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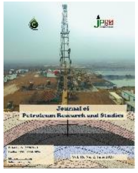

Possibility to Apply Gas Lift Method for Low Production Wells with High Water Cut in (A) Oil Field

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Abstract

Gas lift is one of the oldest methods used to produce hydrocarbon fluids from wells experiencing declining production. It works by aerating the mixture inside production tubing and forcing it to the surface. One of the reasons for declining production in oil wells is an increase in water cut or a drop in reservoir pressure, which requires one of the artificial lift methods to restore production.

(A) oil field suffers from an increase in water cut, which has affected well productivity. The wells under study have a water cut of up to 66%, resulting in very low production rates. In this research, Pipesim software was used to build a physical and fluid model, then design an optimal gas lift system that achieves the highest possible productivity from these wells. The design of the gas lift system depends directly on injection pressure, injection rate, and wellhead pressure, which in turn affect the remaining design variables. The availability of gas in the field is a prerequisite for the system's success, while injection pressure can be provided by suitable compressors. For this reason, optimal injection rates were taken into consideration to avoid excessive gas.

The results showed a significant increase in production for the wells under study, with increases percentage as 238% (from 793 to 2,682 stb/d) and 146% (from 1,100 to 2,706 stb/d). The gas lift system works to lift fluids accumulated in the well, and this does not mean it is a method for treating water cut, as water cut comes into the well from the producing formation. In other words, this increase applies to the fluids as a whole, not just oil production. A prospective study was conducted to simulate the effectiveness of the gas lift system in dealing with changes in well operating conditions, such as increased water cut or decreased reservoir pressure. The results demonstrated the flexibility and success of the gas lift system in dealing with problems and challenges that occur during production, as the simulation procedure was based on an increase in water cut of up to 90 % and a decrease in the reservoir pressure reaching 3200 psi. Despite this, the wells continued to produce at rates of 1549 and 1593 stb/d. Furthermore, this study can be applied to other wells in the field where water cut is high, demonstrating the importance of gas lift in maintaining production and its feasibility in the field.

Keywords: Artificial lift, Gas lift, Oil production, Pipesim, Water cut.

إمكانية تطبيق طريقة الرفع بالغاز للآبار ذات الإنتاج المنخفض وقاطع المياه العالي في حقل (أ) النفطي

الخلاصة:

ان منظومة الرفع بالغاز واحدة من اقدم الطرق المستخدمة في رفع السوائل الهايدروكاربونية للأبار التي تعاني من هبوط في انتاجيتها، حيث تعمل على تهوية الخليط داخل انبوب الانتاج و دفعه الى السطح. ان من اسباب انخفاض الانتاج في الابار النفطية هو زيادة قاطع الماء او هبوط ضغط المكمن مما يتطلب احد طرق الرفع الاصطناعي لأستعادة الانتاج.

يعاني حقل (أ) النفطي من زيادة في نسبة قاطع الماء مما اثر على انتاجية الابار، حيث ان الابار قيد الدراسة تصل نسبة قاطع الماء فيها الى 66% مما جعل معدلات الانتاج منخفضة جدا. في هذا البحث يستخدم برنامج (Pipesim) لبناء الموديل الفيزيائي و الموديل للمائع ثم تصميم امثل منظومة رفع بالغاز و التي تحقق اعلى انتاجية ممكنة من هذه الابار. يعتمد تصميم منظومة الرفع بالغاز بشكل مباشر على ضغط الحقن و معدل الحقن، و ضغط رأس البئر و التي بدورها تؤثر على باقي متغيرات التصميم. ان توفر الغاز في الحقل هو شرط اساسي لنجاح المنظومة اما ضغط الحقن يمكن توفيره من خلال الكابسات المناسبة، لهذا السبب تم الاخذ بنظر الاعتبار امثل معدلات الحقن في سبيل عدم الافراط بالغاز.

اظهرت النتائج زيادة كبيرة في الانتاج للأبار قيد الدراسة، حيث ان نسبة الزيادة كانت 238% (من 793 الى 2682 برميل باليوم) و 146% (1100 الى 2706 برميل باليوم). ان منظومة الرفع بالغاز تعمل على رفع السوائل المتجمعة في البئر و هذا لا يعني انها طريقة لمعالجة قاطع الماء، لان قاطع الماء يأتي الى البئر من الطبقة المنتجة، بعبارة اخرى ان هذه الزيادة هي للسوائل ككل و ليس فقط للنفط. اجريت دراسة مستقبلية لتحاكي فعالية منظومة الرفع بالغاز في مواجهة التغيرات في ظروف تشغيل البئر، مثل زيادة قاطع الماء او انخفاض ضغط المكمن، و اثبتت النتائج مرونة و نجاح منظومة الرفع بالغاز في مواجهة المشاكل و التحديات التي تحدث مع زمن الانتاج. ان اجراء المحاكاة تم من خلال اعتماد زيادة في قاطع الماء تصل الى 90% و انخفاض في ضغط المكمن يصل الى 3200psi حيث بينت النتائج استمرار الابار بالانتاج و بمعدلات 1549 و 1593 برميل باليوم, كما ان هذه الدراسة يمكن تطبيقها على الابار الاخرى في الحقل التي يكون فيها قاطع الماء مرتفع، مما يثبت اهمية الرفع بالغاز في المحافظة على الانتاج و امكانية تطبيقها في الحقل.

