# Optimization of Oil-Gas Separation in the Production Stations at Abo-Sannan Field Case Study

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## Abstract

The study employs Aspen HYSYS simulation and optimization tools to investigate three different scenarios. This optimization aims to determine the optimal separator pressures for a two-stage gas-oil separation plant (GOSP) as well as modified configurations for three- and four-stage separations while targeting maximum profit and best results.

The study consists of three case scenarios. The first case study deals with the existing base station under normal and optimal operating conditions. The second case study involves modifying an existing T-oil plant by rearranging the separators to create sequential separators that operate under ideal conditions. The third case study explores adding one additional separator in series to the three existing separators in the series, all of which operate under optimal conditions. Extracting oil and gas, reducing energy consumption. The crude oil Reed Vapor Pressure (RVP) is set to 10 psi for all scenarios.

This study resulted in significant improvements, including a daily increase in oil recovery of 1.8%, 2.3% and 2%, as well as a daily increase in net profit of 6.4%, 5.8% and 4.3%, respectively. Specifically, simulations conducted in the three case studies revealed significant daily increases in oil recovery also highlight the potential for improved performance and economic benefits through improved T-oil plant and GOSP operations, contributing to a more sustainable and profitable crude oil processing industry.

The crude oil stabilization unit known as the T-oil plant within the Gas-Oil Separation Plant (GOSP) is greatly enhanced by using the multiple separation stages.

## Introduction

The well stream typically contains a mixture of gas, oil, water, and condensates. To separate these components effectively, a series of separators are employed. The primary purpose of these separators is to utilize gravity-based forces to divide the extracted well fluid into its constituent parts (Olugbenga et al. 2021). During this separation process, pressure plays a crucial role in determining the flow of liquids, and the resulting fractions are subsequently transported to a laboratory for analysis. This analysis allows us to discern the composition of gas, oil, and condensates within the well stream. Therefore, not only does pressure impact well flow, but the separation of well fluids also provides valuable insights into each well's conditions (Zeng et al. 2021).

The initial phase of separation focuses on removing water from the well stream, followed by the separation of oil and gas in the production separator. Both of these separation processes are gravity-driven, ensuring the efficient division of the different fluid components (Wang et al. 2022).

The objective of liquid separation is to generate a gas stream that is devoid of propane, as well as other hydrocarbons and crude oil constituents. This gas stream should remain stable under storage conditions to prevent the evaporation of crude oil during transfer to storage tanks. This is particularly important because


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crude oil often contains light components that can evaporate due to slight variations in storage pressure and temperature (Al-Mhanna 2018).

The process for achieving this separation involves a three-stage approach that is employed for separating well fluids. These stages consist of high-pressure, medium-pressure, and low-pressure separators. To reduce the water content in well fluids from 0.4 parts to approximately 0.05 parts, a three-phase high-pressure separator can be utilized. It's crucial to note that the initial stage of oil-gas separation from the well stream is the most critical step in the crude oil field processing. In the reservoir, high-pressure crude oil contains a significant number of dissolved gases (Tian et al. 2022).

To effectively separate the crude oil and obtain it in a stable state, it's essential to gradually reduce both its pressure and velocity. This reduction occurs within the Gas Oil Separation Plant (GOSP). However, a challenge arises during this pressure reduction process in the GOSP, as some of the lighter and more valuable oily hydrocarbons may escape with the gas into the vapor phase (Mosleh et al. 2022).

The purpose of crude oil stabilization is twofold: to align with market specifications and minimize the loss of liquid hydrocarbons within atmospheric storage tanks. This process reduces the volume of intermediate hydrocarbon components like propane and butane that transition to a vapor state, thereby increasing sales liquid volume while reducing vapor pressure (Bakyani et al. 2018).

One of the methods employed in crude oil stabilization is stage separation. In this process, the well stream undergoes a series of equilibrium flashes within a Gas Oil Separation Plant (GOSP), gradually reducing the pressure until it matches atmospheric tank pressure. This results in a more stable tank liquid (Alireza et al. 2008). While increasing the number of separation stages can yield more valuable recovered liquids, practical constraints often limit the actual number of separations due to operational costs (Sarvestani et al. 2009).

For low water and gas oil preparation plants dealing with oils containing minimal water and gas (less than one-third of the total mixture), a single-stage separation is typically sufficient. However, in cases involving oils with higher water and gas content, a two-stage separation system is recommended and commonly employed (Andreasen 2020).

When comparing the three-stage separation process to the four-stage separation process, it has been observed that the four-stage separation provides a higher liquid recovery, with an increase of up to 25%. However, it is important to note that these units are constrained by both capital and operating costs, which can be substantial in many separation facilities (Mahmoud et al. 2019).

While it is theoretically true that increasing the number of consecutive separation stages should result in higher liquid recovery, practical limitations come into play. Factors such as available space, fixed costs, and operating expenses impose constraints on the number of stages that can be effectively employed (Al-Jawad et al. 2010). In practice, the number of stages typically falls within the range of two to four, and the choice depends on variables such as the gas-to-oil ratio (GOR) and the well stream pressure (WSP), as illustrated in **Table 1**.

