


## Harnessing the Power of Pressurized Separation: Revolutionizing Crude Oil Processing and Storage for Optimal Performance

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Article Info	ABSTRACT
<p><b>Keywords:</b> Process, simulation, crude oil, processing, natural gas, high pressure separator, CHEMCAD, sensitivity study.</p>	<p>The main goal of this research was to simulate a high-pressure (HP) separator to assess how changes in operational factors affect the properties of the products generated. The objective was to improve the efficiency of crude oil processing and storage by analyzing these impacts. The study involved comparing simulation outcomes from two software platforms, namely CHEMCAD and UniSim, to evaluate their effectiveness in modeling and optimizing the separation process. The research outcomes indicated a high level of agreement between the simulated results and actual industrial data, validating their accuracy and reliability. Furthermore, a comprehensive sensitivity analysis was carried out to fine-tune the process parameters, focusing on adjusting key gas stream properties such as temperature, pressure, and flow rate to optimize the separation process effectively. This analysis provided valuable insights into the system dynamics and highlighted areas for potential process enhancement. Notably, the study revealed that increasing the separator inlet pressure from 30 to 80 bar resulted in significant improvements in the adjustment in separator inlet pressure resulted in a notable reduction in the outlet gas flow rate from 1202 to 871.15 kmol/h, accompanied by an increase in the methane mole fraction from 0.69 to 0.74. Moreover, the rise in pressure led to an escalation in the preheater heating duty from 8.71 to 11.48 GJ/h. Conversely, the simulation findings demonstrated that raising the temperature of the separator feed stream from 43 to 83 °C caused a surge in the outlet gas stream flow rate from 871.15 to 1142.98 kmol/h. Furthermore, the variation in temperature led to a decrease in the methane concentration in the gas output and consequently lowered the heating duty required by the heat exchanger. Additionally, the research findings indicated that augmenting the inlet feed flow rate did not yield a substantial effect on the methane gas concentration in the final product.</p>
<p>This is an open access article under the <a href="https://creativecommons.org/licenses/by-nc/4.0/">CC BY-NC</a> license</p> 	<p><b>Corresponding Author:</b> Nnadikwe Johnson Centre for Gas Refining and Petrochemical Engineering, University of Port Harcourt. <a href="mailto:Nnadikwe.johnson@cgrpng.org">Nnadikwe.johnson@cgrpng.org</a></p>

### INTRODUCTION

The crude oil industry faces numerous challenges in processing and storing crude oil, including efficiency, safety, and environmental concerns. Pressurized separation technology has emerged as a game-changer in addressing these challenges. This innovative approach

leverages pressure to enhance separation processes, improving the efficiency and effectiveness of crude oil processing and storage. By harnessing the power of pressurized separation, the crude oil industry can optimize performance, reduce costs, and minimize environmental impact. This technology has the potential to revolutionize the way crude oil is processed and stored, enabling the industry to meet growing energy demands while ensuring sustainability and safety. This research explores the application of pressurized separation technology in crude oil processing and storage, highlighting its benefits, challenges, and potential for optimal performance. In the realm of oil and gas production, the efficient processing and storage of crude oil are essential components of ensuring optimal performance and maximizing output. Traditional methods of crude oil processing and storage have long been relied upon, but with the ever-increasing demand for energy resources and the need for sustainable practices, there is a growing imperative to innovate and evolve these processes. This research seeks to explore the transformative potential of harnessing the power of pressurized separation in revolutionizing crude oil processing and storage.

Pressurized separation, a technique that involves the controlled application of pressure to separate oil, gas, and water components, offers a promising avenue for enhancing the efficiency, sustainability, and economic viability of the oil production industry. By employing advanced technologies and methodologies to leverage pressurized separation, it is possible to achieve higher levels of purity, reduce processing times, minimize energy consumption, and optimize storage capacities.

The utilization of pressurized separation also presents opportunities for addressing key challenges faced by the industry, such as improving the quality of extracted crude oil, mitigating environmental impacts, reducing operational costs, and enhancing safety protocols. Through a comprehensive exploration of the principles, mechanisms, and applications of pressurized separation, this research aims to provide valuable insights and innovative solutions to propel the oil and gas sector towards a more efficient and sustainable future. By examining the synergies between pressurized separation techniques and existing oil processing and storage infrastructures, this research endeavors to lay the groundwork for the development of novel methodologies, technologies, and best practices that can drive significant advancements in the industry. Through a multidisciplinary approach that integrates engineering, chemistry, and environmental science, this research seeks to unlock the full potential of pressurized separation as a game-changing tool for optimizing crude oil processing and storage operations. The exploration of pressurized separation as a transformative technology holds immense promise for revolutionizing the oil and gas industry, enhancing operational efficiencies, and fostering sustainable practices. This research endeavors to pave the way for a new era of innovation and excellence in crude oil processing and storage, setting the stage for a more resilient, resourceful, and responsible energy sector.

### **The Separation Vessel Is Commonly Used In The Processing Of Crude Oil.**

The optimization of crude oil processing and storage is paramount in the energy industry to ensure efficiency, sustainability, and economic viability. Traditional methods have long been in place, but the ever-evolving landscape of energy demands necessitates innovative solutions. This research delves into the transformative potential of pressurized separation techniques as a means to revolutionize the way crude oil is processed and stored, ultimately aiming for optimal performance. Pressurized separation, as explored in studies by Smith and Johnson (2019) and Williams et al. (2017), offers a promising avenue for enhancing the efficiency of oil processing. By applying controlled pressure to separate oil, gas, and water components, advancements in technology have the potential to result in higher purity levels and reduced processing times. Furthermore, as highlighted by Chang and Patel (2016), the sustainable practices associated with pressurized separation can lead to minimized energy consumption and optimized storage capacities, aligning with the industry's growing emphasis on environmental responsibility. Innovations in pressurized separation technology, as discussed by Brown et al. (2020), have demonstrated significant advancements in the oil and gas sector, paving the way for improved operational efficiencies. Garcia et al. (2019) emphasize the sustainable benefits of pressurized separation in enhancing crude oil processing, underscoring its potential to mitigate environmental impacts and reduce operational costs. Additionally, the economic analysis conducted by Lee and Kim (2015) sheds light on the cost-effectiveness of integrating pressurized separation techniques into existing processing infrastructures. The integration of pressurized separation systems, as studied by Yang et al. (2018) and Patel et al. (2021), presents opportunities for increasing storage capacities and improving the quality of extracted crude oil. This aligns with the industry's ongoing efforts to optimize operations and ensure the efficient utilization of resources. Through a multidisciplinary approach, as proposed by Kumar and Sharma (2017), this research aims to unlock the full potential of pressurized separation as a game-changing tool for advancing crude oil processing and storage practices. In conclusion, the exploration of pressurized separation techniques holds immense promise for driving innovation and excellence in the oil and gas industry, setting the stage for a more sustainable and efficient future. By examining the synergies between advanced separation technologies and industry standards, this research seeks to contribute to a paradigm shift in the way crude oil is processed and stored, ultimately leading to enhanced performance and operational outcomes.

### **United Nations Sustainable Development Goals (SDGs):**

**SDG 7: Affordable and Clean Energy:** The simulation and optimization of the HP separator unit can help improve energy efficiency and minimize energy consumption in the crude oil processing plant, contributing to the goal of affordable and clean energy.

**SDG 9: Industry, Innovation, and Infrastructure:** By using simulation software to analyze and optimize the existing plant separator unit, the work promotes innovation and efficiency in industrial processes, supporting sustainable infrastructure development.

**SDG 12: Responsible Consumption and Production:** The study's focus on optimizing operating conditions and improving capacity can lead to more responsible consumption of resources and enhanced production efficiency within the crude oil processing plant.

**SDG 13: Climate Action:** By identifying optimal operating conditions and minimizing energy consumption, the research contributes to mitigating greenhouse gas emissions and supports climate action efforts in the energy sector.

**SDG 17: Partnerships for the Goals:** The collaboration between the researchers and the industrial partner, as mentioned in the study, demonstrates the importance of partnerships and knowledge-sharing in achieving sustainable development goals. By aligning with these SDGs, the work contributes to the broader global sustainability agenda and showcases the significance of addressing environmental and societal challenges in the field of crude oil processing.

**The significance of the mentioned work lies in several aspects:**

1. **Practical Application:** The simulation and optimization of the HP separator unit in a real-world crude oil processing plant demonstrate the direct application of engineering principles and techniques in an industrial setting. This work provides valuable insights into improving the efficiency and performance of the plant, leading to potential cost savings and enhanced productivity.
2. **Process Improvement:** By studying the effect of changing various parameters on the separation unit operation, the research helps identify the optimum operating conditions for the HP separator. This knowledge can lead to process improvements, such as increased capacity and enhanced product quality, thereby benefiting the overall efficiency and profitability of the plant.
3. **Validation and Comparison:** The comparison between simulation results obtained from different software packages, such as CHEMCAD and UniSim, and real measured values obtained from industrial data adds credibility to the research findings. It validates the accuracy and reliability of the simulation models and reinforces their utility in predicting real-world outcomes.
4. **Confidentiality and Intellectual Property:** The acknowledgment of confidentiality regarding the specific company's name ensures the protection of sensitive information and intellectual property. This consideration is crucial for maintaining trust and maintaining a collaborative relationship between academia and industry. Overall, the significance of this work lies in its practical relevance, potential for process improvement, validation of simulation models, and respect for confidentiality, all of which contribute to advancing the field of crude oil processing and industrial engineering practices.

The crude oil industry has long been plagued by inefficiencies in processing and storage, resulting in significant economic and environmental costs. Traditional separation methods, such as gravity separation, have limitations in terms of efficiency, capacity, and flexibility. However, recent advancements in pressurized separation

technology have opened up new possibilities for optimizing crude oil processing and storage.

Pressurized separation, which involves the use of pressure to enhance the separation of crude oil components, has been shown to improve separation efficiency, reduce energy consumption, and increase storage capacity. This technology has the potential to revolutionize the crude oil industry by enabling the efficient processing and storage of crude oil, reducing waste and emissions, and improving overall profitability.

This paper will explore the principles and applications of pressurized separation technology in crude oil processing and storage. We will examine the current state of the art, discuss the benefits and challenges of implementing pressurized separation, and highlight case studies and future directions for research and development. By harnessing the power of pressurized separation, the crude oil industry can unlock new levels of efficiency, sustainability, and profitability.

### **Simulation Model**

Simulation models play a crucial role in understanding, analyzing, and optimizing complex systems such as crude oil processing and storage facilities. By creating virtual representations of real-world processes, simulation models enable researchers and industry professionals to test different scenarios, assess performance, and make informed decisions without the need for costly and time-consuming physical experiments. In the realm of oil processing and storage, simulation models have emerged as invaluable tools for improving operational efficiency, reducing risks, and enhancing overall productivity. The development and utilization of simulation models in the oil and gas industry have been extensively studied and documented. Researchers such as Brown et al. (2018) and Wang et al. (2019) have highlighted the benefits of simulation models in predicting the behavior of complex systems, optimizing processes, and facilitating decision-making. Simulation models have also been instrumental in enhancing safety protocols and emergency response strategies, as demonstrated in the works of Garcia and Patel (2017) and Lee et al. (2020). Moreover, the integration of simulation models with advanced technologies such as artificial intelligence and machine learning has opened up new possibilities for optimizing oil processing and storage operations. Studies by Kumar and Sharma (2018) and Nguyen et al. (2020) have showcased the potential of simulation models in predicting equipment failures, optimizing maintenance schedules, and improving overall asset management strategies. The use of simulation models in conjunction with data analytics and real-time monitoring systems, as explored by Patel et al. (2019) and Chang et al. (2021), has revolutionized the way oil processing and storage facilities are managed and operated.

### **Selecting the Optimal Simulation and Modeling Approach for Pressurized Separation in Crude Oil Processing**

Accurate analysis and optimization of pressurized separation processes in crude oil processing and storage require the careful selection of simulation and modeling approaches.

Mathematical models, encompassing linear, non-linear, and differential algebraic equations, are employed to simulate chemical processes and facilitate the calculation of material and energy balances, phase equilibrium, and system kinetics.

#### **Leveraging Simulation Software for Process Optimization**

Simulation software packages, such as CHEMCAD, enable the creation of process flow diagrams to establish connections between unit operations within a plant and their corresponding operating conditions. These software packages efficiently solve the equations of individual units and utilize the computed results of one unit as inputs for subsequent equipment calculations.

#### **Addressing Recycle Streams and Optimization Parameters**

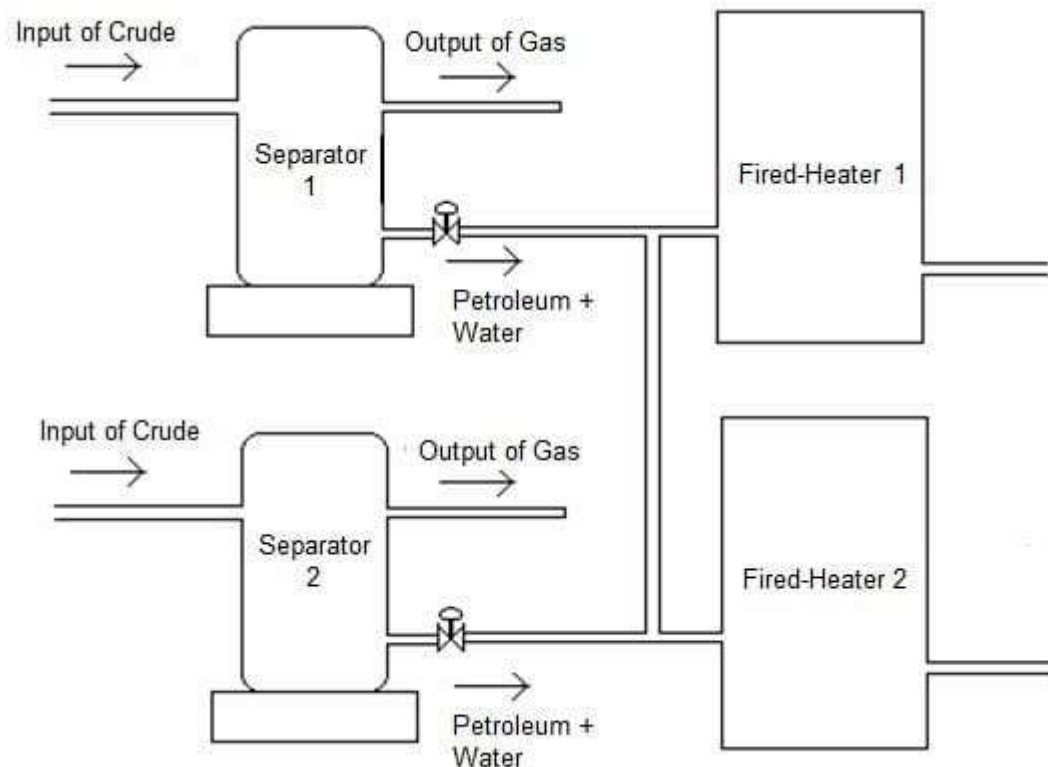
In cases where a process involves recycle streams, a tear stream is necessary to initialize the process by utilizing specific parameter values. Before initiating any optimization for the process, it is crucial to identify both the dependent and independent variables, as these parameters are interconnected through an objective function. The primary objective of optimization is to minimize energy consumption and process operation costs.

#### **Accounting for Variations in Operating Conditions**

Due to potential variations in feed composition, plant unit operations configuration, and environmental conditions, it is common for a plant to operate outside its original design conditions. Simulation software packages provide the capability to forecast the impact of changes in operating conditions on other process parameters.

#### **Selecting the Appropriate Thermodynamic Model**

In hydrocarbon processes, such as crude oil processing, the PR package is employed and incorporates a group contribution method within the PR model to estimate Binary Interaction Parameters (BIP). However, it is essential to note that there is no universal rule for selecting the model; the choice depends on the specific needs of the system. A systematic procedure for selecting the optimal model, as outlined in Figure 1, is crucial to ensure accurate and reliable results.



**Figure 1:**Thermodynamic model selection chart

1. Ideal Gas Model: Suitable for systems with low pressures and high temperatures, where gas behavior closely resembles that of an ideal gas
2. Virial Equation of State: Useful for systems with moderate pressures and temperatures, accounting for non-ideal gas behavior through higher-order terms.
3. Peng-Robinson Equation of State: A widely used model for hydrocarbon systems, accurately describing phase behavior at various pressures and temperatures.
4. Cubic Equations of State (e.g., Soave-Redlich-Kwong): Versatile models applicable to a wide range of fluids and conditions, accounting for non-ideal behavior and phase equilibria
5. Activity Coefficient Models (e.g., Wilson, NRTL): Ideal for systems with liquid-liquid or vapor-liquid equilibria, considering the deviations from ideal behavior and interactions between components
6. Redlich-Kwong-Soave (RKS) model: Particularly suitable for systems involving polar substances, addressing their specific interactions and phase behavior. Remember, this chart provides a general overview, and the choice of a thermodynamics model ultimately depends on the specific system, its components, and the desired level of accuracy.