1. Introduction

Gas lift is one of the most common and widely used artificial lift methods for lifting hydrocarbon liquids to the surface, which is highly reliable in increasing production, even with suboptimal system design. Gas lift was first used in the Pennsylvania oil fields in 1864 [1, 2]. Oil production in the first stage depends mainly on the energy of the reservoir, if it is sufficient to raise fluids to the surface, but over time, this energy decreases and becomes unable to raise fluids, or the flow is low [3]. At the same time, an increase in the water cut conclusively leads to a decrease in oil production from those wells [4]. The problem of increasing water cut leads to an increase in bottom hole flowing pressure of the well, because water production leads to an increase in the weight of the liquid column, in addition to increasing friction losses, and as a result decrease the difference with reservoir pressure and thus reducing the flow of fluids towards the well [5]. In general, one of the artificial lifting methods must be used to restore production within the required limits, but that requires choosing the optimal method that achieves the desired economic benefit and does not cause any great burdens in the operational cost [6]. The gas lift method contributes to increasing production from low-productive wells or re-producing in fully stopped wells [7]. Usually, the gas is injected from the surface with a suitable pressure into the annulus, then to the production tube through the valve of the gas lift system (the last active valve) [8]. It should be noted that, usually, the injection angle is in a downward direction, that is, the opposite of fluid movement, which contributes to a pressure drop, as changing in injection angle of the valve to the upward direction contributes to improving the flow and thus the production[9]. In general, When the injected gas enters the production tube, it raises the hydrocarbon fluid to the surface by first, the gas expansion energy that contributes to the pushing hydrocarbon liquid to the surface, and the other aerated the liquid column and then reduces the density of the mixture [10](Figure 1).

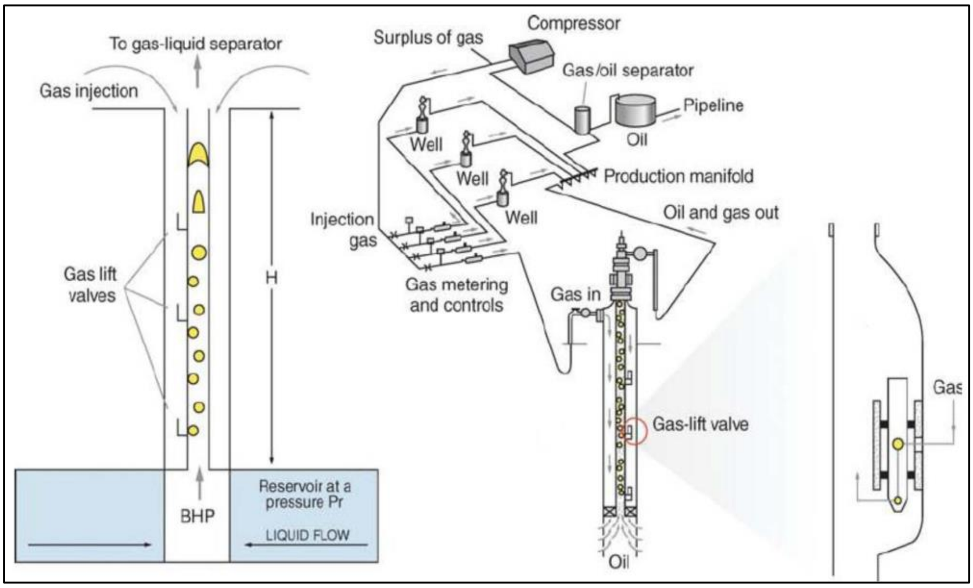

Fig. (1): Gas lift system [11]

The gas lift system includes two types, one of which is called continuous gas lift, and the other type is intermittent gas lift, where both types share the same work principle (gas expansion, reducing density) but differ in the mechanism used in the operation of the system.

The continuous gas lift method is the most common and widely used, as the gas is constantly injected into the well. As for the intermittent gas lift method, the gas is injected for a calculated period, then the injection stops, and thus the process is repeated depending on the production of the well, and it is usually used for wells with a low productivity index [12, 13]. The two types of gas lift have properties that differ from one to the other, and it is very important to choose the appropriate method for the case of the well, which leads to the highest production rate, as the wrong method leads to a lack of achievement of the best productivity and causes increased cost [14]. On this basis, it is very necessary to replace the continuous gas lift system with the intermittent gas lift system when the gas-oil ratio is high (due to reservoir pressure drop that requires the injection of a higher gas rate), but this process is not beneficial in the long run and is of limited benefit [15]. It should be noted that in some cases, the intermittent gas lift method is used in the gas wells to raise the fluids collected at the bottom of the well, which affects the productivity of gas well [16].

The success of the gas lift system depends directly on the availability of the required surface facilities, where the gas must be treated (gas purification and removal of impurities), then compressed by high-capacity compressors before the injection again into the well [17]. In addition, the design of an optimal gas lift system depends on gas pressure and injection rates, which affect the deepest possible injection point and then the highest productivity of the well [18]. The gas lift system is affected by the instability phenomenon and thus affects production rates for the wells that suffer from this problem; therefore, instability phenomenon must be studied and considered during the design of the gas lift system, especially the instability due to gas allocation to the wells. [19]. In general, production rates for wells that operate by gas lift system increase with the increase in gas pressure and injection rate, and reach the highest possible production of the well, and this point is called the critical limit. The increase in gas pressure or injection rate is higher than the critical limit, leading to a decrease in productivity first, then an increase in the cost of operation, and thus, the system's failure to achieve the required economic value [20, 21]. As a result, it is required to understand the current and future well conditions to address the problems that occur with operation, which include the distribution of gas to the wells as much as the need to achieve the maximum benefit and without waste of gas[22].