**Table 1—Stages of oil specifications.**

| No. of stages | Oil specifications |
|---|---|
| 2 stages | Low GOR and WSP |
| 3 stages | Medium GOR and intermediate WSP |
| 4 stages | High GOR and WSP |

Usually, the three-stage separation process represents the economic optimum, offering a liquid recovery rate that is 2-12% higher than that of a two-stage separation process. In certain cases, it can even achieve liquid recovery rates up to 25% higher (AL-Maliki and and Madhi 2019). The quantities of recovered gas and oil at a specific pressure are determined through equilibrium flash calculations, using an equation of state (EOS) (Edwin et al. 2017).

The existing gas/oil separation plant is a two-stage separation Gas/Oil Separation Plant (GOSP) consisting of two parallel separators and an atmospheric tank in series. The plant receives two different pressure streams (high and medium pressures), which are pre-heated and directed to two parallel separators (high and medium pressure separators). These separators separate the oil to meet the required specifications (RVP) for the sales pipeline and send the gas to a compression station to increase its pressure to 650 psig. The operating pressure significantly influences separator performance as it determines the liquid exit rate and can be regulated using a back valve that controls the air pumping, thereby affecting the flow of separated gas into the gas pipeline (Kylling 2009).

While both pressure and temperature are factors in controlling fluid recovery, the ambient temperature within the separators remains consistent, resulting in them operating at the same surface temperature. Consequently, pressure is the primary factor influencing improved results, leading to higher separator pressures and a larger presence of light components in the liquid phase (Kim et al. 2014).

Conversely can lead to the separation of many light components in the liquid phase, while conversely, it can attract significant quantities of medium and heavier contents. Therefore, it is advisable to adjust the separator pressure during both winter and summer seasons to maximize fluid recovery (Hajivand and Vaziri 2015).

This study comprises four HYSYS simulation cases. The first case represents the existing two-stage separation plant, with the process flow outlined in Table 1. The second case involves optimizing the first case to identify the most efficient operating conditions that yield the highest net profit, balancing oil recovery and energy consumption. The third case investigates the impact of rearranging the separators, transforming the two separators into a series of three-stage separations, on oil recovery, energy consumption, and net profit. The fourth case assesses the effects of adding an additional separator in series, resulting in a four-stage separation, on oil recovery, energy consumption, and net profit.

## Methodology

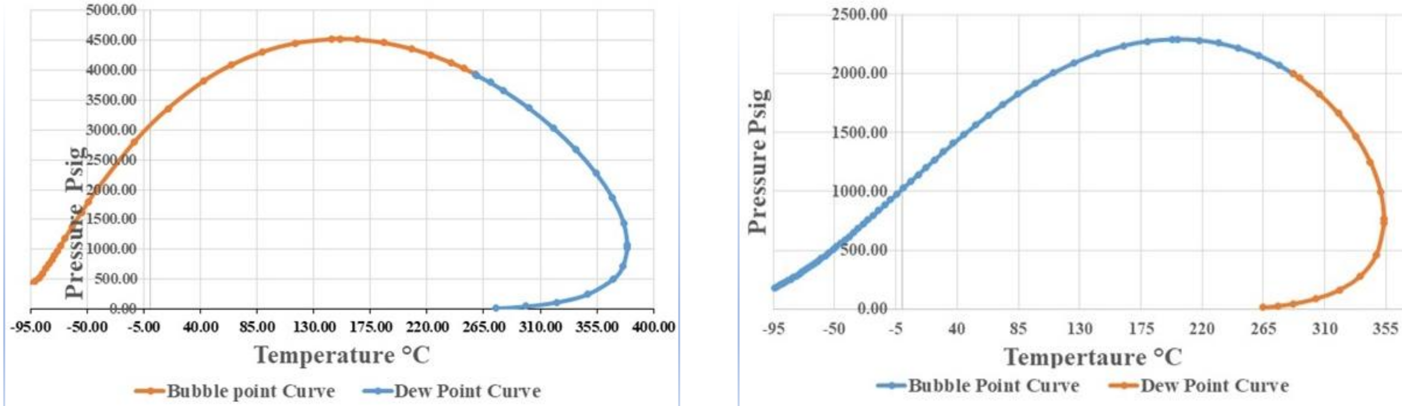
The study employed Aspen Hysys process simulation (version 8.8) using the Peng-Robison equation of state as the primary tool. The main focus of this simulation was the optimization of an existing Gas Oil Separation Plant (GOSP) with the aim of maximizing profit while achieving a Reid Vapor Pressure (RVP) within the range of 10-12 psia. The process involves two manifold streams: one operating at high pressure and the other at medium pressure.

**Table 2** displays the composition of crude oil feeds and the operating conditions of the crude oil streams from the manifold to the GOSP inlet.

**Table 2—Feed streams composition.**

| HP Crude oil Feed-1 | | MP Crude Oil Feed-2 | |
|---|---|---|---|
| S. Pressure (Psi) | 250 | S. Pressure (Psi) | 35 |
| Component | Mole % | Component | Mole % |
| C1 | 56.14 | C1 | 31.09 |
| C2 | 7.24 | C2 | 10.31 |
| C3 | 5.58 | C3 | 15.56 |
| IC4 | 1.55 | IC4 | 3.00 |
| NC4 | 2.28 | NC4 | 4.67 |
| IC5 | 1.47 | IC5 | 1.74 |
| NC5 | 1.37 | NC5 | 0.74 |
| NC6 | 3.14 | NC6 | 3.22 |
| C7+ | 20.39 | C7+ | 29.35 |
| N2 | 0.09 | N2 | 0.01 |
| Co2 | 0.65 | Co2 | 0.05 |
| H2S | 0.00 | H2S | 0.00 |
| H2O | 0.09 | H2O | 0.25 |

Additionally, **Figure 1(A)** illustrates the Pressure-Temperature envelope of the high-pressure crude oil stream, while **Figure 1(B)** presents the Pressure-Temperature envelope of the medium-pressure crude oil stream. In **Figure 2**, a process flow diagram of the Aspen Hysys simulation for the GOSP is depicted.




