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Prosper Software for Gas Lift System Design and Simulation

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ABSTRACT

Artificial lift systems are widely used in the oil and gas industry to improve production rates in wells that cannot produce liquids to the surface under their own pressure. Among various artificial lift methods, the gas lift method is a popular technique used to enhance oil recovery. This involves injecting gas into the well to reduce the density of fluids generated by the reservoir, thereby reducing the weight of the fluid column and allowing the lower reservoir pressure to lift the fluids to the surface. However, building an effective gas lift system requires consideration of present and future operating conditions predicted by reservoir projections. To maximize oil exploration efficiency, it is crucial to evaluate each component of a well system to understand where pressure is lost, and nodal analysis can be used for this purpose. PROSPER software is a useful tool for performing nodal analysis and optimizing artificial lift systems to overcome frictional power losses and improve production rates.

Keywords: PROSPER software; optimizing; production rates; artificial lift systems; oil recovery; reservoir.

1. Introduction

Crude oil is an essential source of energy that plays a vital role in modern civilization, powering transportation and serving as a raw material for many chemical products. Although oil reserves are finite, they are estimated to last for many decades to come, with OPEC reporting a total of 1.3 trillion barrels of oil in proven reserves[1]. As the demand for energy continues to grow, production optimization has become increasingly important in the oil and gas industry. Advances in technology have enabled petroleum engineers to maximize recovery factors and efficiently exploit oilfields. With the constant discovery of new fields and the development of production on existing ones, production optimization has become more crucial than ever before[2].

1.1 Designing Efficient Gas Lift Systems with PROSPER Software

Artificial lift systems are essential for enhancing oil recovery rates in the global oil and gas industry. Most wells require lift technology as they are unable to produce liquids to the surface under their own pressure. Artificial lift systems, especially gas lifts, are widely used in oil and gas wells worldwide to overcome production challenges[2]. Designing an optimized gas lift system using PROSPER software is crucial for efficient production under all operational conditions, including future unfavorable situations based on reservoir projections[3]. The goal of the design process is to ensure maximum production while maintaining economic viability. This article describes the process of designing an efficient gas lift system using PROSPER software.

1.2 PROSPER: Software for Oil and Gas Production Analysis

PROSPER is widely used in the oil and gas industry to design and optimize well performance, from single to multilateral wells. The software is capable of modeling and optimizing most types of well completion and artificial lift methods. Nodal analysis is used to perform sensitivity analysis for different operating conditions, allowing for accurate calculations and better results[3]. PROSPER generates separate models for each component of the well system, which can be verified through performance matching to ensure accuracy. Overall, PROSPER is an essential tool for maximizing production and efficiency in the oil and gas industry.

1.3 Optimizing Well Productivity: Nodal Analysis and Deliverability of Gas Lift Systems

Well deliverability is a crucial factor in the oil and gas industry, as it refers to the ability of a well to produce fluids, such as oil and gas, under different operating conditions. Deliverability is influenced by various factors, including reservoir properties, completion design, and artificial lift systems[4]. One of the commonly used artificial lift systems is the gas lift. It involves injecting gas, typically compressed air or natural gas, into the wellbore to reduce the hydrostatic pressure in the tubing and lift the fluids to the surface[4]. Designing an effective gas lift system requires accurate prediction of the well's performance under various operating conditions.

This is where nodal analysis comes into play. Nodal analysis is a technique used to analyze the performance of individual components of a well, such as a reservoir, tubing, and artificial lift system, and how they interact with each other. It involves creating a nodal network that represents each component and its connections and then applying conservation of mass and energy principles to analyze the fluid flow and pressure drop along the system. In the case of gas lift design, nodal analysis can be used to determine the optimal injection depth and rate, as well as the required compression ratio for the gas lift system[5]. By analyzing the nodal network, the engineer can identify bottlenecks and optimize the system to achieve maximum production rates and economic efficiency.

1.4 Artificial Lift

As a reservoir continues to produce over time, the pressure drops to a level where the oil rate is no longer economically sustainable. This situation can be worsened when the pressure is insufficient to lift the liquids to the surface, resulting in a complete halt in production[6]. To counteract this, artificial lift methods are utilized to prolong or increase production. These methods, which include the use of pumps or gas injection, aim to reduce pressure drop on the wellbore. One of the most commonly used artificial lift methods is gas lift, which involves injecting gas into the well to reduce the weight of the hydrostatic column and increase the flow rate beyond what the existing reservoir pressure would allow[7]. Nodal Analysis is crucial in the design of these methods to optimize production, but financial constraints and field experience should always be taken into account.

1.5 Gas Lift

The gas lift method involves injecting compressed gas into the bottom of the tube through the casing-tubing annulus to boost the oil production rate. This method is not limited by the depth of the well and is suitable for offshore activities. Gas lift is only utilized in wells that produce commercially with relatively high bottom hole pressures, usually in high-productivity reservoirs. The compressed gas improves liquid flow by pushing oil to the surface and aerating the oil, reducing the effective density of the fluid and increasing the pressure differential within the reservoir to achieve the desired flow rate. Nodal analysis is necessary for the design process of gas lift methods to fully exploit their potential in optimizing production, but economic constraints and field experience should also be considered[1].