The gas lift system is characterized by high flexibility and low operating cost when compared to other artificial lift methods, but at the same time, it is very necessary to provide gas, as it requires accurate calculations of design and implementation, in addition to the continuous monitoring of the gas lift system [23, 11].

Optimizing the gas lift system requires making adjustments to many parts, as various improvements have been made since the system was used to this moment, the problems have appeared in the design, for example estimating the optimal injection pressure or the optimal injection rate because the results were different between the calculated and the actual, which required obtaining the latest technologies of control, and the latter is the technique of digital intelligence for artificial lift, where the contributing to increasing increased the efficiency of gas lift system and avoiding operational problems [24, 25].

1.1. Area of study

(A) oil field is the largest producing field belonging to the Midland Oil Company (MdOC), located in the middle of Iraq (Figure 2). This field was discovered in the late 1970s and Production operations began in 2011, and production peaked at 180,000 barrels per day. However, there has been a sharp decline, and today, it produces only 60,000 barrels per day. It also suffers from a high water cut, which in some wells reaches 70% or more, which has negatively affected production [26, 27]. There are three producing formations in (A) oil field (K, M, and R). The wells under study (well-1 and well-2) are horizontal and located in the R formation, and the water cut in both reaches 66%, which will inevitably have a significant impact on oil production, to the point that one of the artificial lift methods is required. [28]

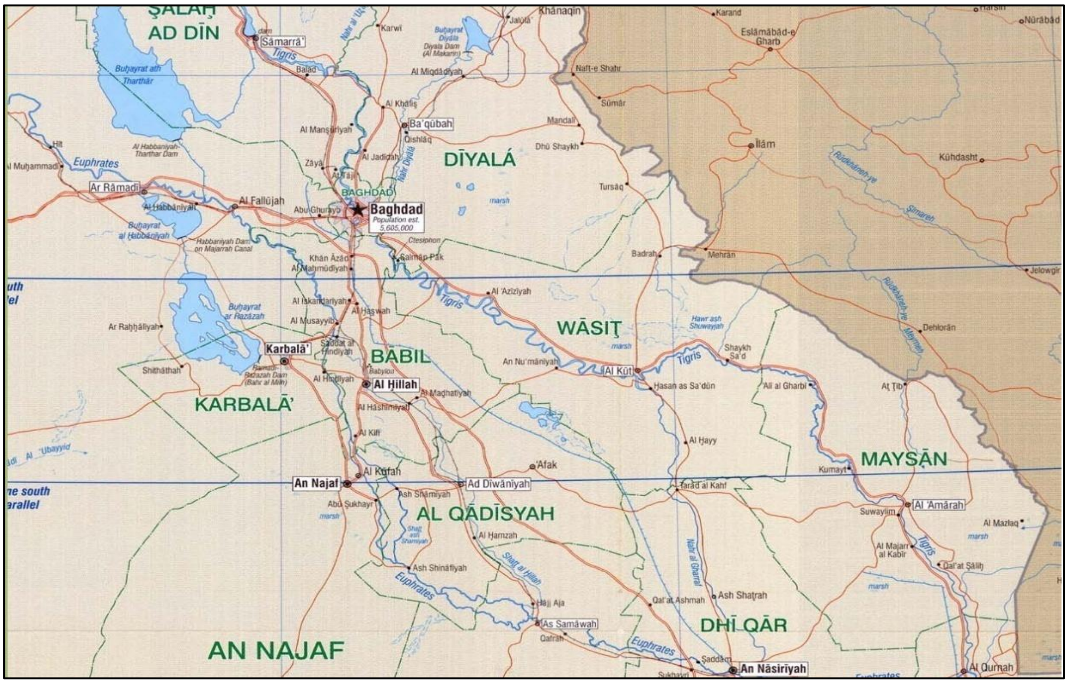

Fig. (2): Midland oil company area [28]

2. Methodology

The research methodology includes several stages that start from obtaining adequate data for the wells under study and then analyzing it, and then building the physical model and fluid model for the wells. After knowing the productivity of the wells in case of natural flow, the optimal gas lift system is designed to give the highest possible production while taking into account the conditions of the well. Finally, a future simulation of the wells will be conducted to assess the response to the gas lift system in response to changes in reservoir pressure or water cut, aiming to determine the impact on well productivity (Figure 3). The research depends on its completion on Pipesim Software program, as the construction of the model and the necessary simulation to know the response of the wells to the gas lift system is done through the Pipesim software, which provides many advantages that allow the provision of appropriate conditions that represent the wells under study and that through many correlations and calibration that represent the basis of oil production engineering.