(A) (B)

**Figure 1—Pressure-temperature envelope diagram of crude oil flow under different pressures: (A) high-pressure region; (B) medium-pressure region.**

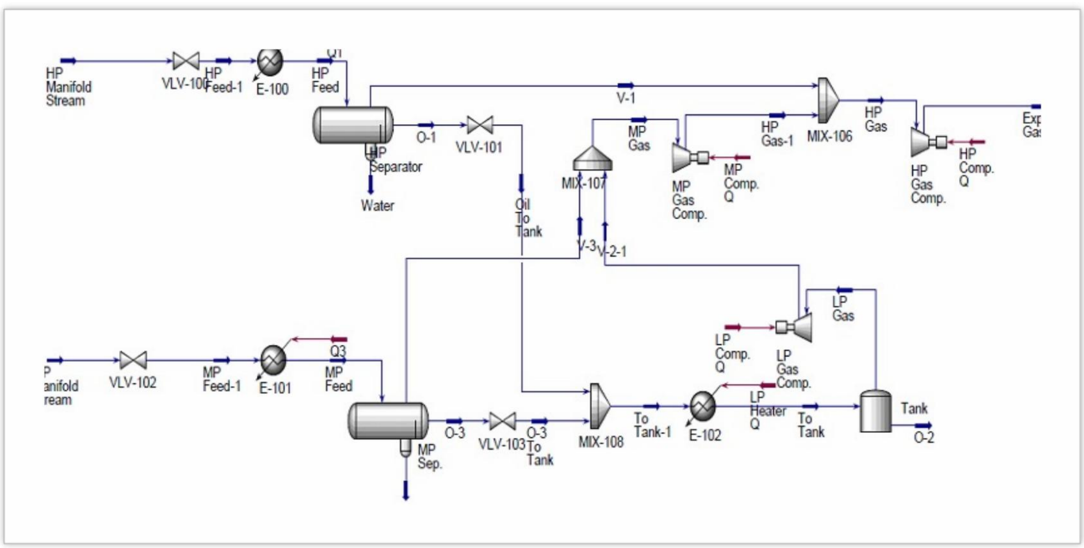



**Figure 2—Aspen Hyses simulation process diagram.**

**Table 3(A)** provides a detailed overview of the operating conditions, including separator pressure, separator temperature, energy consumption, oil recovery, and gas recovery. These streams pass through pre-heaters to adjust the fluid temperature before entering the high-pressure separator (operating at 250 psig and 25°C) and the medium-pressure separator (operating at 35 psig and 30°C). Gases separated in the process are collected and sent to the Abu-Sannan Condensate Recovery Plant via compressors. The oil stream is directed through a heater to raise its temperature to achieve the target RVP of 10-12 psia before being stored in a tank.

Furthermore, **Table 3(B)** provides details on the optimum operating conditions, including separator pressure, separator temperature, energy consumption, and oil recovery, for the actual two-stages GOSP optimization case (the second case) with an RVP of (10-12) psia.

In the third case of GOSP modification, the parallel separators in the main HYSYS case were rearranged into series separators, resulting in a three-stage separation plant. This configuration was then optimized to determine the optimum operating conditions, energy consumption, oil/gas recovery, and net profit, as detailed in **Table 3(C)**. **Figure 3** illustrates the simulation process flow diagram for the three-stage GOSP modification.

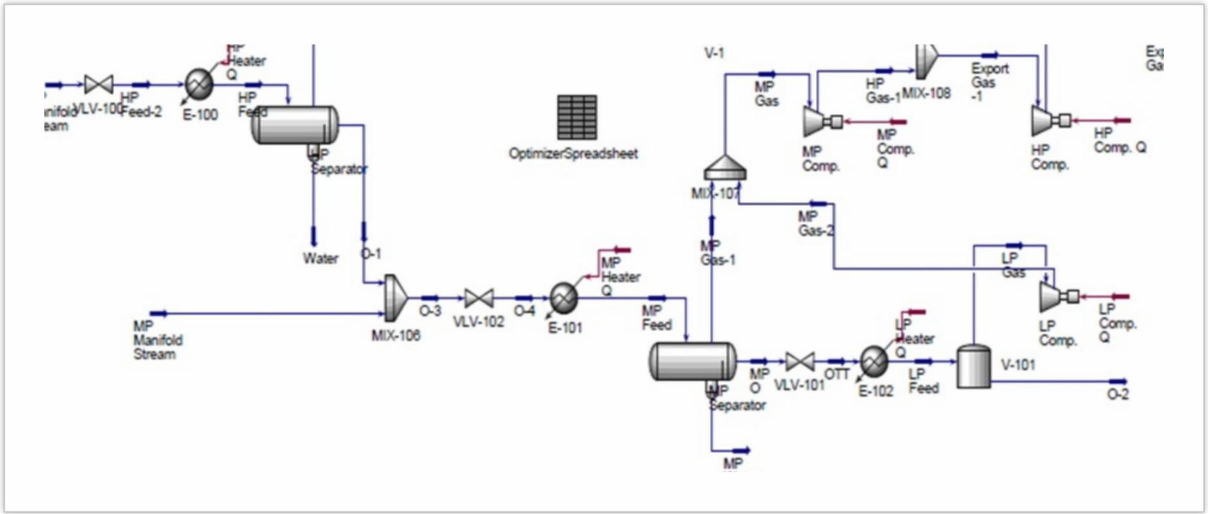



**Figure 3—PFD for the three-stage GOSP modification.**

In the fourth case of GOSP modification, an additional separator was installed in the third case, resulting in a four-stage separation plant. This configuration was subsequently optimized to determine the optimum operating conditions, as presented in **Table 3(D)**. **Figure 4** depicts the simulation Process Flow Diagram (PFD) for the four-stage GOSP modification.