2. Objectives

Project scope: Gain knowledge about artificial lift systems and their applications in petroleum engineering and oil & gas industry. Build a continuous gas lift system for a well to increase production and prevent shutdown due to current design and operating limitations.

- Find the maximum performance you can achieve with a gas lift.
- Determine the optimal lift gas injection rate and depth.
- Design the operating and unloading valves.
- Identify gas lift applications and limitations.
- Identify the major components of a gas lift system.
- Understand the artificial lift concept.

2.1 Problem Definition

Artificial lift is often necessary when reservoir energy is insufficient for the well or when the desired production rate exceeds what the reservoir can naturally provide. However, one of the major challenges in lifting oil and gas from reservoirs to surface facilities is the potential for decreased production or even complete inability to flow due to the viscous nature of the fluid. This problem poses a significant challenge in the oil and gas industry, and it is essential to develop effective artificial lift methods to maintain or increase production rates.

As oil and gas wells age, their natural reservoir energy declines, making it necessary to use artificial lift techniques to recover the remaining hydrocarbons from the well. However, while artificial lift methods can boost production rates, they also come with their own set of challenges. Factors such as solid/sand handling ability, corrosion/scale handling ability, stability, number of wells, flowing pressure and temperature limitations, well depth, production rate, flexibility, high GOR, electrical power, space, and economics must all be considered before deciding on the most suitable artificial lift technology. Ignoring these factors can lead to inefficiencies, reduced lifespan of equipment, and economic losses. As such, proper evaluation and selection of artificial lift systems are crucial for maximizing oil and gas production while minimizing operational and maintenance costs.

2.2 Methodology

To combat the declining production in an offshore field in the Niger Delta, the operator identified gas lift as the most feasible solution to restart or sustain a flow in 45% of the wells on two platforms. By optimizing gas lift, it was estimated that 60% of total production could be secured and enhanced. To achieve this objective, a methodology was developed to ensure success at the site[8].

2.3 Planning

The flow of the Project:

- Well Modelling
- Construction of IPR Curve
- Construction of VLP Curve
- Input Gas lift Data
- Design a Gas lift Well
- Finalization of the well Design and Model
- Reviewing the Design and Model

3. History

3.1 Development Techniques

In the field of Petroleum Engineering, artificial lift techniques are employed to increase the flow of liquids in wells, especially when the reservoir pressure is insufficient to provide sustainable oil production. This method involves the use of mechanical means like pumps or methods that modify the physical properties of the reservoir fluid within the tubing. Gas lift technology, which is a form of artificial lift technique, involves injecting gas into a tube through an annulus, primarily through a valve, to reduce the density of the fluid and lower the required bottom pressure. This results in an increase in the oil flow production rate, making it an important technology in the oil and gas industry, especially in literature fields with decreasing pressure and increasing energy demand.

Gas lift is a widely used artificial lift technique in the oil and gas industry, especially for large fields to improve productivity[9]. However, the performance of gas lift can be affected by various factors, including high water cuts which can lead to reduced oil production or even well shutdown due to higher bottom-hole pressure. Optimizing gas lift operation requires taking into account several factors such as gas injection rate, injection pressure, availability of lift gas, compressor capabilities, and water handling facilities. Achieving an optimal allocation of lift gas injection rate for each well in a network system can be a daunting task due to these limitations. Thus, careful consideration and optimization are essential for successful gas lift operation in the field.

There are various optimization techniques that have been described in the literature to optimize continuous gas lift systems. One such technique is the single well analysis technique that employs nodal analysis to produce the gas lift performance curve of a single well based on actual pressure and temperature surveys along with a suitable multiphase flow correlation. In this technique, each well is considered in isolation from the others, assuming a constant wellhead or gathering-system pressure. This assumption may hold true in cases where the wells are choked at the wellhead to maintain stable wellhead pressure, multiple wells are joined at the separator under the same pressure control system, or the pipeline network is dominated by the pressure drop across the well tubing.

Various optimization techniques have been proposed in the literature to optimize continuous gas lift systems. One such technique is the single well analysis technique, which uses nodal analysis to produce the gas lift performance curve of a single well based on actual pressure and temperature surveys, along with a suitable multiphase flow correlation. However, this technique assumes constant wellhead or gathering-system pressure, which may not be true in all cases. To address this, other optimization techniques have been proposed, such as the equal-slope method and the use of Gas Lift Performance Curves (GLPCs) to maximize oil production while minimizing injection costs. Linear programming has also been used to optimally allocate gas injection with flow rate limitations[8]. Additionally, gas lift optimization has been practically assessed on offshore wells using step-rate injection to construct the well performance curve for optimum gas injection rate while reducing flow obstruction due to freezing and monitoring well stability.