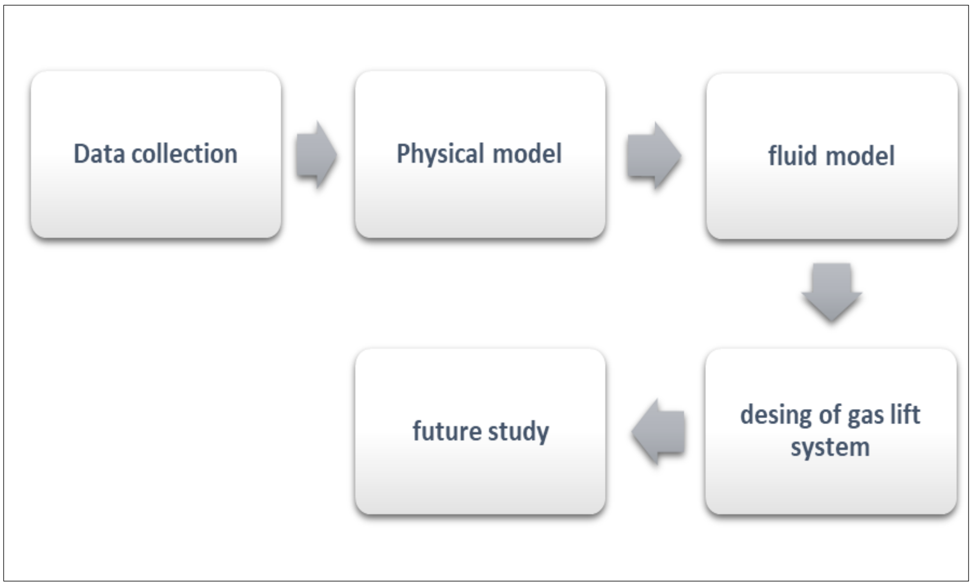

Fig. (3): Flowchart of research methodology

2.1. Physical model

The model is built for the two wells under study, depending on the available data, which include casing data (its depth, type, and diameter), production tube data (depth, type, and diameter), in addition to packer depth and the type of completion. The two wells under study are horizontal (Well-1 and Well-2). The angle of deviation from the vertical axis was obtained for each depth, and the horizontal distance of the two wells that penetrate the productive formation was obtained, in addition to the point of deviation from the vertical (KOP). Data through which the physical model is built can be summarized in Table (1). Whereas the Pipesim relies on this data, it creates the structure of the wells.

Table (1): Data of wells equipment [28]

Equipment/well	Well-1	Well-2
Surface casing	309 m	312 m
Intermediate	2066 m	2047 m
Liner	1900 – 3228 m	1900 – 3000 m
Open hole	3228 – 4335 m	3000 – 4200 m
Tubing depth	2067 m	2100 m
Packer	2050 m	2085 m
KOP	2110 m	2350 m

2.2. Fluid model

Another model is built to simulate the real condition of the wells under study. In this model, data related to the reservoir and data related to the produced formation are collected. The data available for these two wells include the pressure and temperature of the reservoir, wellhead pressure, bubble point pressure, the productivity index, gas-oil ratio, oil formation volume factor, and the density of oil, where these data were summarized in Table (2).

Table (2): Fluid data for wells under study [26]

Data/Well	Well-1	Well-2
Reservoir pressure (psi)	3542 psi	3542 psi
Reservoir temperature (T)	85 C	85 C
Productivity index (PI)	8.74	8.74
Well head pressure (Pwh)	290 psi	305 psi
Bubble point pressure (Pb)	2799 psi	2799 psi
Gas oil ratio (GOR)	660 scf/stb	660 scf/stb
Water cut (wc)	66%	66%
API	27	27
Oil formation volume factor (Bo)	1.281	1.281

To complete the construction of this model, the correlations available in the program must be chosen to calculate the physical properties of the reservoir. Table (3) identifies the correlations selected for each reservoir physical property. Pipesim provides the advantage of a calibration of the physical characteristics calculated from the correlations that were chosen with the measurements in the laboratory to increase the accuracy in this model.

Table (3): Correlation used for each reservoir physical property

Property	Under saturation oil viscosity	Live oil viscosity	Dead oil viscosity	Bo above Pb	Saturation gas at Pb	Bo at Pb	Gas viscosity	Gas Z
correlation	Vasquez & Beggs	Beggs & Robinson	Beggs & Robinson	Vasquez & Beggs	Lasater	standing	Lee et al.	standing

2.3. Design a gas lift system

The design of the gas lift system is directly related to the injection pressure and the injection rate, in addition to the pressure of the wellhead, as these variables greatly affect the rest of the design details and affect more than others on the productivity of the wells. For this reason, the injection pressure, the injection rate, and the pressure of the well head must be chosen with high accuracy by conducting sensitivity analysis, where Pipesim program provides the feature of sensitivity analysis for injection pressure and injection rate according to the current well condition, as it gives a preliminary vision for optimal injection pressure and injection rate that give the highest possible production without problems to the well. The deepest point of injection (the depth of the last valve and the number of valves), plays a large role in increasing the productivity of wells, because the injected gas begins with aerating the mixture from its point of entry to the production tube, directly related to the injection pressure.

Usually, the availability of gas is the biggest problem for the success of the gas lift system. As for the injection pressure, it is possible to provide compressors to reach the required value. For this reason, the availability of gas was taken into account and the lack of deficiency in supplying the wells that will work with the gas lift system, where a suitable and reasonable injection rate was chosen, and the choice of injection pressure gives the deepest possible point to the injection with the lowest possible number of valves and the highest productivity of the wells. Table (4) and Figure (4a, 4b) summarize the final design of the gas lift system that will be installed on the wells under study. Figures (5) and (6) show the number, depth, and type of valves for the two wells.

