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# Feasibility Study of Using a Three-Phase Separator for Increasing NGL Production in an Iranian's Dehydration Plant

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**Abstract**

In this paper, a feasibility study about possibility of installing and utilizing a secondary three-phase separator before entrance of natural gas through dehydration's tower in an Iranian's natural gas dehydration plant is carried out. The required calculations are made by taking into account present plant operational data and simulate it by using AspenOne software package that consists of Aspen Plus and Aspen Hysys. In this simulation, the Peng-Robinson equation of state is employed. Results reveal a maximum 4% increment in producing NGL from Natural gas with assuming 10% pressure drop under adiabatic conditions of flowing gas is obtainable. Water removal rate is also increased up to 10 liters per hour. Additionally, Other important parameters such as NGL production reduction due to changes in the gas well characterizations over time and changes in heating value of natural gas is investigated. In conclusion, by using economical evaluation and calculating the internal rate of return (IRR) equal to 4.5% for this project, possibility of performing this project by considering all of involved parameters is studied.

***Keywords:*** Dehydration; Three-phase separator; NGL, Simulation; Pressure drop.

## 1. Introduction

Natural gas (NG) is one of the world's favorite, promising, and cheap fuels with a wide variety of applications. Natural gas liquids (NGLs) are one of the main products are sourced from NG stabilization units of all industrial gas refineries [1]. NGLs are commonly determined as heavier hydrocarbons of natural gas which tend to be in liquid state at atmosphere condition. They are mainly composed of methane, ethane, propane, butane, pentane, hexane, and heptane [2-4]. The process of water vapor removal from a gas stream to decrease the dew point temperature of water is called the gas dehydration process [5].

In the last few decades, extensive studies have been conducted in the area of natural gas dehydration process [5-7]. Machado *et al.* [6] focused their attention on a novel dehydration process namely supersonic technology (Twister) and showed the superiority of the Twister technology over the conventional absorption method. Zou *et al.* [7] carried out an experimental study on the subject of natural gas adsorption–dehydration using molecular sieves. In the same year, Nemati Roozbahani *et al.* [5]] investigated the simulation, optimization, and sensitivity analysis of a natural gas plant. Their study was focused on significant parameters playing a central role in the dehydration unit and accordingly, the best operating conditions were determined.

The main goal for establishing a dehydration plant in a gas refinery company is to perform primary separation and dehydration of outlet natural gas from wells. In this process after passing natural gas through a three-phase separator, a large amount of its liquids is removed and is produced as NGL, also a fraction of gas' along water is separated from bottom section of vessel due to its higher density. Outlet gas from upper section of separator is exiting in saturated condition and then it is entering in dehydration tower, at this point remaining water in gas is removing by injecting an absorber like TEG. Finally, dehydrated gas is transferring to outside of the unit to be sold as product. Regarding to high value of natural gas liquids and possibility of direct exporting of it. Increasing NGL production has been always an interesting field for Gas processing industries and companies. The purpose of this article is study possibility of installing a secondary three-phase separator on path of outlet saturated gas stream from primary separator for examining how much increment in NGL production amount will occur on daily basis. Moreover, Economic evaluation and study of other effective parameters on this process will be considered.

## 2. An Iranian Dehydration Plant

### 2.1. Simulation by Aspen

This case study is performed by using overall natural gas component analyze before entering to primary 3-phase separator (after exiting from well) and considering operational and design data of dehydration unit as reference data. Table 1 is showing these data in detail.

Table 1. Inlet natural gas to primary 3-phase separator analyze and operational conditions

| Components | Mole Fraction (%) | Conditions | |
|---|---|---|---|
| Methane | 80.66 | Phase Fraction | 0.9853 |
| Ethane | 3.84 | Temperature: (°C) | 38.55 |
| $C_3$+ | 3.65 | Pressure: (barg) | 50 |
| $N_2$ | 10.5 | Molar Flow (MMSCM/D) | 2.86 |
| $H_2S$ | 0 | | |
| Other Components | 1.35 | | |

It should be mentioned that above data has been used for simulation of this unit in Aspen Hysys and Aspen Plus separately and some results for outlet streams has been calculated. These results are shown in Table 2 briefly and can be compared to design data. As it can be seen, deference between calculated data and design data is too small and negligible. Therefore, these data can be used for simulation of using a secondary three-phase separator and calculating the results with an acceptable accuracy. The difference between Aspen Plus and Aspen Hysys results is due to different data bank that is used by them to estimate 3-phase equilibrium coefficients for calculating necessary parameters in Peng-Robinson equation of state, which it leads to a slight disagreement in calculated results. Nonetheless, this disagreement is insignificant and so, negligible [8].

