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A Novel Approach to Obtaining the Optimum Pressure and Stages of Separators

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Abstract

Nowadays, the increasing demand for energy in the world is one of the main concerns for energy supply. In fact, the required energy can be obtained by increasing the production rate of fossil fuels such as oil and natural gas. However, improving the efficiency of the equipment and facilities might have a significant impact on production from hydrocarbon resources. With respect to this subject, the optimization of separation facilities will be a simple and economic choice to increase the amount of the liquid obtained from production units all over the world. One of the parameters which have a noticeable effect on the yield of the production units is the separator pressure. Also, there are other factors such as heptane plus fraction properties, well head pressure, and ambient temperature which can change the optimum separator conditions. In this study, the influence of crude oil properties on the number of stages and pressure of each separator is investigated. The result shows that the most important property of the feed which has the greatest influence on the conditions of separators is the percentage of heptane plus fraction in crude oil. Therefore, a method for the estimation of the number of separators based on the percentage of C_{7+} component is developed. Moreover, the threshold of heptane plus fraction for selecting the optimum number of separator stages was observed to be around 30% in the feed composition. Hence, three separators and a stock tank can separate samples with a C_{7+} molar fraction lower than 30%, but two separators and a stock tank are needed for samples with a heptane plus fraction higher than 30%. Finally, the results indicate an increase of about 1.3% in the oil production for the new optimization method compared to the constant-ratio method.

Keywords: Production Unit, Optimization, Multistage Separation, Flash Calculation, Crude Oil Properties, Plus Fraction

1. Introduction

The growth of energy demand and the security of the energy sources have been issues of concern globally all the times. The coordination of the demand and supply in the energy market is a crucial

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subject, while the lack of the balance in these factors could have irrecoverable damage to the relevant industries. Thus, the industrialized countries are struggling to reduce the energy consumption of the industries by improving the efficiency of the processes and equipment. In addition, energy producer countries employ innovative technologies to increase the efficiency of the production systems. Crude oil and natural gas are the main sources of energy generation. Therefore, the optimization of the production facilities in natural resource industry, particularly oil and gas, could have a major effect on the efficiency of the whole system (Global, 2017; Rahmandoost et al., 2014; Robertson et al., 1989).

One of the important sectors in the upstream of the energy industry is production units. The design of surface facilities, including separators is of significant importance in production unit design. The design of separation facilities is optimized to achieve the maximum liquid at a constant volume of a specified feed. Further, by maximizing the oil production, the small volume of medium components of liquid such as propane and butane is evaporated into the gas phase, so heavy components remain in liquid phase. If a higher pressure drop is exerted on the feed, more vaporized heavy component is resulted. Therefore, adjusting the right pressure of the right stage will result in the highest liquid in the stock tank and more valuable components in the liquid phase. Furthermore, a small volume of hydrocarbon gases will be vaporized from the production unit (Arnold & Stewart, 1999; Kim et al., 2014).

These separation facilities are a series of vessels in which flash equilibrations occur. Based on the operating pressure and temperature of the separators, the amount of each component can be calculated in each phase by using an appropriate equation of state (EOS) (Danesh, 1998). The separator temperature is a function of ambient temperature which is not an economic option to control. Therefore, the separator pressure will be the only factor controlling the equilibrium situation.

In a multi-stage separation system, the pressure decreases continually from the initial feed pressure to the atmospheric pressure in the stock tank. Factors considered in optimizing are petroleum °API, gas oil ratio (GOR), and oil formation volume factor (B_o). The objective of optimization is minimizing the GOR and B_o, but maximizing the °API, which are resulted in increasing the amount of stabilized liquid (Boyer & O'Connell, 2005; Kylling, 2009; Osfouri et al., 2018). One of the first pressure optimization methods was the optimization of the pressure of the second stage separator in a three-stage separation unit. It was a very simple method without any equilibrium calculations (Whinery & Campbell, 1958). A very popular method for optimizing the pressure of separators was proposed by Natco Company, which used a constant ratio to calculate the pressure of the middle-stage separator (Natco, 1972). Due to the nature of the procedure, this method is known as the constant-ratio method. This is a fast but inaccurate method which is used in many production units because of simple calculations used for pressure adjustment. One of the most accurate methods for the optimization of the pressure of separation units was presented by Bahadori et al. who used a series of flash calculations to optimize the pressure of each separation stage (Bahadori et al., 2008).

In addition to equilibrium flash calculations, in the last decade, some empirical formulas have been introduced which have been applicable to a specific condition and could not be used generally; in fact, using them in conditions different from the base correlation conditions might be a source of error. The presented correlations are categorized based on the number of stages in each separation unit. These correlations were developed by more than 6,000 computer model runs to cover various factors in different conditions. The variables include the temperature of the stages and the fractions of some components such as CH_4, H_2S, CO_2, and N_2 in the input stream; in these correlations, the other components of the stream are ignored (Mohammed S Al-Jawad & Omar F Hassan, 2010; Mohammed Saleh Al-Jawad & Omar Falih Hassan, 2010).

