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## Studying the Effect of Installing New Three Phase Separator on the Stabilization of Degassing Station

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### Abstract

The current work, studied the effect of replacing the existing two phase separator by three phase vessel on the off- specification quality for the produced oil. The true vapor pressure is set as the main criteria for the quality of product for an existing plant by using Aspen Hysys V9. To guarantee the process simulation is represent the real plant under operations, a comparative study was conducted between the simulation results and the plant data where it was a closely match with actual data to indicate that the simulation is a powerful tool, and it can be used for predicting the actual results. The existing plant operates with base sediment and water ratio no more than 15% while the studies expect to increase this ratio to 60% in future, for that this work is carried out by using Aspen Hysys V9.0 software to study the manipulating of different operating parameters such as dry oil flow rate, base sediments and water ratio, inlet temperature and the pressure of three phase vessel on the quality of product in term of TVP off-specification. By changing the different operating conditions, it has been found that the value of the true vapor pressure for the produced crude oil is less than 14 Psia/ 96.53 kPa. The obtained results conclude that the replacing of two phase separator by three phase vessel has no significant impacts on the true vapor pressure for the produced crude oil. The operating pressure for the three phase separator is revised and calculated where it is increased from 1176.8 kPa to 1330 kPa.

**Keywords:** Aspen Hysys, true vapor pressure, crude oil stabilization, three phase separator.

## 1. Introduction

### 1.1. Background and Literature review.

A reservoir fluid is a mixture of complex hydrocarbon with different range of properties [1]. It is a fluid including the oil and gas gathers in the reservoir rocks under high pressure and temperature [2]. During the consumption of oil from the reservoir, the pressure is declined to lessen the production of crude [3]. A water injection is used to compensate the pressure depletion, but unfortunately this will lead to high rate of associated water in the surface facilities during the production [4 - 6]. Throughout the flowing of fluids upward within the wellbore the dissolved gas is separated from oil due to the pressure and temperature drop [5]. A mixture of oil, gas and water is brought to the surface production plant where they are separated and processed and then sent through a pipeline to the end user [7].

Several papers in the literature utilize process simulation by Aspen Hysys to optimize systems performance by optimizing operating parameters. For instance, AL-Ali 2021 proposed a solution for an existing process plant to handle a reservoir fluid rich with light components by adding a fourth stage stabilization vessel to release off the remaining gases to reduce the TVP to less than 82.7 kPa at different operating condition studied by his work [8]. Najah M. Al-Mhanna et al. 2021 validate the molar flow rate for oil and gas in three phase separator where he found that the operating conditions for the vessel is 8000 kPa and 43 °C and the gas flowrate and oil flow rate were dependent on the temperature and pressure conditions for the plant [9]. Alabdulkarem and Rahmanian 2020 studied the steam consumption for condensate process plant by using Aspen Hysys and MATLAB where the minimum steam consumption found by using the algorithm genetic algorithm optimization method, the optimized results for the process plant saved more than 34 % of steam consumption as compare to the baseline while the product specifications are maintained [10]. Rahmanian et al. 2018 assessed the process simulation for Terengganu Crude Oil Terminal, Malaysia by conducting the Aspen Hysys. In this study he found that the true vapor pressure for the stabilized crude can be achieved to less than 82.7 kPa by manipulating different operating parameters [11]. N.Rahhmanian et al. 2016 studied the stabilization of an industrial scale condensate b using the Aspen Hysys where the