Table 2. Comparison of obtained volume flow rate for outlet streams from primary separator

| Source Data | Outlet Gas (Kmol/hr) | NGL ($m^3$/day) | Drain Water ($m^3$/day) |
|---|---|---|---|
| Design Data (Reference Data) | 4920.3 | 190.8 | 4.34 |
| Aspen Hysys | 4926 | 188.35 | 4.35 |
| Aspen Plus | 4925.5 | 193.8 | 4.21 |

It is important to bear in mind that the main goal for installing the secondary separator is to produce more NGL while the other required costs for performing this project still are reasonable and economical [9-10]. Fig. 1 is showing a schematic view of this separation process along with the secondary separator. Since the Outlet Gas stream is in saturated condition, for producing more NGL from it, a change in thermodynamic parameters of gas is necessary which in this case the most applicable industrial solution is to reduce pressure. According to the simulation, this pressure drop is possible in two different conditions: adiabatic and isothermal [11]. This pressure drop can be performed by installing a simple control valve on path of Outlet Gas stream before entering to the secondary separator or by assuming pressure loss in pipeline and second separator due to friction and other sources. It has to be mentioned that in actual industrial operating conditions using a control valve will decrease both pressure and temperature simultaneously, therefore this process is more close to adiabatic conditions [12]. Assuming the isothermal condition for this pressure dropping process, Maximum production of NGL in secondary separator with average pressure drop of 6.5 bar will be calculated about 0.8 m³/day.

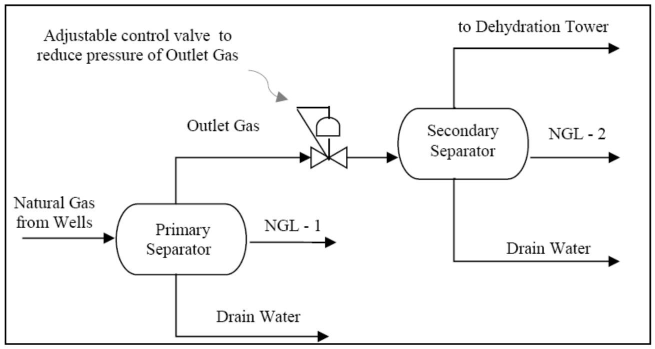


Fig. 1. A schematic view of elementary separation of natural gas process

As it illustrates in Fig. 2, due to thermodynamic equilibrium conditions of Outlet Gas stream, under an isothermal process, for higher pressure drop, NGL production flow rate is reduced again, therefore the optimum limit for pressure drop in this situation will be assumed 6.5 bar. In adiabatic condition as the result of decreasing Outlet Gas stream's temperature and pressure simultaneously, NGL production will be much higher.

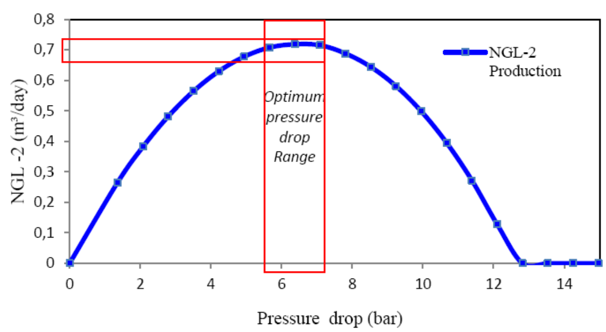


Fig. 2. Effect of various values of pressure drop on NGL production under an isothermal pressure reduction procedure, calculated by Aspen Plus.

As it has been shown in Fig. 3, for pressure reduction up to 6.5 bar, NGL production from the secondary separator will be calculated about 7.5 m³/day, this pressure drop also leads to a 2.4°C temperature reduction of Outlet Gas stream. Since this process is taking place under adiabatic condition, for any amount of pressure reduction, produced NGL will increase. However, due to operational failures and limits such as maximum tolerable pressure drop by transmission pipes, installed controlling instruments on pipeline and minimum required pressure for transmission of treated gas, pressure drops above 6.5 bar will be ignored on calculations [13-14]. Summary of calculation's results by Aspen Plus and Hysys can be seen on Table 3.