In addition to these two methods, another calculation method for optimizing the separator pressure is based on the compression unit costs; the method minimizes the costs by decreasing the required horsepower of the compression units although the previous experiences show that horsepower optimization could not be as simple as pressure optimization. Moreover, previous results on this optimization did not show any significant effect on the amount of stabilized oil and its gravity, while optimizing the separator pressure could increase the °API of the stock tank liquid, which means that both the quality of and the amount of the liquid increase (Bahadori et al., 2008; Ghaedi et al., 2014).

In the current study, an in-house code is used for the optimization of the separator pressure based on the equilibrium flash calculations (Darvish Sarvestani et al., 2019). The composition of the sample; properties of plus fraction, such as molecular weight (MW) and specific gravity (SG); pressure and temperature of the feed; ambient temperature; the tuned EOS for the fluid; and initial pressure of separators are used as the inputs to the mentioned code. Furthermore, the variables and their constraints are specified in the code in addition to the selection of the objective function. For the calculation of the initial pressure of separators, the constant-ratio method is used because it is simple and fast (Natco, 1972).

Samples with different compositions (particularly various plus fraction characteristics, °API, and molecular weight of the fluid) are provided for the optimization process. Furthermore, a sensitivity analysis of the pressure and volume rate of the feed was carried out to examine the effect of these variables on the results of the present study. The current method is more accurate compared with the previous correlations and is faster than the old flash calculations because of the optimization which accelerates the convergence.

2. Methodology

The calculation of optimum separator pressure is a trial and error process which could be time consuming, so developing a method for shortening the calculation runtime can be very useful. In this context, optimization is a reliable method for decreasing the time of convergence procedure for separator pressure adjustment (Kim et al., 2014). To perform the optimization calculations, the feed stream composition is used as the input to the model, and the objective functions minimize B_o and GOR but maximize °API, which results in a higher volume of the stock tank liquid (Danesh, 1998). In this study, the volume of the stock tank liquid is selected as a single objective function and the independent variable is the pressure of the separators. As the instruments and facilities cause a pressure drop, some constraints on variables should be considered in the optimization process. The first constraint includes the maximum acceptable pressure of the first separator, which is equal to or less than the inlet pressure. The second limitation is the minimum pressure of the last separator before the stock tank, which must be greater than 33.0 psia. This limitation is because of the pressure drop in control valve and pipelines after the separators and should be considered as a pressure constraint to reach the atmospheric conditions in the stock tank. The last constraint is the constant pressure of the stock tank which must be 15.7 psia. A schematic of the optimization process representing the procedure for the optimization is illustrated in Figure 1. The first step is defining the fluid composition and plus fraction optimization. Afterward, the initial pressure values of all the separators are calculated by the constant-ratio method. Then, the optimization process is conducted for the first separator by considering the defined constraints. After the convergence of the pressure of the first separator, the second separator is optimized, and the same procedure is repeated for the other separators. By reaching the final separator, the whole procedure is repeated for all the separators again until full convergence is achieved. It should be noted that in optimizing the pressure of each separator, the pressure is set at the optimized pressure values of the separators which are optimized before the current one (Michalewicz et al., 1996).