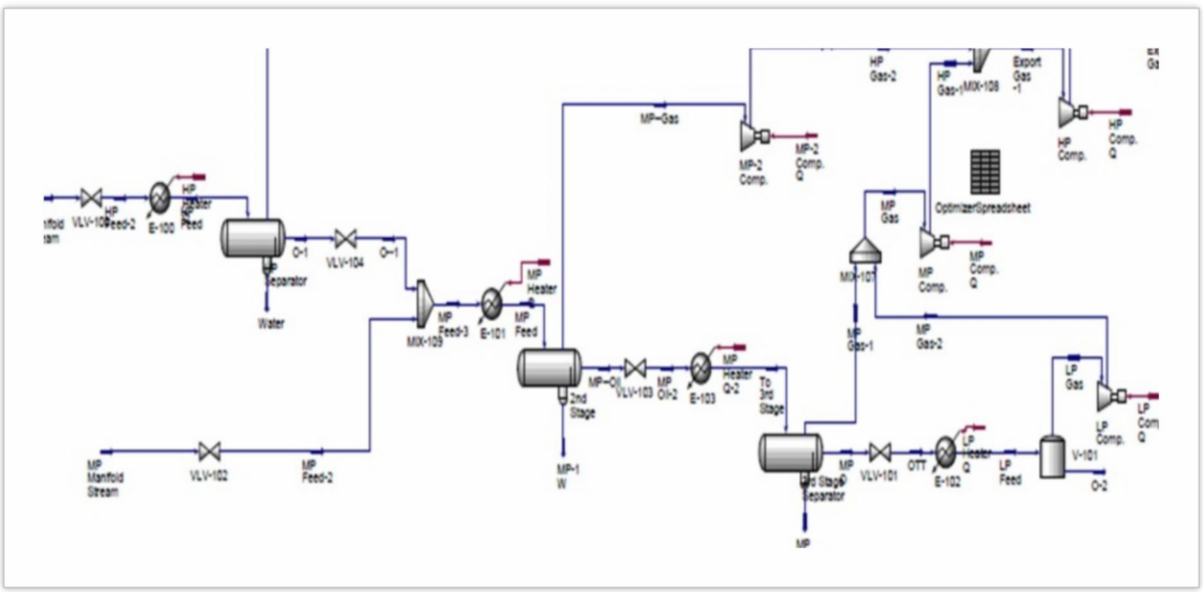



**Figure 4—PFD of the four-stage GOSP modification.**

## Results and Discussion

There exists a great effect of separators pressure on the oil, gas recoveries, the required heaters duty, compressors power and therefore the net profit of the GOSP. The idea of stage separation is essential as it reduces the propensity of intermediate and heavy hydrocarbons to be vaporized as the pressure decreases gradually.

**Table 3—All scenarios' operating conditions.**

| (A) Actual 2 stages Separation Operating Conditions | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Pressure Psig | Temp. ºC | Pr-Heater Duty Kw | Gas Comp. Power Kw | Gas Rate MMSCFD | Oil Production Bbl/d | Gas Recovery MMSCFD |
| HP Separator | 250 | 25 | 250.2 | 2192 | 23.63 | 18410 | 33.56 |
| MP Separator | 35 | 30 | 178.6 | 721.7 | 9.93 | RVP (Psig) | H.V. (mJ/m3) |
| LP Separator | 7 | 66 | 2831 | 77.59 | 3.5 | -4.729 | 54.41 |
| (B) Optimization of 2 stages Separation Operating Conditions | | | | | | | |
| | Pressure Psig | Temp. ºC | Pr-Heater Duty Kw | Comp. Power Kw | Gas Rate MMSCFD | Oil Production Bbl/d | Gas Recovery MMSCFD |
| HP Separator | 281 | 23 | 0 | 1604 | 23.29 | 18750 | 33.2 |
| MP Separator | 20 | 14 | 23.02 | 1127 | 9.903 | RVP (Psig) | H.V. (mJ/m3) |
| LP Separator | 0 | 31 | 1240 | 147.1 | 3.556 | -4.697 | 53.09 |
| (C) Optimization of 3 stages Separation Operating Conditions | | | | | | | |
| | Pressure Psig | Temp. ºC | Pr-Heater Duty Kw | Gas Comp. Power Kw | Gas Rate MMscfd | Oil Production Bbl/d | Gas Recovery MMSCFD |
| HP Separator | 400 | 27 | 0 | 958 | 22.42 | 18830 | 33.09 |
| MP Separator | 30 | 23 | 383 | 1230 | 10.67 | RVP (Psig) | H.V. (mJ/m3) |
| LP Separator | 0 | 39 | 1224 | 82 | 1.482 | -4.697 | 52.84 |
| (D) Optimization of 4 stages Separation Operating Conditions | | | | | | | |
| | Pressure Psig | Temperature ºC | Pr-Heater Duty Kw | Gas Comp. Power Kw | Gas Flow MMscfd | Oil Production Bbl/d | Gas Recovery MMSCFD |
| HP Separator | 440 | 27 | 0 | 758 | 22.22 | 18770 | 33.14 |
| MP Separator | 200 | 28 | 0 | 195 | 5.648 | RVP (Psig) | H.V. (mJ/m3) |
| 3rd Stage | 36 | 51 | 2000 | 614 | 3.592 | -4.793 | 53.09 |
| LP Separator | 0 | 43 | 0 | 104 | 1.679 | | |