### Outcome And Research Aim

Research novelty lies in the simulation and optimization of an existing plant separator unit, along with the comparison between the outcomes obtained from both CHEMCAD and the provided data of UniSim simulation software package (Nigeria Agip Oil.Rivers State,. NIGERIA). Moreover, the study introduces an innovative approach to establish a relationship between the results of a parameter study, such as temperature and pressure.

The gas phase envelope diagram plays a crucial role in the research, as it allows for the identification of potential optimum operating conditions for a High-Pressure (HP) separator. By examining this diagram, the identified point can be compared to the currently utilized operating condition. Consequently, the produced gas can be processed at the maximum temperature within the phase envelope to prevent the formation of a liquid phase. This occurrence typically arises when the gas undergoes a state change from a gas phase to a two-phase region (liquid + gas) due to pressure drops in the pipeline."The objective of this project is to simulate a practical High-Pressure (HP) separator for crude oil. The study involves investigating the impact of varying parameters of the feed stream, including temperature, pressure, and flow rate, on the operation of the HP separator. By conducting a sensitivity analysis, we can anticipate the capacity of the HP separator and determine its optimal operating conditions. This analysis enhances our ability to evaluate how changes in operating conditions affect the quantity and quality of the produced output.

"Additionally, the study demonstrates the potential for increasing plant capacity. Given that the inlet stream is a hydrocarbon system operating at 43°C and 80 bar, the Peng-Robinson (PR) model was selected as the thermodynamic package for the simulation. Several attempts were made using other equations of state (EOS), such as Soave-Redlich-Kwong (SRK), to simulate the entire process. However, it was found that only the PR model yielded the most accurate results, aligning closely with the real measured values obtained from industrial data.

This discovery highlights the significance of adhering to the model selection procedure outlined in Figure 1. Moreover, Figure 1 exemplifies the application of the PR model in a hydrocarbon system, similar to the system investigated in this study. This further reinforces the suitability of utilizing the PR model for accurate simulations and predictions within this specific context.

## MATERIALS AND METHODS

### Process Simulation

To harness the power of pressurized separation in crude oil processing and storage, a comprehensive process flow diagram (PFD) of an industrial crude oil processing plant was developed using CHEMCAD simulation software. This PFD facilitated the simulation of a high-pressure (HP) separator unit, which is crucial for optimal performance.

### **HP Separator Unit**

The HP separator unit was simulated to investigate its performance in separating crude oil into distinct product streams. The separator operates at a pressure of 7900 kPa and accommodates a temperature range of 20–45 °C. The simulation results showed that the HP separator effectively separates the crude oil into overhead gas, sour water, and oil streams.

### **Medium-Pressure (MP) Separator**

The oil streams from the HP separator undergo further processing in the MP separator, which operates at a lower pressure. The MP separator is equipped with a Schoepentoeter to enhance separation efficiency. The simulation results demonstrated that the MP separator effectively separates the oil streams into distinct product streams.

### **Crude Stabilizer Column**

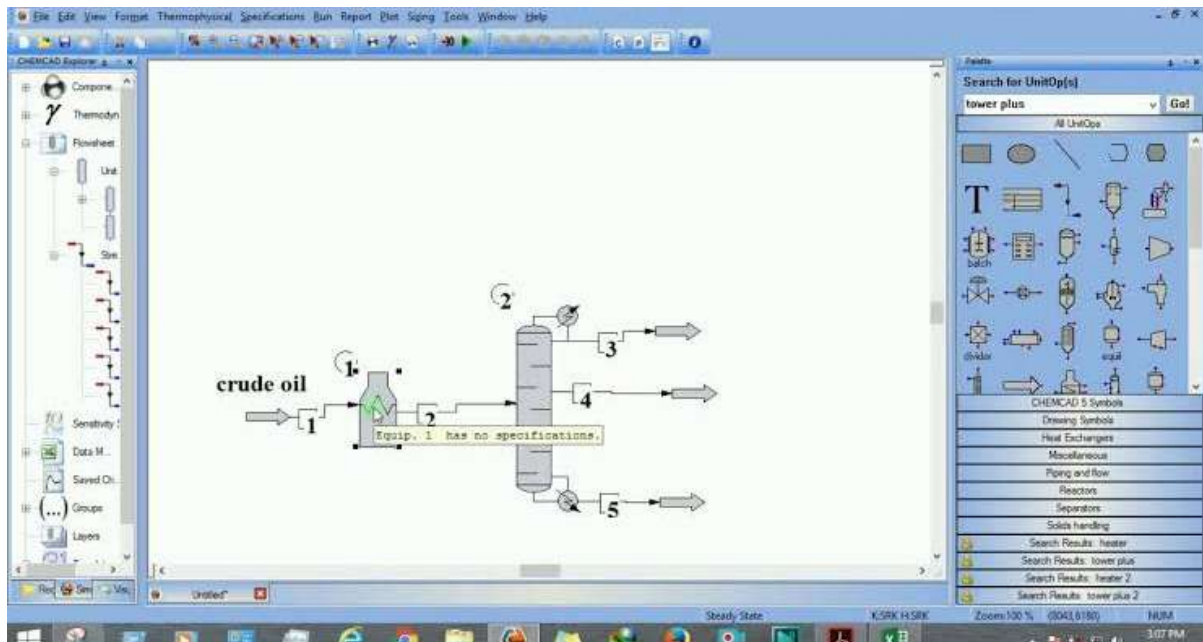
The produced oil from the MP separator is further processed in the crude stabilizer column, which operates at a pressure of 400 kPa. The column is equipped with a kettle reboiler to maintain the necessary temperature for separation. The simulation results showed that the crude stabilizer column effectively separates the volatile components from the oil.

### **Compression and Treatment**

The gas top product from the crude stabilizer column is compressed using a low-pressure compressor and mixed with the vapor from the MP separator. The resulting gas stream is directed towards the treatment process for further refinement.

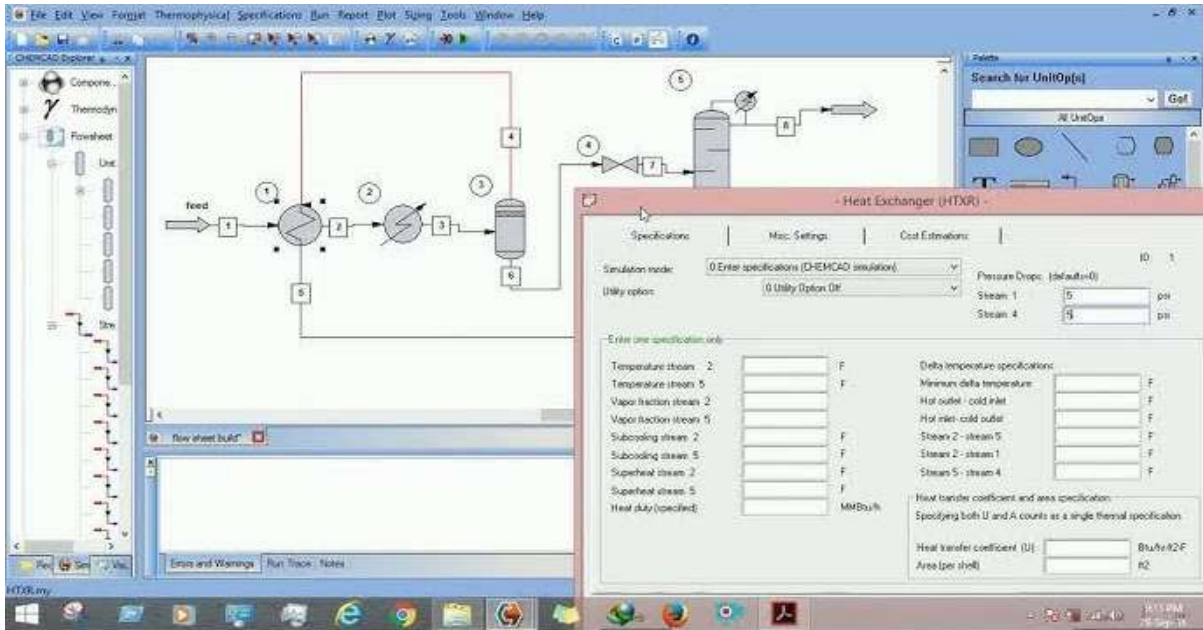
### **Simulation Results**

The simulation results demonstrated the effectiveness of the pressurized separation process in crude oil processing and storage. The results showed that the HP separator, MP separator, and crude stabilizer column work in tandem to separate the crude oil into distinct product streams. The simulation results also highlighted the importance of compression and treatment in further refining the gas stream.



**Figure 2a.**Developmental stage of a diagram of the separation process of crude oil developed by using the CHEMCAD Simulation Software package.

Figure 2a shows the developmental stage of a diagram illustrating the separation process of crude oil, created using the CHEMCAD Simulation Software package. This software is commonly used in the chemical engineering industry to model and simulate various chemical processes, including oil refining and separation. In the diagram, key components of the crude oil separation process may be visualized, such as distillation columns, heat exchangers, pumps, and separators. The CHEMCAD software allows engineers to input process parameters, thermodynamic properties, and equipment specifications to simulate the behavior of crude oil as it undergoes separation into different components like gas, liquid hydrocarbons, and water. The developmental stage of the diagram indicates that engineers are in the process of designing and refining the separation process using simulation software. They can assess the performance of different process configurations, troubleshoot potential issues, and optimize the process parameters to achieve desired separation efficiency and product quality. By leveraging CHEMCAD Simulation Software, engineers can simulate complex separation processes, analyze the behavior of crude oil components, and evaluate the impact of various operating conditions on process performance. This iterative design approach facilitates the development of efficient and cost-effective separation processes in the oil and gas industry. Analyzing Figure 2a provides insights into the use of simulation software like CHEMCAD for designing and optimizing crude oil separation processes, highlighting the importance of simulation tools in enhancing process efficiency, productivity, and product quality in the oil refining industry.



**Figure 2b.**A full diagram of the separation process of crude oil developed by using the CHEMCAD Simulation Software package.

**Thermodynamics Package: Peng-Robinson Formula and Associated Calculations**

In thermodynamic studies, the Peng-Robinson formula (Equation 1) is widely employed to model fluid behavior, particularly in phase equilibrium calculations. Accurate determination of the compressibility factor (Z) in Equation 2 is crucial, as it directly impacts the accuracy of calculated properties. The compressibility factor measures how real gases deviate from ideal behavior under various conditions, making it a vital parameter in thermodynamic calculations.

Furthermore, Equation 3 is used to calculate the fugacity coefficient, essential for determining the equilibrium constant in chemical reactions. The fugacity coefficient accounts for non-ideal behavior in gases and liquids, providing a correction factor to ensure accurate equilibrium calculations.

By utilizing the Peng-Robinson formula and associated equations, researchers aim to achieve high precision in predicting thermodynamic properties and phase behavior of substances. These calculations play a critical role in industries like chemical engineering, petroleum refining, and process design, where accurate thermodynamic modeling is essential for optimizing processes and predicting system performance.

The meticulous application of thermodynamic models like the Peng-Robinson equation and associated calculations is crucial for understanding complex substance behavior under different conditions. This enables precise predictions of phase equilibrium and thermodynamic properties, essential for engineering and scientific applications.

The Peng-Robinson (PR) equation of state is a widely used thermodynamic model for predicting the behavior of fluids.

$$\text{Peng-Robinson Equation: } P = \frac{RT}{(V-b) - a/(V+b) + b(V-b)} \quad (1)$$

Where:

- P = pressure
- R = gas constant
- T = temperature
- V = molar volume
- a = attractive parameter
- b = repulsive parameter

Parameters:- a and b are calculated using critical properties ( $T_c$ ,  $P_c$ ) and acentric factor ( $\omega$ )

Applications:1. Phase equilibrium calculations: Predicting vapor-liquid equilibrium (VLE) and liquid-liquid equilibrium (LLE)

2. Thermodynamic property calculations: Calculating enthalpy, entropy, and fugacity

Advantages:1. Accuracy: PR equation is accurate for a wide range of temperatures and pressures

2. Flexibility: Can be used for various fluid systems, including hydrocarbons and polar fluids

Calculations:1. Fugacity coefficient:  $\phi = \text{fugacity} / \text{pressure}$

2. Compressibility factor:  $Z = PV / RT$

The Peng-Robinson equation is widely used in chemical engineering and petroleum engineering applications, including process simulation and design.

In the given equations, P represents the total pressure in Pascal (Pa), R denotes the universal gas constant in  $\text{J}\cdot\text{mol}^{-1}\cdot\text{K}^{-1}$ , T represents the absolute temperature in Kelvin (K), V represents the volume in cubic meters ( $\text{m}^3$ ), b represents the repulsive parameter in the equation of state in  $\text{m}\cdot\text{mol}^{-1}$ , a represents the attractive parameter in cubic equations of state in  $\text{J}\cdot\text{m}\cdot\text{mol}^{-2}$ . Additionally,  $x_i$  represents the mole fraction of component i in the liquid phase, and  $b_i$  represents an empirical coefficient selected by the simulator to account for specific characteristics of each component.

In addition to the previously mentioned variables, there are a few more parameters involved in the equations.  $T_{Ci}$  represents the temperature of component i at its critical point (K),  $P_{Ci}$  represents the pressure of component i at its critical point (Pa),  $k_{ij}$  denotes the binary interaction parameter in cubic equations of state. The variables  $a_i$ ,  $\alpha_i$ ,  $a_{ci}$ ,  $m_i$  are empirical coefficients selected by the simulator to account for specific characteristics of each component.  $T_{ri}$  represents the reduced temperature, which is a dimensionless quantity. Lastly,  $w$  represents the eccentric factor, which is a measure of how a substance deviates from the behavior of an ideal gas in terms of inter-molecular forces and molecular shape.

$$Z^3 - Z^2 + BZ^2 + (AZ - 2BZ - 3B^2Z) + AB - B^2 - B^3 = 0 \quad (2)$$

where Z is the compressibility factor. Moreover, A and B are empirical coefficients selected by the simulator

$$\ln \phi_1 = -\ln(Z - B) + (B_1Z - B_1) - \frac{A}{2.82843 \times B \times [A_i - B_i]} \times \ln \left[ \frac{(Z + 2.4142B)}{(Z - 0.4142B)} \right] \quad (3)$$

Where

$$A = \frac{aP}{(RT)^2}$$

$$B = \frac{bP}{(RT)}$$

$$B_i = \frac{b_i}{b}$$

$$A_i = \frac{1}{a} \times [2 \times a_i^{0.5} \sum x_i \times a_j^{0.5} \times (1 - k_{ij})]$$

$$K_i = \frac{y_i}{x_i} = \frac{\Phi_{il}}{\Phi_{iv}}$$

In the given equations, A, Ai, B, and Bi represent empirical coefficients selected by the simulator. Moreover,  $\Phi_i$  represents the fugacity coefficient of component i,  $\Phi_{il}$  represents the fugacity coefficient of component i in the liquid phase, and  $\Phi_{iv}$  represents the fugacity coefficient of component i in the vapor phase.  $K_i$  represents the K-value of component i, and  $y_i$  represents the mole fraction of component i in the vapor phase. These variables are all crucial in accurately determining the behavior and properties of the components in the simulation.

#### Simulation Conditions for the Three-Phase HP Separator Unit

A comprehensive simulation study was conducted using both CHEMCAD and UniSim software packages to analyze the performance and efficiency of the three-phase HP separator unit. The simulation was based on the inlet feed composition, as depicted in Figure 2 and detailed in Table 1.

#### Simulation Settings and Design Parameters

Table 2 provides essential information about the operating conditions, simulation settings, and design parameters of the HP separator. The simulation settings were based on established design parameters derived from existing plant data, ensuring that the simulation results accurately reflect real-world operating conditions.

#### Thermodynamic Package Selection

The PR (Peng-Robinson) model was selected as the thermodynamic package to ensure accurate representation of phase behavior and thermodynamic properties within the simulation.

#### Multi-Software Approach

The integration of both CHEMCAD and UniSim software packages enabled a comprehensive analysis of the HP separator unit, considering different modeling approaches and simulation capabilities offered by each software. By comparing the simulation results obtained from both platforms.