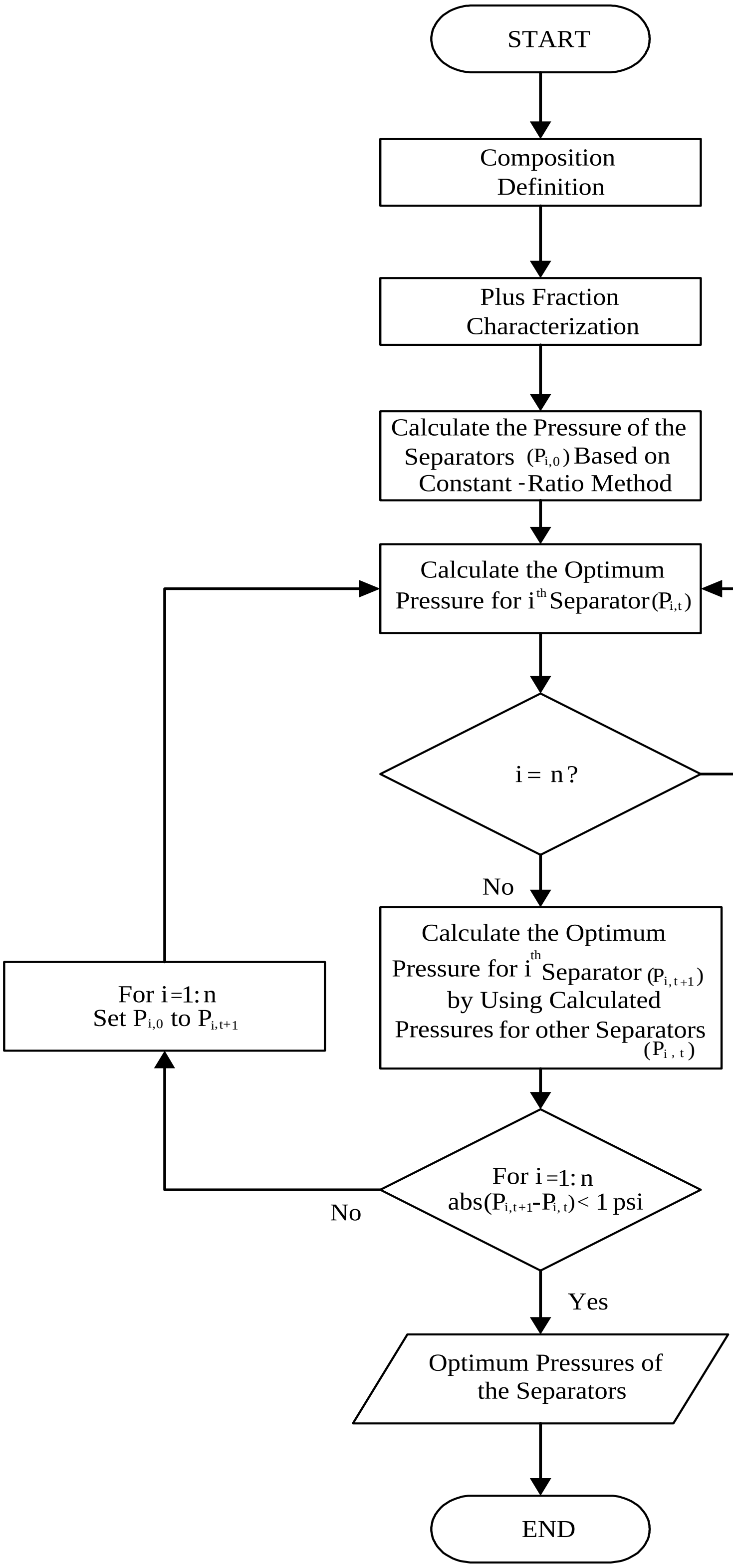


Figure 1

A schematic of the pressure optimization process of separators; "*n*" is the total number of the separators and "*i*" represents the identifier of each separator from the first separator to the *n*th separator.

In all the steps of the procedure shown in Figure 1, the stock tank is excluded because the pressure of this vessel is constant, and the optimization is not implemented for the calculation of the pressure of the stock tank.

In the equilibrium method, the flash calculations determine the composition of the liquid and vapor and the amount of each phase with respect to the feed composition and flash pressure using a pre-tuned equation of state. In this study, Peng-Robinson (PR) EOS is used for calculation because the previous studies show that PR EOS provides the most accurate results under surface conditions (Peng & Robinson, 1976). Equations 1-3 are used to obtain the mentioned factors which are important for the optimization of the pressure of the separators.

$$°API = \frac{141.5}{\gamma_{o,sc}} - 131.5 \tag{1}$$

$$GOR = \frac{V_{g,sc}}{V_{o,sc}} \ (SCF/STB) \tag{2}$$

$$B_o = \frac{V_{reservoir}}{V_{o,sc}} \ (barrel/STB) \tag{3}$$

where, $\gamma_{o,sc}$ is the specific gravity of the oil in a standard condition; $V_{g,sc}$ and $V_{o,sc}$ stand for the volume of gas and oil in a standard condition respectively, and $V_{reservoir}$ represents the volume of the oil at reservoir pressure and temperature.

The optimization of the pressure of the separators is not enough to obtain the best results. The number of the separators could also change the results significantly. Theoretically, increasing the number of the separators results in more liquid in the stock tank, but the economic factors and the footprint of the facilities are the constraints which have limited the number of the separators in a production unit. In addition, the incremental percentage of the liquid in the stock tank decreases if the number of the separators increases beyond a certain limit. According to the mentioned points, a method for estimating the number of the separator stages is needed alongside the pressure optimization to access the best results. For this purpose, 17 different sample compositions with various properties are selected to determine the factors influencing the number of the separator stages. Table 1 tabulates the range of the variations of different factors in the studied samples.

Table 1

Ranges of different properties of the studied samples.

