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Gas Lift Design Using PROSPER Software

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ABSTRACT

One of the most important production issues in the oil field is high water production, which may lead to wells a reduction in an economic period. The increment of water production or decrease of reservoir pressure causes a decline in the oil production rate or kills the well. An artificial lift technique should be implemented to return the wells back to production. A continuous gas lift system is the best method. In this study, the offshore well C-1 located in a Field in Libya revived production by utilizing the gas lift technique to achieve incremental reserve recovery after the well was shut in due to a significant increase in water production, which reached 50% and the well died. In this paper, Nodal Analysis has been carried out utilizing the PROSPER Software for well performance evaluation, Gas lift design and optimisation. The effect of valve spacing on the gas lift optimization and gas injection rate depth of gas injection was studied by performing a sensitivity analysis. The results show that a constant gas injection of 3.9199 MMscf/day with an injection pressure of 1700 psi can deliver 3866.41 bbl/day of oil and valve spacing information at various depths, the maximum depth is at 10,000 feet.; This was achieved by changing the depth of injection for three different cases to ascertain the effect on the liquid production rate.

Keywords: the gas lift design, injection gas, depth effect, gas lift valve spacing, stability.

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تصميم نظام الرفع بالغاز باستخدام برنامج بروسبير

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ملخـــــص البحـــــث

من أهم قضايا الإنتاج في حقل النفط ارتفاع إنتاج المياه، مما قد يؤدي إلى انخفاض الآبار في فترة اقتصادية. إن زيادة إنتاج المياه أو انخفاض ضغط الخزان يتسبب في انخفاض معدل إنتاج النفط أو يقتل البئر. لإعادة الآبار إلى الإنتاج، يجب تنفيذ تقنية الرفع اصطناعية. نظام رفع الغاز المستمر هو أفضل طريقة يمكن استخدامها. في هذه الدراسة، أحيت البئر البحرية **C-1** الموجودة في حقل في ليبيا الإنتاج من خلال استخدام الغاز تقنية رفع بالغاز لتحقيق استرداد احتياطي تدريجي بعد إغلاق البئر بسبب زيادة كبيرة في إنتاج المياه، والتي وصلت إلى 50٪ ونفدت البئر في هذه الورقة، تم إجراء تحليل باستخدام برنامج PROSPER. لتقييم الأداء الجيد وتصميم رفع الغاز والتحسين. تمت دراسة تأثير تباعد الصمامات على تحسين رفع الغاز وعمق معدل حقن الغاز من خلال إجراء تحليل الحساسية. تظهر النتائج أن الحقن المستمر للغاز

3.9199 مليون متر مكعب في اليوم مع ضغط حقن 1700 psi يمكن أن يوفر 3866.41 برميل /يوم من معلومات تباعد صمامات الرفع بالغاز وإعادة التصميم الأمثل لها وتحديد ذلك على أعماق مختلفة، الحد الأقصى للعمق هو 10000 قدم ؛ تم تحقيق ذلك عن طريق تغيير عمق الحقن لثلاث حالات مختلفة للتأكد من تأثير ذلك على معدل إنتاج البئر من النفط والغاز.

الكلمات المفتاحية: تباعد الصمام، تأثير معدل حقن الغاز، تأثير العمق، حالة الاستقرار

1. Introduction

Petroleum is a non-renewable natural resource coupled with the present undulating trend in terms of its price value, demand and supply trend. It is therefore important for producers to ensure that production meets required demands as much as its operational cost is maintained to its minimal level. With the increasing maturity of the reservoir resulting from continuous hydrocarbon production, the natural energy essential for oil production at a preferred rate becomes insufficient. Inconsistency and unpredictability in oil production rate therefore result from varying well conditions such as depleting pressure of the reservoir as well as an increase in reservoir water cuts, amongst others

Originally, Petroleum Reservoirs existed with sufficient formation pressure potentials good enough to push crude oil into the wellbore as well as to the surface through the production tubing. Many oil reservoirs are produced with formation pressure that is just enough to get the oil into the wellbore but not capable of pushing it up the production tubing to the surface. The rate at which reservoir pressure declines is piloted by the type of natural energy drive of the reservoir, as well as aspects that alter the gas-oil ratio and cumulative production Influence of gravitational forces in the reservoir, aquifer permeability and oil properties such as compressibility, viscosity etc. are among the factors responsible for reservoir pressure decline.

