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Evolutionary Synthesis Process For Methane Liquefaction

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Abstract
The present work focuses on the generation and development of various alternatives of process for the liquefaction of natural gas (essentially methane) using the methodology of Evolutionary Design, taking as the cycle start scheme of Linde simple. It presented four alternatives of process, generated on the basis of thermodynamic principles of efficient use of energy. The balance sheets of matter and energy are carried out using a commercial simulator processes. It finally discusses the energy evaluation and comparison of the cases and their relation with the minimum work for the process. It has managed to define an outline of process that can reduce power consumption to a very low value, which in this case is only 4 times the minimum work, although requires an increase in the complexity of the process as well as the number of required equipment. The final selection of the optimum scheme requires to make an economic analysis, which include the costs of investment and operation involved in each case and that ensure the maximum profitability

***Keywords:* Liquefaction, Natural Gas, Evolutionary Design, Methane**

1. Introduction

There are various routes of process for the liquefaction of natural gas, of which must be selected that present lower total cost (investment and operation) where the last item is strongly linked with the energy consumption of the process. To find an optimum scheme of process one can use a conceptual tool known as evolutionary design, where a scheme of base process is carried out for an analysis of energy consumption primarily, operability and equipment requirement. This procedure will detect the advantages and disadvantages of base schema which leads to propose certain modifications to obtain a new scheme of process that retain the positive aspects and reduce the negative aspects (Aguilar, 2007; Biegler and col., 1997). To follow an evolutionary design of the process, it is necessary to establish a reference in terms of energy consumption; therefore, it is necessary to know the minimum required energy which is independent of the "real" process in which it is carried out. It is a property of point of the system and is obtained by considering a process that is performed in reversible.

It is assumed that the natural gas is essentially methane to the deposit output conditions (15.6 °C and 5516 kPa) and we want to convert it to a liquid saturated at atmospheric pressure (-161.6°C and 101 kPa) as shown in Fig. 1. From these conditions it is possible to determine the minimum power consumption. Given that the methane has a critical temperature of -82.5°C, it cannot be liquefied under any circumstances at higher temperatures.

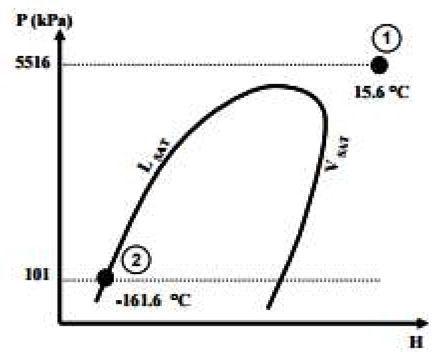

Figure 1 Initial and end conditions of methane in a Mollier diagram

To achieve a cooling of gas from conditions in the reservoir, we will have 3 possible processes: exchange of heat with a cold current, isentropic expansion with production of work and Adiabatic Expansion in a valve (Joule process - Thompson) (Aguilar and col., 2005). For this study, it was considered as base scheme of the Joule process - Thompson along by exchange of heat. The reason for cooling the load must be that if we can make an expansion from 5516 kPa and 15.6°C to the atmospheric pressure, the temperature will drop only until -12.2°C, so that there will be no liquefaction.

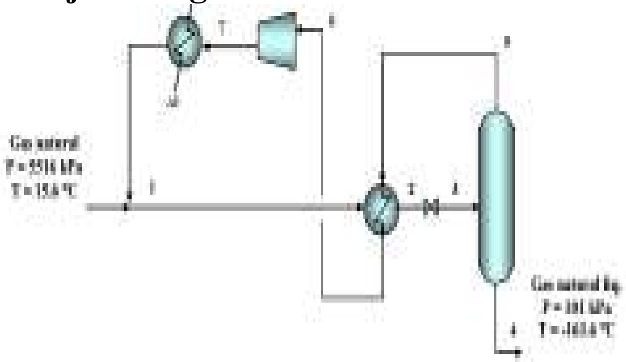

Figure 2 Cycle of Linde Simple

The combination of these concepts gives origin to the cycle of Linde simple (Fig. 2), which is represented in a diagram of Mollier according to Fig. 3. This process consists of a cooling of the load by exchange of heat with the flow of cold gas obtained from the expansion, followed by an adiabatic expansion of the gas. The compressor of the recirculation gas produced by the expansion represents the point of injection power of the process and the main team to analyze in this study