results are compared with plant data and with the results obtained by PRO/II software, he studied four parameters on the product specification of Reid Vapor Pressure (RVP). It was found that the reboiler temperature is the main parameter that control the product properties [12]. Kim et al. 2014 considered in his study the Reid Vapor Pressure as the key specification of oil product for the offshore oil and gas production plant. He added another factor in his research to the optimal process condition and the operating cost which is the environmental constraint. Where he found that his design is efficient and eco-friendly for offshore process plant [13]. Al-Zahrani et al. 2020 demonstrates the effect of the operating parameters changes by lessen the total oil shrinkage for the Gas Oil Separation Plant (GOSP) throughout three case studies. In case study I, a 3.5 MBD increased with gas compression power reduced by 10 MW for the pressure optimization of the intermediate and low pressure vessel. In case study II, 2 MBD gained in the product crude with 50 % drop of water load in the exported gas pipeline by optimizing the air cooler operating conditions for the recovered the cooled condensate from the compressors to the light crude production. In case study III, saved up to 2 MBD of the stoke tank crude by optimizing the inlet temperature for the light crude to enhance the stripping column to meet the requirement of vapor pressure and H<sub>2</sub>S specifications for the product [14]. Soliman et al. 2020 proposed a new design for a compact gas oil separation plant to meet the specifications of produced with higher yield and low operating cost by rerouting the discharged gas from the low pressure compressors and mixed it with the inlet crude to result a simultaneous cooling the compressor's outlet gas stream and heating the incoming oil before entering the process plant [15]. Okafor and Kalagbor 2017 achieved higher plant profitability as compare with the current practice for the gas – oil separation plant in Niger Delta area. He increased the plant recovery by 1,620-bbl/day and 0.21 MMSCFD for the crude oil and associated gas, respectively [16]. Gaidhani and Hollaar 2013 proposed a solution to increase the crude temperature slightly with gas venting from the cargo tank to increase the oil production by 20 MBD without doing any physical modifications [17]. Al-Dossary et al. 2020 evaluated the Aramco Gas-Oil Separation Plant to maximize the oil recovery by optimizing the operating parameters [18]. H. Ali 2020 suggested to

add a fourth stage vessel to reduce the TVP in the export product stream for the existing process stabilization plant [19].

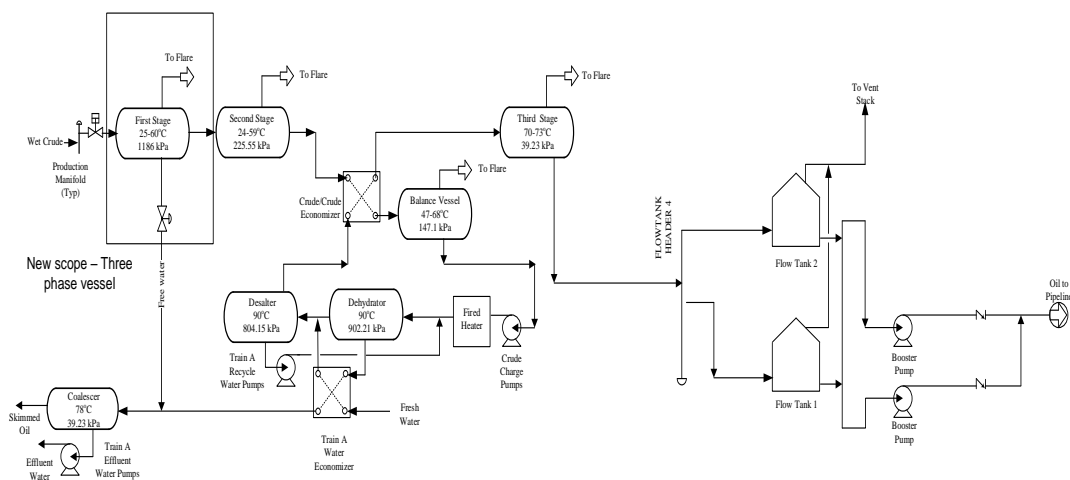
The aim of this project is to study the effect of replacing two phase separator by three phase on the off-specification criteria for the produced crude oil, the main criteria in this study is the true vapor pressure, and to do process simulation by using Aspen Hysys software for crude stabilization plant to study the impacts of working conditions (inlet temperature, inlet flow rate, vessel pressure, etc.) on stabilized crude oil.

### **1.2. Problem statement**

Reservoir water injection rate is increasing to maintain the reservoir pressure, control the production and giving high water production with the produced fluid. The existing separation train consists of two phase separators and electrostatic vessels which are designed to handle water cut no more than 15 %. In order to separate the free water from the crude oil, a three phase separator suggested to replace the two phase stage separator to separate the free water from the fluid. The new three phase vessel modules will utilize to achieve less than 15% BS&W with up to 60% water cut being produced from the field.