As the formation matures, due to degeneration in reservoir pressure always resulting from continuous petroleum production, primary recovery via a natural drive system is not sustainable, which results in some form of artificial lift system being installed to optimize production.

Production Optimization can exist as far back as the emergence of commercial hydrocarbon exploration. Petroleum production is known to involve two discrete but somewhat closely connected broad systems- the hydrocarbon reservoir, and well assemblies, encompassing surface gathering, separation and storage facilities.

2. Methodology

In this paper, Nodal Analysis has been carried out utilizing the PROSPER Software [1] for well performance evaluation, Gas lift design and optimisation. Gas lift systems can be designed for optimum production optimization considering variables such as gas lift valve performance, water cut, productivity index, tubing size, reservoir pressure and injection gas pressure. Also, the economic viability of the design depends on keeping the injection gas at equilibrium to maintain the gas lift injection rate (GLIR) which will enhance the oil production rate [2,3] Furthermore, the spacing calculation must be made in a way that allows displacement of liquid from the casing into the tubing down to the desired operating depth with the available gas pressure, and it must be possible to open any valve under operating condition without opening the valves above or below it. Table 1 illustrates the reservoir parameters that were utilized to build the model.

Table 1: Data Input

Parameter	Values	Units
Solution GOR	780	Scf/STB
Oil Gravity	38	API
Gas Gravity	0.75	Sp. gravity
Water salinity	60000	Ppm
Impurities	None	
Bubble point pressure	3450	Psia

2.1 Pressure, Volume and Temperature (PVT) Matching

Reservoir fluid properties are significant data in the design of various features of production and reservoir engineering, containing designing surface apparatus, optimizing separator surroundings, investigative multiphase flow in pipes, performing well test examination, estimating hydrocarbon reserves, making reservoir simulation models, forecasting reservoir performance, and examining hydrocarbon flow concluded porous media, as well as important to enhanced oil regaining.

For preparing the well model in PROSPER, the PVT data had been taken from the report's composition and PVT analysis of the separator sample from C-1 well of X-field in Libya oil Field.

For matching bubble point pressure, solution gas oil ratio (GOR) and Oil formation volume factor (FVF), PROSPER uses the following Black oil correlations.

Beal [4] developed a correlation based on 600 PVT laboratory measurement data points from samples taken from over all the world. The authors demonstrated that the gas specific gravity is related to conditions of separation. They thus proposed an equation to correct this gas specific gravity to separator conditions before determining the oil formation volume factor and bubble pressure. Furthermore.

In this study, for matching oil viscosity, with the Prosper Software's correlations that were developed by Vazquez and Beggs [5] were selected to build the Prosper software model.

Table 2 demonstrates the reservoir static pressure, reservoir temperature and the total gas oil ratio that required for inspecting the correlation parameters in PROSPER, the following correlations had been identified for the best overall fit for the matched PVT, Bubble point pressure (Pb), oil formation volume factor (Bo) and oil viscosity, Hence, the best-fit correlations, PVT input data were matched with measured data and PROSPER software.

Table 2: Reservoir input data

Parameter	Value	Unit
Static reservoir pressure	4000	Psig
Reservoir temperature	200	^{o}F
Total GOR	780	Scf/STB

2.2 Downhole Equipment

To build up a well model in PROSPER; it is important to define the deviation survey and downhole equipment data accurately. The equipment to specify in PROSPER is the one that the fluid sees from the bottom hole up to the wellhead. The downhole equipment includes the tubing, casings, sub-surface safety valves, etc. Thus, the equipment through which the fluid flows had been entered for the tubing, casing, tubing inside diameter and inside roughness is the downhole equipment summary.

Table 3 illustrates the well completion data required to determine the sketch of the wellbore and deviation survey shown in Figure 1 which demonstrates the well downhole equipment before the gas list is implemented.

Table 3: Downhole Equipment

Parameter	Value	Unit
Tubing	4.7	inch
SSSV	3.72	inch
Casing	6.4	inch

3. Modelling the Gas Lift System

Appropriate design parameters in the design of the new well were inputted by clicking on ‘Design’, a new dialog box pops up, click on ‘Gas lift’ upon clicking on gas lift ‘New Well’ and the parameters are inputted. Table 4 demonstrates the summary for the Gas lift design modelling as shows the operating injection pressure was 1500 psig, the minimum spacing between valves which located at 250 ft. and the maximum depth of injection was set at 11000 ft. In this paper, a “Camco R-20 Normal” valve is chosen from the PROSPER database. The software calculates which port sizes will generate optimal production performing the actual Gas lift design, select ‘Next’ and click on ‘Design’. After a while, the design is completed, and the result can be visualized with the ‘plot’ tab in the lower half of the screen.