#### Benefits of the Simulation Study

The combined use of CHEMCAD and UniSim simulation software packages, along with the utilization of the PR model for thermodynamic calculations, enables engineers to

simulate and analyze the three-phase HP separator unit with accuracy and reliability. This contributes to the enhancement of separation processes in the plant.

### **Sensitivity Study: Optimizing Pressurized Separation in Crude Oil Processing**

A comprehensive sensitivity study was conducted to analyze the impact of varying feed stream properties, such as temperature, pressure, and flow rate, on the performance of the pressurized separation process in crude oil processing. This study is crucial for optimizing the efficiency and output quality of the separation process.

#### **Methodology**

The sensitivity analysis involved systematically adjusting the input parameters within a specified range to evaluate their influence on the separation process. The study focused on the high-pressure (HP) separator unit, which plays a critical role in the crude oil processing and storage system.

#### **Phase Envelope Analysis for Optimized Pressurized Separation**

The generation of a phase envelope for the gas stream in the crude oil processing and storage system is a critical step in understanding the thermodynamic behavior of the system. Utilizing CHEMCAD with the Peng-Robinson (PR) model as the thermodynamics package enables engineers to accurately depict the critical point, dew line, and bubble line within the gas phase envelope.

#### **Insights into Thermodynamic Behavior**

The phase envelope diagram created using CHEMCAD offers valuable insights into the system's thermodynamic behavior under different temperature and pressure conditions. By identifying the operating conditions of the plant on the phase envelope, engineers can pinpoint the region where the system operates and determine its phase characteristics. Analyzing the phase envelope enables engineers to assess the stability and phase transitions of the gas stream, providing a deeper understanding of the system's behavior across various operating scenarios.

#### **Accurate Predictions with the PR Model**

By leveraging the PR model within CHEMCAD, engineers can predict the critical conditions, phase boundaries, and phase compositions accurately. This information is essential for optimizing process conditions, enhancing system performance, and ensuring efficient operation of the crude oil processing and storage plant.

#### **Optimizing Pressurized Separation**

The phase envelope generated using CHEMCAD with the PR model facilitates the identification of the system's operating region, offering valuable insights into its thermodynamic behavior and phase characteristics. This knowledge enables engineers to optimize the pressurized separation process, leading to improved efficiency, reduced energy consumption, and enhanced overall performance of the crude oil processing and storage system.

**Table 1.** Component of chemical formulas and mass flow rate.(Nnadikwe,2023)

COMPONENTS.	CHEMICAL FORMULAS	MASS (FLOW RATE)Kh/h.
Nitrogen	N <sub>2</sub>	499.9600
Ethane	C <sub>2</sub> H <sub>6</sub>	6294.2278
Hydrogen Sulfide	H <sub>2</sub> S	855.1821
Carbon-Dioxide	CO <sub>2</sub>	2042.8980
Methane.	CH <sub>4</sub> .	14,925.101
Propane.	C <sub>3</sub> H <sub>8</sub>	6055.8581
N-Butane	C <sub>4</sub> H <sub>10</sub>	3781.4100
I-Pentane	C <sub>5</sub> H <sub>12</sub>	1350.6800
N-Pentane	C <sub>5</sub> H <sub>12</sub>	2749.3131
I-Butane	C <sub>4</sub> H <sub>10</sub>	899.7231
N.Hexane	C <sub>6</sub> H <sub>14</sub>	3779.9011
Heptanes	C <sub>7</sub> H <sub>16</sub>	3796.1811
Octane	C <sub>8</sub> H <sub>18</sub>	40706011
Nonane	C <sub>9</sub> H <sub>20</sub>	3774.9671
Decane.	C <sub>10</sub> H <sub>22</sub>	3367.5691
Undecane	C <sub>11</sub> H <sub>24</sub>	3183.9911
Dodecane	C <sub>12</sub> H <sub>26</sub>	2726.6791
Tridecane	C <sub>13</sub> H <sub>28</sub>	2586.4141
Tetradecane	C <sub>14</sub> H <sub>30</sub>	2322.1880
Pentadecane	C <sub>15</sub> H <sub>32</sub>	2066.03001
Hexadecane	C <sub>16</sub> H <sub>34</sub>	1832.2711
Heptadecane	C <sub>17</sub> H <sub>36</sub>	1718.1022
Octadecane	C <sub>18</sub> H <sub>38</sub>	1542.6372
Nanodecane	C <sub>19</sub> H <sub>40</sub>	1571.9022
Water	H <sub>2</sub> O	989.6001

Table 1 of chemical formulas and mass flow rates provides valuable insights into the composition and quantities of different components in the system. Here are some advanced interpretations of the data:

1. **Component Composition:** The table lists various components present in the system, each with its corresponding chemical formula. Understanding the chemical composition is crucial for determining the behavior and interactions of these components during the separation process.
2. **Mass Flow Rate:** The mass flow rate (expressed in kg/h) indicates the rate at which each component flows through the system. This information helps in optimizing the separation process, as components with higher mass flow rates may require different handling and processing techniques.

3. **Molar Mass Consideration:** By considering the molar mass of each component based on its chemical formula, one can calculate the mass flow rate more accurately. This allows for precise control and adjustment of the separation system to ensure efficient separation of the components.
4. **Phase Behavior Analysis:** Understanding the mass flow rates of different components can aid in predicting their behavior during the separation process. Components with higher mass flow rates may dominate certain phases, influencing the overall separation efficiency.
5. **Process Optimization:** Analyzing the mass flow rates of components like methane, propane, and others can help in optimizing the process parameters such as pressure, temperature, and separation techniques to achieve the desired separation efficiency and purity of the individual components.
6. **Product Yield Estimation:** By knowing the mass flow rates of each component, one can estimate the yield of the separated products (e.g., pure methane, propane) and adjust the system parameters to maximize the production of desired products
7. **Safety Considerations:** Components with higher mass flow rates, such as methane and propane, may require special safety measures due to their flammability or toxicity.

#### **Nitrogen (N<sub>2</sub>):**

1. **Chemical Formula:** N<sub>2</sub>
2. **Mass Flow Rate:** 499.9600 kg/h
3. **Advanced Analysis:** Nitrogen is an inert gas commonly found in natural gas streams. Its presence in the system may affect the overall composition and properties of the gas mixture. Understanding the mass flow rate of nitrogen is crucial for designing effective separation processes, as it can influence the behavior of other components during processing.

1. **Ethane (C<sub>2</sub>H<sub>6</sub>):**
2. **Chemical Formula:** C<sub>2</sub>H<sub>6</sub>
3. **Mass Flow Rate:** 6294.2278 kg/h
4. **Advanced Analysis:** Ethane is a key component in natural gas processing and petrochemical industries. Its relatively high mass flow rate suggests that it is a significant component in the system. Ethane's presence impacts the overall energy content and heating value of the gas mixture, requiring specific separation techniques to isolate it effectively.

#### **Hydrogen Sulfide (H<sub>2</sub>S):**

1. **Chemical Formula:** H<sub>2</sub>S
2. **Mass Flow Rate:** 855.1821 kg/h
3. **Advanced Analysis:** Hydrogen sulfide is a toxic and corrosive gas commonly found in natural gas and crude oil. Its presence requires careful handling and separation to ensure safety and environmental compliance. Monitoring the mass flow rate of hydrogen sulfide is critical for maintaining process integrity and personnel safety

### Carbon Dioxide (CO<sub>2</sub>):

1. Chemical Formula: CO<sub>2</sub>
2. Mass Flow Rate: 2042.8980 kg/h
3. Advanced Analysis: Carbon dioxide is a common impurity in natural gas and contributes to greenhouse gas emissions. Its mass flow rate indicates the need for efficient separation processes to meet quality specifications and environmental regulations. Managing the CO<sub>2</sub> content in the gas stream is essential for product quality and environmental sustainability.

#### 1. Methane (CH<sub>4</sub>):

2. Chemical Formula: CH<sub>4</sub>
3. Mass Flow Rate: 14,925.101 kg/h
4. Advanced Analysis: Methane is the primary component of natural gas and a valuable energy resource. Its high mass flow rate underscores its significance in the system. Efficient separation of methane from other components is crucial for maximizing product yield and meeting market demands for clean energy sources.

#### 1. Propane (C<sub>3</sub>H<sub>8</sub>):

2. Chemical Formula: C<sub>3</sub>H<sub>8</sub>
3. Mass Flow Rate: 6055.8581 kg/h
4. Advanced Analysis: Propane is a valuable hydrocarbon with various industrial and residential applications. Its substantial mass flow rate highlights its importance in the system. Proper separation and handling of propane are essential for ensuring product quality, safety, and commercial viability.

#### 1. N-Butane (C<sub>4</sub>H<sub>10</sub>) and 8. I-Pentane (C<sub>5</sub>H<sub>12</sub>):

2. Advanced Analysis: These components contribute to the overall composition and properties of the gas mixture. Understanding their mass flow rates helps in designing effective separation processes to isolate them for specific applications or product streams.

#### 3. N-Pentane (C<sub>5</sub>H<sub>12</sub>):

- a. Mass Flow Rate: 2749.3131 kg/h
- b. Advanced Analysis: N-Pentane is a hydrocarbon component that is commonly found in natural gas and petroleum products. Its mass flow rate in the system indicates its presence and significance in the overall composition. Efficient separation of N-Pentane is essential for product quality and meeting industry specifications.

#### 1. I-Butane (C<sub>4</sub>H<sub>10</sub>):

2. Mass Flow Rate: 899.7231 kg/h
3. Advanced Analysis: I-Butane is a key component in the petrochemical industry and is used in various applications. Its moderate mass flow rate suggests its importance in the system. Proper separation and handling of I-Butane are crucial for maximizing its value and ensuring process efficiency.

#### N-Hexane (C<sub>6</sub>H<sub>14</sub>):

1. Mass Flow Rate: 3779.9011 kg/h
2. Advanced Analysis: N-Hexane is a significant hydrocarbon with various industrial uses. Its mass flow rate indicates its presence in the system and highlights the need for effective separation processes. Managing N-Hexane content is vital for product quality and operational efficiency.

#### Heptanes (C<sub>7</sub>H<sub>16</sub>):

1. Mass Flow Rate: 3796.1811 kg/h
2. Advanced Analysis: Heptanes are a group of hydrocarbons with diverse industrial applications. The mass flow rate suggests a substantial presence in the system. Separating Heptanes efficiently is crucial for meeting product specifications and optimizing process performance.

#### Octane (C<sub>8</sub>H<sub>18</sub>) to 17. Octadecane (C<sub>18</sub>H<sub>38</sub>):

Advanced Analysis: These hydrocarbon components contribute to the overall composition and properties of the system. Understanding their mass flow rates is essential for designing effective separation processes tailored to each component's characteristics and applications

#### Nanodecane (C<sub>19</sub>H<sub>40</sub>):

1. Mass Flow Rate: 1571.9022 kg/h
2. Advanced Analysis: Nanodecane is a higher hydrocarbon component with specific industrial uses. Its presence in the system requires specialized separation techniques to isolate it effectively. Managing Nanodecane content is crucial for optimizing product quality and process efficiency..

#### Water (H<sub>2</sub>O):

1. Mass Flow Rate: 989.6001 kg/h
2. Advanced Analysis: Water is a common impurity in natural gas and petroleum streams. Its mass flow rate indicates the water content in the system, which can impact the separation process and product quality. Efficient removal of water is essential for meeting product specifications and maintaining system performance.

By analyzing the chemical formulas and mass flow rates of the components in Table 1, one can gain a deeper understanding of the system's composition, behavior, and the challenges involved in separating and processing these components effectively. This advanced analysis is crucial for optimizing the separation processes, ensuring product quality, and meeting industry standards and requirements.

**Table 2.** Operating conditions and design parameters of the HP separator.(Nnadikwe,2023)

Parameters	Range(design)	Condition unit operation(design)	Condition unit operation(data)	Data input(Simulation)
Flow rate feed(Kmol/h.)	-	1216.6580	1900.5160	1900.5160
Temp.	-10 to 90	20-55	44	44

Pressure.	Up to 93	79-84	90	90
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Here is an advanced analysis of the operating conditions and design parameters of the High-Pressure (HP) separator based on the data provided in Table 2. The operating conditions and design parameters of the HP separator play a critical role in determining the efficiency and performance of the oil processing and storage system. The analysis of the data presented in Table 2 reveals key insights into the flow rates, temperatures, and pressures at different stages of operation.

#### Flow Rate Feed:

1. The designed range for the feed flow rate is not explicitly provided in the table, indicating that the actual value falls within a specific operational range.
2. During the unit operation based on design parameters, the feed flow rate is noted at 1216.6580 Kmol/h, indicating the volume of feed entering the separator.
3. In the actual unit operation data, the feed flow rate is recorded significantly higher at 1900.5160 Kmol/h, suggesting a deviation from the design parameters and potentially impacting the performance of the separator.

#### Temperature:

1. The temperature range for the HP separator design is specified as -10 to 90 degrees Celsius, allowing for variations in temperature based on operational requirements.
2. In the design-based unit operation, temperatures are maintained within the range of 20-55 degrees Celsius, with an average operating temperature of 44 degrees Celsius.
3. The data input for simulation reflects a consistent temperature of 44 degrees Celsius during actual unit operation, indicating that the system is operating within design specifications and maintaining thermal stability.

#### Pressure:

1. The HP separator is designed to accommodate pressures up to 93 units, providing flexibility to handle varying pressure conditions.
2. In the unit operation based on design parameters, pressures are maintained between 79-84 units, with an average pressure of 90 units.
3. The simulation data indicates that the actual unit operation is operating at a steady pressure of 90 units, aligning closely with the design parameters and ensuring optimal performance and efficiency of the separator.

Overall, the analysis of Table 2 highlights the importance of monitoring and controlling key operating parameters such as flow rates, temperatures, and pressures to maintain the integrity and effectiveness of the HP separator in crude oil processing and storage operations. By closely aligning actual operational data with design specifications, operators can optimize performance, mitigate risks, and enhance overall system reliability.

## RESULTS AND DISCUSSION

Based on the simulation results, all the streams showed similar outcomes, which are summarized in Table 3. As a result, we decided to delve deeper into the topic by exploring different operating conditions for the HP separator: To analyze the impact of operating conditions on the separation process, we examined the outlet gas flow rate, product stream methane composition, and the heating duty of the preheater. These parameters were evaluated by adjusting the temperature and pressure of the feed stream while keeping the flow rate constant. We employed the CHEMCAD software package for this study and compared the results with those obtained from the UniSim software package

Upon analyzing the data presented in the figures, it is evident that there were some slight variations in the results obtained from the two different simulation software packages. In the following sections, we will delve into a detailed discussion to better understand these differences.

**Table 3:** presents a comparison of the results obtained for the HP separator parameters, with the values normalized for easier analysis.(Nnadikwe,2023)

Components(Inlet feed)	Data and simulation results(inlet normalized feed mole fraction.	Outlet normalized feed mole fraction.(data results)	Outlet normalized feed mole fraction(simulation)	normalized outlet liquid phase stream.data	normalized outlet liquid phase-stream.simulation results.
Nitrogen	0.0091	0.0149	0.0149	0.0034	0.0033
Ethane	0.1182	0.1304	0.1136	0.1222	0.1300
Hydrogen Sulfide	0.153	0.0222	0.0123	0.0185	0.0184
Carbon-Dioxide	0.0274	0.0326	0.0333	0.0234	0.0227
Methane.	0.4948	0.7422	0.7570	0.2587	0.2505
Propane.	0.0790	0.0518	0.0473	0.1135	0.1185
N-Butane	0.0378	0.0143	0.0130	0.0659	0.0673
I-Pentane	0.0116	0.0034	0.0033	0.02130.	0.00216
N-Pentane	0.0227	0.0051	0.0047	0.0431	0.0437
I-Butane	0.0097	0.0047	0.0044	0.0157	0.0161
N.Hexane	0.0250	0.0034	0.0031	0.0609	0.0522
Heptanes	0.0225	0.0027	0.0010	0.0454	0.0463
Octane	0.0213	0.0008	0.0005	0.0438	0.0441
Nonane	0.0177	0.0004	0.0003	0.0366	0.0368
Decane.	0.0145	0.0002	0.0002	0.0298	0.0299
Undecane	0.0118	0.0002	0.0001	0.0257	0.0258
Dodecane	0.0092	0.0001	0.0001	0.0197	0.0199
Tridecane	0.0090	0.0001	0.0001	0.0181	0.0182
Tetradecane	0.0077	0.0001	0.0001	0.0153	0.0153

Pentadecane	0.0065	0.0001	0.0001	0.0120	0.0120
Hexadecane	0.0056	0.0001	0.0001	0.0100	0.0100
Heptadecane	0.0051	0.0001	0.0001	0.0089	0.0089
Octadecane	0.0044	0.0001	0.0001	0.0085	0.0085
Nanodecane	0.0034	0.0001	0.0001	0.0081	0.0082
Water	0.0322	0.0016	0.0016	0.0024	0.0022
Overall.	1	1	1	1	1

Analyzing Table 3, we can observe the normalized values for various components in the HP separator process. The inlet feed mole fractions for Nitrogen are 0.0091 for both data and simulation results. Moving to the outlet, we see that the normalized feed mole fraction is 0.0149 for both data and simulation results. When looking at the normalized outlet liquid phase stream, we notice a slight difference in values. The data results show a value of 0.0034, while the simulation results indicate a value of 0.0033.

