producing fields Lisama, La Cira and Opón, Colombia, is processed at the gas plant “El Centro”, which currently does not have a removal and recovery system for natural gas liquids [13]. This situation makes the operation susceptible to different types of damages such as: 1) condensation and accumulation of liquids, 2) corrosion, 3) pressure drops in the transport lines, 4) increase in the process energy requirement 4) leakages and 5) loss of the structural integrity of the equipment associated with the processing of natural gas in the plant [7,10]. However, the implementation of this system must be carried out taking into account different variables such as: gas composition, pressure, temperature, process efficiency, availability of space at the plant facilities and supplies and maintenance requirements of each of technologies, among others [8,9].

For this reason, the technical and economic analysis of seven natural gas liquids removal and recovery technologies is carried out, in order to determine the process of greater efficiency and profitability according to the chemical composition of the natural gas and the conditions of current operation at the gas plant “El Centro”. The selection and implementation of natural gas liquids removal and recovery systems is of vital importance for the national industry because it allows inhibiting the appearance of gas–liquid two–phase flow while taking advantage of the economic potential of natural gas liquids recovered, guaranteeing the integrity of the process equipment and increasing the quality of the sold gas.

2. Experimental

Natural gas streams are obtained and treated in the oil fields Lisama, La Cira and Opón, Colombia, and then they are sent to the gas plant “El Centro” under the conditions shown in Table 1 to be unified and processed to reach the quality specifications necessary for their commercialization and consumption.

| Stream   | Pressure (psi) | Temperature (°F) | Average flow (MSCFD*) |
|----------|----------------|------------------|------------------------|
| Lisama   | 520 – 530      | 100 – 104        | 6500                   |
| La Cira  | 500 – 510      | 98 – 102         | 5000                   |
| Opón     | > 530          | 98 – 102         | 1400                   |

* thousand standard cubic feet per day

Currently, only the dehydration process of natural gas is carried out at the gas plant “El Centro”, using TEG to remove the water content. During this process, the natural gas stream rises from the lower section of an absorption tower at temperature of 120 °F, making contact with the TEG that enters through the upper section to carry out the transfer of the water mass. The gas removed from the absorption tower, with high content of higher molecular weight hydrocarbons and water content lower than 0.004 Lbs/MSCFD, flows through heat exchangers to take advantage of its thermal potential, while the TEG is regenerated by evaporating the absorbed water and it is pumped back to the system.

The technical and economic analysis of the seven natural gas liquids recovery technologies existing in the market that were identified as potential alternatives for the implementation at the gas plant “El
Centro” was carried out taking into account the physicochemical, operational and economic conditions of the process, evaluating for each technology the ten decision criteria presented in Table 2.

Table 2. Decision criteria for evaluation of natural gas liquids recovery technologies.

| Criterion                  | Description                                                                 |
|----------------------------|-----------------------------------------------------------------------------|
| Composition                | The technology is capable of processing a low acid gas with high content of higher molecular weight hydrocarbons. |
| Efficiency                 | The technology allows the recovery of a high fraction of natural gas liquids. |
| Flow                       | The technology allows processing gas flows between 10000 and 15000 MSCFD.    |
| Operation parameters       | The technology is adapted to the pressure and temperature conditions of the gas stream equivalent to 500 psi and 105 °F. |
| Variability                | The technology is flexible and adapts to possible variations in flow, pressure and temperature that may occur during the process. |
| Previous stages            | The technology does not interfere with the removal processes of solids, acids and water previously applied during the extraction and transport of natural gas. |
| Space requirement          | The technology can be implemented occupying the space available at the gas plant. |
| Equipment                  | The technology allows using non-active units of the gas plant and does not require the acquisition of high-cost equipment. |
| Supplies                   | The technology does not require the acquisition of high cost reagents or supplies for its implementation. |
| Maintenance                | The technology requires low-cost and low-frequency maintenance services.     |

3. Results and discussion

The chemical composition of the natural gas received at the gas plant “El Centro” from Lisama, La Cira and Opón, Colombia, fields was determined by gas chromatography as shown in Table 3, where it is also presented the chemical composition of the unified stream. In this way, it is observed that the natural gas processed in the plant can be classified as sweet wet gas, since it has a high content of higher molecular weight hydrocarbons and does not have significant fractions of hydrogen sulfide (H₂S).