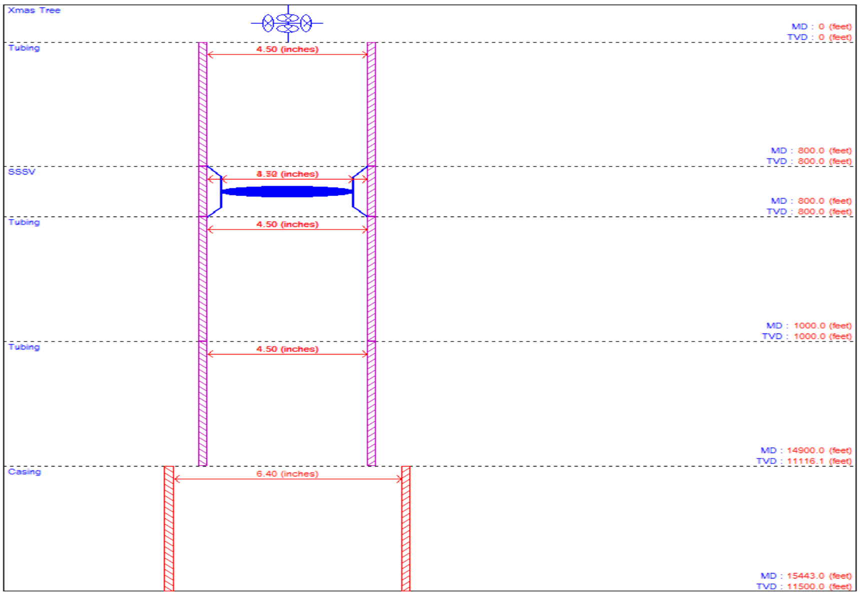


Figure 1. Downhole equipment sketch Before Gas lift

Table 4: Well data summary

Parameters	**Values**	**Units**
Flowing top node pressure	250	Psig
Unloading top node pressure	250	Psig
Operating injection pressure	1500	Psig
Kick off injection pressure	1500	Psig
Maximum depth of injection	11000	Feet
Water cut	50	Percent
Target gas lift injection rate	0.5	MMscf/day
Solution GOR	780	scf/STB

4. Results

4.1 Inflow and outflow

The purpose of artificial lift is to maintain a reduced producing BHP so the formation can give up the desired reservoir fluids [6]. A well may be capable of performing this task under its own power. In its latter stages of flowing life, a well can produce only a portion of the desired fluids. During this stage of a well is flowing life and particularly after the well dies, a suitable means of artificial lift must be installed so the required flowing BHP can be maintained, Figure 2. Illustrate the Inflow/outflow performance by using artificial lift methods. Maintaining the required flowing BHP is the basis for the design of any artificial lift installation; if a predetermined drawdown in a pressure can be maintained, the well will produce the desired fluids. A system sensitivity analysis was carried out on the natural flow. IPR and VLP were plotted on the same graph.