### **1.3. Process Plant Description**

Figure (1) illustrates the process flow diagram of the plant process simulation. The inlet reservoir fluid to the station manifold in the stabilization plant at temperature and pressure of 48 °C and 1373 kPa, respectively and BS&W of 15 Vol%. Firstly, the incoming reservoir fluid is handled by two phase's separator. The associated gas is going to flare and the liquid is dumping to the second stage separator across level control valve. The first stage and the second stage vessels are operate at pressures 1186.6 kPa and 225.55 kPa, respectively.



**Fig. (1): Process flow diagram for the crude stabilization unit.**

Wet crude from the second stage separator flows into a balance vessel operating at 147.1 kPa. The Balance vessel release-off the remaining gas in the crude oil prior to be pumped into the Fired Heater. The outlet temperature from Fired Heater is controlled and set at 90 °C to enhance the separation of emulsion from crude oil in the Dehydrator and Desalter. Dehydrator and Desalter are liquid filled vessels that operate at 902.21 kPa and 804.145 kPa, respectively which is above the bubble point pressure to prevent gas break out in these vessels. Electrostatic grids are used in Desalter and Dehydrator to improve water/oil separation by coalescing small water droplets to larger sizes so that the water will separate via gravity.

The crude oil outlet from the Dehydrator contains 0.5 Vol% of water which mix with fresh water to dissolve the salt particles in water. The discharged oily water from Dehydrator and Desalter is collected by a Coalescer to skim any oil before it is pumped to the Produced Water treating system. The dry crude flows to the two phase separator which is elevated to make sure the crude is flow down to the flow tanks by gravity. Both Coalescer and third vessel are operating at pressure 39.23 kPa. The crude/crude Heat Exchanger is located upstream of the balance vessel and it should help vapor separation from the liquid in the balance vessel and to save the energy losses from the system.

## 2. Process Simulation Methodology

### 2.1. Peng Robinson fluid package.

For the current situation of Oil – Gas – Water separation, the Peng Robinson (PR) equation of state is the generally recommended property package. The PR model is widely used to predict the phase behavior for the petroleum fluids [20]. It is ideal for predicting the vapor pressure for pure components and the equilibrium mixture ratios [21] and the vapor liquid equilibrium (VLE) calculations and more accurate for calculating the properties of multicomponent mixture such as liquid densities [22]. The PR property package rigorously solves any single, two, or three-phase system with a high degree of efficiency and reliability, it is applicable over a wide range of conditions:

- Temperature Range > -271°C
- Pressure Range < 100,000 kPa

The PR package also contains enhanced binary interaction parameters for all hydrocarbon-hydrocarbon pairs.

### 2.2. Stream basis of the study.

The incoming oil from wells collected in the production manifold to feed the first stage separator by one stream, which consists of a mixture of oil, gas and associated water. This process is represented by using the Aspen Hysys software by mixing two streams. The first stream contains dry oil and the other stream includes only pure water to control the percentage of water to be studied through this research. Tables (1) and (2) show the properties of the inlet stream and the composition of dry crude oil, respectively.