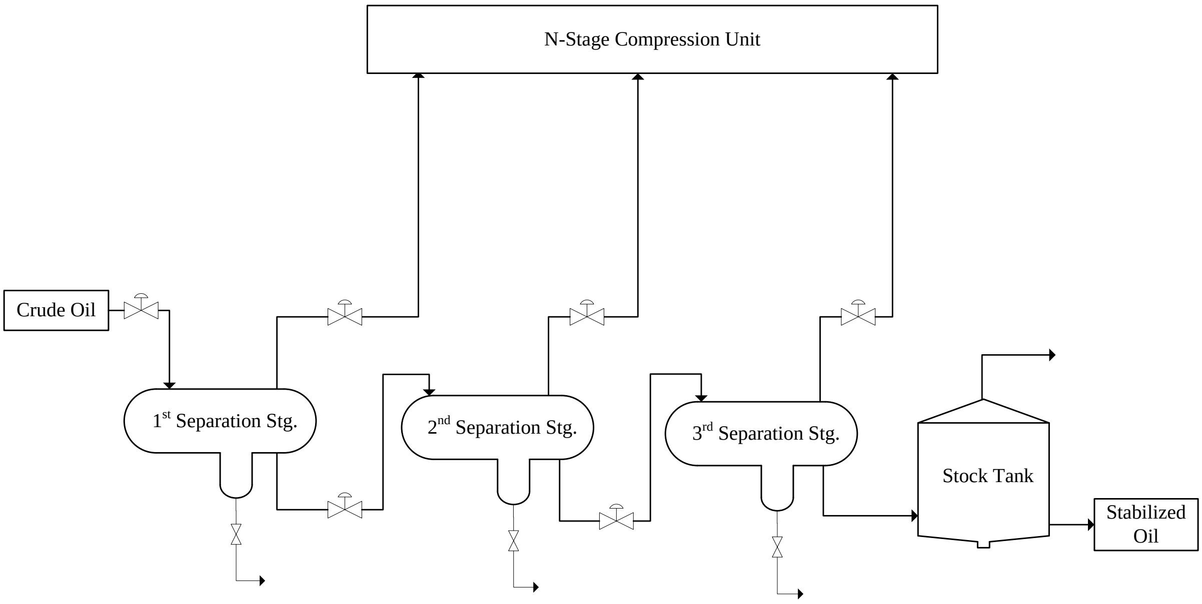
°API	25.75-70.49
C_{7+} (mol.%)	8.21-56.40
MW_{C7+} (g/mol)	115-334.66
SG_{C7+} (g/cc)	0.796-0.960
Inlet pressure (psia)	440-1000
Inlet rate (barrel/day)	20,000-200,000

The optimization procedure is executed for two-, three- and four-stage separators (excluding the stock tank) at each composition. Then, the incremental percentage of the stock tank liquid, °API, and the decrease in GOR are determined. A typical separation facility with three-stage separators plus the stock tank is shown in Figure 2.

Figure 2

A schematic of a typical three-stage separation unit plus the stock tank.

The decision on the selection of the number of the separator stages is related to the economic analysis. The incremental oil obtained in the stoc



k tank is the profit of the optimization, while changing the number of the separators could neutralize the extra profits due to the increase of capital expenditure (CAPEX) and operating expenditure (OPEX).

CAPEX includes any investment costs which should be paid at the beginning of the project. These costs consist of the separator vessels, valves, pipeline, foundation, and any additional stages of compressor units which may be added to the investment costs due to the additional separators. On the other hand, OPEX increases when the number of the facilities and equipment rises.

One of the main factors increasing OPEX is the operation and maintenance of the compressors, while any other equipment has its own considerable operating and maintenance costs. With respect to these costs, adding one stage of separation to the system will be economic if the stock tank liquid is increased by more than 0.4%. Based on these calculations and the simulation of 17 samples, the critical number of separator stages is represented.

3. Results and discussion

The optimization process is implemented by using a base case and followed by the novel method described above. For the base case, 100,000 barrel/day of the crude oil is considered as the input feed at 440 psia and 50 °C. The initial pressure of the separators is set by using the constant-ratio method. Furthermore, the initial condition of the optimization code consists a step which is set at 0.1 psi. Reducing the steps results in a higher degree of accuracy, but a higher number of iterations must be performed, which causes the process to be time consuming. Therefore, with respect to the runtime and accuracy, 0.1 psi per step is considered for the optimization process. Each sample has a set of optimization calculations for two-, three-, and four-stage separators without the stock tank. The simulation results of the volatile oil and heavy oil samples are presented in Table 2.

Table 2

The amount of the stock tank liquid, GOR, and °API of two volatile oil and heavy oil samples.

Sample	C_{7+}(%)	MW_{C7+} (g/mol)	SG_{C7+} (g/cc)	Number of stages (without the stock tank)	Produced oil (STBD)	°API	GOR (SCF/STB)
1	40.32	232	0.867	2	83,018.08	40.25	396.373
				3	83,270.46	40.40	391.299
				4	83,334.85	40.44	389.980
2	9.99	115	0.844	2	26,127.41	52	5780.456
				3	26,379.91	52.41	5712.743
				4	26,446.48	52.53	5694.077

According to Table 2, the number of the separator stages could change both quantity and quality of the stabilized liquid. Also, a decrease in the produced gas could greatly affect the negative environmental impacts of gas flaring. In addition, the optimization of the pressure of the separators without any equipment installation has a great effect on the amount of the stock tank liquid and improvement in properties such as °API. Table 3 also lists the results of the mentioned samples before optimization. The comparison between these two tables at the same number of stages confirms the positive effect of optimization without any additional equipment.

Table 3

The amount of the stock tank liquid, GOR, and °API before the optimization of two volatile oil and heavy oil samples.