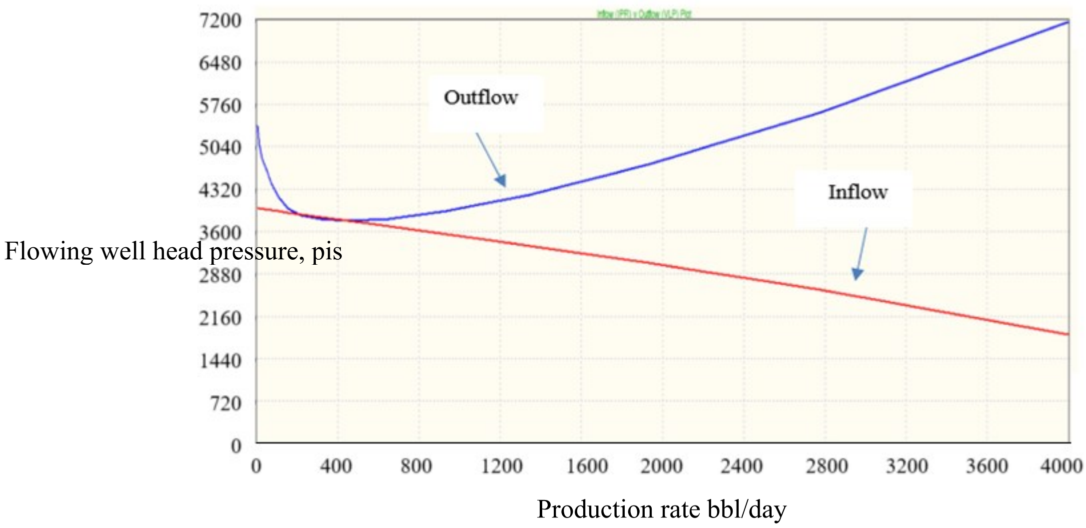


Figure 2. VLP and IPR curves

4.2 Gas Injection Effect

Figure 3 provides the optimum injection rate that constitutes a design parameter for the valve spacing process. After 6 MMscf/day of gas injected, the curve is declining because when large quantities of gas are present in the tubing friction forces prevail in the system (friction is dominant over gravity term reduction) and pressure drops in the tubing become larger, which eventually reduces the production rate.

4.3 The Effect of injection depth on oil flow rate

The injection depth sensitivity of various injection depths for the same injection gas can be analysed [7]. This is done by selecting the gas lift injection rate in variable one of system three variables and injection depth in variable two. As shown in Figure 4 below of injection sensitivities, the deeper injection of gas lift gas rate leads to a rise in the oil rate/or liquid rate. This occurs because, once the gas is injected at a deeper point, this will result in an extra reduction in oil column density inside the vertical tubing. As of lightening the fluid, the hydrostatic pressure will reduce, hence the BHP. In the design consideration of any gas lift system; there is a limit of injection depth, which is just above the tubing shoe. Figure 4 illustrates the effect of the depth of the injection rate vs. the oil flow rate

The results indicate that Production through gas-lifting does not only depend on injection rate, but also can be optimized depth of injection and monitoring the gas-lift supply pressure, total gas available, and other variables. Accordingly, the gas injection rate can be adjusted to yield maximum production rates.

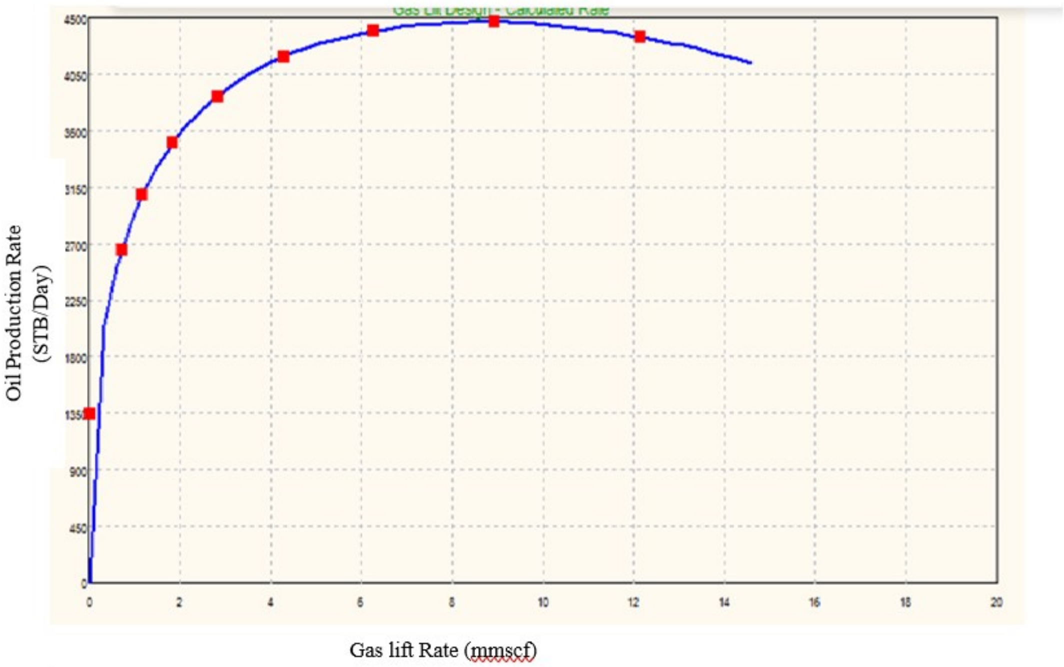


Figure 3. Gas lift optimization

Furthermore, the results indicated that the deeper injection of gas lifts the gas rate and leads to a rise in the oil rate/or liquid rate. This appears as, once gas is injected at an extreme point, this will result in an extra reduction in oil column density inside the vertical tubing.