Table (4): Final design of gas lift system

Property/well	Well-1	Well-2
Injection pressure (Pi)	1950 psi	1950 psi
Injection rate (Qi)	1.25 mmscf/d	1.25 mmscf/d
Well head pressure (Pwh)	475 psi	475 psi
Depth of the last valve	2019.3 m	2054.3 m
Gas specific gravity	0.75	0.75
Minimum valve spacing	98.3 m	98.3 m

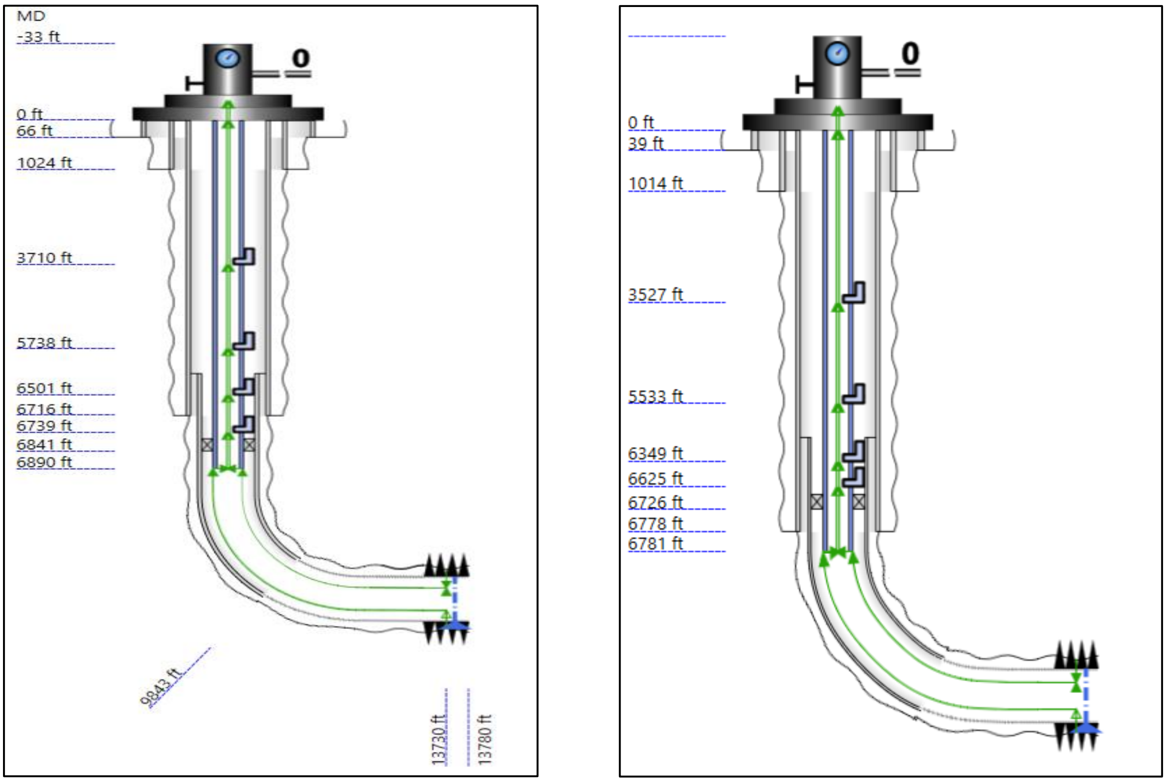

Fig. (4a, 4b): The wells under study after installing the gas lift system

GAS LIFT

Injection option: ○ Fixed injection ports ◉ Injection valve system

	Gas lift	Active	MD (m)	Manufacturer	Series	Valve type	Port size (in)	Ptro (psia)	St (psia)	Discharge coe...	DP to fully open (psi)
1	SLB (Camco)_...	☑	1074.937	SLB (Camco)	R20	IPO	0.25	1827.148		0.76	529
2	SLB (Camco)_...	☑	1686.585	SLB (Camco)	R20	IPO	0.25	1878.226		0.76	529
3	SLB (Camco)_...	☑	1935.294	SLB (Camco)	R20	IPO	0.25	1893.678		0.76	529
4	SLB (Camco)_...	☑	2019.203	SLB (Camco)	R20	IPO	0.375	2069.688		0.76	382.6

GAS PROPERTIES

Gas specific gravity: ◉ Specify ○ Use fluid model

0.75

Fig. (5): Depth and type of valves for well-1

GAS LIFT

Injection option: ○ Fixed injection ports ◉ Injection valve system

	Gas lift	Active	MD (m)	Manufacturer	Series	Valve type	Port size (in)	Ptro (psia)	St (psia)	Discharge coe...	DP to fully open (psi)
1	SLB (Camco)_...	☑	1130.767	SLB (Camco)	R20	IPO	0.25	1826.888		0.76	529
2	SLB (Camco)_...	☑	1748.89	SLB (Camco)	R20	IPO	0.25	1879.715		0.76	529
3	SLB (Camco)_...	☑	1981.44	SLB (Camco)	R20	IPO	0.25	1893.802		0.76	529
4	SLB (Camco)_...	☑	2054.164	SLB (Camco)	R20	IPO	0.5	2384.245		0.76	302

GAS PROPERTIES

Gas specific gravity: ◉ Specify ○ Use fluid model

0.75

Fig. (6): Depth and type of valves for well-2

2.4. Future study

The simulation of future well behavior, depending on its current condition, can be conducted through the Pipesim Software. With the advancement of the well, the pressure of the reservoir will decrease and water cut will increase, in this study the effect of water cut will be observed on the productivity of the well, clarifying the difference when installing gas lift system and knowing the well's response to changes on its current conditions, to know the importance of gas lift system as a possible artificial lift method for wells under study.