**Actual Two-stages Separation Case without Optimizer**. Table 3(A) presents the initial separators' pressure in the un-optimized two-stage GOSP. This pressure is notably influenced by wellhead pressures and pressure losses incurred through production pipelines. Furthermore, Table 3(A) displays the operating conditions of the high pressure separator (250 psig, 25°C), the medium pressure separator (35 psig, 30°C), the low pressure stage (7 psig, 66°C), which was achieved by a 3259.8 kW pre-heating process, aimed at meeting the final product of 18,410 bbl/d of oil recovery while maintaining a Reid vapor pressure of 10 psia.

***The effect of separators pressure on the oil/gas recovery in two-stage GOSP***. **Figures 5** illustrate the pressure effects on oil and gas recovery in a two-stage separation plant. Figure 5(A) demonstrates how the high-pressure separator reduces oil recovery while increasing gas recovery. Figure 5(B), on the other hand, shows how the medium pressure separator initially increases oil recovery but decreases gas recovery.

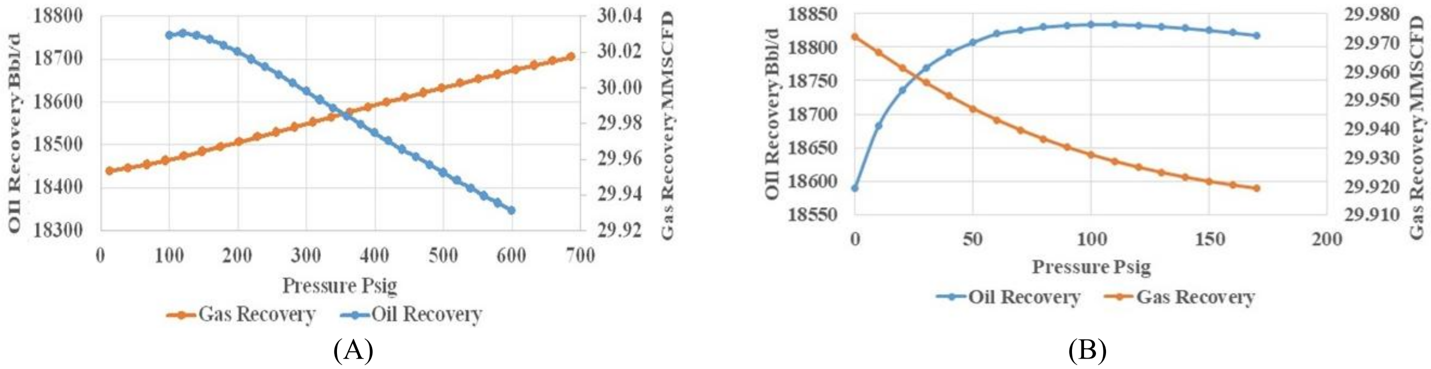



**Figure 5—The influence of pressure on oil and gas recovery in a two-stage separation plant.**

**Optimization of Two-stages Separation**. Table 3(B) presents the separators' operating conditions obtained after optimizing the two-stage Gas Oil Separation Plant (GOSP), along with the corresponding the high-pressure separator (283 psig, 23 °C), the medium pressure separator (20 psig, 14°C), the low pressure stage (0 psig, 31 °C), achieved through a pre-heaters duty of 1263.02 kW. These adjustments were made to fulfill the reid vapor pressure requirement of 10 psia for a final product of 18,750 bbl/d oil recovery.

**Optimization of Three-stages Separation**. In Table 3(C), the separators' operating conditions for the optimized three-stage GOSP are displayed, along with the high-pressure separator (400 psig, 27°C), the medium pressure separator (30 psig, 23 °C), the low-pressure stage (0 psig, 39 °C). To meet the Reid vapor pressure specification of 10 psia for a final product of 18,830 bbl/d oil recovery, a pre-heaters duty of 1607 kW was necessary.

***The Effect of Separators Pressure on the Oil/Gas Recovery in Three-stage GOSP***. We examine the pressure effects on oil and gas recovery in a three-stage separation plant (**Figure 6**). Figure 6(A) reveals that the high-pressure separator leads to a dome-shaped curve for oil recovery (an initial increase followed by a decrease) while increasing gas recovery. Figure 6(B), focusing on the medium pressure separator, shows a similar pattern with an initially increasing curve for oil recovery and an initially decreasing curve for gas recovery.