Sample	C_{7+}(%)	MW_{C7+} (g/mol)	SG_{C7+} (g/cc)	Number of stages (without the stock tank)	Produced oil (STBD)	°API	GOR (SCF/STB)
1	40.32	232	0.867	2	82,472.16	39.94	407.246
				3	83,043.81	40.26	395.778
				4	83,244.57	40.38	391.765
2	9.99	115	0.844	2	26,007.60	51.85	5812.645
				3	26,265.65	52.27	5750.032
				4	26,382.97	52.45	5711.740

It could therefore be concluded that the optimized separators have three major positive factors compared to the unoptimized separation units. The first factor focuses on the amount of the stock tank oil. The incremental oil in the stock tank is around 0.5% in most cases by only adjusting the separator pressure and can reach 0.8% in some cases while no additional costs are imposed on the project expenditures. This additional oil is become more remarkable when extra costs are paid for the implementation of enhanced oil recovery (IOR/EOR) projects. The achievement of the IOR or EOR projects needs long-time studies in addition to more costs and equipment. Furthermore, the rate of success in these projects is not hundred percent, while the optimization of the pressure of the separators can result in extra profits without any additional costs. The improvement to liquid quality is another positive outcome of the optimization of the pressure of the separators, which can be considerable in large volumes of feed. Also, the optimization of the separation unit reduces the produced gas, which can significantly decrease the environmental damage in case of gas flaring.

After finishing the procedure for the optimization of all the samples, a precise analysis of the factors influencing the optimization process was conducted. The factors considered in this work include the percentage, molecular weight, and specific gravity of the plus fraction; °API; inlet pressure; and the inlet volume rate of the feed samples. Figure 3 represents the properties of the plus fraction of different samples as a function of the stabilized liquid in the stock tank in an optimized situation. Using normalized values of the properties allows to easily compare the values with different orders. It is clear that there is no relation between any of the proposed properties and the stock tank liquid.

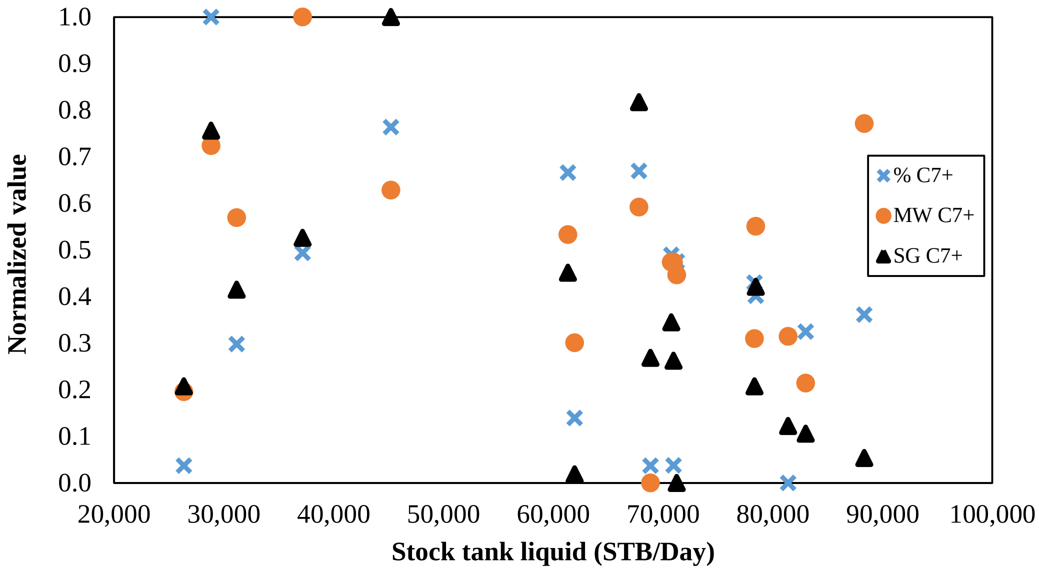


Figure 3

The normalized plus fraction properties versus the stock tank liquid.

For instance, the stock tank liquid of two different sample compositions with almost 40% of C_{7+} are 83,018 and 78,340 STB/day, which are noticeably different. In the case of the molecular weight of plus fraction, the obtained amounts of liquid of two samples with an equal molecular weight of 219 g/mol are 36,980 and 71,270 STB/day. In three other cases, the specific gravity of plus fraction is equal to 0.8; however, the stabilized liquid of the stock tank in these cases varies from 45,240 to 70,765 STB/day. All these examples, and many others not explained here, show that there is no relation between a single plus fraction property and the stock tank liquid and confirm that many factors simultaneously influence the yielded liquid of the samples.

To analyze the effects of different parameters on the stabilized liquid, a simulation approach is adopted for all the samples. The results are categorized based on the properties of plus fraction and °API of the input samples. The ranges of these properties of the samples are illustrated in Figure 4. As mentioned before, based on the economic evaluations, the incremental oil percentage of an *n*-stage separation unit must be higher by 0.4% compared to the similar (*n*-1)-stage separation unit to make it profitable. Therefore, for all of the 17 samples, the optimization processes are performed, and the percentage of incremental oil is recorded.