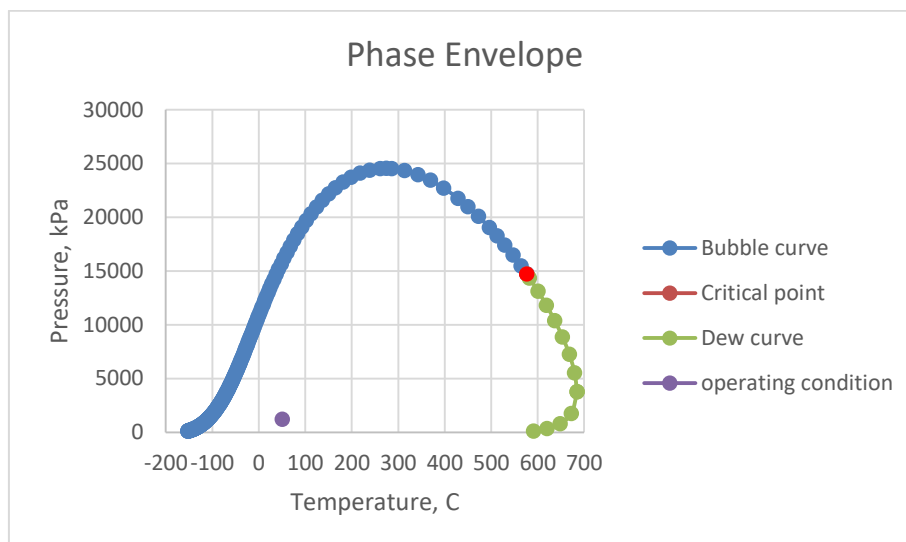
**Table (1): Inlet stream properties.**

Vapor/Phase Fraction	0.4873
Temperature, °C	48
Pressure, kPa	1176.8
Molar Flow, kgmole/h	3939.9
Mass Flow, kg/h	474810.5
Std Liquid Volume Flow, STB/Day.	88945.7
Molecular Weight	120.5
Liquid Mass Density @ std cond., kg/m <sup>3</sup>	853.6

Table (2): Compositional analysis of crude oil.

Component	Reservoir Composition		M.wt (g/mol)	Density (g/Cm <sup>3</sup> )	Component	Reservoir Composition		M.wt (g/mol)	Density (g/cm <sup>3</sup> )
	Wt.%	Mol%				Wt.%	Mol%		
N <sub>2</sub>	0.061	0.316	-	-	C14	2.098	1.546	-	-
H <sub>2</sub> S	0.025	0.108	-	-	C15	1.990	1.370	-	-
CO <sub>2</sub>	0.340	1.128	-	-	C16	1.924	1.242	-	-
C1	3.445	31.402	-	-	C17	1.995	1.213	-	-
C2	1.809	8.798	-	-	C18	1.797	1.033	-	-
C3	1.882	6.241	-	-	C19	1.484	0.808	-	-
iC4	0.439	1.104	-	-	C20	1.689	0.874	-	-
nC4	1.467	3.691	-	-	C21	1.609	0.793	-	-
neo-C5	0.004	0.008	-	-	C22	1.490	0.701	-	-
iC5	0.811	1.644	-	-	C23	1.419	0.639	-	-
nC5	1.062	2.152	-	-	C24	1.328	0.573	-	-
C6	1.984	3.366	-	-	C25	1.269	0.526	-	-
Benzene	0.057	0.106	-	-	C26	1.228	0.490	-	-
C7	2.155	3.145	-	-	C27	1.188	0.456	-	-
Toluene	0.217	0.344	-	-	C28	1.173	0.434	-	-
C8	2.282	2.921	-	-	C29	1.154	0.413	-	-
Ethylbenzene	0.101	0.138	-	-	C30	1.099	0.380	-	-
m-and p-Xylenes	0.254	0.350	-	-	C+31	1.098	0.368	436.84	0.906
o- Xylene	0.151	0.208	-	-	C+32	1.003	0.325	450.87	0.909
C9	2.033	2.317	-	-	C+33	0.957	0.301	464.89	0.912
C10	2.508	2.577	-	-	C+34	0.919	0.281	478.92	0.914
C11	2.332	2.181	-	-	C+35	0.877	0.260	492.94	0.917
C12	2.208	1.895	-	-	C+36	39.421	7.118	810	0.955
C13	2.164	1.716	-	-	Total	100%	100%	-	-

Figure (2) represents the phase diagram for the inlet dry stream, which is a P-T projection for the hydrocarbon mixture [23-25]. From the phase envelope, it seems that the operating condition is lied between the Dew and Bubble curves, therefore the fluid entering the first stage separator is two phase, and the vessels can handle the entering fluid.