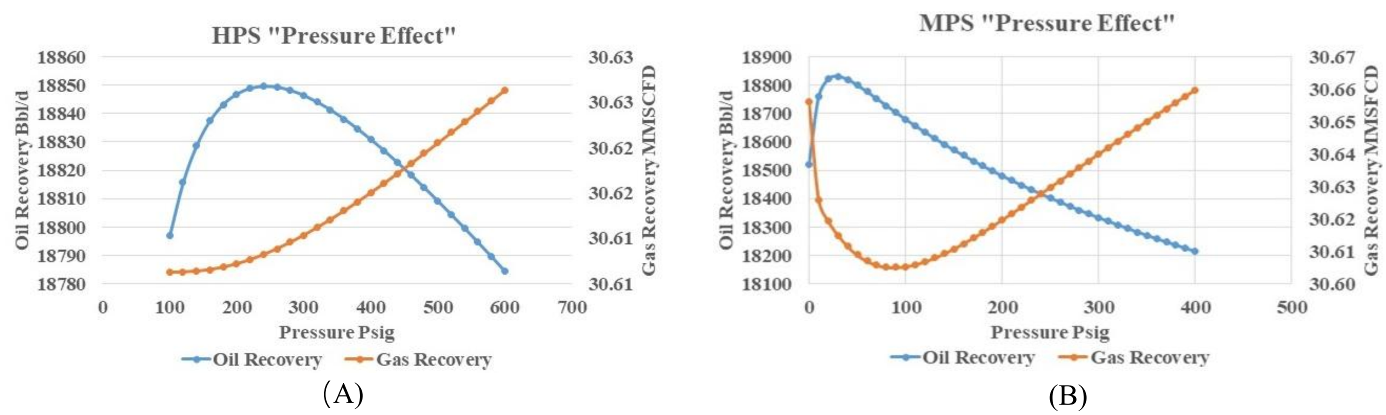
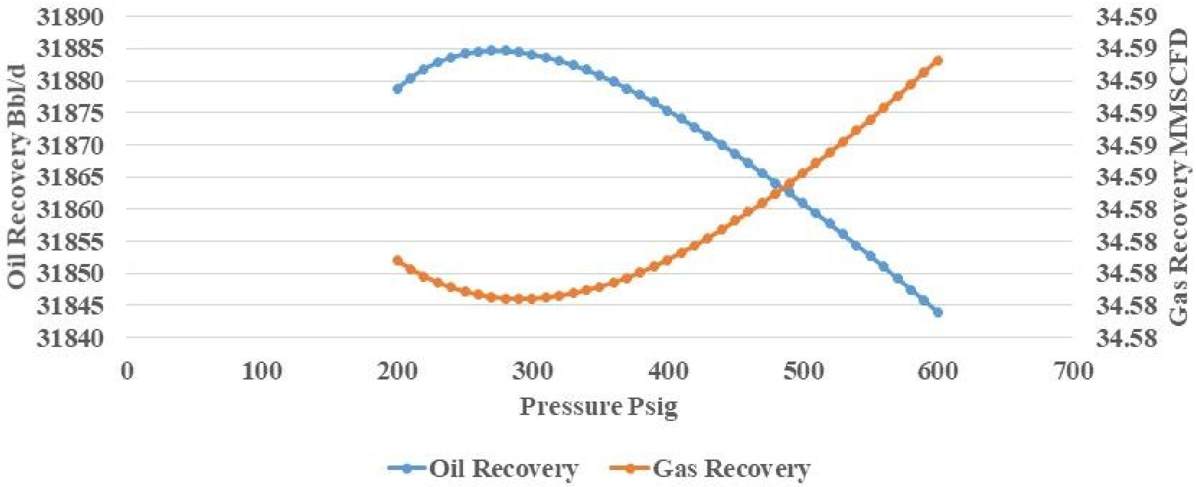
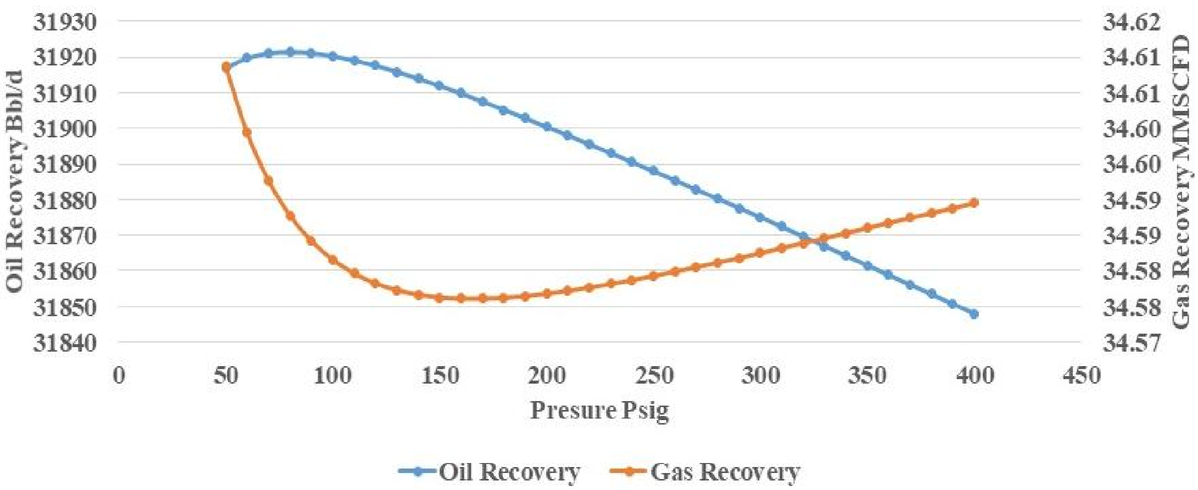