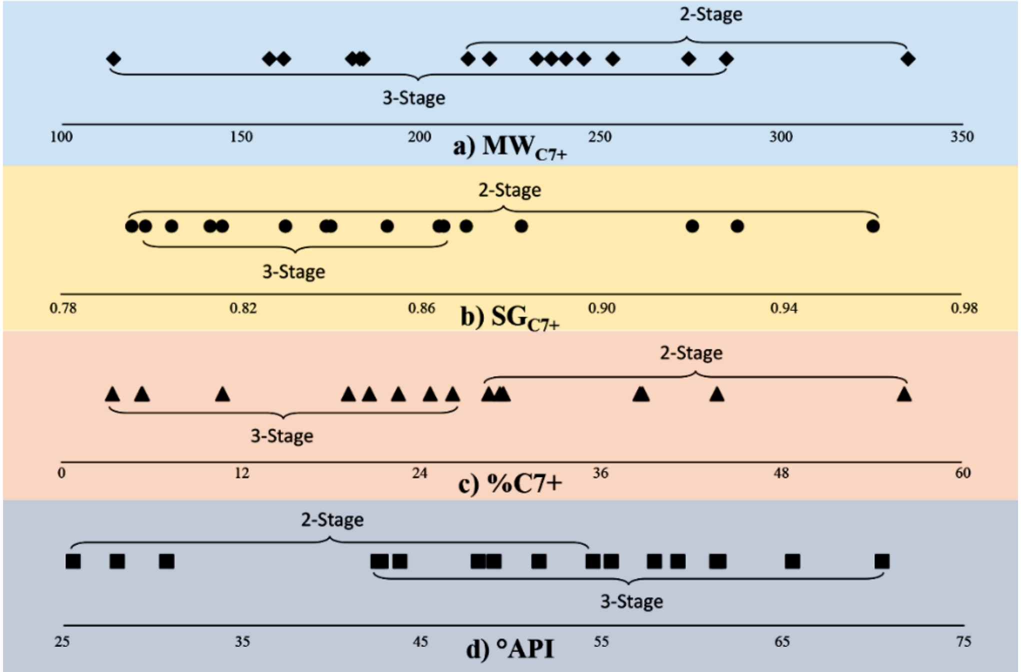


Figure 4

Optimization of the number of separator stages based on the different properties of the samples.

In a general view, the effects of molecular weight and percentage of plus fraction in the samples are the same but opposite to that of the number of separators in the optimized production units, which means that the number of the separators increases when the percentage and molecular weight of the plus fraction in the sample drop. In contrast to these two factors, the °API of the feed sample has a straight forward relation with the optimized number of separator stages. Moreover, the number of separators increases if the °API of the feed sample rises. Also, the coverage of all the specific gravity values of plus fraction with two-stage separators and almost half of them with three-stage separators shows that there is no relation between the specific gravity of plus fraction in the samples and the optimum number of separators. Therefore, it is not possible to obtain the optimum number of separators with respect to the changes in the specific gravity of plus fraction in the samples.

Figure 4a analyzes the molecular weight of plus fractions to optimize the number of separator stages. It is clear that a wide range of molecular weight of plus fractions is covered with both of the two- and three-stage separators. The minimum value of the molecular weight of plus fractions which could be set in a two-stage separation unit is 213 g/mol, and the maximum value of the molecular weight of plus fractions applicable to three-stage separators is 284 g/mol. The molecular weight values ranging between these minimum and maximum values could be set in both two- and three-stage separators. The samples containing plus fractions with a molecular weight lower than 213 g/mol should be treated by a three-stage separation unit, while a two-stage separator can be used for the samples containing plus fractions with a molecular weight higher than 284 g/mol. Accordingly, the molecular weight of plus fractions is not a perfect factor for optimizing the number of separators in a production unit. Nonetheless, a rough approximation might be possible by comparing the molecular weight of plus fractions of a feed sample with the determined minimum and maximum values of the two- and three-stage separators respectively.

Figure 4b shows the range of specific gravity of plus fractions in different samples. It could be seen that the minimum and maximum values of the specific gravity of plus fractions, respectively 0.796 and 0.960, are covered by the two-stage separation unit. Furthermore, the three-stage separation unit covers a considerably wide range of specific gravity values. Therefore, there is no relation between the specific gravity of plus fractions and the optimum number of separators in a production separation unit. In addition, unlike the molecular weight of plus fractions, there is no minimum or maximum value used to specify the number of separators, which means that knowing the specific gravity of plus fractions could not be used for optimizing the number of separators under any conditions.

Figure 4c illustrates the ranges of the percentage of plus fractions in the sample to optimize the number of separators in a production unit. It is obvious that the maximum percentage of plus fractions which can be optimized by a three-stage separator is 29%, and the minimum percentage of plus fractions in the case of a two-stage separation optimization is 32%. Also, there is no interface between the two- and three-stage separator optimization, from which it can be concluded that the percentage of plus fractions in the feed sample is a reliable factor in optimizing the number of separator stages.

Finally, Figure 4d displays the variation of the °API of the input samples. It is clear that there is no specific interface between the two- and three-stage separators in the optimized cases, and there is a wide range of °API values covered by both two- and three-stage separators. Hence, the °API of the feed sample cannot be used as a trustworthy parameter for optimizing the number of separator stages. However, it can help with the optimization process in some cases. Thus, it can be concluded that the maximum °API of the samples applicable to a two-stage separator is 54.5, and the minimum °API covered by a three-stage separator is 42.8. Therefore, the samples with the °API value lower than 42.8 should be separated by two-stage separation units, and the samples with the °API value larger than 54.4 need a three-stage separator to achieve an optimum separation process.