Dynamic programming algorithm method has been used to allocate gas injection rate optimally. However, the cost for this type of solution is considerably higher compared to the single-well solution. The particle swarm algorithm developed by others has also been used along with a penalty function for optimum gas allocation in some wells to obtain a fast result and accurate model. However, implementing this approach in a routine industry environment could be very challenging. Another study worked on a large Iraqi field to achieve the optimum design of a gas lift that covers many unsolved difficulties[1]. They created a new model intended for matching PVT data, matching vertical pressure drop calculations, creating sensitivity analysis of productivity index variation, making sensitivity analysis of wellhead temperature variation, the action of optimum design of the gas lift, and finding optimum values of injected gas rate and oil production.

The optimization techniques discussed earlier have certain limitations, such as the inability to handle network systems and neglecting back pressure and facility constraints. These conventional methods are not suitable for accurately modeling and simulating large network systems due to the high computational time required and the possibility of obtaining misleading results. In addition, finding a local solution to the problem is part of the suboptimal solutions[10]. Therefore, to overcome these issues, dynamic global algorithms may be necessary. One example of such an algorithm is the derivativefree algorithm presented by researchers who used a heuristic method to optimize gas lift distribution by addressing the issues of non-instantaneous flow (NIF) and unsmooth curves for a significant number of wells.

3.2 Background example of this Field Corvina block Z-1 Peru offshore

Automatic gas lift systems are designed to optimize production and reduce operating costs by utilizing gas from the reservoir to lift oil to the surface. This process reduces the density of fluids produced, allowing for proper flow to the production facilities. These systems are commonly used in wells completed in gas and oil locations, and the gas is used to lighten the oil column, allowing it to be produced more efficiently. Compared to traditional gas lift systems, automatic gas lift systems require less capital investment to build the necessary equipment, such as compressors, separators, dehydrators, and distribution lines. However, the design of the downhole flow control valve in the gas area must be carefully considered to ensure that it can handle the gas volume and oil sand performance, fluid composition, and reservoir pressure throughout the life of the well.

The mesh adaptive direct search (MADS) method is an optimization technique that does not require the use of derivatives and can be effective for systems with noisy or discontinuous structures. This method is particularly useful when solving optimization problems for conditions that may be viable but difficult to solve using traditional techniques. MADS works by iteratively evaluating function values at different points in the search space and adapting the mesh size and pattern based on the function evaluations to find the optimal solution. The method is widely used in various applications such as engineering design, economics, and machine learning. MADS has shown promising results in solving complex optimization problems and is a valuable tool in the field of optimization.

3.3 STATEMENT OF PROBLEM

It is important to note that while crude oil reserves may seem abundant at present, they are a finite resource that will eventually run out. This is why production optimization is crucial to extract the maximum amount of oil from a reservoir while minimizing waste and maximizing efficiency. With advancements in technology, such as improved reservoir modeling and enhanced oil recovery techniques, engineers are able to increase recovery factors and extend the life of oilfields. However, it is also important to invest in alternative sources of energy and work towards reducing our reliance on fossil fuels in order to ensure a sustainable future.

4. Experimental Method

4.1 PROSPER Simulator

PROSPER is a widely used software package in the oil and gas industry for the production and well performance analysis. It allows engineers to model and simulate different scenarios to optimize well performance and increase production. PROSPER can handle various variables such as well configuration, fluid properties, and multiphase flow correlations, making it a versatile tool for production optimization. Its ability to analyze and optimize existing systems also helps companies identify areas for improvement and reduce production costs.

4.2 ALPHA Field WELL A-1 Data summary

Table 1PVT DATA

Property	Value
Pressure	2240 psig
Gas oil ratio	493 scf/stb
API gravity	38.7 API
Gas specific gravity	0.798
Viscosity	0.42 Cp
Water salinity	80000 Ppm

Table 2 WELL DATA

Name	Value
KOP	1000
building angle rate	3 degree/100
target inclination	45 degree
target tvd	11500 ft.
wellbore diameter at the pay zone depth	8.5
tubing id diameter	4.052
production packers	11000 TVD
overall heat transfer coefficient	8.2 BTU/hr/ft2/F.
subsurface safety valve (sssv) of internal diameter	3.72 has set at 800

Table 3 IPR DATA

Parameter	Quantity
RESERVOIR PRESSURE	3800 psig
RESERVOIR TEMPERATURE	250 °F
WATER CUT	20.3%
PI	9 STB/day/psi

Table 4 DEVIATION SURVEY

MEASURED DEPTH (feet)	TVD (feet)
0	0
1000	1000
1100	1099.9
1300	1298
1500	1494
1800	1776.5
2000	1954.5
2200	2122.2
2400	2277
2500	2348
2715	2500
4836	4000
6250	5000
9079	7000
11907	9000
15443	11500

Table 5 DOWNHOLE EQUIPMENT INPUT DATA

Type	Measured Depth (feet)	Tubing Inside Diameter (inches)	Tubing Inside Roughness (inches)	Tubing Outside Diameter (inches)	Tubing 0utside Roughness (inches)	Casing Inside Diameter (inches)	Casing Inside Roughness (inches)	Rate Multiplier
Tubing	800	4.052	0.0006	4.5	0.0006	6.4	0.0006	1
SSSV	-	3.72	-	-	-	-	-	1
Tubing	14900	4.052	0.0006	4.5	0.0006	6.4	0.0006	1
Casing	15443	-	-	-	-	6.4	0.0006	1