**Figure 6—The influence of pressure on oil and gas recovery in a three-stage separation plant.**

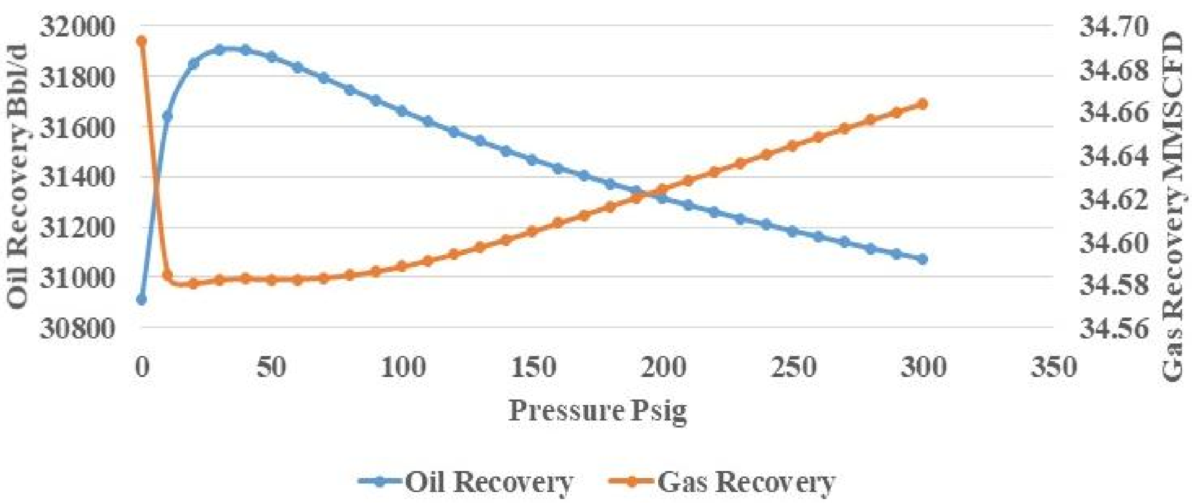
**Optimization of Four-stages Separation**. Table 3(D) illustrates the separators' operating conditions for the optimized four-stage GOSP, which involves the addition of a third separator incurring an additional cost. The corresponding high-pressure separator (440 psig, 27°C), the 1st medium-pressure separator (200 psig, 28°C), the 2nd medium-pressure separator (36 psig, 51°C), the low-pressure stage (0 psig, 43°C) were achieved through a pre-heater's duty of 2000 kW, aiming to meet the vapor pressure requirement of 10 psia for a final product of 18,770 bbl/d oil recovery.




(A)




(B)




(C)

**Figure 7—The influence of pressure on oil and gas recovery in a four-stage separation plant.**

***The Effect of Separators Pressure on the Oil/Gas Recovery in Four-stage GOSP***. **Figure 7** explore the pressure effects on oil and gas recovery in a four-stage separation plant. Figure 7(A) displays a dome-shaped curve for oil recovery with the high-pressure separator, along with an increase in gas recovery. Figure 7(B) depicts the impact of medium pressure separator 1, resulting in a decrease in oil recovery and an initial decrease followed by an increase in gas recovery. Figure 7(C), focusing on medium pressure separator 2, shows a similar pattern to Figure 7(B), with an initially increasing curve for oil recovery and an initially decreasing curve for gas recovery.

**Summary of Result**. The summary table of optimization results (**Table 4**) reveal the following findings for various scenarios. Comparison of multistage optimizers with actual GOSP case (Table 4(B)), which provides a comparison between the actual and optimization cases, reveals significant improvements in oil recovery, energy efficiency, and overall profitability across the different scenarios.

Case-1 represent actual GOSP scenario. The actual Gas-Oil Separation Plant (GOSP) consumed 3259 kW of energy by pre-heaters and achieved an oil recovery rate of 18410 barrels per day (bbl/d) with a net profit of $1,530,000 per day.

Case-2 is the optimization case for actual GOSP. In this scenario, optimization reduced the energy consumption to 1263 kW by pre-heaters, increased the oil recovery rate to 18750 bbl/d, and raised the net profit to $1,630,000 per day. The Comparison Table 4(B) showed that an increase in oil recovery achieved by 1.8%, a reduction in total energy consumption by 34%, and an increase in net profit by 6.4% in comparison with the actual GOSP.

Case-3 represents optimization scenario for three-stage separation modified plant. The optimization of a modified plant with a three-stage separation process resulted in an energy consumption of 1607 kW by pre-heaters, an oil recovery rate of 18830 bbl/d, and a net profit of $1,620,000 per day. The Comparison Table 4(B) showed an increase in oil recovery by 2.3%, a reduction in total energy consumption by 38%, and an increase in net profit by 5.8%.

Case-4 is the optimization result for four-stage separation modified plant. The optimization led to an energy consumption of 2000 kW by pre-heaters, an oil recovery rate of 18770 bbl/d, and a net profit of $1,597,000 per day. The Comparison Table (4B) showed an increase in oil recovery by 2.0%, a reduction in total energy consumption by 41%, and an increase in net profit by 4.3%.

Through optimization efforts, the energy consumption of the GOSP was significantly reduced to only 1263 kW, indicating a substantial improvement in energy efficiency.The optimization also led to an increase in the oil recovery rate, reaching 18750 bbl/d, which is higher than the initial scenario.These findings highlight the positive impact of optimization on the GOSP's performance in several key aspects.