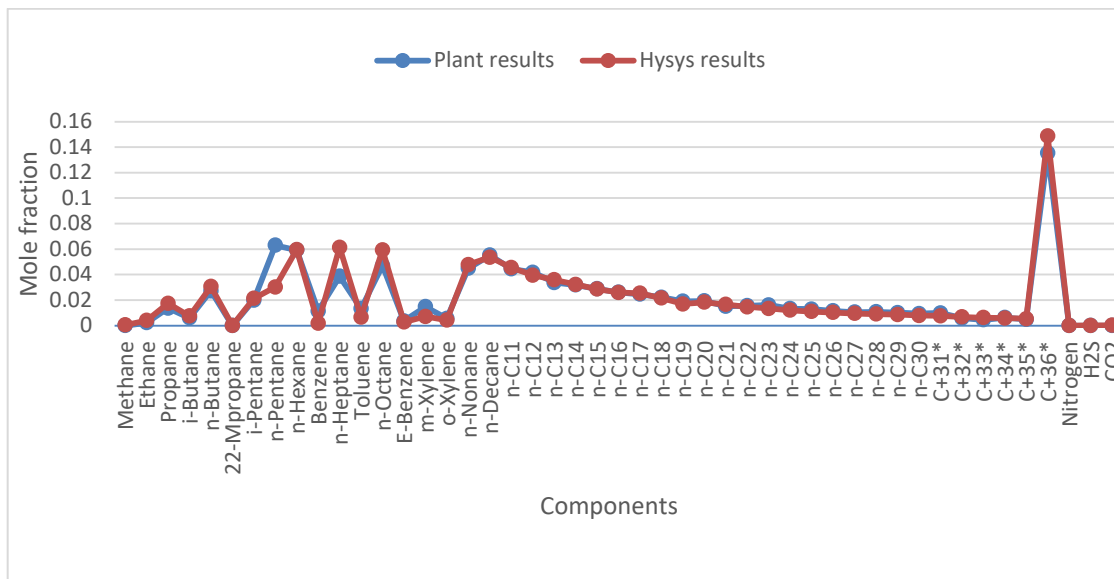


**Fig. (2): Phase Envelope Curve for Inlet Feed**

### 2.3. Simulation validation.

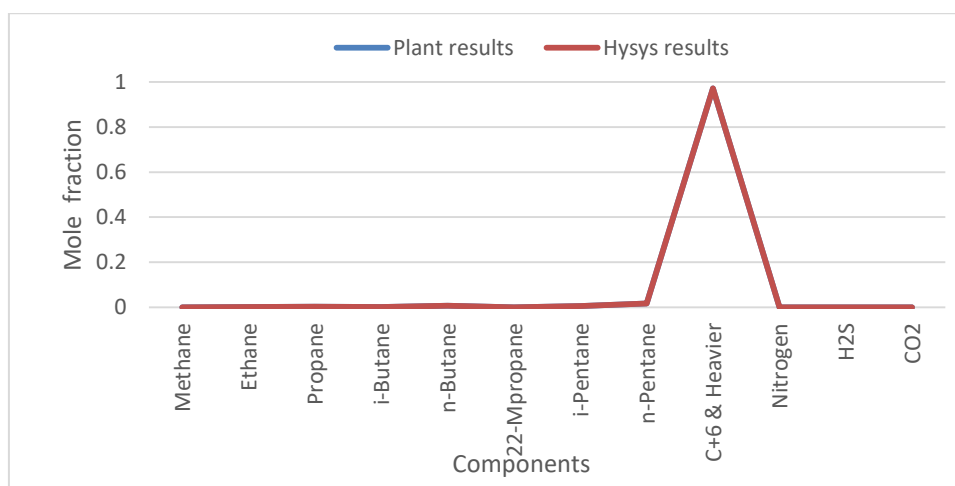
The main objective of this section is to validate the simulation model and to know how close its result to the real data by compare the mole fraction of real plant data with those obtained from process simulation. The validation results for compounds in the product stream are showing in Figure (3).The chart appears a slightly difference in the mole fraction for components (n-pentane to n-heptane) that obtained by Aspen Hysys and the plant, this is because these components are flashed off with gas in the separation vessels. Whereas the light and heavy components have a good matching with the real plant data. Furthermore, the model generated by Aspen Hysys has no significant contrast with the real plant data.





**Fig. (3): Comparison between the Hysys simulation and Lab results for the stock tank composition.**

Figure (4) illustrates the total validation between the simulation and the real data. It shown that C6 and heavier are substituted by the summation of the concentration for those components to represent the heavy compounds. The product crude oil has more than 93 % of heavy components which gives the benefit during storing the crude where the vapor pressure is low. On the other hand the, the light components such as (C1 - C5) and N<sub>2</sub>, CO<sub>2</sub> and H<sub>2</sub>S are released with gas during the stabilization process.