Table 6 GEOTHERMAL DATA

DEPTH (feet)	TEMPERATURE (°F)
0	70
4000	250

A representation of the downhole equipment, is obtained by PROSPER, is presented below

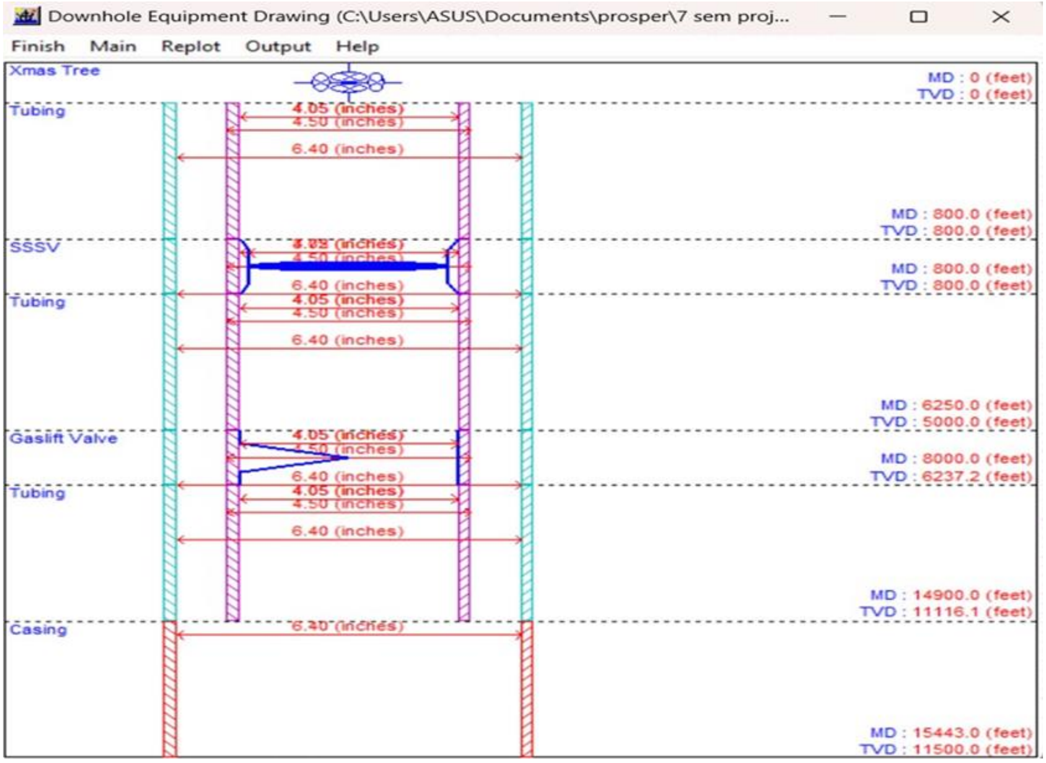

Figure 1 Schematic of the downhole equipment

4.3 System summary

In this section, the most characteristics of the well are entered. As a continuous gas lift system is near to be designed, the suitable choice at the artificial lift possibility is created as seen below. the options chosen are the following:

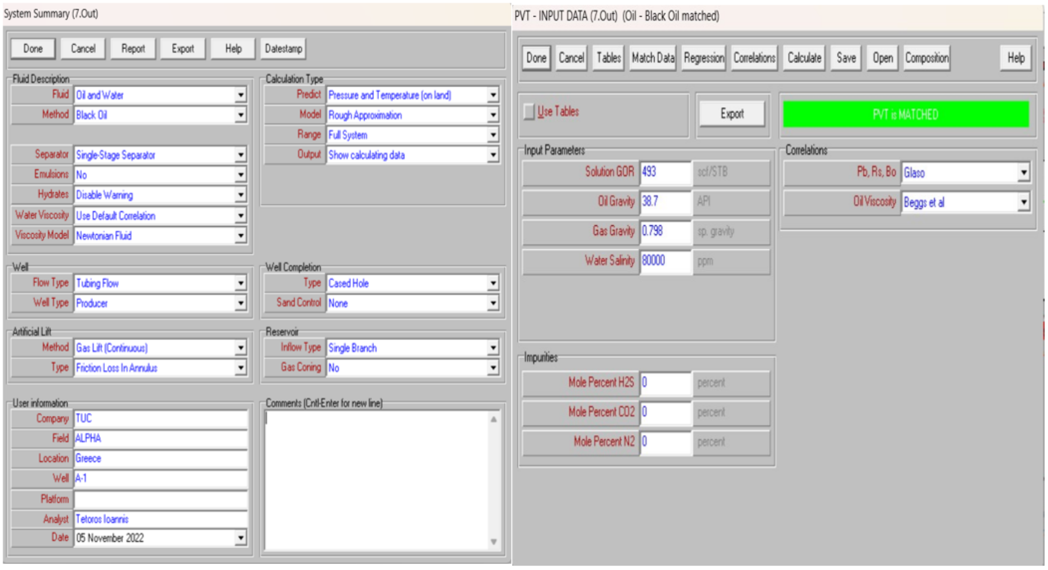

Figure 2 (a) Prosper System Summary interface (b) Input PVT data interface

4.4 IPR Data Entry Interface

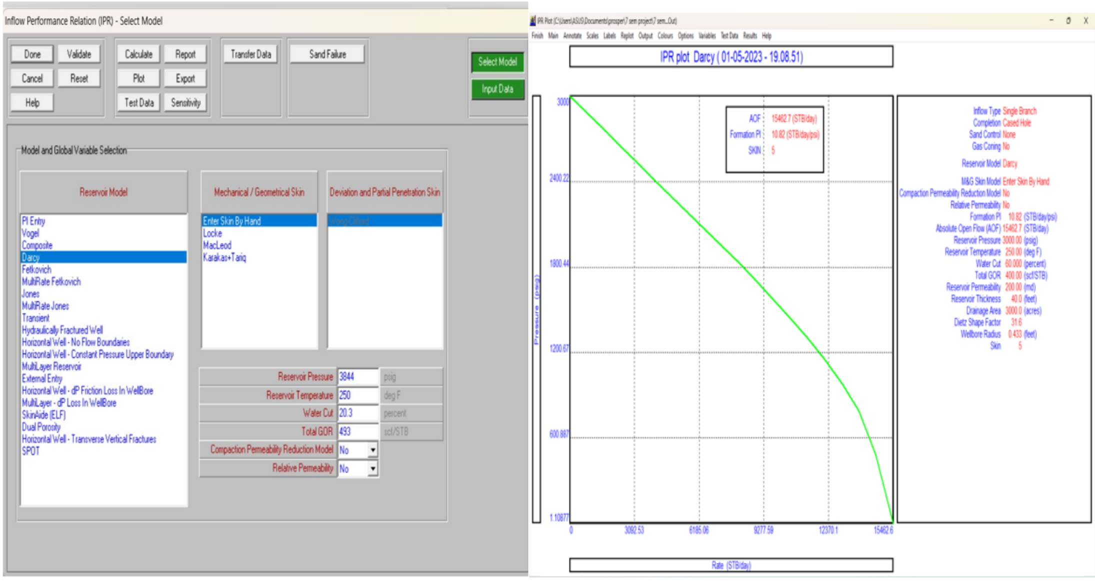

Figure 3 (a) Select IPR Model (b) IPR Curve

4.5
IPR/VLP Matching

The final step of the well found out is that the IPR/VLP matching section. Since the VLP is currently matched and trusted, it should be examined whether or not the reported liquid rate at the surface from well test one i.e. the intersection between the IPR and the VLP curve is close to of the operative point.