1. *Energy Efficiency*. The optimization efforts led to a remarkable reduction in energy consumption by the pre-heaters, indicating a more energy-efficient operation. This not only reduces operating costs but also contributes to environmental sustainability by lowering energy usage.
2. *Increased Oil Recovery*. The GOSP's ability to recover more oil per day is a crucial metric in the oil and gas industry. The optimization resulted in a significant increase in oil recovery, which can lead to higher revenue generation for the company.
3. *Improved Profitability*. The combination of reduced energy costs and increased oil recovery directly contributed to a higher daily net profit. This is a clear indicator of the financial benefits of optimization efforts.

In summary, the optimization of the Gas-Oil Separation Plant had a positive impact on both its operational efficiency and financial performance. These improvements not only enhance profitability but also demonstrate a commitment to resource conservation and environmental responsibility. Further analysis and monitoring may be necessary to ensure the sustainability and long-term success of these optimization efforts.

The provided information discusses the optimization of a modified plant with three-stage and four-stage separation processes in the context of the Gas Oil Separation Plant (GOSP) industry. The goal of these optimizations is to improve oil recovery, reduce energy consumption, and increase net profit. Let's break down the key findings and implications of these optimization cases.

The four-stage separation process, despite slightly lower oil recovery, benefited from Optimizer-3 by achieving significant reductions in energy consumption and a moderate increase in net profit.

**Overall Implications**. These optimization cases demonstrate that investing in advanced optimization strategies can lead to substantial improvements in the GOSP industry. Optimizations across different scenarios consistently showed enhanced oil recovery, reduced energy consumption, and increased profitability.

The choice between four-stage and three-stage separation processes depends on a trade-off between energy efficiency and oil recovery, with the three-stage process showing better performance in these specific cases. These findings underscore the importance of ongoing research and optimization efforts in the energy sector to maximize resource utilization and economic benefits.

**Table 4—Results summary and comparisons.**

(A) Final results summary

| | Energy Consumed | | Oil Recovery | Gas Recovery | Net Profit ($/d) |
|---|---|---|---|---|---|
| | Heaters (Kw) | Comp.s (Kw) | Prod. (Bbl/d) | Prod. (MMSCFD) | |
| Case 1: one-stage separation | 3259 | 2991.29 | 18410 | 33.56 | 1532285 |
| Case 2: one-stage separation optimization | 1263.02 | 2878.1 | 18750 | 33.2 | 1630396 |
| Case 3: two-stages separation optimization | 1607 | 2270 | 18830 | 33.09 | 1621818 |
| Case 4: three-stages separation optimization | 2000 | 1671 | 18770 | 33.14 | 1597739 |

(B) Multistage profits' comparisons with actual case

| | Energy Consumed Diff. | | Oil Recovery Diff. | Gas Recovery Diff. | Net Profit Diff. $/d | Total Energy Diff. 2&3 stages KW |
|---|---|---|---|---|---|---|
| | Heaters (Kw) | Comp.s Kw | Prod. Bbl/d | Prod. MMSCFD | | |
| 1 stage Comparison (actual /optimization cases) | -1995.98 | -113.19 | 340.00 | -0.36 | 98111.00 | -2109.17 |
| | -61.2% | -3.8% | 1.8% | -1.1% | 6.4% | -33.7% |
| 1&2 stages Comparison (actual /optimization cases) | -1652.00 | -721.29 | 420.00 | -0.47 | 89533.75 | -2373.29 |
| | -50.7% | -24.1% | 2.3% | -1.4% | 5.8% | -38.0% |
| 1&3 Stages Comparison (actual /optimization cases) | -1259.00 | -1320.29 | 360.00 | -0.42 | 65453.91 | -2579.29 |
| | -38.6% | -44.1% | 2.0% | -1.3% | 4.3% | -41.3% |

## Conclusions

The study focused on simulating and optimizing the Gas-Oil Separation Plant (GOSP) process using the Aspen HYSYS model, considering real-world conditions and fluid compositions. The main objectives were to maximize oil recovery, minimize energy consumption, and maintain a target Reid vapor pressure. Key findings include:

1. Optimizing the existing two-stage separation process was the most economically advantageous scenario, increasing net profit by $98,000 per day (a 6.4% improvement).
2. The optimization significantly reduced energy consumption, with heaters using 61% less energy and gas compression seeing a 4% decrease.
3. The optimization also increased oil recovery by 2.3%, demonstrating its effectiveness.
4. Separator pressure was crucial in optimizing the process for maximum profit and minimal energy consumption, emphasizing the need for careful control and adjustment.
5. Considering wellhead pressure and pressure drop in upstream pipelines impacting delivered pressure and separation stages is essential for optimization.

In summary, this comprehensive study not only validates the effectiveness of optimizing the two-stage separation process but also underscores the significance of pressure control and upstream factors in achieving the desired outcomes of increased profitability, energy efficiency, and oil recovery. These findings provide valuable insights for the ongoing operation and future improvements of the GOSP process.

## Nomenclature

| | | |
|---|---|---|
| RVP | = | Reid Vapor Pressure |
| GOR | = | Gas Oil Ratio |
| GOSP | = | Gas Oil Separation Plant |
| API | = | American Petroleum Institute |
| HV | = | Heating Value |

## Conflicting Interests

The author(s) declare that they have no conflicting interests.

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