Table 3. Comparing maximum producible NGL in m³/day after installment of the secondary separator for pressure drop up to 6.5 bar calculated on various simulators

| Simulator program | Adiabatic conditions | Isothermal conditions |
|---|---|---|
| Aspen Plus | 7.5 | 0.77 |
| Aspen Hysys | 7 | 0.72 |

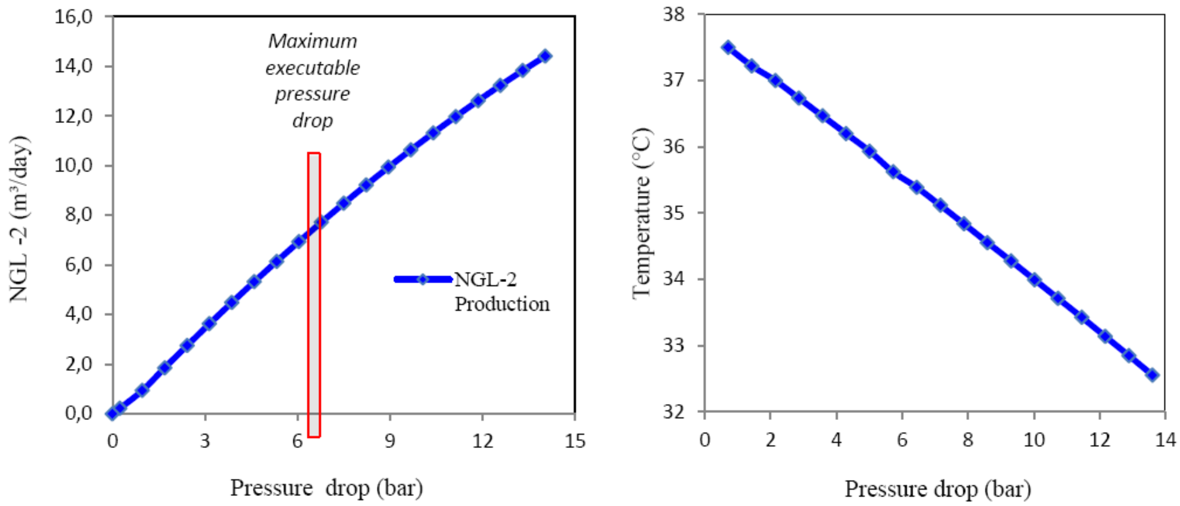


Fig. 3. Effect of various values of pressure drop on NGL production (left figure) and on stream's temperature (right figure) under an adiabatic pressure reduction process, calculated by Aspen Plus.

## 3. Effective parameters

### 3.1. Production reduction over time

NGL production decrement in this plant due to Well lifetime passage and natural gas specifications change on inner layers of the well over the time is another important issue that has to be mentioned. In this situation, various NGL productions' amounts in consecutive years must be compared to each other and then the average decreasing in NGL production coefficient should be calculated [15-16]. By using actual data about NGL production in different years, Fig. 4 can be drawn.

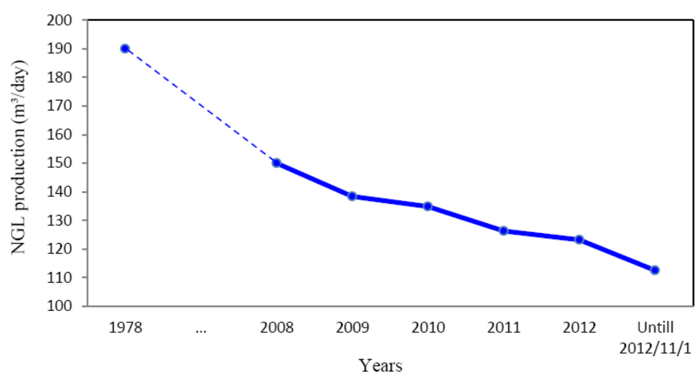


Fig. 4. Overall NGL production from primary separator in different years by assuming maximum capacity

These data are based on maximum capacity of dehydration plant in treating natural gas, which is around 2.86 MMSCM/d. According to this figure, NGL production has a negative slope and a descending rate in every year as it falls from 190 m³/day in the beginning days to approximately 110 m³/day on second half of 2012. By considering average of 130 m³/day for NGL production from primary separator during last 5 years and dividing it to reference production, i.e. 190 m³/day, a modification coefficient equal to 0.68 is calculated. Multiplying this coefficient in the results of Table 3 will give a better assumption about actual NGL production increment in case of installing a new secondary separator. Table 4 shows these new results and according to it, maximum amount of NGL production is about 5.2 m³/day under adiabatic conditions.