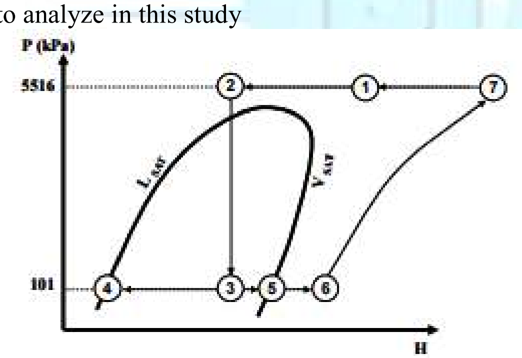

Figure 3Representation of the cycle of Linde simple in a diagram of Mollier

Taking as a schema to start the cycle of Linde simple, we follow an evolutionary design of the process by making modifications in order to reduce the compression work. Possible modifications are based on two concepts:

a. Expansion in multistep processes a corollary of the second law of thermodynamics is that between more stages are carried out in a process, it has a lower dissipation of energy and therefore improve the overall energy efficiency, i.e. it requires less energy to be performed. However, the greater the number of stages requires greater number of computers. Consequently, investment costs compete with the energy cost savings achieved. This idea is outlined in Fig. 4.

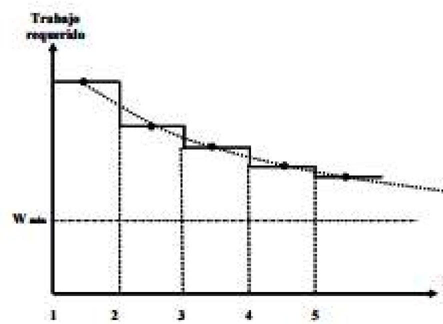

Figure 4 Number of stages and energy consumption of the process

b. Pre-cooling of the load before the expansion. A feature of fluids in the supercritical region is that the drop in temperature caused by an expansion in valve is more severe if the initial temperature is lower. In thermodynamic terms, the coefficient of Joule- Thompson is greater at low temperatures of start of expansion (Fig. 5).

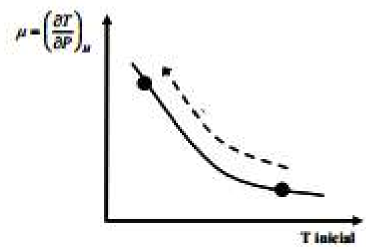

Figure 5 Effect of the initial temperature in the coefficient Joule-Thompson

Finally, both modifications can be integrated in a scheme of more complex process but with much lower power consumption. Based on the foregoing, the objective of this study is to develop various alternatives of process for the liquefaction of natural gas following the methodology of Evolutionary Design, taking as the cycle start scheme of Linde simple. Also, it is necessary to make a comparison from a point of view of energy of the alternatives proposed.

2. Methodology

The generation of alternative process for the liquefaction of methane is based on the following methodology:

1. Approach of several cases of process alternatives for the liquefaction of natural gas based on the cycle of Linde. The cases raised were:
   - Case 1: Linde Cycle simple.
   - Case 2: Linde cycle with double expansion.
   - Case 3: Linde cycle with simple load with different refrigerants and cooling levels (ammonia, Freon 12, propylene, ethylene, and methane).
   - Case 4: Linde cycle with double expansion and with pre-cooling of the load using ethylene as refrigerant.
2. Balance sheets of matter and energy of the cases through the use of a simulator of processes (Hysys v. 3.1), using the equation of state of Peng-Robinson for the calculation of the thermodynamic properties.
3. Analysis and comparison of the cases from the point of view of energy.

3. Results and Discussion

3.1 Case 1: Linde Cycle Simple
In this case the Linde cycle simple is analyzed, where a fraction of 5.9 % of liquefaction is achieved. The compression work required is 14,575 kJ/kgGL, that is 34 times greater than the minimum work. Both data are presented in the last row of the Table 1.

3.2 Case 2: Linde cycle with double expansion.
In this scheme of process introduces the use of two stages of expansion (Fig. 6). The representation of the process is in a Mollier diagram shown in Fig. 7.

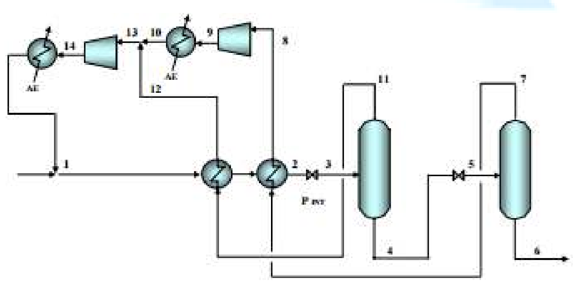

Figure 6 Linde cycle with double expansion

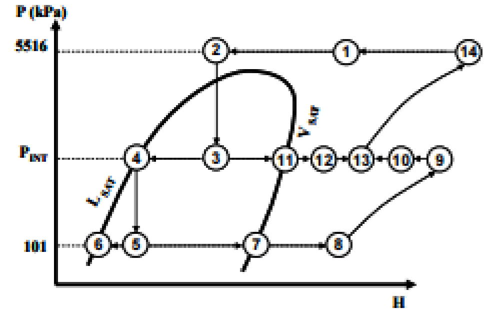

Figure 7 Representation of Case 2 in a Mollier diagram

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