3. Results and Discussion

It is very important to conduct the nodal analysis of the wells under study at each stage of production, as this procedure helps in knowing the productivity of the well under the conditions of the well itself. However, the actual production data of the wells under study have not been obtained (it will depend on production rates calculated by the Pipesim program). Production rates appear in the case of natural flow, the effect of the water cut on the productivity, as entering the water into the well works to increase the density of the mixture (the density of water is higher than oil, and when the amount of water inside production tube increase, the density of the mixture increase) and increase the friction losses, then as a result increase in bottom hole flowing pressure, which reduces the difference with the pressure of the reservoir and thus the fluids flow at lower rates as well as the volume that this water takes from the total volume of production (Table 5).

Table (5): Production in the case of natural flow

Property/well	Well-1	Well-2
Liquid rate (Ql)	1100 stb/d	793 stb/d
Water cut (wc)	66%	66%
Oil rate (Qo)	374 stb/d	269 stb/d

At this stage, the use of one artificial lift method is required to increase the production of the wells. The gas lift system was used to help raise hydrocarbon liquids to the surface and, therefore, increase the productivity of the wells.

Optimizing the gas lift system to achieve the highest production rate requires choosing the appropriate injection pressure and injection rate. Excessive injection rates or pressures lead to a decrease in production and an increase in costs. Therefore, appropriate injection rates and pressures are essential. The chosen injection rates and pressures were among the most important values, as increasing them did not yield effective results in well production. Instead, gas was overused for a small increase in production, which is not economically viable.

The installation of the optimal gas lift system led to amazing results and a very large increase in production, as the increase in well-2 was 238%, and well-1 was 146%. The two wells are located in the same formation that is characterized by a very high productivity index and a suitable reservoir pressure, but the water cut directly affected the decrease in productivity. For this reason, after entering the compressed gas into the two wells through the injection valve, it worked to raise the fluid accumulated at the bottom of the wells, first through the energy expansion capacity that pushed the fluids to the surface, and secondly, during the aeration of the mixture and reducing its density.

Reducing the density of the mixture inside the production tubing and reducing friction losses reduces the bottom hole flowing pressure, which increases the differential with the reservoir pressure. This fluid flows into the well at higher rates due to the increased pressure differential. Production from well-2 (Figure 7) increased from 793 barrels per day to 2,682 barrels per day (238%), while production from well-1 (Figure 8) increased from 1,100 barrels per day to 2,706 barrels per day (146%).

Figure (9) is a comparison between production in the case of natural flow and the flow after installing the gas lift system, which shows the importance of this method in achieving an increase in production rates for wells that may stop with an increase in the water cut without the gas lift system. The gas lift method is used to increase production rates, this does not mean reducing the percentage of water cut, as the produced water is from the productive layer (formation). A gas lift system is used to lift fluids regardless of the type of fluid. This is the working principle of gas lift, as the production rates of wells are for all fluids, not just for oil.