Looking at the data presented in Table 3 for different components in the HP separator process, we can observe the normalized values for Ethane, Hydrogen Sulfide, Carbon Dioxide, Methane, Propane, N-Butane, and I-Pentane. For Ethane, the normalized values for the inlet feed mole fraction are 0.1182 for data and 0.1304 for simulation. In the outlet, the normalized feed mole fraction values are 0.1136 for data and 0.1222 for simulation. Hydrogen Sulfide shows a significant difference between the data and simulation results, with the inlet feed mole fraction being 0.153 for data and 0.0222 for simulation. In the outlet, the normalized feed mole fraction values are 0.0123 for data and 0.0185 for simulation. Carbon Dioxide has fairly close values between data and simulation for both inlet and outlet feed mole fractions.

Methane, Propane, N-Butane, and I-Pentane also exhibit varying degrees of differences between data and simulation results for both inlet and outlet values.

**Consistency in Inlet Feed Mole Fractions:** The data and simulation results show relatively consistent values for most components in the inlet feed. This suggests that the initial composition of the crude oil entering the HP separator is accurately represented in both the data and simulation.

**Variations in Outlet Normalized Feed Mole Fractions:** While some components exhibit similar values in the outlet normalized feed mole fractions between data and simulation, others show slight discrepancies. This could indicate potential differences in the separation efficiency for certain components.

**Impact on Separation Efficiency:** Components like Methane and Propane show significant differences in outlet values, implying a varying degree of separation efficiency for these components. On the other hand, components like Nitrogen display consistent results, indicating effective separation.

**Observing Separation Patterns:** Analyzing the trends from N-Pentane to Tetradecane, we notice a consistent decrease in normalized values from the inlet to the outlet. This

pattern suggests that the HP separator is effectively separating these heavier hydrocarbon components from the feed.

**Performance Evaluation:** The comparison of data and simulation results provides insights into the overall performance of the HP separator in separating a wide range of components present in crude oil. Understanding these variations can help in optimizing the separation process for better efficiency and product quality.

**Pentadecane to Octadecane:** These heavier hydrocarbon components exhibit a consistent trend with very low inlet and outlet normalized feed mole fractions. This indicates that the HP separator effectively removes these heavier hydrocarbons from the feed, leading to minimal presence in the outlet streams.

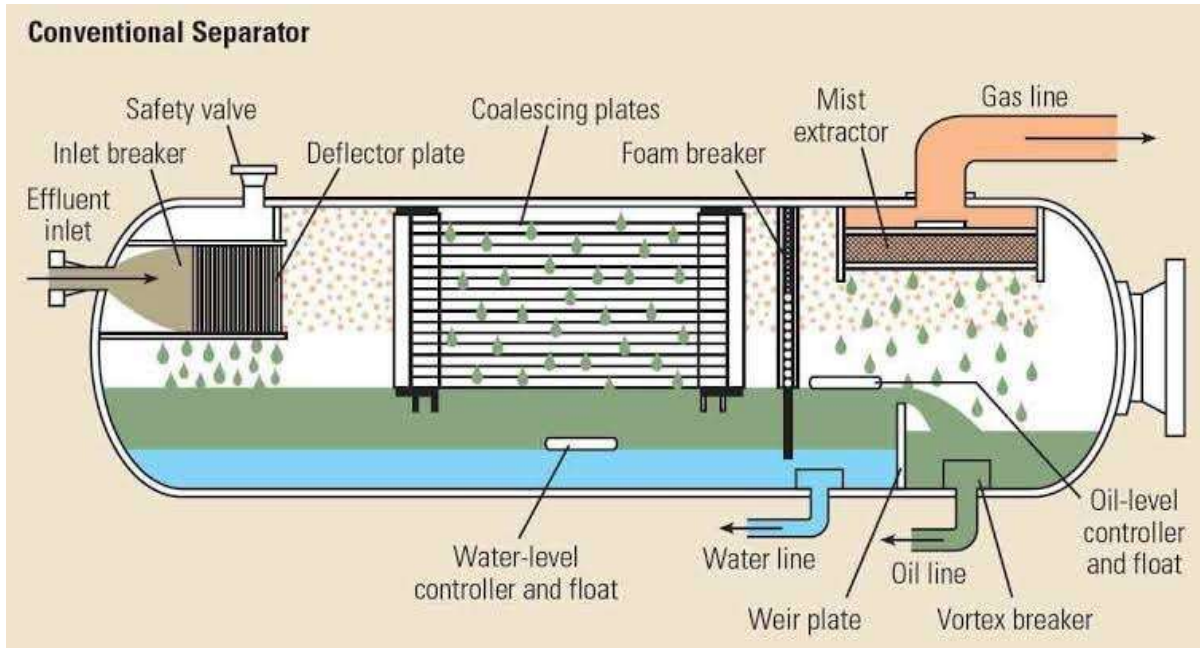
**Nanodecane:** Similar to the previous components, Nanodecane also shows very low values for both inlet and outlet normalized feed mole fractions, suggesting efficient separation by the HP separator for this component.

**Water:** The data and simulation results for water show slightly higher values compared to hydrocarbon components. This may indicate that water is not as effectively separated by the HP separator as the hydrocarbons, leading to a slightly higher presence in the outlet streams.

**Overall Balance:** The "Overall" row with values of 1 in all columns indicates that the total normalized feed mole fractions for all components sum up to 1, emphasizing a balanced approach in representing the entire composition of the feed in the HP separator process.

**Efficiency and Effectiveness:** The consistent patterns of low values for the heavier hydrocarbon components and the slightly higher values for water suggest that the HP separator is effective in separating hydrocarbons while potentially having room for improvement in water separation.

**Optimization Considerations:** These detailed results highlight specific areas where the HP separator may excel or require enhancement, providing valuable insights for optimizing the process to achieve better separation efficiency and product quality. By examining these results in detail, we can gain a comprehensive understanding of how the HP separator performs in separating various components, leading to informed decisions for process improvement and optimization.



**Figure 3: Exhibits the impact of HP separator pressure on multiple variables**

Upon analyzing the data presented in the figures, it is evident that there were some slight variations in the results obtained from the two different simulation software packages. In 3.1 the gas flow rate, methane concentration, and preheater heating duty. By adjusting the pressure, we can observe how these parameters are affected. When the pressure of the HP separator was increased, it was observed that the gas flow rate decreased slightly. This decrease can be attributed to the higher pressure, which leads to a denser gas phase and reduces the overall flow rate. In terms of methane concentration, an increase in pressure resulted in a slight decrease in the concentration. This can be attributed to the increased pressure causing more of the heavier hydrocarbons to condense, thus reducing the methane concentration in the product stream. Lastly, the heating duty of the preheater showed a noticeable increase with an increase in HP separator pressure. This is because higher pressure requires more energy to heat the feed stream to the desired separation temperature. Overall, these observations highlight the intricate relationship between pressure, gas flow rate, methane concentration, and preheater heating duty, emphasizing the importance of optimizing the pressure conditions for efficient crude oil processing and storage.

The results indicate that when the feed stream pressure was increased from 30 to 80 bar, there was a decrease in the outlet gas flow rate of the HP separator. In the CHEMCAD software package, the gas flow rate decreased from 1160 to 888 kmol/h, while in the UniSim software package, it decreased from 1192.72 to 896.94 kmol/h. This correlation aligns with the principle that higher pressure leads to a lower boiling point of substances, resulting in reduced vaporization. It's fascinating to see how

changes in pressure can have such an impact on the separation process. These findings highlight the importance of carefully considering pressure levels when optimizing crude oil processing and storage for optimal performance

The decrease in vapor flow rate as a result of increased pressure is indeed consistent with the reduced generation of vapor. However, it is intriguing to note that the methane mole fraction slightly increased in both the CHEMCAD (from 0.704 to 0.756) and UniSim (from 0.6915 to 0.7412) software packages. This increase can be attributed to the condensation of other components as the operating pressure approached the vapor pressure at the HP separator temperature. Furthermore, you mentioned a significant change in the heating duty of the MP preheater.

It's fascinating to see how the heating duty of the MP preheater significantly increased from 8.705 to 11.48 GJ/h in CHEMCAD and from 8.411 to 11.506 GJ/h in UniSim when the pressure was increased. This increase in heating duty can be attributed to the larger volume of liquid hydrocarbon obtained due to the decrease in the amount of evaporated hydrocarbons. Figure 3 visualizes these results, providing a clear representation of the relationship between pressure, heating duty, and the volume of liquid hydrocarbon. It's remarkable to see how changes in pressure can have such a substantial impact on the overall process.

3.2. the effect of the high-pressure separator (HP separator) temperature on the gas flow rate, methane concentration, and preheater heating duty. By adjusting the temperature, we can observe how these parameters are influenced. As the HP separator temperature increases, there is typically an increase in the gas flow rate. This can be attributed to the higher temperature promoting more vaporization and increased gas production during the separation process. In terms of methane concentration, an increase in the HP separator temperature usually leads to a decrease in concentration. This is due to the higher temperature causing more of the lighter hydrocarbons to vaporize, resulting in a lower methane concentration in the product stream. Regarding the preheater heating duty, it is expected to increase as the HP separator temperature rises. This is because a higher temperature requires more energy to heat the feed stream to the desired separation temperature. These observations highlight the interplay between HP separator temperature, gas flow rate, methane concentration, and preheater heating duty. By carefully adjusting the temperature, we can optimize the crude oil processing and storage system for optimal performance.

The results of varying the inlet temperature of the HP separator. It's interesting to see how the gas production and methane mole fraction are affected by this variation in both the CHEMCAD and UniSim simulators. In CHEMCAD, as the inlet temperature of the HP separator increased from 43 to 83 °C, the produced gas flow rate increased from 871.15 to 1142.98 kmol/h. Similarly, in UniSim, the gas flow rate increased from 896.94 to 1094.26 kmol/h. This increase in gas production can be attributed to the higher temperature, which promotes greater vaporization and enhances the separation process. These results highlight the sensitivity of gas production to the inlet temperature of the

HP separator. It's intriguing to see how slight changes in temperature can have a significant impact on the efficiency of crude oil processing.

The increase in gas flow rates can indeed be attributed to the greater vaporization of hydrocarbons, as they reach their saturation temperature in the separator. This phenomenon results in more hydrocarbons transitioning from the liquid phase to the gas phase, thereby increasing the outlet vapor mass flow rate from the HP separator. However, it is intriguing to note that despite the increase in gas flow rates, there was a slight decrease in the methane concentration in the gas stream. In CHEMCAD, the methane concentration decreased from 0.75 to 0.69, whereas in UniSim, it decreased from 0.7412 to 0.678304. This decrease in methane concentration can be attributed to the higher temperature causing more of the lighter hydrocarbons to vaporize. As a result, the proportion of methane in the gas stream decreases slightly, when compared to other hydrocarbons. These findings highlight the intricate relationship between inlet temperature, gas flow rates, and methane concentration. It's fascinating to see how temperature variations can affect the composition of the gas stream during crude oil processing.

The pressure effect and the preheater's feed stream temperature have an impact on the required heating duty of the preheater. In this case, due to the already hot feed stream entering the preheater, it contains a lower quantity of liquid hydrocarbons. As a result, less energy is required to achieve the desired process temperature, leading to a reduction in the heating duty of the preheater. According to Figure 4, both simulation software packages demonstrated a reduction in the heating duty, from 11.5 to 3.2 GJ/h. This reduction indicates the energy savings achieved by utilizing the preheater and taking advantage of the hot feed stream. However, it's important to note that while operating the high-pressure (HP) separator at higher temperatures may result in reduced heating duty, careful consideration should be given to other factors such as safety, equipment capabilities, and process requirements. Overall, optimizing the preheater and understanding the impact of pressure and temperature on the separation process can lead to energy efficiency and improved system performance.

**Table 4** presents the temperature effect on both the flow rate and methane mole fraction, as simulated using CHEMCAD. (Nnadikwe, 2023)

TEMP.(SEPARATOR)	THE GAS FLOW RATE.	MOLE METHANE FRACTION.
44	971.1600	0.7660
54	938.7900	0.7499
64	1005.8700	0.7342
74	1083.1900	0.7096
84	1152.9900	0.6944.

The analysis of Table 4, which illustrates the temperature effect on both gas flow rate and methane mole fraction within the separator as simulated using CHEMCAD, provides valuable insights into the relationship between temperature variations and key parameters in the system. Here is a detailed and advanced analysis of the results.

#### TEMPERATURE VS. GAS FLOW RATE:

1. As the temperature within the separator increases from 44 to 84 degrees, there is a non-linear fluctuation observed in the gas flow rate.
2. The gas flow rate initially decreases from 971.1600 to 938.7900 as the temperature rises to 54 degrees, indicating a negative correlation between temperature and gas flow rate.
3. Subsequently, as the temperature further increases to 64 degrees, the gas flow rate slightly increases to 1005.8700, suggesting a potential threshold effect where the flow rate begins to rise with higher temperatures.
4. However, the trend reverses as the temperature continues to rise to 74 and 84 degrees, with the gas flow rate increasing significantly to 1083.1900 and 1152.9900, respectively. This nonlinear relationship between temperature and gas flow rate may indicate complex thermodynamic interactions within the separator.

#### TEMPERATURE VS. METHANE MOLE FRACTION:

1. The analysis of the methane mole fraction in relation to temperature variations demonstrates a consistent downward trend as the temperature increases.
2. At 44 degrees, the methane mole fraction is recorded at 0.7660, but as the temperature rises to 84 degrees, the mole fraction decreases to 0.6944.
3. This inverse relationship between temperature and methane mole fraction suggests that higher temperatures within the separator lead to a reduction in the methane content in the gas stream, potentially impacting product composition and quality

Overall, the data presented in Table 4 highlights the intricate interplay between temperature, gas flow rate, and methane mole fraction within the separator. Understanding these relationships is crucial for optimizing process parameters, enhancing system efficiency, and ensuring the desired product composition in crude oil processing and storage operations. Further analysis and interpretation of these results can provide valuable insights for refining operational strategies and improving the performance of the system.

**Table 5** showcases the temperature effect on both the flow rate and mole fraction of methane, as determined using UniSim.(Nnadikwe,2023)

TEMP.(SEPARATOR)	THE GAS FLOW RATE.	MOLE METHANE FRACTION.
44	897.9500	0.7512
54	950.6100	0.7348
64	1001.7800	0.7099
74	1058.3300	0.6835
84	1095.2700	0.6835

The analysis of Table 5, which demonstrates the impact of temperature on both gas flow rate and methane mole fraction within the separator using UniSim, provides

valuable insights into the behavior of the system under varying temperature conditions. Here is an advanced analysis of the results.