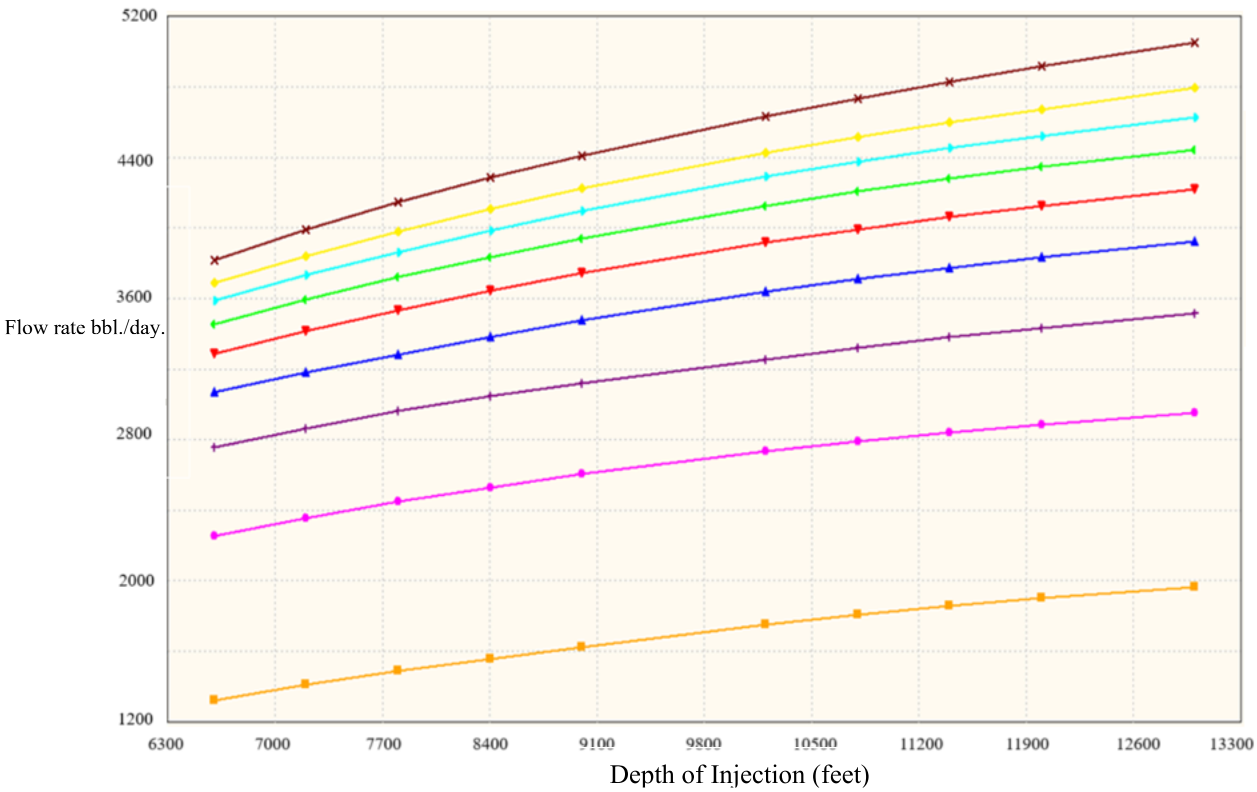


Figure 4. Injections depths vs. flow rate bbl/day

In this work, scenarios were carried out to investigate the effect of injection rate on well performance. Table 5 illustrates the date, which was entered to Prosper Software. The maximum injection depth for this case is 14000 feet, which is the deepest point of the injection.

From the result obtained from PROSPER Software that the well produces from valve number 4 which is at depth 10807.7 md, 8222.59 (TVD) ft. in this case the gas injection pressure and the gas gradient are not able to displace the fluid in the annulus at 1400 feet.

Table 5: Well-input date with depth 1400 ft.

Parameters	Unit
Maximum liquid flow rate 1000	Stb/day
Maximum gas available 4	Mmscf/day
Flowing top node pressure 250	psig
Unloading top node pressure 250	psig
Operation injection pressure 1800	psig
Kick-off injection pressure 1800	psig
Desired deferential pressure across the valve 150	psi
Maximum depth of injection 14000	Feet
Water cut 50	%
Minimum spacing 1500	Feet
Total GOR 780	Scf/stb

Knowing the points at which the pressure lines intersect on a pressure verse depth diagram of the orifice or a valve. However, even if the desired depth of injection was not achieved as stated we still obtained an oil rate greater than our target. It was observed that the gas injection is not at optimum compared to the maximum gas available. Therefore, the newly calculated rate is the optimum rate for this depth where the orifice is positioned. The explanation of this can be associated with the effect that at the specified depth of oil production gas is also produced, so if 4MMscf/day is injected this will lead to pressure losses due to the velocity of gas in the tubing. Table 6 illustrates the results indicated by applying 2049.5 psig injection gas pressure from the surface that reaches to depth 1845.7 feet only.