**Fig. (4): Total validation of Pseudo Component vs. plant data**

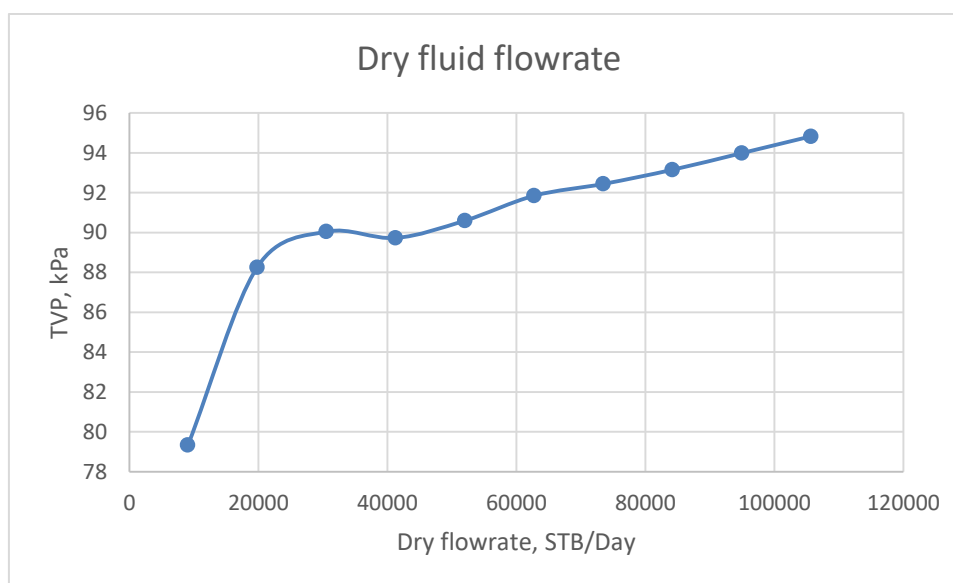
From what has been put forward in the validation, it can be consider this simulation as a tool to predict the operation parameters at different conditions.

### 3. Results and Discussion

#### 3.1. Effect of the operating parameters.

##### 3.1.1. Effect of dry fluid flowrate.

The figure below illustrates the effect of changing the dry hydrocarbon flow rate on the true vapor pressure of crude oil where the flow rate range in between 9057.3 STB/Day to 105668.5 STB/Day with intervals as 10566.9 STB/Day.



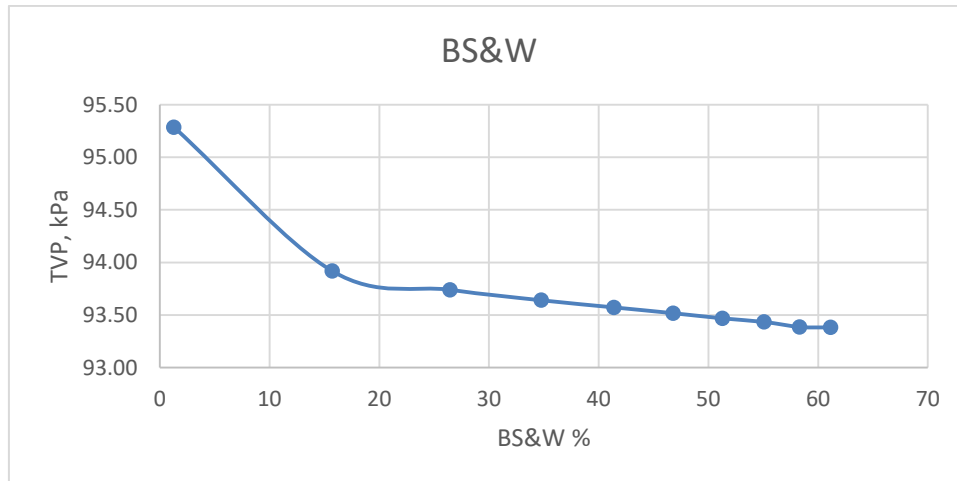
**Fig. (5): Effect of dry fluid flow rate.**

The increase in the flow rate of hydrocarbon fluids leads as a result to an increase in the value of the true vapor pressure of the produced crude oil because of the increase in light compounds that are difficult to release through the separation vessels used in the production plant.