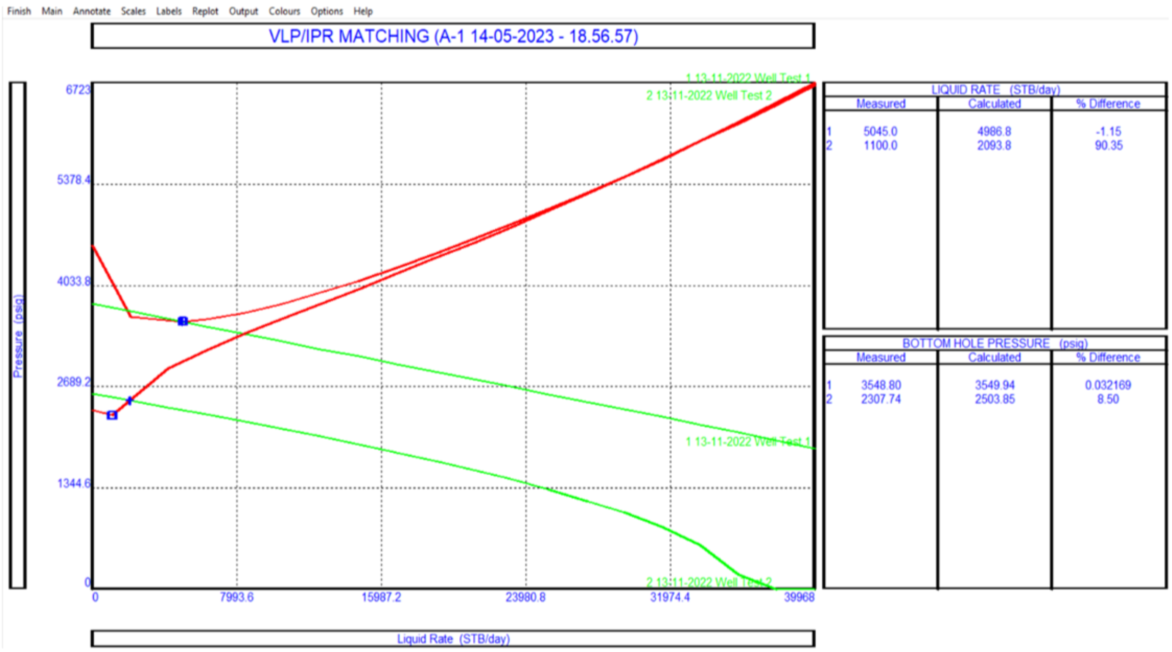

Figure 4 IPR Vs VLP Curve

4.6 Gas Lift Input Data

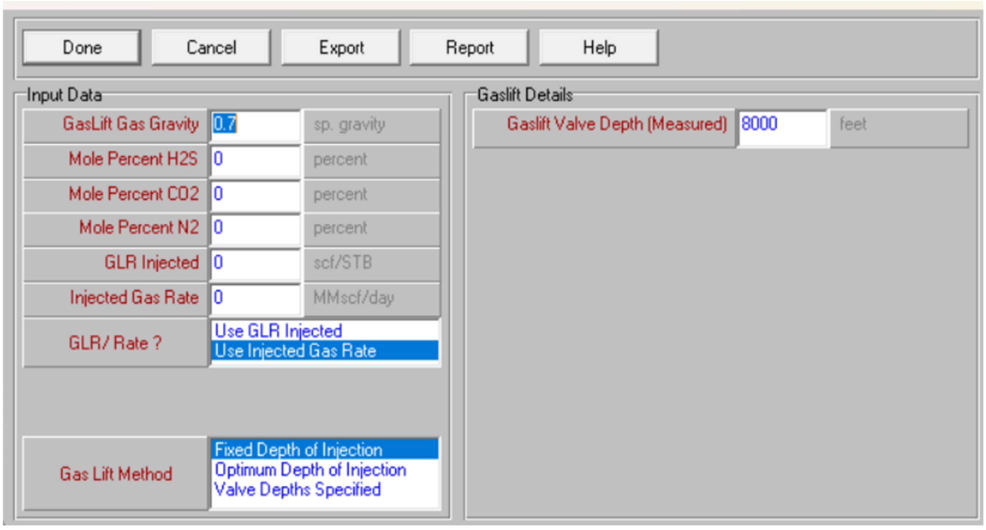

Figure 5 Input Gas Lift Data

5. Result and Discussion

5.1 Gas Lift Design Process

The first step is to generate the IPR curve for the new reservoir conditions. New Pr and water cut level are used as input in the IPR section of PROSPER. The next step now is the design of a new continuous gas lift system. In the main gas lift design screen, the following input data are inserted.

Taking average reservoir pressure 2850 psig and water cut 50%. We use the maximum injection depth set at 14000 feet MD. Calculations will come to an end if it is determined that the next valve is located at a depth of less than 250 feet. The static pressure gradient of the finishing fluid, a brine with a weight somewhat more than that of pure water, is 0.45 psig/ft. Finally, normal R- 20 valves manufactured by Camco are selected with port sizes varying from 8 to 32 64th inch. After the introduction of the basic data input, the design process takes place. The optimum injection rate calculated by PROSPER can be seen at the top of Figure 6(b). The optimum gas injection rate according to the calculations is 8.000 MMscf/day, the maximum gas injection rate available. The gas lift performance curve is plotted in Figure 7(a)

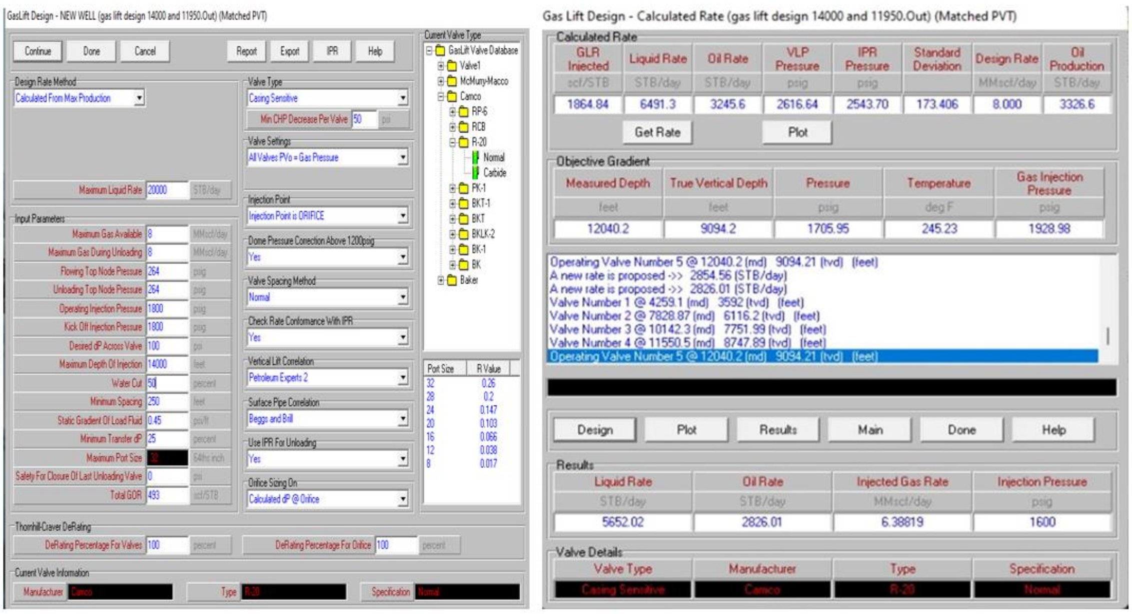

Figure 6 (a) Gas lift design input: Main screen (b) Gas lift design: Calculated Screen