Table 6: Well, enters data.

Parameters	unit
GLR Injected 1393.9	Scf/stb
Oil rate 3978.35	Stb/day
Gas injection rate 4	Mmscf/day
Measured depth 10845.7	feet
Gas injection pressure 2049.5	Psig

4.4 The Gas Lift Valve Spacing

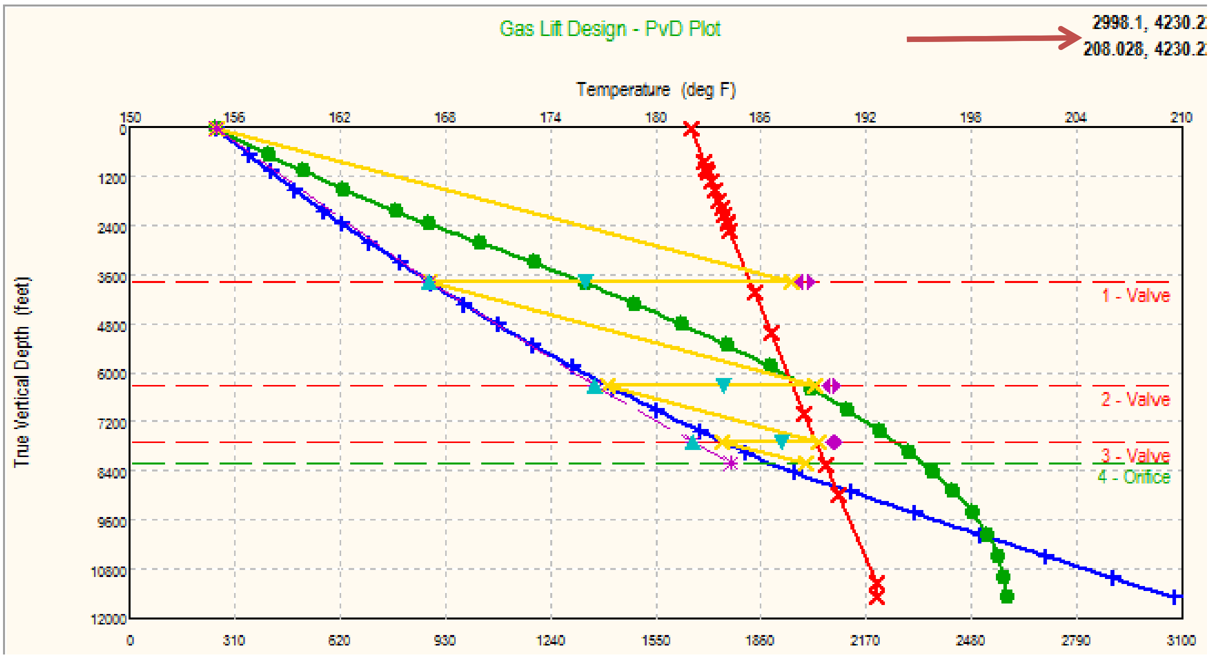
The effect of valve spacing impacts the gas lift optimization of the C-1 well by performing a sensitivity analysis; this was achieved by changing the depth of injection for three different cases to ascertain the effect on liquid production rate. Figure 5 and Table 7 illustrate the gas lift design and the valve setting depth.