The simulation of the optimization process demonstrates that the impact of the inlet pressure and inlet rate on the incremental stock tank liquid is negligible when switching from *n*-stage separators to (n+1)-stage separators. The maximum change caused by these two factors is a 0.02% increase in the stabilized oil. Table 4 represents an example of incremental oil recovery with different numbers of stages in a separation unit at different inlet pressures. The increase in the amount of the stabilized liquid, which is resulted from the compressibility of the fluids, is acceptable when a higher pressure of 440 psia is applied.

Table 4

Percentage of incremental oil at an inlet pressure of 700 psia using different numbers of stages in separator.

Sample	**C_{7+} (%)**	**MW_{C7+} (g/mol)**	**SG_{C7+} (g/cc)**	**Number of stages (without the stock tank)**	**Produced oil (STBD)**	**Percentage of the incremental oil (%)**	**°API**	**GOR (SCF/STB)**
1	40.32	232	0.867	2	83,190.97	-	40.35	392.831
				3	83,444.30	0.30	40.50	387.743
				4	83,509.40	0.08	40.54	386.411
2	9.99	115	0.844	2	27,528.34	-	54.18	5421.450
				3	27,790.39	0.95	54.61	5357.748
				4	27,860.88	0.25	54.73	5340.852

However, in this study, the important factor is the incremental liquid in each case with respect to the case with a fewer number of separators; comparing different cases, no remarkable change is noticed. For instance, in sample 2, the percentage of incremental liquid obtained by increasing the number of separators from two to three is 0.95% at an inlet (feed stream) pressure of 700 psia, while it is 0.96% at a feed stream pressure of 440 psia. The negligible difference between these two results shows that a 75% increase in the inlet pressure cannot raise the percentage of the incremental liquid by more than 0.01%. Hence, it can be concluded that the increase in the inlet pressure of the feed stream cannot affect the percentage of the incremental liquid, so it is independent of the inlet pressure. The same procedure is implemented for other different inlet pressures, and similar results are obtained.

In the case of changing the input feed rate, the simulations are conducted at different feed volumes; some of the simulation results are tabulated in Table 5. Changing the inlet rate also leads to the results similar to changing inlet pressure. As an example, the change in the percentage of the incremental oil in sample 2 at 200,000 barrel/day when shifting from three-stage to four-stage separators is 0.25%. The increase in the produced oil is the same as the case having an input feed of 100,000 barrel/day. The difference in results of these cases is of an order of 10^{-4}, which is negligible.

Table 5

Percentage of incremental oil at an input feed of 200,000 barrel/day using different numbers of stages in separator.

Sample	C_{7+}(%)	MW_{C7+} (g/mol)	SG_{C7+} (g/cc)	Number of stages (without the stock tank)	Produced oil (STBD)	Percentage of the incremental oil (%)	°API	GOR (SCF/STB)
				2	166,036.77	-	40.25	396.366
1	40.32	232	0.867	3	166,541.36	0.30	40.40	391.294
				4	166,678.80	0.08	40.54	386.411
				2	52,254.92	-	52.00	5780.470
2	9.99	115	0.844	3	52,759.81	0.97	52.42	5712.743
				4	52,892.96	0.25	52.53	5695.098

To compare the method presented in the current work with the constant pressure ratio method introduced by Ling (Ling et al., 2013), 12 samples were modeled, and the corresponding results are summarized in Table 6. The results indicate an increase of about 1.3% in oil production for the new optimization method compared to the constant-ratio method.

Table 6

Comparing the produced oil between the method presented in the current work and the constant pressure ratio method.

Sample ID	B_o		Improvement (%)
	Constant-ratio method	Optimization method presented in this work	
1	1.3125	1.3228	0.785
2	1.1075	1.1193	1.065
3	1.1654	1.1683	0.249
4	1.3431	1.3608	1.318
5	1.5597	1.5656	0.378
6	1.2264	1.2364	0.815
7	1.2845	1.2878	0.257
8	1.3169	1.3244	0.570
9	1.1837	1.1985	1.250
10	1.3614	1.3764	1.102

11	1.2833	1.2893	0.468
12	1.2909	1.2988	0.612

4. Conclusions

In the present study, an in-house simulation code based on a novel approach, which is faster and more accurate compared to the previous methods, was used to optimize the pressure of separators. According to the simulations conducted herein, the following conclusions are drawn:

- The optimization process can lead to higher profits without any additional costs. The maximum stabilized oil in the stock tank can be obtained at a higher quality by adjusting the separator pressure. In addition, the improvement in the quality of the stabilized oil can result in higher profits and lower GORs, which reduces the negative environmental effects of gas flaring.
- The optimization threshold of heptane plus fraction was observed to be around 30% in the feed composition. The optimum separator for the samples containing a heptane plus fraction lower than 30% is a three-stage separator plus a stock tank; however, for the samples having a heptane plus fraction higher than 30%, a two-stage separator along with a stock tank is the suitable option.
- The simplicity of the process is a good reason for the implementation of the separator pressure optimization. The procedure has no complexity, and both of the economic and environmental impacts are noticeable.
- For further works, other parameters could be analyzed for the optimization of separators. In addition, new optimization techniques such as multi-objective and artificial intelligence algorithms could be utilized for a wider range of samples.
- In addition to the optimization of separator pressure, the optimization of the number of separators may significantly improve the oil production efficiency too. To this end, the influencing factors are investigated, and the results of the simulations show that heptane plus fraction plays a prominent role in choosing the optimum number of separators.