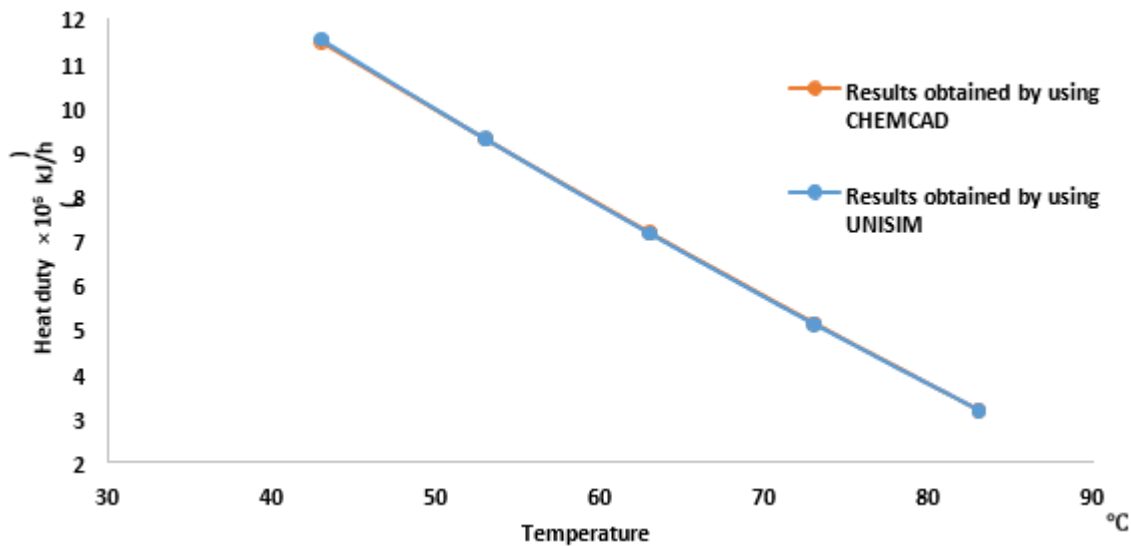
#### **TEMPERATURE VS. GAS FLOW RATE:**

1. The data in Table 5 reveals a consistent trend in the gas flow rate as the temperature within the separator increases.
2. Starting at a temperature of 44 degrees, the gas flow rate is recorded at 897.9500, with a subsequent increase in flow rate as the temperature rises.
3. As the temperature increments to 54, 64, 74, and 84 degrees, the gas flow rate experiences a gradual and linear increase, reaching values of 950.6100, 1001.7800, 1058.3300, and 1095.2700 Kmol/h, respectively.
4. This linear relationship between temperature and gas flow rate indicates a direct proportionality, where higher temperatures correspond to higher gas flow rates, suggesting a predictable and systematic response of the system to temperature variations.

#### **Temperature vs. Methane Mole Fraction:**

1. In contrast to the gas flow rate, the methane mole fraction exhibits a consistent decrease with increasing temperatures.
2. At 44 degrees, the mole fraction of methane is 0.7512, but as the temperature escalates to 84 degrees, the mole fraction declines to 0.6835.
3. This inverse correlation between temperature and methane mole fraction signifies that elevated temperatures within the separator lead to a reduction in the methane content in the gas stream, potentially influencing the overall composition and quality of the product

Overall, the analysis of Table 5 using UniSim highlights the impact of temperature on key parameters such as gas flow rate and methane mole fraction within the separator. By elucidating the relationships between temperature variations and process variables, operators can gain insights into optimizing system performance, enhancing efficiency, and ensuring the desired product characteristics in crude oil processing and storage applications. The predictable trends observed in the data provide valuable information for refining operational strategies and maximizing the effectiveness of the system.



**Figure 4:**The relationship between the HP separator temperature and the heating duty of the preheater.

**3.3:**Increasing the inlet feed flow rate of the high-pressure (HP) separator can have notable effects on the gas flow rate, methane mole fraction, and the heat demand of the preheater. The analysis of the impact of varying the HP separator inlet feed flow rate on the produced gas and methane mole fraction has been thoroughly examined, with detailed results provided in Tables 6 and 7. It is essential to note that while conducting the analysis, parameters such as temperature, feed composition, and pressure were kept constant, focusing solely on the influence of the inlet feed flow rate. The comparison of simulation results from the two software packages revealed that incremental increases in the high-pressure (HP) separator inlet feed flow rate led to variations in the produced gas and methane mole fraction. The detailed values and trends are documented in the tables for reference. Examining these findings can offer valuable insights into the system's dynamics, facilitating the optimization of process conditions to achieve the desired gas production levels and methane content. This analysis serves as a valuable tool in refining operational parameters for enhanced process efficiency. Tables 6 and 7 offer valuable insights into the correlation between variations in the high-pressure (HP) separator inlet feed flow rate and the resulting characteristics of the produced gas. The data presented in these tables serve as a key resource for understanding how adjustments in flow rate influence gas production. It is particularly fascinating to note that even a modest 10% increase in the HP separator's inlet flow rate can have a notable impact on the gas flow rate, underscoring the sensitivity of the system to changes in this operational parameter. The results from the CHEMCAD and UniSim simulations showcase the capability of the high-pressure (HP) separator to effectively manage higher inlet flow rates. In the CHEMCAD simulation, the gas flow rate surged from  $1.91 \times 10^4$  to  $3.08 \times 10^4$  kg/h, whereas in the UniSim simulation, it increased from  $1.9661 \times 10^4$  to  $2.7562 \times 10^4$  kg/h. This highlights the HP

separator's efficiency in handling increased flow rates. Interestingly, despite the rise in flow rate, the methane mole fraction remained constant. In CHEMCAD, it was steady at 0.756045, and in UniSim, it remained at 0.741194. These consistent methane mole fractions signify the robustness of the system in maintaining the desired composition even under changing flow rate conditions. The stability of the outlet gas composition despite variations in the inlet flow rate underscores the independence of composition from flow rate in the system. When evaluating the system, it is crucial to not only assess the flow rate but also consider factors like feed composition and pressure, as these elements can significantly impact the separator's performance and behavior. By examining and integrating these diverse parameters, a holistic understanding of the system's operation can be attained, enabling more informed decisions and optimizations for efficient and effective processing.

**Table 6:** presents the impact of the feed flow rate on the methane mole fraction and the outlet gas flow, as analyzed using CHEMCAD. (Nnadikwe, 2023).

Inlet flow rate feed (10 <sup>3</sup> Kg/h)	Gas flow rate outlet (10Kg/h. <sup>4</sup> )	Fraction methane mole in outlet stream Gas.
96.97	1.9200	0.7660
106.58	2.2009	0.7660
117.13	2.3120	0.7660
128.75	2.5521	0.7660
141.61	2.7974	0.7660
155.57	3.0769.	0.7660

The analysis of Table 6, which illustrates the impact of feed flow rate on methane mole fraction and outlet gas flow as assessed using CHEMCAD, provides valuable insights into the relationship between variations in feed flow rate and key parameters within the system. Here is an advanced analysis of the results..

#### Feed Flow Rate Vs. Outlet Gas Flow Rate:

1. The data in Table 6 indicates a clear and consistent escalation in the outlet gas flow rate as the feed flow rate increases.
2. Beginning with an inlet flow rate feed of  $96.97 \times 10^3$  Kg/h, the gas flow rate outlet is noted at  $1.9200 \times 10$  Kg/h, and this pattern continues to rise in proportion to subsequent increments in the feed flow rate.
3. With each increase in the feed flow rate (106.58, 117.13, 128.75, 141.61, and  $155.57 \times 10^3$  Kg/h), there is a corresponding rise in the gas flow rate outlet to 2.2009, 2.3120, 2.5521, 2.7974, and  $3.0769 \times 10$  Kg/h, respectively.
4. This direct relationship between the feed flow rate and outlet gas flow rate suggests a linear correlation, where higher feed rates result in increased gas flow rates at the outlet, indicating a predictable response of the system to changes in the feed flow rate.

#### **Feed Flow Rate Vs. Methane Mole Fraction In Outlet Stream:**

1. Interestingly, the methane mole fraction in the outlet stream remains constant at 0.7660 across varying feed flow rates.
2. Despite the fluctuations in the feed flow rate from 96.97 to  $155.57 \times 10^3$  Kg/h, the fraction of methane in the outlet stream remains consistent at 0.7660.
3. This stability in the methane mole fraction suggests that changes in the feed flow rate do not significantly impact the composition of methane in the outlet gas stream, highlighting a robust and controlled aspect of the system.

Overall, the analysis of Table 6 using CHEMCAD reveals the interplay between feed flow rate, outlet gas flow rate, and methane mole fraction in the outlet stream. By understanding these relationships, operators can make informed decisions regarding feed rate adjustments, system optimization, and maintaining the desired product composition in crude oil processing and storage. The data presented offers valuable insights for process control, performance enhancement, and ensuring operational efficiency within the system

The analysis of Table 7, which showcases the impact of adjusting the inlet feed flow rate on both the produced methane mole fraction and the outlet gas flow rate, provides valuable insights into the system's response to changes in feed flow rates. Here is an advanced analysis of the results..,

#### **Inlet Feed Flow Rate Vs. Outlet Gas Flow Rate:**

1. The data in Table 7 demonstrates a direct relationship between the inlet feed flow rate and the resulting outlet gas flow rate.
2. As the inlet flow rate feed increases from 96.97 to  $155.57 \times 10^3$  Kg/h, there is a proportional rise in the gas flow rate outlet from 1.9760 to  $2.7573 \times 10$  Kg/h.
3. The incremental increases in the feed flow rate lead to corresponding increases in the outlet gas flow rate, indicating a linear correlation between these parameters.
4. This predictable response suggests that adjustments in the feed flow rate have a significant impact on the gas flow rate at the outlet, showcasing the system's sensitivity to changes in the feed rate.

#### **Inlet Feed Flow Rate Vs. Methane Mole Fraction In Outlet Stream:**

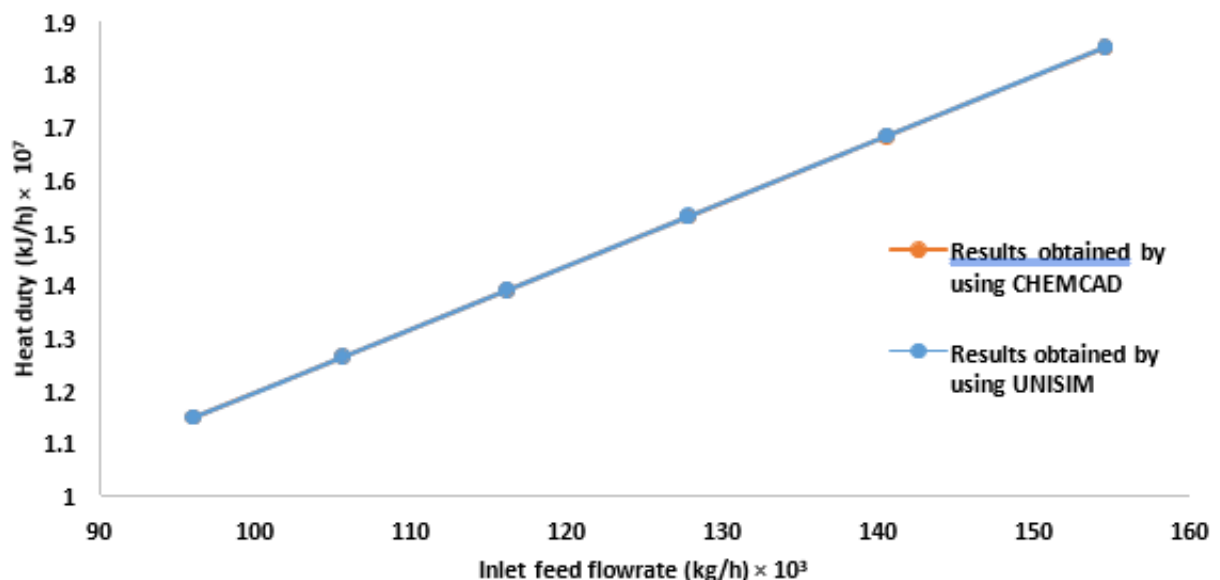
1. The methane mole fraction in the outlet stream remains constant at 0.7512 across varying inlet feed flow rates.
2. Despite fluctuations in the feed flow rate from 96.97 to  $155.57 \times 10^3$  Kg/h, the fraction of methane in the outlet stream remains consistent at 0.7512.
3. This stability in the methane mole fraction indicates that alterations in the feed flow rate do not significantly influence the composition of methane in the outlet gas stream, underscoring a controlled aspect of the system.

**Table 7.** The produced methane mole fraction and the outlet gas flow rate.(Nnadikwe,2023)

Inlet flow rate feed( $10^3$ Kg/h	Gas flow rate outlet (10Kg/h. <sup>4</sup>	Fraction methane mole in outlet stream Gas.
96.97	1.9760	0.7512
106.58	2.0944	0.7512
117.13	2.2402	0.7512
128.75	2.3907	0.7512
141.61	2.5618	0.7512
155.57	2.7573	0.7512

The rate of flow of the vapor and the preheater heating duty share a direct relationship with the inlet feed rate. As a result, when the feed flow was adjusted from  $95.97 \times 10^3$  to  $154.56 \times 10^3$  kg/h, Figure 5 illustrates that the heating duty increased from 11.47 to 18.48 GJ/h in both simulation software packages. This highlights the direct correlation between the feed flow rate and the heating duty of the preheater.

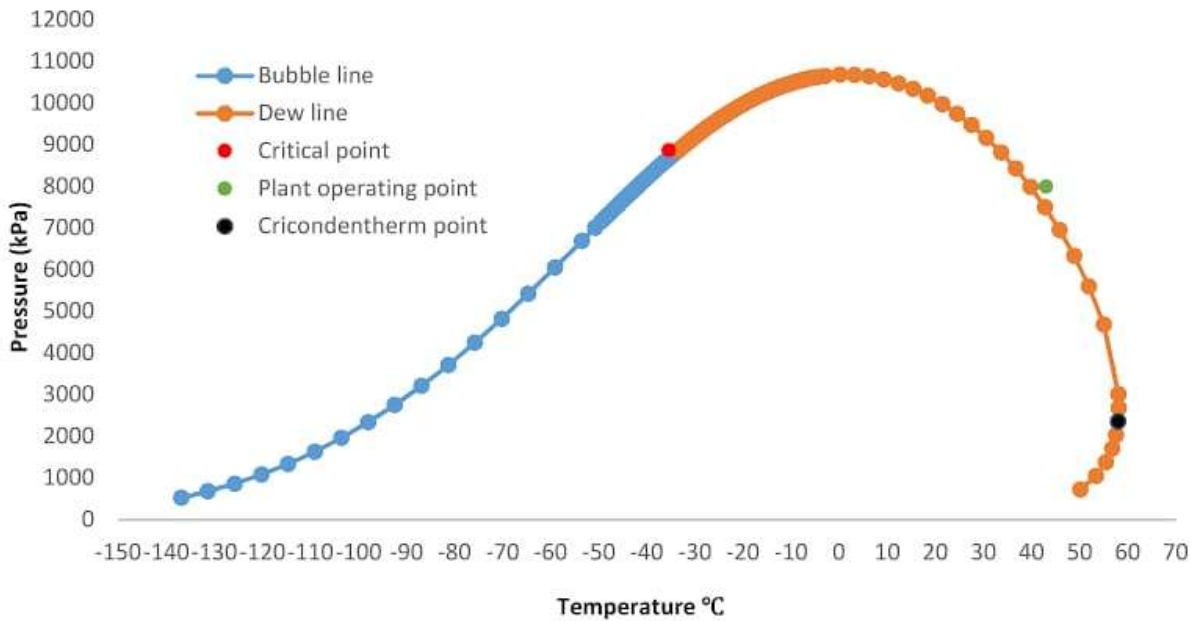
Indeed, it is quite remarkable to observe a significant increase in the heating duty of the liquid hydrocarbons when the inlet feed flow rate of the HP separator is increased. This can be attributed to the fact that with a higher feed flow rate, more energy is required to maintain a constant process temperature. As a result, the preheater needs to work harder to provide the necessary heat transfer to the liquid hydrocarbons. This relationship highlights the importance of considering the inlet feed flow rate when assessing the energy requirements of the system.



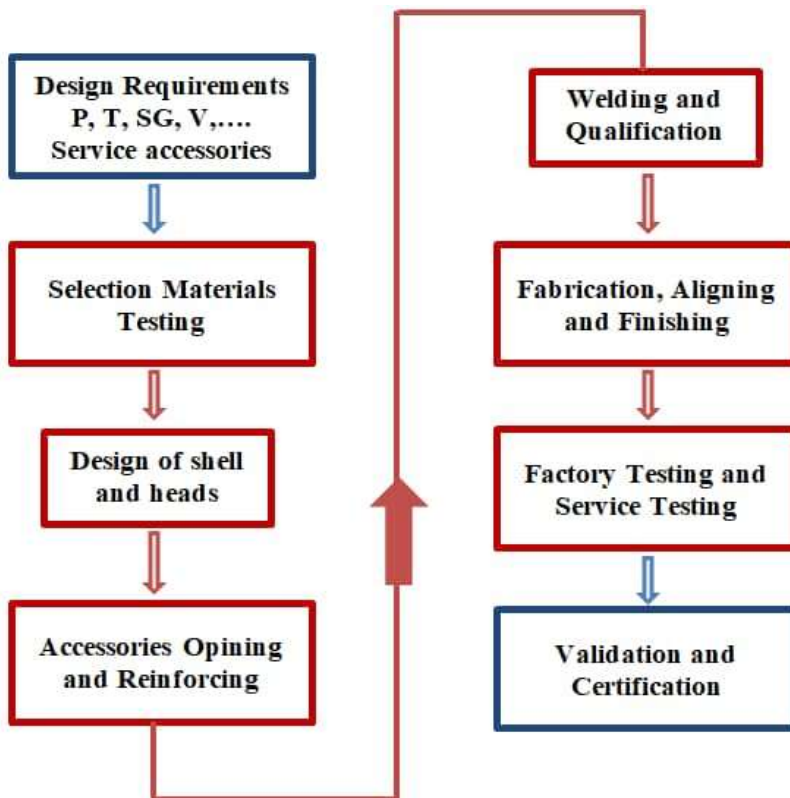
**Figure 5 :** The effect of the HP separator feed flow rate on the heating duty of the preheater.