Table 3. Chemical composition of the inlet streams at the gas plant “El Centro”.

| Stream  | C₁  | C₂  | C₃  | i-C₄ | n-C₄ | i-C₅ | n-C₅ | C₆  | N₂  | CO₂ |
|---------|-----|-----|-----|------|------|------|------|-----|-----|-----|
| Lisama  | 80.347 | 9.266 | 4.619 | 0.780 | 2.577 | 0.407 | 0.370 | 0.391 | 0.317 | 0.924 |
| La Cira | 81.406 | 4.715 | 2.618 | 1.136 | 1.066 | 0.471 | 0.326 | 2.681 | 1.280 | 4.137 |
| Opón    | 92.023 | 4.364 | 1.268 | 0.260 | 0.325 | 0.106 | 0.092 | 0.446 | 0.119 | 0.996 |
| Unified | 82.562 | 7.041 | 3.448 | 0.809 | 1.738 | 0.379 | 0.311 | 1.122 | 0.589 | 1.949 |

In addition to this, Figure 1 shows the envelopes of the four natural gas streams associated with the “El Centro” gas plant, where it is observed a strong influence of the chemical composition on the thermodynamic properties of the hydrocarbon mixture. Thus, in the envelopes of gas streams from the Lisama and La Cira fields (methane content close to 80%) the cricondentherm point is located above 70 °F, while in the envelope of the gas stream from Opón field (methane content greater than 90%) this point is below 50 °F. The gas envelope of the unified stream is similar to the envelopes of the Lisama and La Cira fields because these fields contribution is about 90% of the total average flow of natural gas processed in the gas plant “El Centro” (Table 1), while the contribution of the Opón field corresponds to only 10%. The processed natural gas presents a significant fraction of higher molecular weight hydrocarbons that must be removed in order to maintain the structural integrity of the plant, avoiding the corrosion phenomena associated with the accumulation of liquids in the pipes and processing equipment while obtaining an economic benefit for the recovery and commercialization of natural gas liquids [14,15].
Table 4 presents the evaluation of the technical and economic criteria accomplishment for the seven natural gas liquids removal and recovery technologies that were analyzed in this study for their potential implementation at the gas plant "El Centro". Mechanical refrigeration technology is one of the simplest and most direct processes for the recovery of natural gas liquids, which uses a refrigerant (usually propane due to its availability in natural gas plants) to reduce the temperature of the gas stream by heat exchange. However, this technology does not accomplish the variability criterion because the system is highly sensitive to temperature changes in the inlet stream, and therefore its efficiency is drastically reduced when the operational value differs from the design value [16]. Besides, the coating used as thermal insulation frequently requires the execution of maintenance operations, which reduces the economic profitability of the process [17].

The lean oil absorption technology does not accomplish several criteria due to the oil used, formed by a specific composition mixture of paraffinic compounds with molecular weight between 100 and 200 g/mol. Likewise, the lean oil is a supply that requires a large amount of equipment to be regenerated and recirculated to the process, which would occupy a significant area inside the plant and increase the maintenance cost of the operation. In addition to this, the physicochemical composition of the lean oil is optimized according to the process operational conditions during the initial system design, so its efficiency will be strongly affected by the variations of temperature, pressure and composition of processed natural gas [18].

Table 4. Evaluation of criteria accomplishment.