If Figure 6(b) is recurred, at the bottom of the design screen and after the valve spacing process, the final operating conditions are visible. A constant gas injection rate of 6.38819 MMscf/day with an injection pressure of 1600 psig, can deliver 2826.01 bbl/day of oil. The maximum depth of injection of 14000 feet MD has been reached by the PROSPER design.

The final step in the gas lift design process is to ensure that the system is stable. By checking the both criteria F1&F2 should be greater than 1 for stable flow. The system is deemed unstable and the design has to be revised if both numbers are less than one. A gas lift system is unstable in this situation because Criteria F1 and F2 equal 0.71 and 1.21, respectively (Figure 7(b)). It is emphasized that adjustments to the design parameters are necessary to guarantee stability.

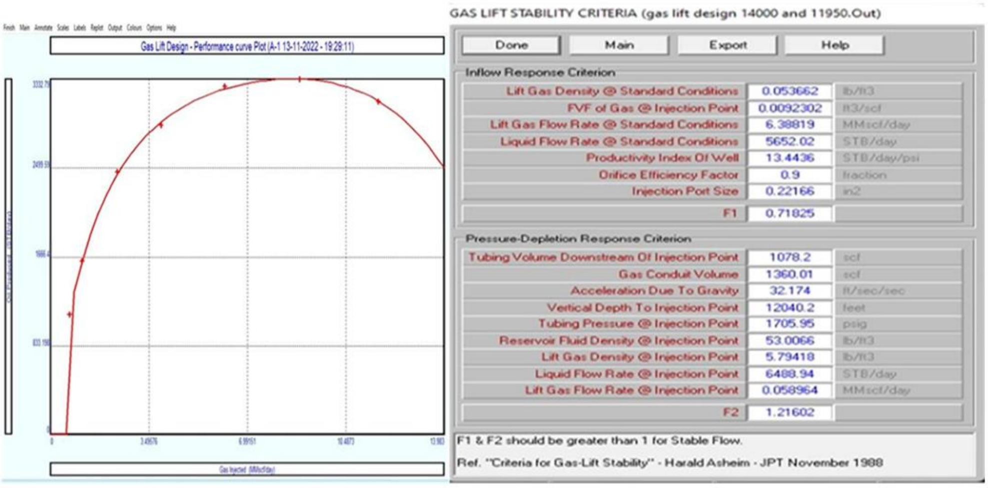

Figure 7(a) Gas lift: Performance Curve (b) Gas Lift: To check Stability Criteria

5.2 Revision of Case

According to Asheim's original research-based stability criteria F1 and F2, the fundamental situation is unstable. The modification to the maximum injection depth is the sole distinction between Case and the updated version discussed in this section.

The maximum injection depth is set at 11950 feet Measured Depth rather than the previously established 14,000 feet Measured Depth, which is the only difference from upper Case.

The design process starts after the fundamental data input is introduced. The bottom of Figure 8(b) displays the PROSPER-calculated optimal injection rate. Figure 9(a) shows the performance curve for gas lift. The calculations show that 7.154 MMscf/day, the highest gas injection rate possible, is the best gas injection rate.