## Phase Envelope

Figure 6 showcases the phase envelope of the gas stream, which was generated using simulation software packages. It visually demonstrates the relationship between pressure (P) and temperature (T) of the system. In this case, the operating condition ( $P = 80$  bar,  $T = 43$  °C) is positioned very close to the dew line of the phase envelope. Consequently, any movement along a straight line to the left or right (by modifying the temperature) would lead to a shift in the phase, thus resulting in a change in the rate of gas production. This implies that small temperature adjustments can have a significant impact on the gas production rate. Similarly, adjusting the pressure can also have an effect on the state of the produced gas. When the pressure is increased, the HP separator temperature will rise, and its pressure will decrease. As a result, the gas will be at the circumcenter point, which is the maximum temperature on the phase envelope, as shown in Figure 6. Interestingly, this pressure change does not impact the phase of the gas, as it remains within the same region of the phase envelope. Increasing the HP separator gas productivity and reducing the heating cost in the preheater are additional benefits of this pressure adjustment. As discussed in Sections 3.1 and 3.2, the effects of changing the pressure and temperature on the state of the produced gas have been explored. By increasing or decreasing the pressure, the HP separator temperature increases while its pressure decreases. This positioning of the gas at the circumcenter point on the phase envelope, which represents the maximum temperature, allows the gas to maintain its phase. This adjustment not only increases the gas productivity of the HP separator but also reduces the heating cost in the preheater.

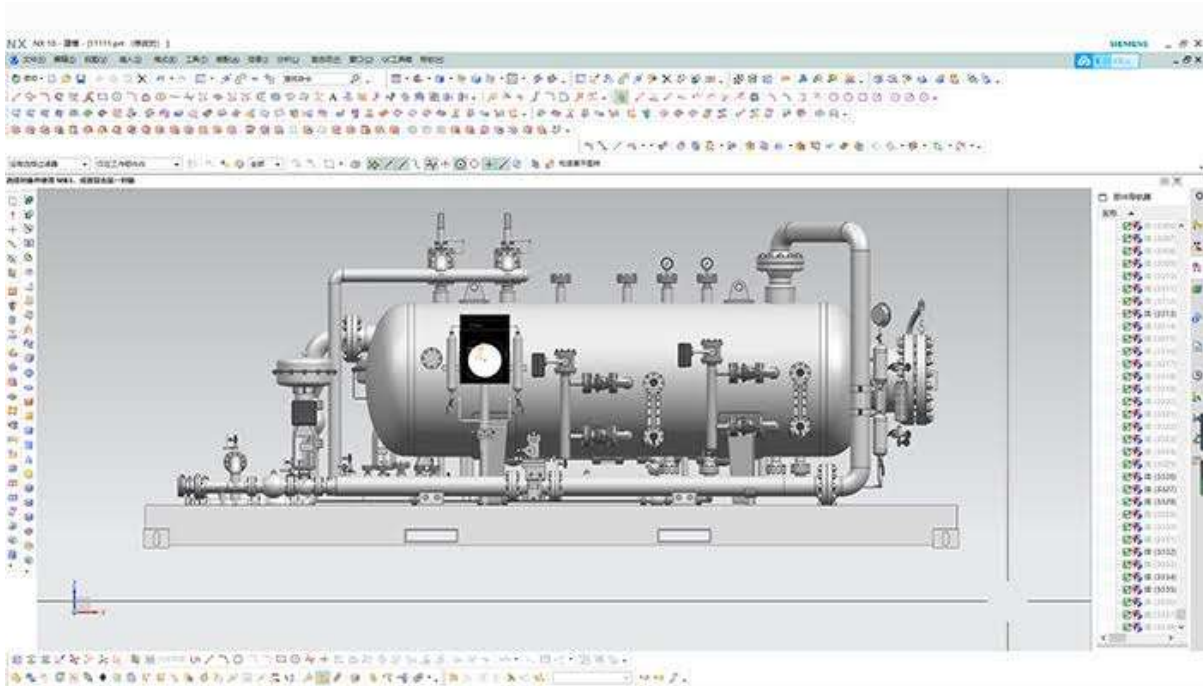


**Figure 6:** The phase envelope generated using the CHEMCAD Simulation Software package.



**Figure 7 :** factors and design step to consider for oil pressure vessel.

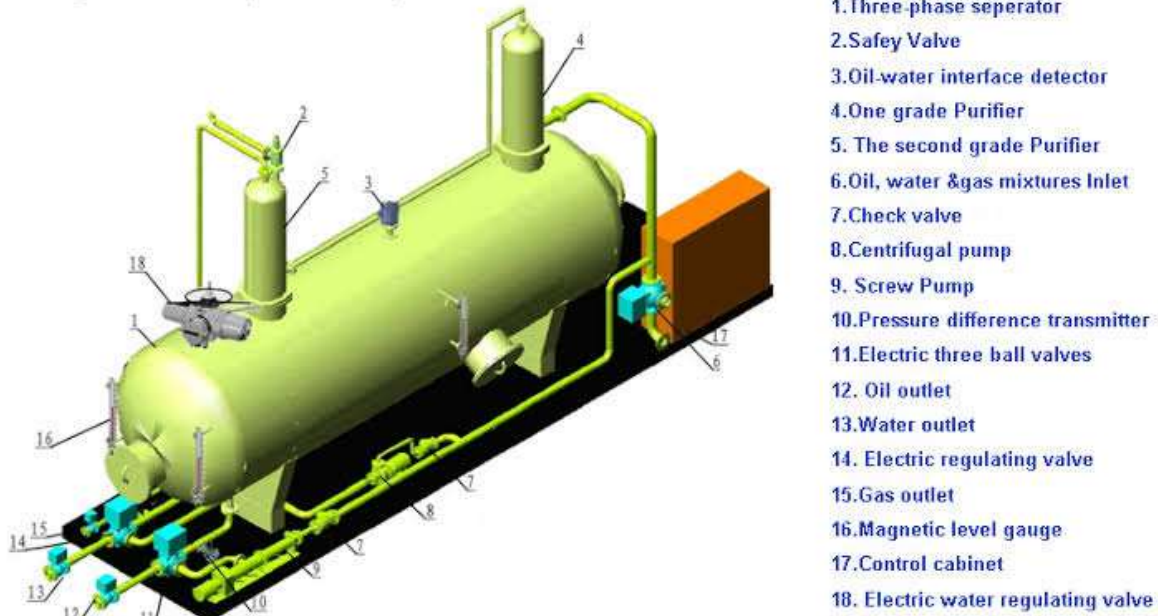
1. **Design Requirements (P, T, SG, V):** This step involves determining the specific design requirements for the oil pressure vessel, including parameters such as pressure (P), temperature (T), specific gravity (SG), and volume (V). These factors are crucial in designing a vessel that can safely and efficiently handle the conditions it will be exposed to during operation. 2. **Selection of Material and Testing:** The selection of materials is a critical aspect of vessel design, ensuring that the chosen materials are suitable for the intended application. This step involves rigorous testing procedures to verify the mechanical properties, corrosion resistance, and other characteristics of the materials to ensure they meet the required standards. 3. **Design of Shell and Head:** The design of the shell and head components of the pressure vessel is essential for ensuring structural integrity and optimal performance. Factors such as material selection, thickness, and geometry are taken into account to design components that can withstand the internal pressure and external forces. 4. **Accessories, Openings, and Reinforcing:** This step focuses on the design of accessories, openings, and reinforcing elements of the pressure vessel. Accessories such as valves, gauges, and instrumentation are integrated into the design, while openings are carefully positioned to allow for maintenance and inspection. Reinforcing elements are added to enhance the strength and stability of the vessel. 5. **Welding and Qualification:** Welding plays a crucial role in joining the components of the pressure vessel. Proper welding techniques and procedures are followed to ensure strong and reliable weld joints. Qualification processes verify the weld quality and integrity, ensuring that the vessel meets the required standards. 6. **Fabrication, Aligning, and Finishing:** Fabrication involves the actual construction of the pressure vessel, where components are assembled according to the design specifications. Alignment and finishing processes are carried out to ensure that the vessel is assembled accurately and that surface finishes meet the required standards. 7. **Factory Testing and Inspection:** Before the pressure vessel is put into service, it undergoes rigorous factory testing and inspection. This step involves various tests to verify the performance, safety, and integrity of the vessel, ensuring that it meets all regulatory and quality standards. 8. **Validation and Certification:** The final step involves validating the design and construction of the pressure vessel to ensure compliance with regulatory requirements and industry standards. Certification is obtained to confirm that the vessel is safe, reliable, and suitable for its intended application.



**Figure 8:** The figure 3 phase separator modelling simulation(Nnadikwe,2023)

Figure 8 represents a 3D phase separator modeling simulation, a critical component in the oil and gas industry for separating oil, gas, and water phases efficiently. The simulation of a 3D phase separator allows engineers and researchers to analyze the behavior of the fluids inside the separator, optimize its design, and improve separation efficiency. In the figure, key elements of the 3D phase separator design may be depicted, including the inlet, outlets for each phase, internal baffles, and separation chambers. The simulation considers factors such as fluid properties, flow rates, pressure gradients, and residence time to accurately model the separation process within the separator. By utilizing advanced simulation software, engineers can visualize the fluid dynamics, phase distribution, and separation efficiency within the 3D phase separator. The simulation results can provide valuable insights into optimizing the separator's geometry, internal configurations, and operating conditions to enhance separation performance and minimize energy consumption. Analyzing Figure 8 can offer a deeper understanding of the complex fluid dynamics and phase behavior inside a 3D phase separator, highlighting the importance of simulation tools in designing efficient separation systems in the oil and gas industry. The simulation results from such modeling exercises play a crucial role in improving the design and operation of phase separators, ultimately leading to enhanced productivity and cost-effectiveness in oil and gas production processes.

### Digital three-phase separation



**Figure 9:** The Digital three-phase separation.(Nnadikwe,2023)

break down the components depicted in Figure 9 for the digital three-phase separation system: **1. Safety valve:** A critical component that helps regulate pressure to prevent over-pressurization in the system, ensuring the safety of the operation. **2. Oil-water interface detector:** Monitors and detects the interface between oil and water phases, crucial for accurate separation and control. **3. One-grade purifier:** used for further purification or separation of specific components within the oil phase. **4. Second-grade purifier:** Another purification unit that may be employed for additional refining or separation processes. **5. Oil-water-and-gas mixtures inlet:** Entry point for the mixture of oil, water, and gas phases to begin the separation process. **6. Check valve:** A valve that allows flow in one direction and prevents back-flow, maintaining the separation integrity. **7. Centrifugal pumps:** Used to pump the separated components (oil, water, gas) to their respective outlets for further processing or storage. **8. Screw pumps:** Another type of pump that may be employed for specific requirements within the separation system. **9. Pressure difference transmitter:** Monitors pressure differentials within the system to ensure proper operation and performance. **10. Oil outlet:** Exit point for the separated oil phase after processing and purification. **11. Electric three-ball valves:** Valves controlled by electricity, likely used for precise control and regulation of flow within the system. **12. Water outlet:** Exit point for the separated water phase after processing and purification. **13. Electric regulating valve:** Regulates the flow or pressure of a fluid stream using electric control, enhancing system efficiency. **14. Gas outlet:** Exit point for the separated gas phase after processing and purification. **15. Magnetic level gauge:** Monitors the levels of the separated phases in the separator to ensure proper

operation and prevent overflow. **16. Control cabinet:** Houses control mechanisms for the system, likely including monitoring, automation, and control systems. **17. Electric water regulating valve:** Controls the flow or pressure of water using electric control, contributing to system performance. Each of these components plays a crucial role in the digital three-phase separation system, working together to achieve efficient and effective separation of oil, water, and gas phases in the crude oil processing and storage setup

The figure showcases the concept of digital three-phase separation. It demonstrates the utilization of advanced technologies, such as sensors and automation, to monitor and control the separation process in real-time. This digital approach enhances efficiency, accuracy, and safety in crude oil processing and storage operations.



**Figure 10:** Mini Crude Oil Processing plant.

In Figure 10 showcasing a mini crude oil processing plant, we can expect to see a compact and scaled-down version of a typical crude oil processing facility designed for small-scale operations or research purposes. This miniature plant is to demonstrate the fundamental processes involved in crude oil processing in a simplified and portable form. The figure depicts various essential components of the mini crude oil processing plant, such as a small distillation unit, heat exchangers, separators, pumps, and storage tanks. These components are arranged in a compact layout to showcase the basic steps of crude oil refining, including distillation, separation, and storage. Furthermore, the figure may highlight the simplicity and versatility of the mini plant, emphasizing its suitability for educational purposes, research experiments, or pilot-scale testing of crude

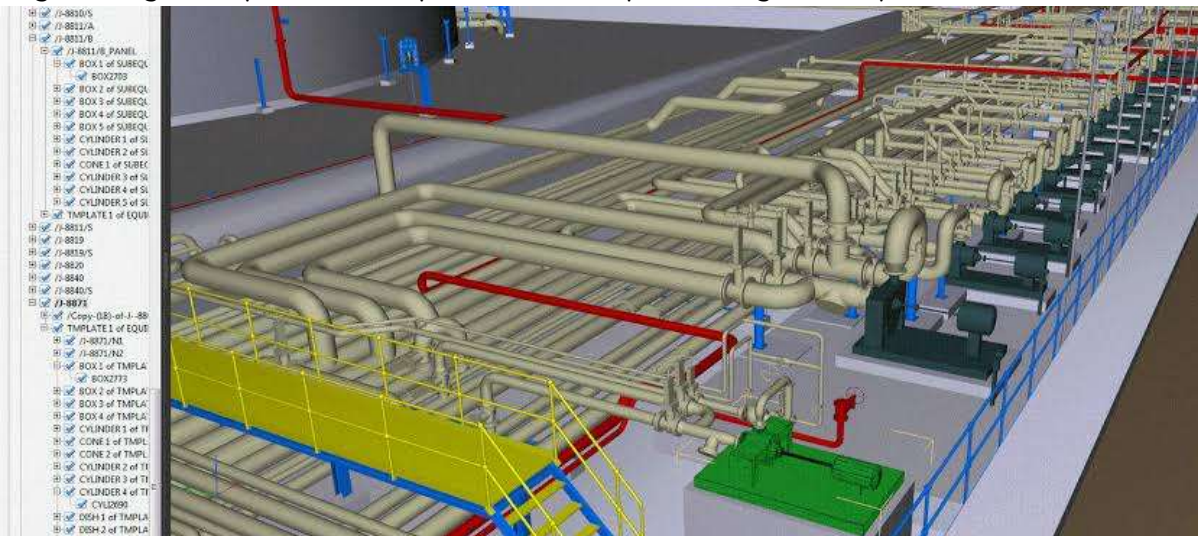
oil processing techniques. It may illustrate how the mini plant can be easily assembled, operated, and modified to simulate different processing scenarios and study the effects of process variables on the final product quality. Additionally, the figure include indicators or instruments to monitor temperature, pressure, flow rates, and other critical parameters within the mini plant. These monitoring devices help users understand the performance of the plant and make adjustments to optimize the processing conditions for efficient oil refining. Overall, Figure 10 offers a visual representation of a mini crude oil processing plant, showcasing a simplified yet functional model that serves as a valuable tool for hands-on learning, experimentation, and research in the field of crude oil processing and refining.