Table 4. Comparing maximum producible NGL in m³/day after installment of the secondary separator for pressure drop up to 6.5 bar calculated on various simulators by considering coefficient of production decrement

| Simulator program | Adiabatic conditions | Isothermal conditions |
|---|---|---|
| Aspen Plus | 5.2 | 0.51 |
| Aspen Hysys | 4.8 | 0.49 |

### 3.2. Net heating value

Effect of producing more NGL on possible changes in net heating value of dehydrated natural gas is another important parameter that should be deliberated. Since molar fraction of $N_2$ in inlet feed from wells is significantly high and it doesn't remove in any steps of dehydration from natural gas, therefore producing more NGL from it may decrease net heating value of final sale gas even lower which will lead to unsatisfactory among household and other users [17-18]. Hopefully, according to simulating results these changes can be investigated. Fig. 5 displays variations of net heating value of natural gas per pressure drop increment for both adiabatic and isothermal conditions. As it can be seen, these variations are very low and negligible as in isothermal conditions a maximum reduction of 0.5 kJ/kg for gas heating value is expected while these changes under adiabatic condition are slightly larger and about 0.8 kJ/kg at the same pressure drop. By the way, these amounts are still inconsiderable compare to natural gas net heat value itself, which is approximately larger than 4180 kJ/kg.

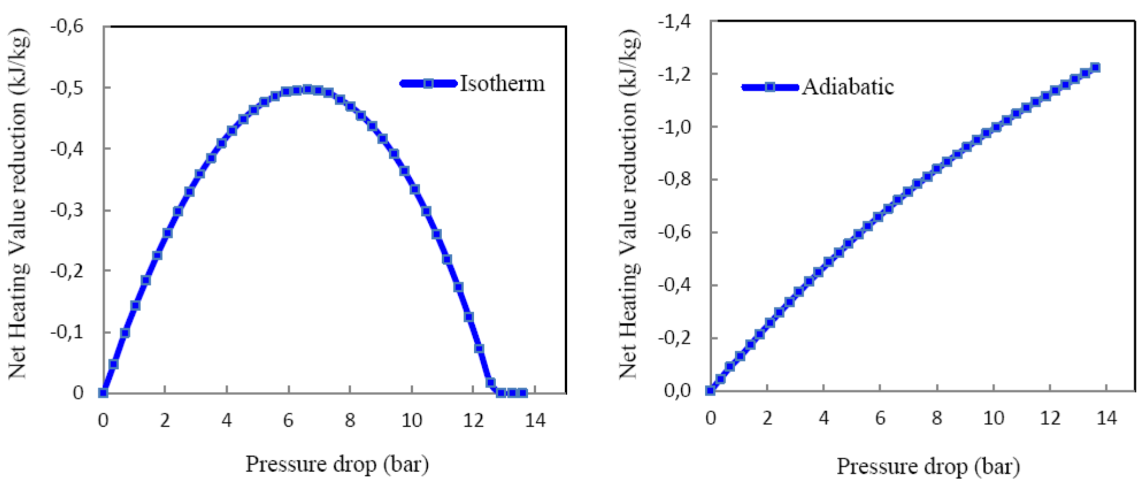


Fig. 5. Net heating value reduction of natural gas per pressure drop for isothermal (left figure) and adiabatic (right figure) conditions.

### 3.3. Water removal

The next important parameter that must be investigated is effect of installment of the new separator on removing extra water from natural gas. The along water with natural gas may cause severe problems during transmission by pipelines such as possibility to form hydrate or even ice at specific temperature and pressure range, which will lead to pipeline plugging or bursting. As a result, natural gas dew point must not exceed from standard value and removing water content from gas will strongly help to decrease its dew point [19-20]. According to sensitivity analyze by Aspen Plus under isothermal conditions, increasing pressure drop cannot remove any considerable amount of water from saturated gas, while under adiabatic conditions; as shown in Fig. 6; volume flow rate of water removal will increase up to 0.25 m³/day at pressure drop of 6.5 bar. For more pressure drop, more water is removed from gas due to decreasing temperature and consequently unbalancing saturated conditions for this along water.