Nomenclature

B_o	Oil formation volume factor
CAPEX	Capital expenditure
EOR	Enhanced oil recovery
EOS	Equation of state
GOR	Gas oil ratio
IOR	Improved oil recovery
OPEX	Operating expenditure
PR	Peng-Robinson
SC	Standard condition
SCF	Standard cubic feet
ST	Stock tank
STB	Standard barrel
STBD	Standard barrel per day

V_g	Gas volume
V_o	Oil volume
$V_{reservoir}$	Reservoir volume

References

Al-Jawad, M. S., and Hassan, O. F., Correlating Optimum Stage Pressure for Sequential Separator Systems, SPE Projects, Facilities & Construction, Vol. 5, No. 01, p. 13-16, 2010.

Al-Jawad, M. S., and Hassan, O. F., Optimum Separation Pressure for Heavy Oils Sequential Separation, Paper Presented at the Abu Dhabi International Petroleum Exhibition and Conference, 2010.

Arnold, K., & Stewart, M., Surface Production Operations, Design of Gas-handling Systems and Facilities, Vol.2, 2nd Edition, Burlington, MA: Elsevier, 1999.

Bahadori, A., Vuthaluru, H. B. & Mokhatab, S., Optimizing Separator Pressures in the Multistage Crude Oil Production Unit, Asia-pacific Journal of Chemical Engineering, Vol.3, No.4, p.380-386, 2008.

Boyer, B. E., & O'Connell, S.,Optimize Separator Operating Pressures to Reduce Flash Losses, Paper Presented at the SPE/EPA/DOE Exploration and Production Environmental Conference,2005.

Danesh, A., PVT and Phase Behavior of Petroleum Reservoir Fluids, Developments in Petroleum Science, Vol. 47, 1998.

Darvish Sarvestani, A., Moazami Goodarzi, A., & Hadipour, A., Integrated Asset Management: A Case Study of Technical and Economic Optimization of Surface and Well Facilities, Petroleum Science, Doi: 10.1007/S12182-019-00356-6, 2019.

Ghaedi, M., Ebrahimi, A. N., & Pishvaie, M. R., Application of Genetic Algorithm for Optimization of Separator Pressures in Multistage Production Units, Chemical Engineering Communications, Vol.201, No.7, p.926-938, 2014.

Global, B. P., BP Statistical Review of World Energy June 2017, Relatório, Disponível Em: http://Www.Bp.Com/En/Global/Corporate/Energy-Economics/Statistical-Review-Of-World-Energy, 2017.

Kim, I. H., Dan, S., Kim, H., Rim, H. R., Lee, J. M., & Yoon, E. S., Simulation-based Optimization of Multistage Separation Process in Offshore Oil and Gas Production Facilities, Industrial & Engineering Chemistry Research, Vol.53, No.21, p.8810-8820, 2014.

Kylling, Ø. W., Optimizing Separator Pressure in a Multistage Crude Oil Production Plant, Institutt for Teknisk Kybernetikk, 2009.

Ling, K., Wu, X., Guo, B., & He, J., New Method to Estimate Surface-separator Optimum Operating Pressures, Oil and Gas Facilities, Vol.2, No.03, p.65-76, 2013.

Michalewicz, Z., Dasgupta, D., Le Riche, R. G., & Schoenauer, M., Evolutionary Algorithms for Constrained Engineering Problems, Comput. Ind. Eng., Vol.30, No.4, p. 851-870. 1996.

Natco, C.-E., Technical Development Program, C-E Natco Company, 1972.

Osfouri, S., Azin, R., Rezaei, Z., & Moshfeghian, M., Integrated Characterization and a Tuning Strategy for the PVT Analysis of Representative Fluids in a Gas Condensate Reservoir, Iranian Journal of Oil & Gas Science and Technology, Vol.7, No.1, p.40-59,2018.

Peng, D. Y., & Robinson, D. B., New Two-constant Equation of State, Industrial & Engineering Chemistry Fundamentals, Vol.15, p.59-64,1976.

Rahmandoost, E., Roozbehani, B., & Maddahi, M. H., Experimental Studies of CO_2 Capturing from the Flue Gases, Iranian Journal of Oil & Gas Science and Technology, Vol.3, No.4, p.1-15,2014.

Robertson, J., Chilingarian, G., & Kumar, S., Surface Operations in Petroleum Production, II: Elsevier, 1989.

Whinery, K. F., & Campbell, J. M., A Method for Determining Optimum Second Stage Pressure in Three Stage Separation, Journal of Petroleum Technology, Vol.10,No.04, p.53-54,1958.