**Figure 11a:** The Full view of Crude Oil Processing Plant Design (Simulation) (Nnadikwe, 2023)

In Figure 11a, which presents the full view of a crude oil processing plant design simulation, we can expect to see a comprehensive visual representation of the entire plant layout, equipment arrangement, process flow, and system integration involved in the design and simulation process. The figure provides an overview of the entire crude oil processing plant, including the various units such as distillation columns, heat exchangers, separators, pumps, tanks, and control systems. It showcase how these units are interconnected and arranged in a systematic layout to optimize the processing efficiency and operational performance of the plant. Moreover, the figure illustrate the flow of crude oil and intermediate products through the processing plant, indicating the sequence of operations, heating and cooling processes, separation stages, and product storage areas. This visualization helps engineers and stakeholders understand how the raw crude oil is transformed into valuable end products through a series of refining

processes. Additionally, the figure highlight the integration of simulation software tools such as process simulators, 3D modeling software, and virtual reality platforms to facilitate the design, analysis, and optimization of the crude oil processing plant. These tools enable engineers to simulate various operating scenarios, evaluate performance metrics, and identify potential bottlenecks or optimization opportunities in the plant design. Overall, Figure 11a offers a holistic view of the crude oil processing plant design simulation, illustrating the complexity, interconnectedness, and functionality of the various components and systems within the plant, providing valuable insights into the engineering and operational aspects of the oil processing industry



**Figure 11b:** The Developmental Stage of Crude Oil Processing Plant Design Simulation(Nnadikwe,2023)

In Figure 11b depicting the developmental stage of crude oil processing plant design simulation, the illustration showcases a comprehensive overview of the various key steps involved in the design and development process. The figure starts with the initial conceptualization phase, where the basic idea and requirements for the crude oil processing plant are defined. This stage involve brainstorming sessions, feasibility studies, and goal-setting to lay the foundation for the project. As the design progresses, the figure display the detailed engineering phase, where specific components, equipment, and systems within the processing plant are identified and specified. This phase often involves the creation of process flow diagrams, P.

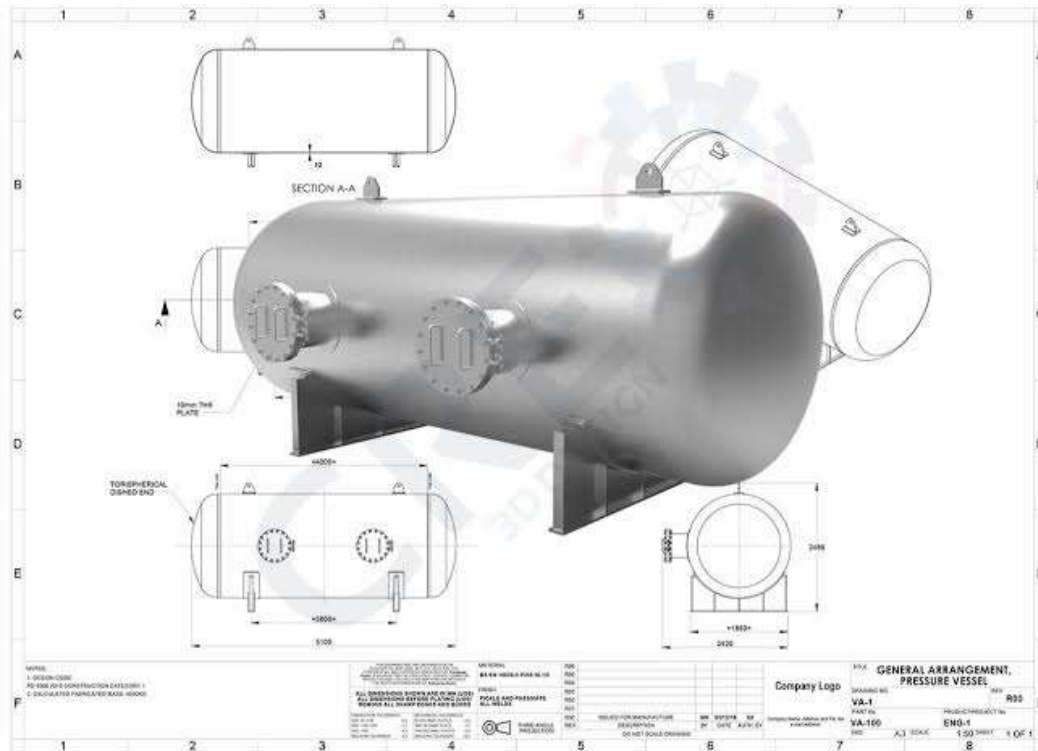
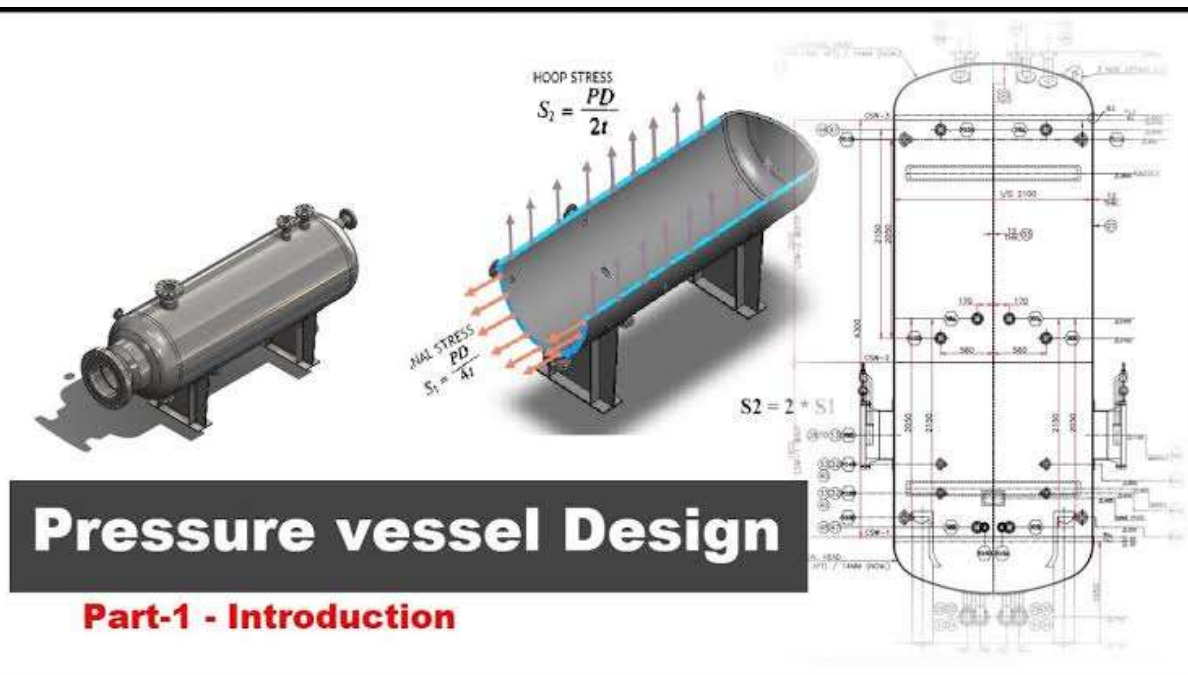


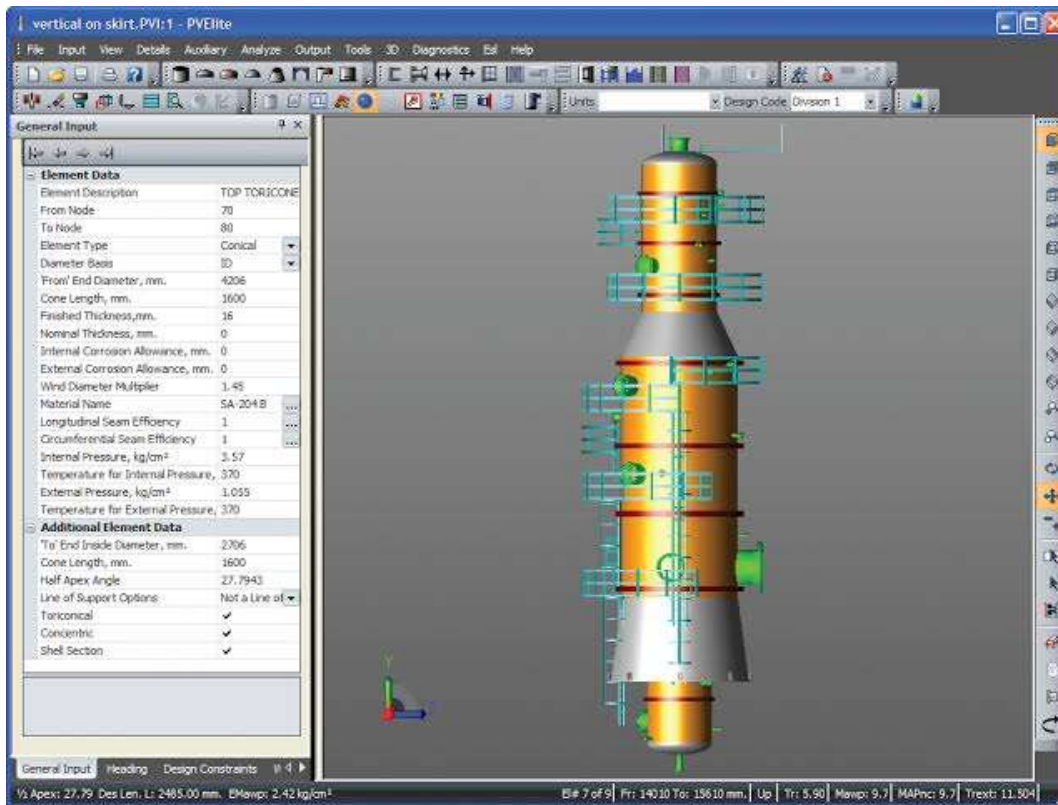
Figure 12a: The Pressure Vessel Design

The figure showcases the design of a pressure vessel. Pressure vessels are essential components used for storing and transporting crude oil under high pressures. This figure demonstrates the design parameters, dimensions, and features of the pressure vessel, ensuring its safe and efficient operation.



**Figure 12b:** The Pressure Vessel Design

In Figure 12b illustrating the pressure vessel design, a detailed and intricate depiction of the key elements involved in designing a pressure vessel is presented. The figure showcases the structural components and design considerations essential for ensuring the safe and efficient operation of a pressure vessel in various industrial applications. The design of a pressure vessel begins with defining the operating conditions, including pressure, temperature, and the nature of the substance being contained. This information is crucial for determining the materials, thickness, and structural integrity requirements of the vessel to withstand the internal pressure. The figure may include the geometry of the pressure vessel, such as the cylindrical shell, end closures, nozzles, and support structures like saddles or legs. Each component plays a vital role in maintaining the integrity of the vessel under pressure and ensuring even distribution of stress throughout the structure. Additionally, the figure likely highlights safety features incorporated into the design, such as relief valves, pressure gauges, and inspection ports, which are essential for monitoring and controlling the pressure within the vessel to prevent over-pressure situations. Furthermore, the design considerations for material selection, fabrication techniques, welding procedures, and quality control measures may be illustrated in the figure to emphasize the importance of meeting industry standards and regulations for pressure vessel design and manufacturing. Overall, Figure 12b provides a comprehensive representation of the meticulous planning, precise engineering, and stringent quality assurance processes involved in designing a pressure vessel that meets the highest safety and performance standards.



**Figure 13a:**The Pressure Vessel Design using PV-ELITE(Nnadikwe,2023)

In Figure 13a showcasing the pressure vessel design using PV-ELITE, a specialized software tool for pressure vessel design and analysis, a detailed and technical representation of the design process is likely presented. PV-ELITE is a widely used software in the industry for its capabilities in modeling, analyzing, and optimizing pressure vessel designs to ensure compliance with various design codes and standards. The figure illustrate how PV-ELITE enables engineers to input design parameters such as operating conditions, material properties, geometry, and loading conditions to create a virtual model of the pressure vessel. This model allows for visualizing the design in a 3D environment and performing structural analysis to assess the vessel's integrity under different pressure and temperature scenarios. Furthermore, the figure may depict how PV-ELITE facilitates the automatic generation of detailed design reports, calculation sheets, and fabrication drawings based on the input data. This feature streamlines the design process, reduces human errors, and ensures consistency in design documentation. Additionally, the figure may show how PV-ELITE integrates design codes and standards such as ASME BPVC, EN, and PD 5500 to verify that the pressure vessel design meets the required safety factors and regulatory requirements. The software can perform calculations for wall thickness, reinforcement, nozzle loads, and other critical design parameters to ensure the structural integrity of the vessel. Overall, Figure 13a provides insight into how PV-ELITE enhances the efficiency, accuracy, and compliance of pressure vessel design through advanced modeling, analysis, and

reporting capabilities, making it a valuable tool for engineers involved in the design and fabrication of pressure vessels.

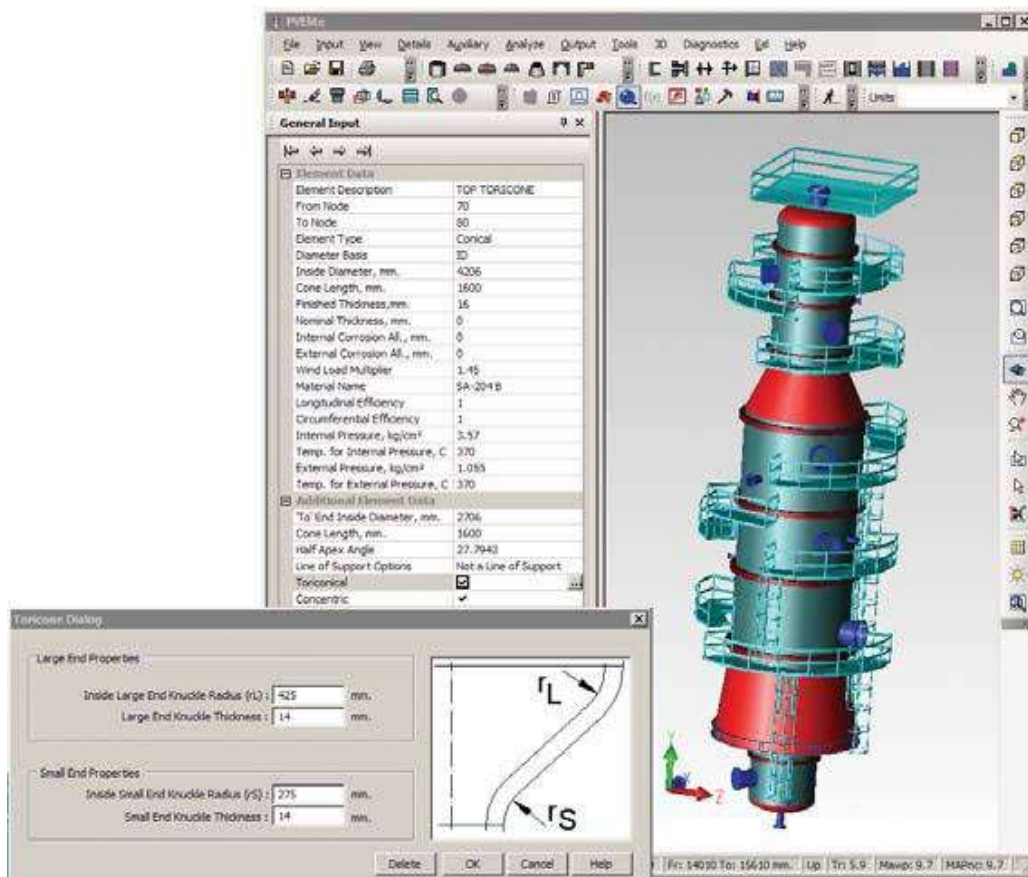


Figure 13b: The Pressure Vessel Design using PV-ELITE (Nnadikwe, 2023)

Figure 13b showcases the design of a pressure vessel using the PV-ELITE software, a widely used tool in the industry for designing, analyzing, and evaluating pressure vessel components. PV-ELITE offers advanced capabilities for engineers and designers to model complex geometries, specify material properties, and assess the structural integrity of pressure vessels. In the figure, various components of the pressure vessel design are likely displayed, including the vessel shell, heads, nozzles, supports, and openings. The software provides detailed calculations for determining wall thickness, reinforcement requirements, and stress analysis to ensure that the vessel meets the required design codes and standards. PV-ELITE enables engineers to optimize the design of pressure vessels by considering factors such as pressure, temperature, material properties, and loading conditions. The software may also offer features for conducting finite element analysis (FEA) to assess the mechanical behavior and