##### 3.1.2. Effect of Base Sediment and Water Ratio.

The design capacity for the crude oil is 70195 STB/Day. Although, it has the ability to treat the BS&W of 15% or less, but the current study assumes that the first two-phase vessel to be replaced with a three-phase vessel that can treat the amount of associated water entering the plant by no more than 60%, where the outlet from this separator is less than 15 % of BS&W.

The following figure shows the relationship between BS&W and the TVP of the produced oil when the water ratio ranges between 2 to 60% in this study.

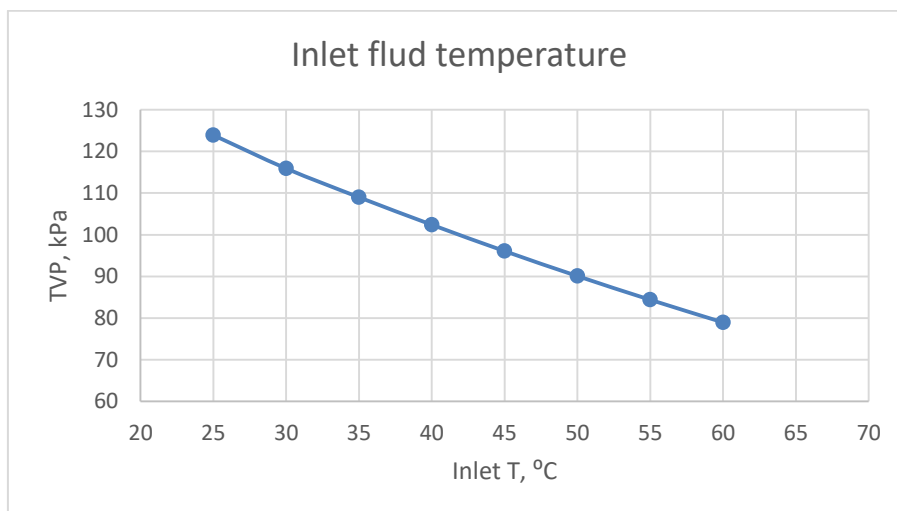


**Fig. (6): Effect of base sediment and water ratio.**

Through the above figure, we notice that as the water ratio increases, the TVP decreases, this is due to the fact that with the increase in the amount of water entering the plant, the proportion of light compounds in the reservoir fluid decreases, that means that the two-phase separators are capable to release-off the remaining gas from the liquid to reduce the value of TVP in the product stream.

### 3.1.3. Effect of inlet fluid temperature.

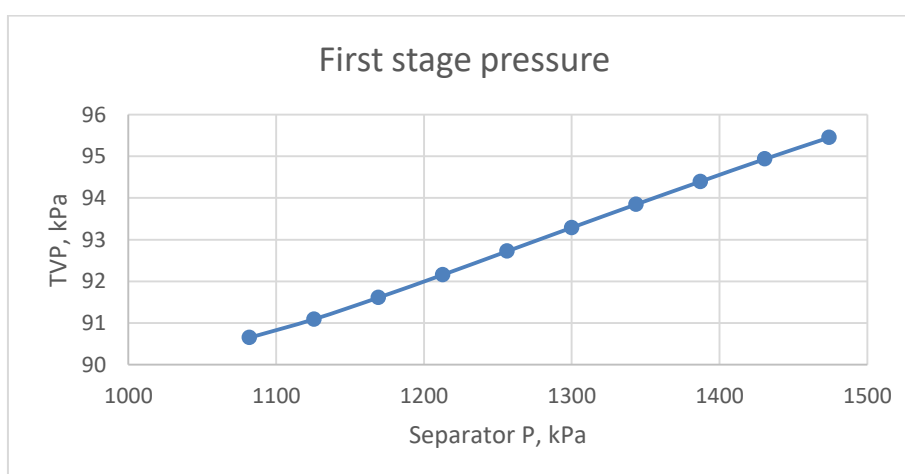
Figure (7) shows the relationship between the temperatures of the entering fluid and the value of the TVP of the produced oil, where the value of the inlet temperature ranges between the lowest values recorded in the winter, which is 25 °C and the highest recorded temperature in the summer, which is 60 °C. As can be seen from the figure, the increase in feed temperature leads to decrease the value of TVP. The reason for this is by increasing the feed temperature, the amount of light gases in the fluid entering the plant increases to be easily released off through the two-phase separators. . This is leads to a noticeable decrease in the value of TVP for the exported oil.