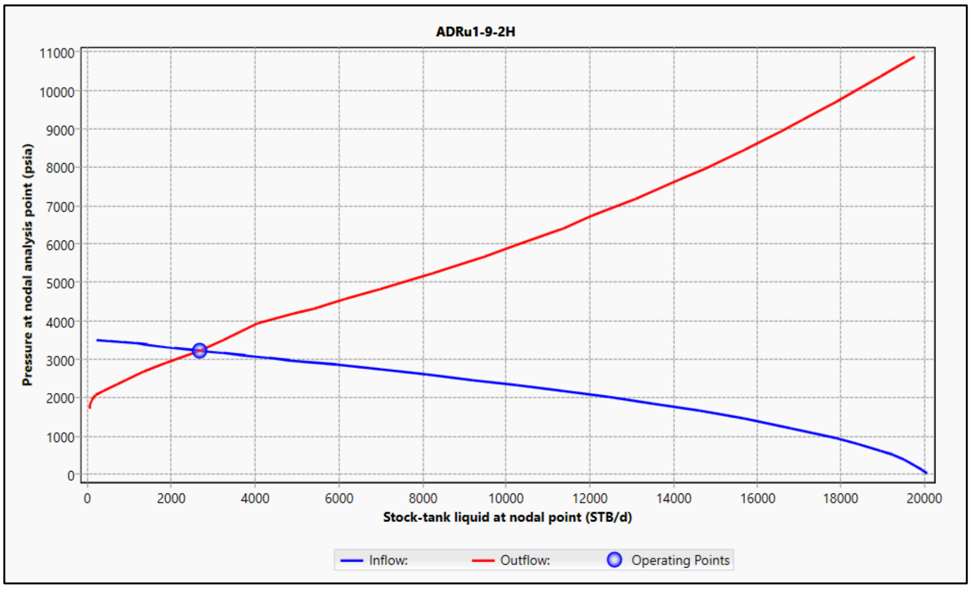

Fig. (7): The flow for well-2 after installing the gas lift system

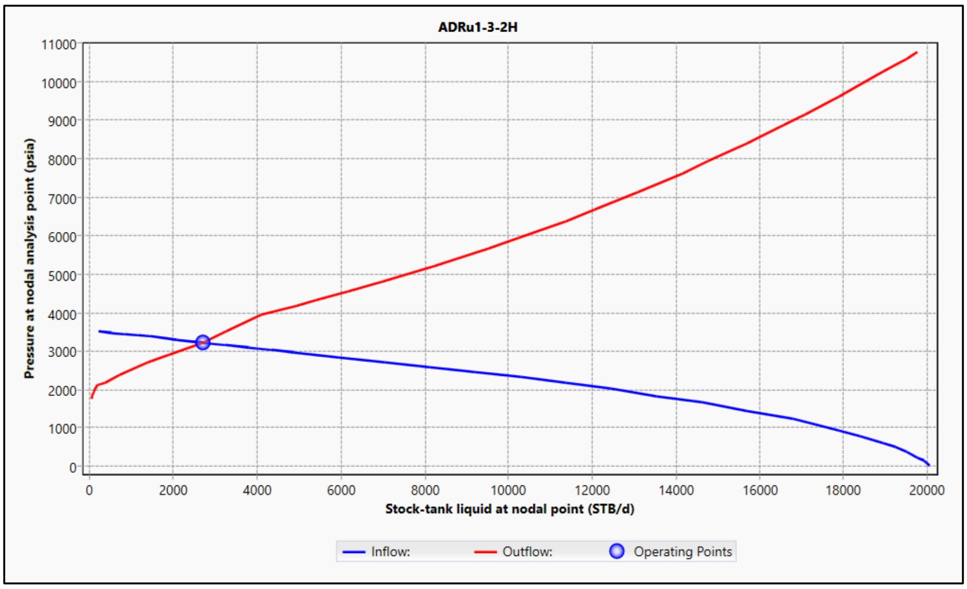

Fig. (8): The flow for well-1 after installing the gas lift system

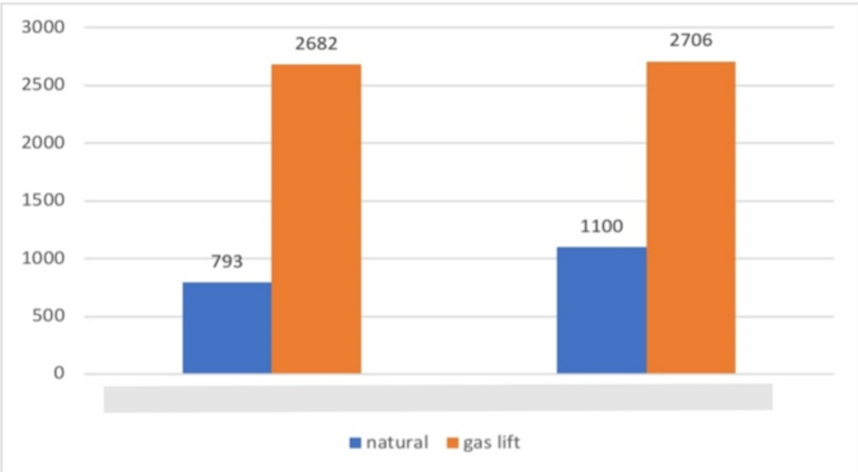

Fig. (9): Flow in case of natural condition and under gas lift system

It is important to conduct a future study to know the response of the gas lift system to changes in the conditions of the well, as it is certain that the water cut will increase and that the pressure of the reservoir will decrease, which affects the productivity of wells even with the installation of the gas lift system. The future study aims to know the success of the gas lift system with these changes and how to face the problems that occur over time. However, the expected period for this scenario is not far away, as (A) oil field suffers from a continuous increase in water cut and a decrease in reservoir pressure as a natural result of draining the reservoir through continuous production.

The results demonstrated the efficiency of the gas lift system in addressing future challenges that impact production, as well as conditions change. The results demonstrated that production from these wells continues even within economically unprofitable limits, demonstrating that this system is highly flexible and adaptable to change, leading to greater profitability and greater utilization of the producing wells.

This can be observed by performing a nodal analysis of wells with decreasing reservoir pressure and increasing water cut, as shown in Figures (10) and (11). This study also serves to simulate other wells experiencing a water cut increase of more than 70% and to determine the feasibility of implementing a gas lift system to increase production in all wells.

Tables (6) and (7) summarize the gas lift system's performance to address the challenges that wells face over production time. In the first case, the water cut is assumed to increase to 90%, assuming constant reservoir pressure, as illustrated by the nodal analysis below. In the second case, the reservoir pressure is assumed to drop with increased water cut, meaning worse well conditions. Despite this, the wells did not stop production, and despite the economic infeasibility, it demonstrates the value of the gas lift system in maintaining production.