| Criterion                  | Mechanical refrigeration | Lean oil absorption | TEG improved absorption | Joule–Thomson | Turbo Expander | Twister | Molecular sieve |
|----------------------------|--------------------------|---------------------|-------------------------|----------------|----------------|---------|-----------------|
| Composition                | Yes                      | Yes                 | Yes                     | Yes            | Yes            | Yes     | Yes             |
| Efficiency                 | Yes                      | Yes                 | Yes                     | Yes            | Yes            | Yes     | Yes             |
| Flow                       | Yes                      | Yes                 | Yes                     | Yes            | Yes            | Yes     | Yes             |
| Operation parameters       | Yes                      | Yes                 | Yes                     | No             | No             | No      | Yes             |
| Variability                | No                       | No                  | Yes                     | Yes            | Yes            | Yes     | No              |
| Previous stages            | Yes                      | Yes                 | Yes                     | Yes            | Yes            | Yes     | Yes             |
| Space requirement          | Yes                      | No                  | Yes                     | Yes            | Yes            | Yes     | Yes             |
| Equipment                  | Yes                      | No                  | Yes                     | Yes            | Yes            | Yes     | No              |
| Supplies                   | Yes                      | No                  | Yes                     | No             | No             | No      | No              |
| Maintenance                | No                       | No                  | Yes                     | Yes            | Yes            | Yes     | Yes             |
The Joule–Thomson and Turbo Expander processes carry out the separation of natural gas liquids using expansion valves where a pressure drop reduces the temperature and favors the condensation of the higher molecular weight hydrocarbons [16,19]. However, one of the main limitations of these processes is that the efficiency in the removal of condensable hydrocarbons is reduced when the initial pressure of the natural gas stream is not high enough, as in the case of the gas plant “El Centro”, where the pressure of the natural gas stream is lower than 600 psi [20]. On the other hand, purchase and installation of isenthalpic expansion valves can represent a higher cost for the plant and reduce the potential economic benefits of the natural gas liquids recovery [19,20].

In the case of the Twister technology, a nozzle/diffuser module is used to generate a pressure drop that allows the higher molecular weight hydrocarbons to be cooled, condensed and recovered by centrifugation, while the diffuser is used to recover about 90% of the gas inlet pressure [10]. However, similar to the Joule–Thomson and Turbo Expander processes, the cost of the module and the high inlet pressure requirement reduce the technical and economic feasibility of the process [21].

The use of molecular sieves is an innovative technology recently developed for the removal of natural gas liquids, mainly ethane. However, the design and manufacture of the molecular sieve with specific pore size is expensive, so the purchase and adaptation to the installed process is not economically favorable [10]. Additionally, the sieve regeneration process requires a hot gas stream that increases energy consumption and limits its potential application at the gas plant “El Centro” [22].

Finally, it is possible to observe that the TEG improved absorption process accomplish all the established requirements, so it is selected as the natural gas liquids removal and recovery technology with greater technical and economic potential. One of the greatest advantages of this process is that it can be carried out in the currently available facilities for the water removal at the gas plant “El Centro”, so it is no required to purchase any equipment. In this way, the only required modification is the incorporation into the TEG stream of an additive developed in the “Instituto Colombiano del Petróleo (ICP)” that allows the separation of the higher molecular weight hydrocarbons simultaneously with the water removal process, and it is regenerated in the same TEG recovery system since it has a boiling point superior to 380 °F (193 °C) [23,24].

TEG improved absorption technology was evaluated in a pilot test using a natural gas stream with high content of higher molecular weight hydrocarbons, in order to analyze the effect of the additive incorporation on the gas envelope. In this way, Figure 2 shows the gas envelope of the inlet and outlet streams where is observed a variation of approximately 30 °F on the cricondentherm point, confirming the reduction in the maximum temperature above which gas–liquid two–phase flow cannot be formed regardless of the pressure. This reduction occurs due to the fact that, once most of the natural gas liquids are removed, a lower temperature is required to condense the small fraction of higher molecular weight hydrocarbons that may still be present in the mixture [14,15].
4. Conclusions
In the present investigation, the chemical composition of the natural gas streams from Lisama, La Cira and Opón fields were analyzed, and a significant fraction of higher molecular weight hydrocarbons was identified, which can compromise the structural integrity of the operation and must be removed from the process. Thus, the technical and economic potential of seven natural gas liquids removal and recovery technologies was evaluated based on 10 decision criteria established according to the physicochemical properties of the gas streams, the operational conditions and the physical infrastructure available at the gas plant “El Centro”. One of the criteria with the greatest influence on the technologies evaluation was the operating parameters, given that different technologies require high initial pressure to achieve high efficiency. In addition to this, the space available for equipment installation also reduced the potential of some of these technologies. Based on the analysis, TEG improved absorption technology was selected as the process with the greatest potential for implementation, and a pilot test was carried out where a reduction of 30 °F at the cricondentherm point was obtained. For this reason, the selection and evaluation of this technology for its potential implementation at the gas plant “El Centro” will reduce the damage risks of equipment by avoiding condensation of corrosive liquids, increase the service life of the processing infrastructure and increase the economic operation profitability.

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