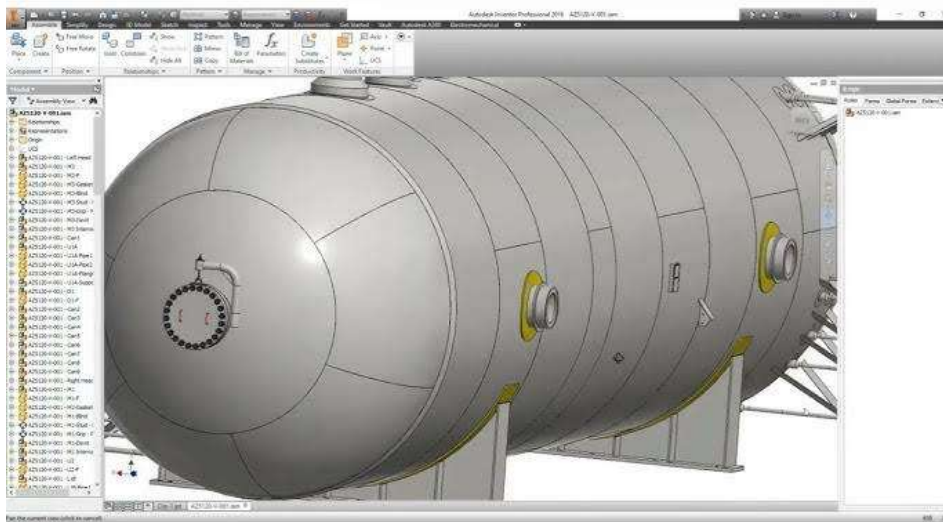
performance of the vessel under different operating scenarios. By utilizing PV-ELITE for pressure vessel design, engineers can streamline the design process, reduce errors, and ensure compliance with industry regulations and codes. The software's intuitive interface and comprehensive capabilities make it a valuable tool for designing safe, reliable, and cost-effective pressure vessels for various industrial applications. Analyzing Figure 13b can provide valuable insights into the use of PV-ELITE for pressure vessel design and demonstrate the software's capabilities in optimizing vessel performance and safety



**Figure 14a:** Pressure Vessel Vacuum Tank Design(Nnadikwe,2023)

In Figure 14a showcasing the design of a pressure vessel vacuum tank, we can expect to see a detailed representation of the structural components, features, and considerations specific to a vacuum tank application. The figure illustrates the unique design aspects required for a vacuum tank, which is designed to operate under negative pressure or vacuum conditions. This include specialized reinforcement techniques, thicker walls, and additional safety features to withstand the external forces exerted on the tank when operating under vacuum. Furthermore, the figure highlight the presence of vacuum pumps, valves, and gauges as integral components of the vacuum tank system. These components play a crucial role in creating and maintaining the desired vacuum pressure within the tank for the intended application, such as storage, processing, or transportation of materials. The design considerations for material selection, surface finishes, welding procedures, and leak testing methods specific to vacuum tanks may also be depicted in the figure. These aspects are essential for ensuring the reliability, integrity, and longevity of the vacuum tank under vacuum conditions. Moreover, the figure may include safety features such as vacuum relief valves, burst discs, and pressure monitoring systems designed to safeguard the tank

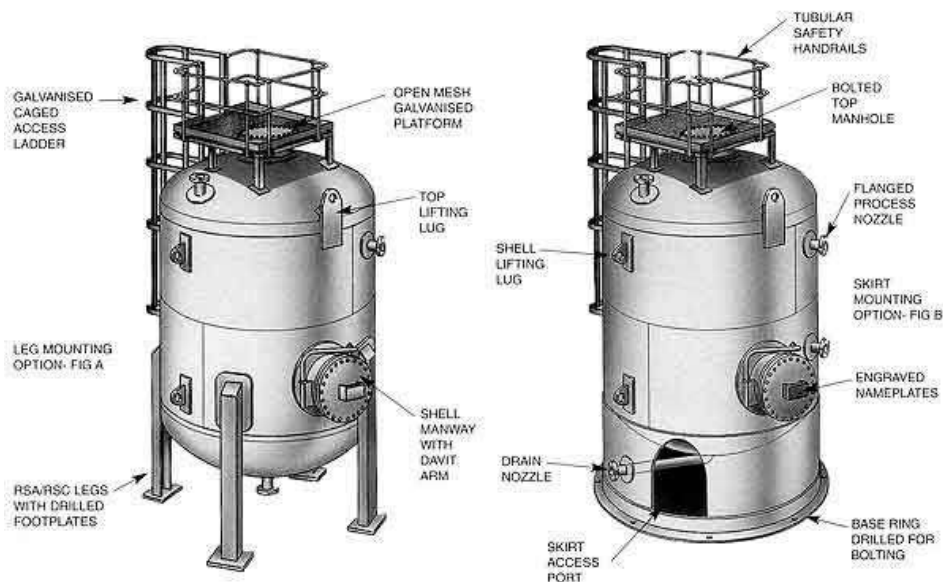
and its surroundings in the event of pressure fluctuations or equipment malfunctions. Overall, Figure 14a provides a visual insight into the specialized design and engineering principles involved in creating a pressure vessel vacuum tank, highlighting the key components, features, and safety considerations essential for its successful operation in vacuum applications



**Figure 14b:** Pressure Vessel Vacuum Tank Design(Nnadikwe,2023)

Figure 14b illustrates the design of a pressure vessel vacuum tank, which is a crucial component in various industries such as manufacturing, pharmaceuticals, and chemical processing. The design of a vacuum tank is essential for creating and maintaining low-pressure environments necessary for specific processes like distillation, evaporation, and drying. The figure may depict key elements of the vacuum tank design, including the tank body, nozzles, connections, and pressure relief mechanisms. Attention to detail in material selection, structural design, and sealing mechanisms is vital to ensure the tank can withstand the negative pressure and operate safely and efficiently. The design of pressure vessel vacuum tanks involves considerations such as minimizing air leakage, ensuring structural integrity under vacuum conditions, and incorporating safety features to prevent implosions or over-pressurization. Proper insulation and heating elements may also be included in the design to control temperature and maintain vacuum levels within the tank. Analyzing Figure 14b can provide insights into the design principles and engineering considerations involved in creating reliable and functional pressure vessel vacuum tanks. Understanding these design aspects is crucial

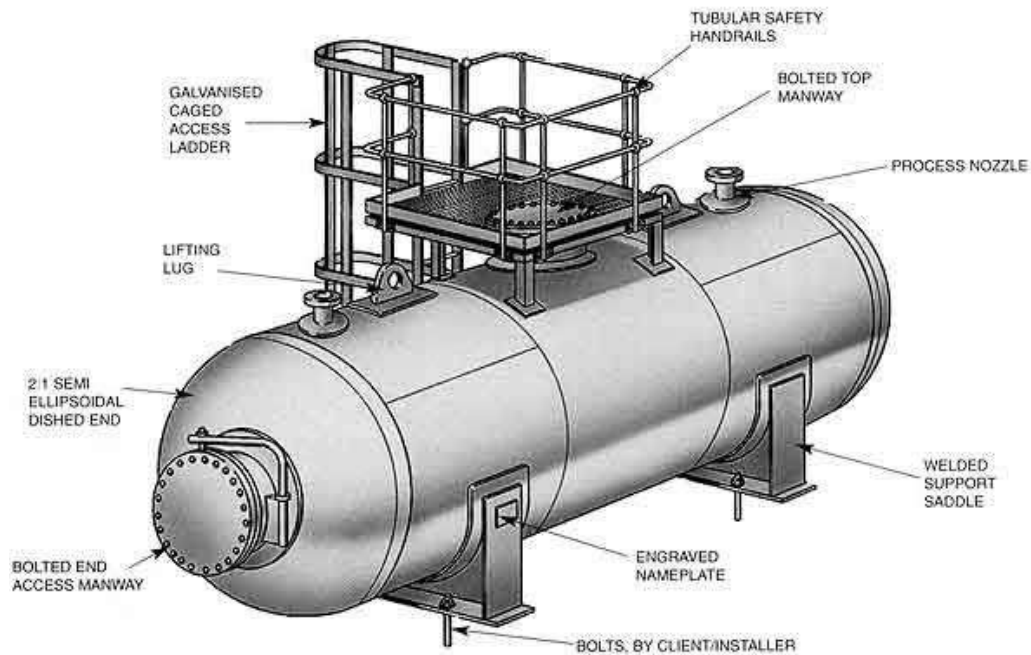
for industries that rely on vacuum technology for their processes, as it influences the performance, safety, and efficiency of the equipment.



**Figure 15a:** Vertical Cylindrical pressure vessel of oil processing storage

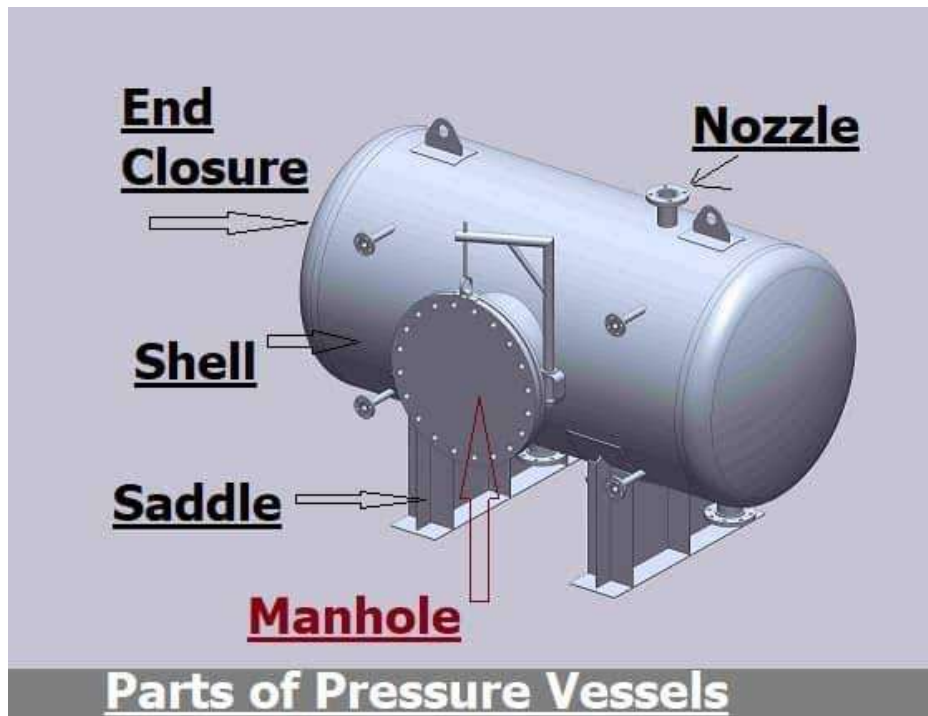
In Figure 15a depicting a vertical cylindrical pressure vessel for oil processing storage, we can anticipate a visual representation of the design features, components, and structural characteristics specific to storing and processing oil within a vertical cylindrical vessel. The figure showcase the overall cylindrical shape of the vessel, which is commonly used for storage applications due to its efficient use of space and ease of maintenance. The vertical orientation allows for gravity-assisted flow and extraction of oil, making it suitable for various oil processing operations. Additionally, the figure highlight the presence of inlet and outlet nozzles on the vessel, which serve as entry and exit points for the oil and other processing fluids. These nozzles are strategically positioned to facilitate the loading, unloading, and transfer of oil within the vessel. Furthermore, the figure may illustrate support structures such as saddles, legs, or foundations designed to provide stability and structural integrity to the vertical cylindrical vessel. These supports help distribute the weight of the vessel and its contents evenly to prevent tilting or shifting during operation. The design considerations for insulation, corrosion protection, access points for maintenance, and safety features specific to oil processing storage vessels also be depicted in the figure. These features are essential for ensuring the efficient and safe storage of oil while maintaining the quality and integrity of the stored product. Overall, Figure 15a offers a depiction of the key design elements and considerations essential for a vertical cylindrical pressure

vessel used for oil processing storage, highlighting its functionality, efficiency, and safety features in the context of the oil industry.



**Figure 15b:** Horizontal Cylindrical pressure vessel of oil processing storage

Figure 15b illustrates a horizontal cylindrical pressure vessel utilized in oil processing and storage applications. This type of vessel is commonly employed in the industry for its efficient storage and processing capabilities. The horizontal orientation of the vessel allows for optimal space utilization, making it suitable for installations where vertical space is limited. The cylindrical shape of the vessel ensures uniform distribution of pressure and facilitates easy maintenance and inspection. The figure showcases key components such as the shell, heads, and accessories, highlighting the design considerations necessary for safe and efficient operation. Factors such as material selection, thickness, reinforcing elements, and weld joints are crucial for ensuring the structural integrity of the vessel. Additionally, features such as access openings, instrumentation, and pressure relief systems may be depicted to demonstrate the vessel's functionality and safety measures. Understanding the design and operation of horizontal cylindrical pressure vessels is essential in the oil processing and storage industry to ensure compliance with regulatory standards and to optimize operational efficiency. By analyzing Figure 15b, researchers and industry professionals can gain valuable insights into the key features and considerations associated with these vessels, ultimately contributing to enhanced safety, performance, and reliability in oil processing and storage systems.



**Figure 16:** Parts of pressure vessel

break down the different parts of the pressure vessel as shown in Figure 16 from your research on harnessing pressurized separation for crude oil processing and storage: **1. Manhole:** The manhole is an access point on the pressure vessel that allows for inspection, maintenance, and cleaning activities to be carried out inside the vessel. It is typically a large opening with a cover that can be easily removed for access. **2. Nozzle:** Nozzles are openings on the pressure vessel through which various components such as pipes, valves, or instruments can be attached. They serve as connection points for input, output, and monitoring of the contents inside the vessel. **3. Shell:** The shell of the pressure vessel is the main body or container that holds the pressurized substance, in this case, crude oil. It is designed to withstand high pressures and temperatures while ensuring the safety and integrity of the vessel. **4. Saddle:** The saddle is a support structure or base on which the pressure vessel rests. It helps distribute the weight of the vessel evenly, providing stability and support to prevent any shifting or tilting. **5. End Closure:** The end closure, also known as the head or cap, is the component that seals off the ends of the pressure vessel. It is designed to contain the pressurized substance within the vessel and prevent any leaks or ruptures

### CONCLUSIONS AND RECOMMENDATION

The study underscores the significant impact of employing advanced commercial simulation software, such as CHEMCAD, for the precise modeling of industrial processes. It emphasizes the remarkable ability of these tools to effectively analyze and simulate intricate systems, particularly those found in hydrocarbon processes. The research findings bring to light that utilizing the PR (Peng-Robinson) model as the

thermodynamics package in the simulation yields the most accurate representation when compared to actual industrial data, showcasing its superiority in capturing real-world values. The study's findings affirm the PR model's appropriateness and trustworthiness for simulating hydrocarbon processes, solidifying its relevance in industrial contexts. Through highlighting the successful utilization of commercial software packages and emphasizing the PR model's efficacy, the research significantly propels the evolution of process simulation. Furthermore, it advocates for the adoption of dependable tools and models in engineering analysis, thus enhancing decision-making processes within the hydrocarbon industry.

Validating the accuracy and appropriateness of the model is a pivotal prerequisite before delving into subsequent studies like sensitivity analysis or optimization. Through verifying the chosen thermodynamics method, such as the PR model, against actual measured data, the research lays a robust groundwork for future exploration. This validation step guarantees the reliability and suitability of the simulation methodology for accurately representing industrial processes.

This validation process instills confidence in the upcoming analyses and optimizations, rendering the results more impactful and relevant to real-world applications. By confirming the suitability of the thermodynamics method and simulation approach, the research establishes a sturdy framework for choosing and implementing appropriate tools in industrial process simulations. This methodology enhances the overall precision and dependability of future studies, contributing to more accurate and reliable outcomes.

Based on the sensitivity analysis results, it is evident that adjusting the pressure significantly influences gas production. Therefore, to optimize gas production, it is advised to operate the high-pressure (HP) separator at a lower pressure. However, it is crucial to ensure that the chosen operating pressure aligns with the requirements of other process unit operations. Moreover, it is important to consider that increasing the temperature or inlet feed flow rate can also have a similar effect on enhancing gas production, underscoring the need to carefully balance these factors for optimal performance. It is crucial to conduct a thorough assessment of this adjustment as it may impact the heating duty of the preheater. Specifically, the heating duty is directly linked to the inlet flow rate but inversely related to the temperature of the feed stream. The selected operating condition ( $P = 80$  bar,  $T = 43$  °C) is critical as it falls on the dew point line of the phase envelope. Therefore, any decrease in temperature or pressure might lead to the gas entering the two-phase region, indicating the importance of carefully balancing these operational parameters to avoid such a scenario. To unlock the full potential of the high-pressure (HP) separator, it is advisable to delve into further investigations and fine-tune the process-operating conditions for maximum efficiency. This optimization will enable the HP separator to operate at its peak capacity. Moreover, conducting energy analyses can be beneficial in capturing and utilizing any excess heat that would otherwise be lost, allowing for efficient heat recovery and overall process improvement.

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