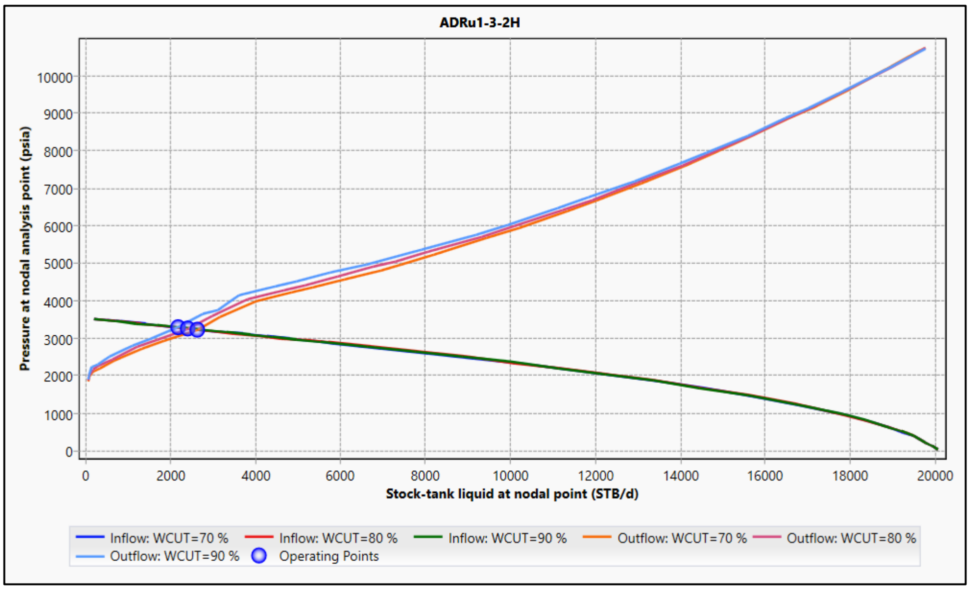

Fig. (10): Effect of water cut on productivity of well-1 under gas lift system at reservoir pressure 3542 psi

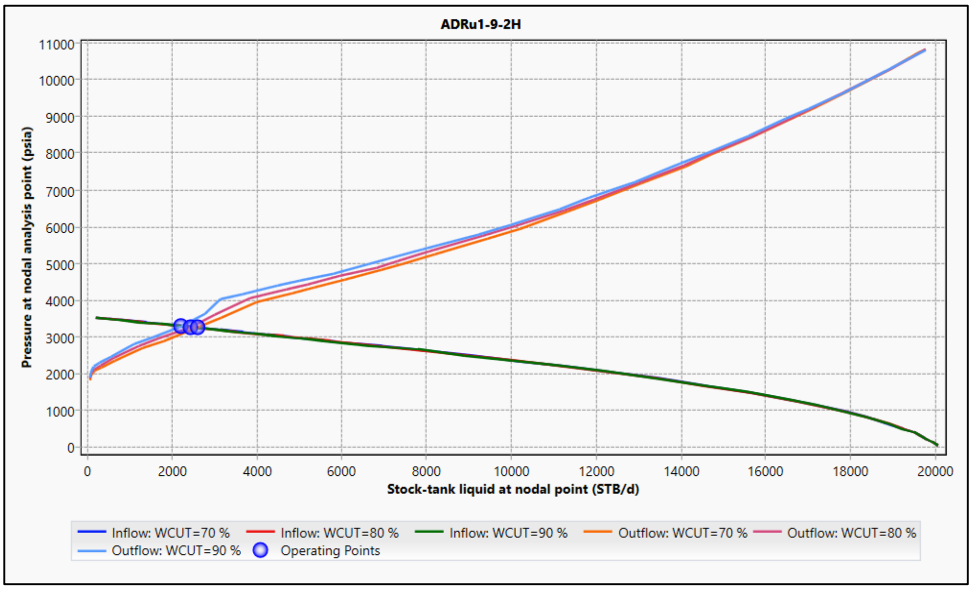

Fig. (11): Effect of water cut on productivity of well-2 under gas lift system at reservoir pressure 3542 psi

Table (6): Effect of an increase in water cut at reservoir pressure 3542 psi on productivity

Water cut/well	Well-1	Well-2
70%	2618 stb/d	2593 stb/d
75%	2508 stb/d	2536 stb/d
80%	2398 stb/d	2428 stb/d
85%	2289 stb/d	2321 stb/d
90%	2181 stb/d	2215 stb/d

Table (7): Effect of an increase in water cut at reservoir pressure 3200 psi on productivity

Water cut/well	Well-1	Well-2
70%	1937 stb/d	1927 stb/d
75%	1838 stb/d	1875 stb/d
80%	1740 stb/d	1780 stb/d
85%	1644 stb/d	1686 stb/d
90%	1549 stb/d	1593 stb/d

4. Conclusions

Gas lift has proven remarkably successful in increasing production from wells suffering from excessive water cut. Results showed that the wells under study achieved increases of 238% and 146%. It is well known that increased water cut or decreased reservoir pressure leads to a decrease or complete cessation of oil production in the future. After installing a gas lift system, increasing production from these wells does not mean treating water cut, as water cut comes from the producing formation, and the gas lift system works to raise the fluids accumulated in the well to the surface by aerating the mixture and pushing it upward from the gas entry point into the production tubing. In other words, increased production is the flow of all fluids, not just oil. The simulation of the wells under study has proven that the gas lift system is very effective and flexible with changing well operating conditions. Increasing water cut and decreasing reservoir pressure have reduced production, but production from these wells continues even when uneconomical (90% water cut). Predicting the future is very important, as the gas lift system can meet future challenges, as well as simulate the conditions of other wells in the field that produce under these adverse conditions, proving the effectiveness of the gas lift system in maintaining production.

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