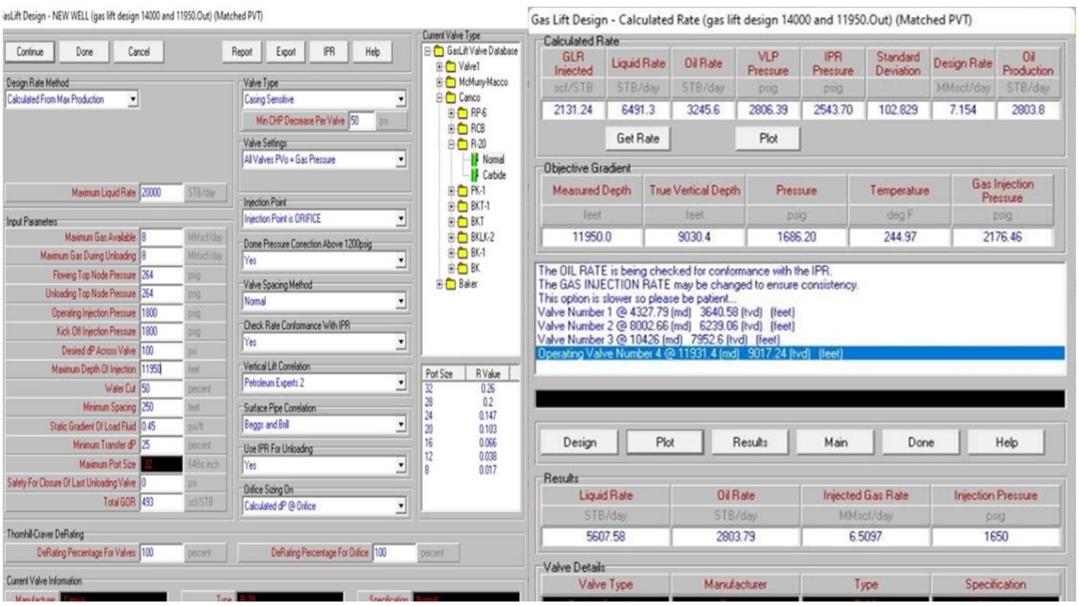

Figure 8 (a) Gas lift design input: Main screen (b) Gas lift design: Calculated Screen

2803.79 bbl/day of oil may be produced with a constant gas injection rate of 6.5097 MMscf/day and an injection pressure of 1,650 psi.

A stable gas lift system is present in this instance, as shown by Criteria F1 and F2 being equal to 1.03 and -10.06, respectively in (Figure 36).

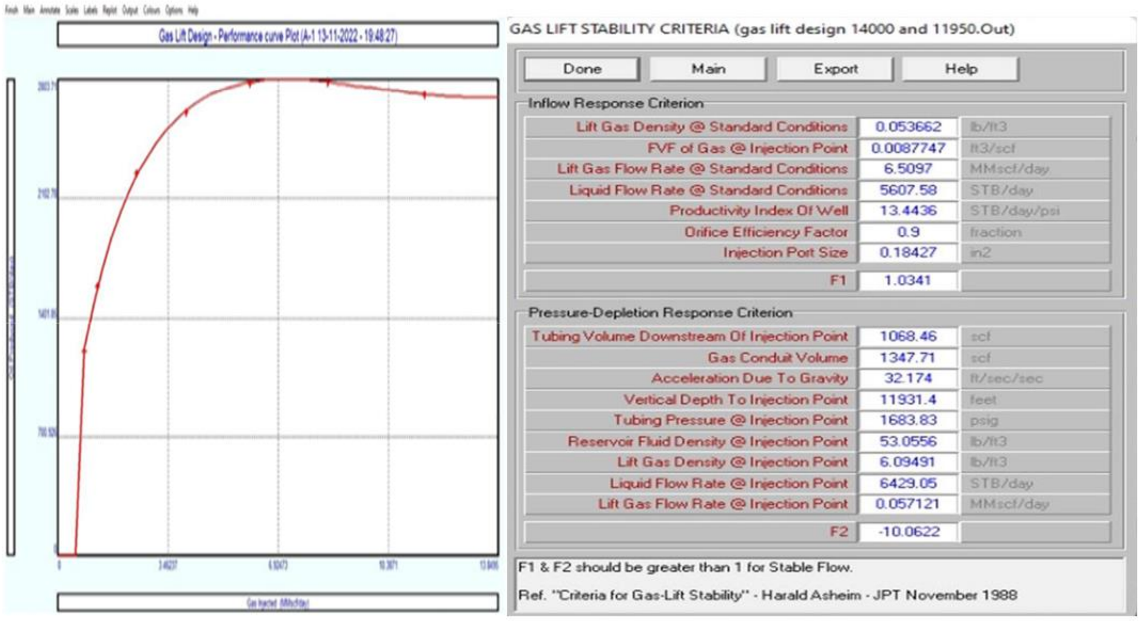

Figure 9 (a) Gas lift: Performance Curve (b) Gas Lift: To check Stability Criteria

Conclusion

The primary objective of this project was to develop a continuous gas lift system for a poorly designed and operated well that was scheduled to be shut down in the near future. PROSPER was employed to create a complex mathematical model that took into account several sub-models to predict potential fluid production rates under different operating conditions. We successfully modelled all of the well characteristics, including IPR curves, PVT data, downhole equipment, and temperature profiles along the well.

However, during the VLP/IPR correction, we discovered some discrepancies between the simulated and measured results. We had to change the IPR curves since the VLP curves had already been fitted. We fit the IPR using either Pr or S and conducted a series of sensitivity analyses at different water cut levels and peak nodal pressures to gain a better understanding of the well's behavior.

One of the key challenges we encountered was the possibility of jeopardizing the entire system if the gas injection took place at a very deep point (14,000 feet). Although this increased injection depth could lead to greater oil rates, it also posed a risk to the gas lift system.

It is important to note that production optimization problems are incredibly complex, and it is not possible to optimize every well individually. When dealing with multiple wells, a comprehensive field optimization program such as GAP from PETEX is required to maximize income and ensure the efficient operation of the entire field. While our project yielded successful results, it is critical to consider the bigger picture and the impact on the entire field.

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