Table 7: Valve Spacing Result

Valve	Valve type	MD (ft.)	TVD (ft.)	Tubing Pressure (psig)	Casing pressure (psig)	Opening CHP (psig)	Gas lift rate MMscf/day	Port size 64 inches
1	Valve	4512.76	3371.4	881.915	1997.13	1800	0.3819	8
2	Valve	8086.75	6298.51	1406.9	2069.13	1750	0.3819	8
3	Valve	10034.1	7675.46	1743.9	2076.53	1700	0.3819	8
4	Orifice	10807.7	8222.59	1886.42	2040.11	1650	3.81896	28

4.5 *Stability of system*

It is also of great importance to check the stability of the system. This can be achieved by using two criteria; the first (F1) criterion is by using the inflow response of the well. In a case where the gas lift rate is less sensitive to pressure than the reservoir fluid rate [8, 9], then the average density of the mixture will increase in response to a decrease in tubing pressure. This results in an increase in the tubing pressure, which in turn stabilizes flow. If this is not achieved the tubing pressure will in turn decrease which will lead to the injected gas flow rate increasing more than the liquid flow rate. This will cause tubing and casing pressure to decrease. If the casing pressure decreases faster than the tubing pressure, then the pressure difference between the tubing and the casing pressure will decrease as well as the injected rate.
The second criterion for system stability is that any one of (F1) and (F2) must be greater than one for a stable flow [10]. From the above-stated criterion, it is seen that there is a stable flow.



Reservoir Pressure (psi)

Figure 5. Valve Spacing Result

4.6 Well Design Revised

As seen from the initial case 1, it was clearly observed from tables 8 and 9 that the scenario had stability in terms of the stability criteria F1 and F2 based on Atheism work. The well was redesigned by reducing the depth of injection from 14000 to 10000 feet and another parameter remains the similar as illustrates in the table 8 below.

Moreover, the figures 6 and 7 that illustrates the results that shown that a constant gas injection of 3.9199MMscf/day with injection pressure of 1700psi can deliver 3866.41bbl/day of oil and valve spacing information at various depths, the maximum depth is at 10000 feet. Hence, the red line shows the injection gas pressure gradient, the blue line illustrates the gas lifted flowing gradient, the green line demonstrations the reservoir flowing gradient and the yellow line displays the tubing loading fluid pressure gradient.

Table 8: Well Design Revised

Parameters	**Unite**
GLR Injected 1393.9	Scf/stb
0il rate 3866.4	Stb/day
Gas injection rate 3.9199	Mmscf/day
Measured depth 10000	Feet
Gas injection pressure 1700	Psig

Table 9 demonstrates the redesign results that the well operated with two gas lift valves and one orifice calves located at 10000 ft. with a twenty-two-inch port.

Table 9: Valve Spacing Result for Revised

valve	**Valve type**	**MD (ft.)**	**TVD (ft.)**	**Tubing Pressure (psig)**	**Casing pressure (psig)**	**Opening CHP (psig)**	**Gas lift rate MMscf/day**	**Port size 64 inches**
1	valve	4514.93	3372.93	871.657	1997.13	1800	0.39199	8
2	valve	8129.02	6328.4	1388.36	2069.13	1750	0.39199	8
3	orifice	10000	7651.34	1704	2076.53	1700	3.91988	22