**Fig. (7): Effect of fluid inlet temperature.**

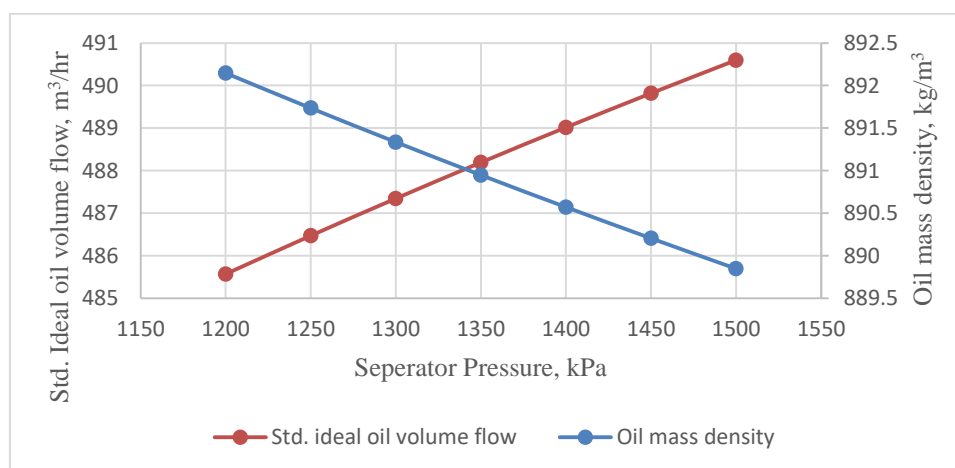
#### 3.1.4. Effect of separator's pressure.

The simulated three phase separator is the first vessel to handle the reservoir fluid in the crude stabilization plant that normally operated at 1186.6 kPa. In order to achieve the production requirement with respect to TVP, the pressure of the three phase separator was lowered to 980.7 kPa and then increased to 1372.93 kPa. Figure (8) discusses the effect of the three phase operating pressure on crude product TVP. As shown in the figure, as the operating pressure increases, the TVP increases. Increasing the TVP of the product leads to lower the pressure difference between the fluid entering the three phase separator and the separator pressure. This results a very small quantities of volatile gases to liberate from this vessel.



**Fig. (8): Effect of separator pressure.**

In case to determine the optimum operating pressure for the three phase separator. Figure (9) shows the relationship between the separator pressure and the fluid density and volumetric flow rate. The intersecting point between the two curves represents the optimum pressure. From the figure, we recorded that the operating pressure for the three phase separator increased to 1330 kPa instead of the current operating pressure for the two phase vessel.



**Fig. (9): The optimum operating pressure.**

#### **4. Conclusion and Summary**

This research is discussed the impact of replacing two phase separator by three phase vessel on the product stabilization where a process simulation is conducted by using Aspen Hysys software to study the effect of manipulating different operating parameters on the TVP of the product.

In order to verify the validity of the results obtained by the simulation, a comparison was made between the results that obtained from the software with the real plant data. It was found that there is a great matching between the results from the simulation and the plant data to indicate that the process simulation represents reality and can be used as a powerful tool to predict operational changes occurring in the plant.

The effect of manipulating the operating parameters such as dry feed flow rate, base sediment and water ratio, fluid inlet temperature and operating pressure for the new three phase separator on the product quality were examined by using Aspen Hysys to

check the effect of varying these parameters on the crude oil specifications to investigate that by changing the inlet conditions has no extremely impact on the product quality and the TVP of the produced oil is maintained within acceptable limits even by reaching the BS&W up to 60 % , the operating pressure for the new vessel is also evaluated and calculated as 1330 kPa to operate the three phase separator.

All in all, the modification in an existing plant to the new three phase separator instead of using two phase vessel has been successfully investigated and has no impact on the product quality in order to true vapor pressure within acceptable limits to less than 96.53 kPa.

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