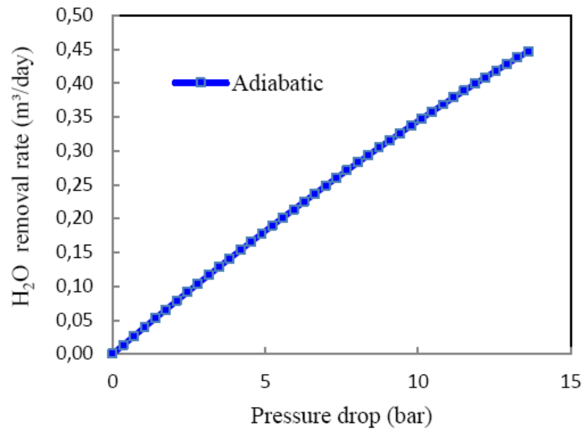


Fig. 6. Volume flow rate of removed water from secondary separator per pressure drop under adiabatic conditions

### 3.4. Economic evaluation

Finally, after considering major effective parameters on NGL production while separation by the secondary separator, it is vital to study economic evaluation of this project to reveal its feasibility of being practical. According to latest statistics, net profit of selling each cubic meter of NGL is about 63 US$ for this dehydration plants. Concerning discussed subjects and calculated data by Aspen Plus simulator, which estimates a maximum extra production of 5.2 $m^3$/day for NGL, a yearly profit of 120,000 US$ will be obtained by selling this NGL. Since other mentioned parameters such as gas heating value changes and extra water removal from natural gas are too low, therefore their effects on economic evaluation of this project can be neglected. Estimating initial required investment and fixed cost for this project is the next step [21]. These capital costs are consisting of buying a new three-phase separator and transferring it to the plant, piping and fitting installment's costs, foundation placement, installing and purchasing required amount of control and safety valves, performing important safety tests on pipeline after piping and eventually paying workers who need to work on this project [22].

Based on latest available data [23-25], all of mentioned costs are estimated approximately 1,000,000 US$ until the end of the year 2012. By dividing this amount to yearly profit of project, a minimum 8 years margin is needed for this project to be profitable. To specify whether this project is economically attractive or not, the internal rate of return (IRR) index can be used. Larger positive values of IRR in shortest period are favorable. Calculation formula of IRR is shown on equation 1.

$$NPV = \sum_{n=1}^{8} \left( \frac{C_n}{(1+r)^n} \right) \tag{1}$$

In this equation, NPV and $C_n$ are representing net present value of this project and net incomes minus costs respectively and are calculating on annual basis. For NPV=0, 'r' will become IRR. 'n' is minimum year (or any period of time) that IRR on it will be greater than zero, which is assumed around 8-9 years. Solving equation 1 by using try and error method, will give an IRR equal to +1.6% after spending 9 years minimum without considering equipment' fatigue and maintenance cost which assume as a relatively low value. Investing on this project, therefore, is not economically attractive.

### 4. Conclusion

In this work, installation of a secondary three-phase separator in an Iranian dehydration plant was simulated by using steady state flowsheet simulators (Aspen Plus & Aspen Hysys). It was found that by performing a controllable pressure drop on natural gas entrance to this vessel up to 10% of its average flowing pressure on pipeline, under adiabatic conditions, a maximum 4% increment on NGL daily production is obtainable. In addition, dehydration process on this plant was slightly enhanced by increasing water removal from natural gas up to 6%. Required initial investment for this project was estimated 1,000,000 US$, no fixed cost was taken into account after exploitation of this separator and net profit of selling extra NGL was calculated as 12% of total costs in each years. By considering calculated IRR after 8 years, equal to 1.6%, investing on this project was found unreasonable and non-economic.

**Nomenclature**

| | | |
|---|---|---|
| NGL | : | Natural Gas Liquids |
| NPV | : | Net Present Value |
| IRR | : | Internal Rate of Return |
| $C_n$ | : | Net incomes minus costs for an specific project |

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