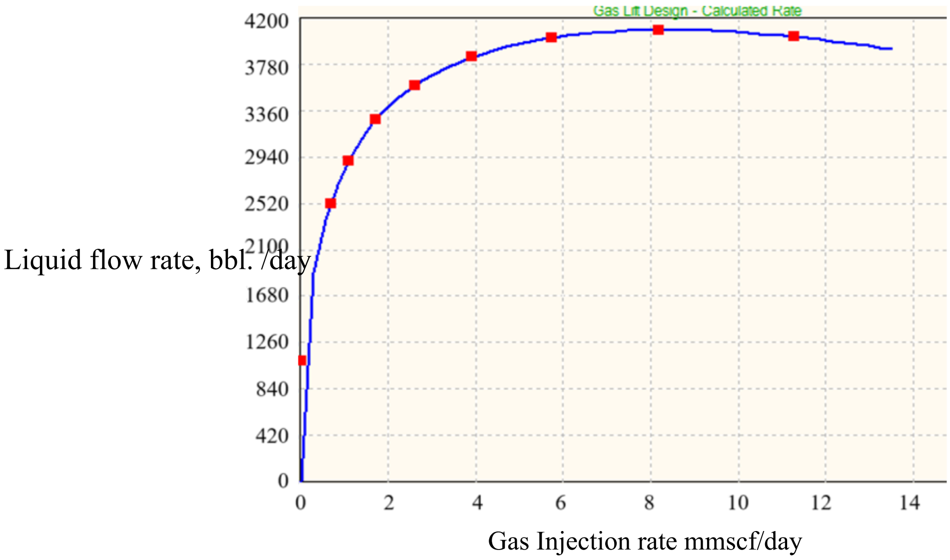


Figure 6. Gas Performance Curve Revised

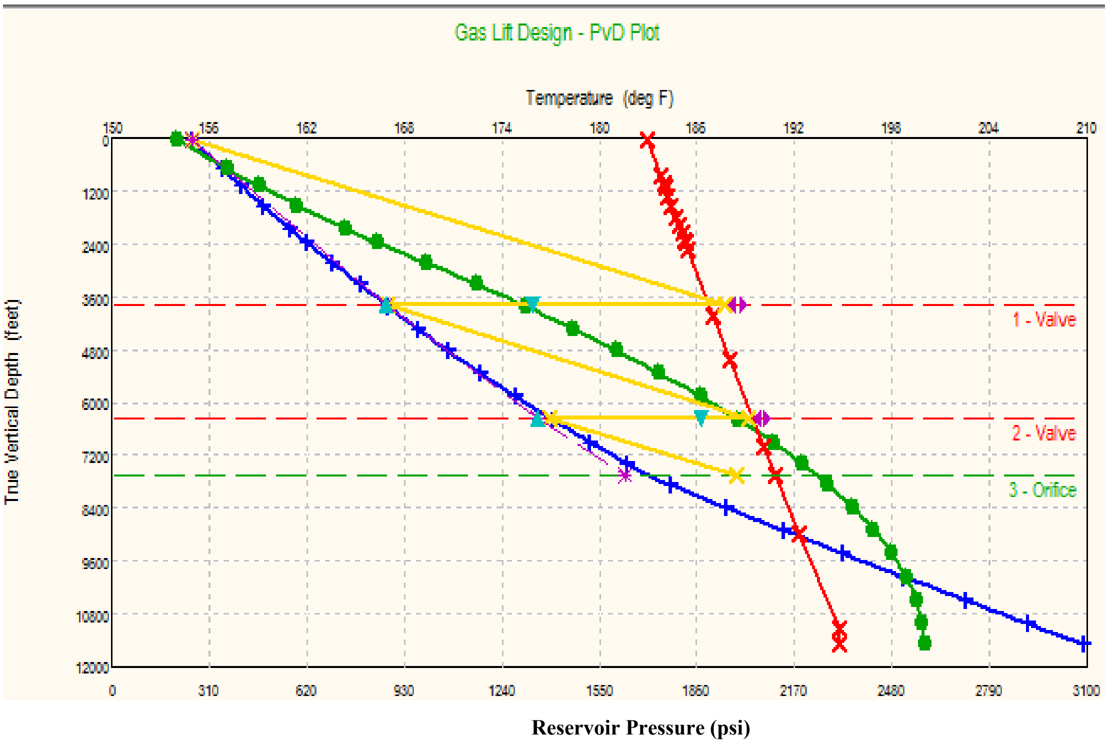


Figure 7. Gas lift design: PvD plot

From the well redesign, it was observed from Figure 7 and Table 10 that at deeper depth the gas rate required for optimum production rate is less. This can be associated with the fact that when oil enters the wellbore, pressure is dropped below the bubble point and gas is produced alongside oil so less gas injection will be needed. Another observation is that at a depth of 14000 feet in case one it required three valves and the orifice but with the revised case 1, the operation requires just two valves and the orifice.

Table 10: The Gas lift design results

Parameters	Unite	Design with injection depth of 14000 ft.	New design with injection depth of 1000 ft.
GLR Injected	Scf/stb	1393.9	1393.9
Oil rate	Stb/day	3978.35	3866.4
Gas injection rate	Mmscf/day	4	3.9199
Measured depth	feet	10845.7	10000
Gas injection pressure	Psig	2049.5	1700
Valve required		4	3

5. Conclusions

This study was carried out to design model systems in the flow simulator PROSPER to analyse a production well using nodal analysis to solve the problem of under-utilisation of continuous gas lift.

- The results show that a constant gas injection of 3.9199 MMscf/day with an injection pressure of 1700psi can deliver 3866.41bbl/day of oil and valve spacing information at various depths, the maximum depth is at 10000 feet.
- From the well redesign, it was observed that at deeper depth the gas rate required for optimum production rate is less. This can be associated with the fact that when oil enters the wellbore,

pressure is dropped below the bubble point and gas is produced alongside oil so less gas injection

- In this paper, the effect of valve spacing on the gas lift optimization of the C-1 well by performing a sensitivity analysis; was achieved by changing the depth of injection for three various cases to ascertain the effect on liquid production rate.

  The result demonstrates that the well will be considerably enhanced in the production of oil from the injection of gas and the depth of injection.

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