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DESIGN OF CONTINUOUS GAS-LIFT FOR A DEAD WELL AND STEP-UP OF ITS PRODUCTIVITY

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Summary

The present paper aims to design a continuous gas-lift system in order to activate the dead well X and optimise the recovery of hydrocarbons by gas injection. The data taken into account are those of the reservoir and the well. All the simulation operations and the well diagram are carried out with the PIPESIM 2017 2.0 software. Moreover, the nodal analysis of the dead well X is carried out by finding the injection pressure of the gas in the well. The number of valves to be installed, the optimal injection heights and the flow rates received by each valve are also included in the gas-lift device. Then the evaluation of the system performance as well as the sensitivity analysis are carried out to make it possible to fix the optimal flow rate of production. The results obtained show that for a continuous gas injection of 3 million standard ft^3 per day (MMscf/d) per valve into the well with a wellhead pressure of 2,500 psi and an optimal flow rate of 2,718 standard barrels per day (STB/d), a profitability of USD 182,887,219 is obtained. In this field, this design can be applied to all wells having a production tube of 2.5 inches inside diameter. On the other hand, wells with different diameters will require a new evaluation.

Key words: Non-eruptive well, gas-lift, nodal analysis, PIPESIM software, production optimisation, economic evaluation.

1. Introduction

Crude oil is the most important natural energy source in the world because the modern civilisation and its remarkable achievements would not exist without oil. What makes it so important in our daily lives is its wide variety of uses. Apart from refuelling cars and planes, etc., its components can be used to make many kinds of chemicals such as plastics, drugs, detergents, and many more things [1 - 3].

The exploitation of crude oil contained in the subsoil goes through several stages, namely: prospecting, exploration, development and production [4, 5]. The main factor governing the gas-lift is the availability to reinforce

the pressure if the quantity of gas is high enough. Gas-lift is the most common well activation method, especially in offshores, with the principle of reducing hydrostatic pressure by injecting gas into the well [6, 7]. The gas-lift promotes the optimisation of production when the effluent no longer has enough energy to reach the surface under the conditions set by the process [8 - 10].

The reasons for using gas-lift are multiple, such as cleaning a well (crossover), restarting the well, and lightening the production string [11 - 13]. Two methods are mainly used for the activation of a well: The pumping method and the gas-lift method [14 - 17]. The dead well studied in this article is designated as well X for confidentiality reasons. The field designated as well X has been developed by using 5 wells and reached its peak production in 1997. Since then, production from the oil well has rapidly declined due to an increase in water

content. An economic limit of 1,500 barrels of oil has been set. Producing at lower rates is not economical. With regard to the static pressure of the reservoir, the gas-lift method is the most appropriate for well X [6, 18]. Continuous gas-lift is an artificial-lift method that consists of injecting gas through the producing well to lower gravity pressure losses in order to reduce the pressure at the bottom of the well [19]. This gas-lift application is based on several injection and production parameters as well as process modelling to facilitate decision-making. What mainly concerns this article is to optimise the production of the dead well X by the continuous gas-lift activation method. Therefore, finding the optimal gas flow rate to be injected downhole to lighten the hydrostatic column is at the forefront. The aim here is to improve the productivity of the dead well X by determining both the operating parameters of the gas-lift and the production prediction. The paper is sliced into four sections: the first one presents the introduction; the second devotes to the presentation of data; the third highlights the obtained results and the last is for conclusion.

2. Materials and methods

The data used for this study are divided into different categories: pressure-volume-temperature data, well data, reservoir data, gas-lift data, and well test data. Table 1 presents the data of the reservoir, the pressure-volume-temperature (PVT), and the well.

Under current reservoir conditions, it is single-phase as the reservoir pressure is above the bubble point. The main equipment installed is presented in Table 2.

In the study, the nodal and sensitivity analyses are performed by using PIPESIM 2017 2.0 software.

3. Results

This section presents the results of the nodal analysis, the sensitivity analysis and the economic evaluation obtained from the data of the reservoir, the pressure-volume-temperature and the well.

Table 1. *Reservoir, pressure-volume-temperature, and well data*

Reservoir data		
Parameters	**Values**	**Unit**
Pressure	4,200	psi
Temperature	220	°F
Productivity index	1.82	STB/day/psi
Pressure - volume-temperature data		
Temperature	109	°F
Bubble pressure	4,080	psi
Bubble temperature	197	°F
Formation volume factor (FVF)	1.87	Rb/STB
Well data		
API density	42.30	°API
Gas specific gravity	0.84	-
Gas oil ratio (GOR)	1,577	SCF/STB
Water cut	89.50	%
Specific gravity of water	1.20	-

Table 2. *Well equipment data*

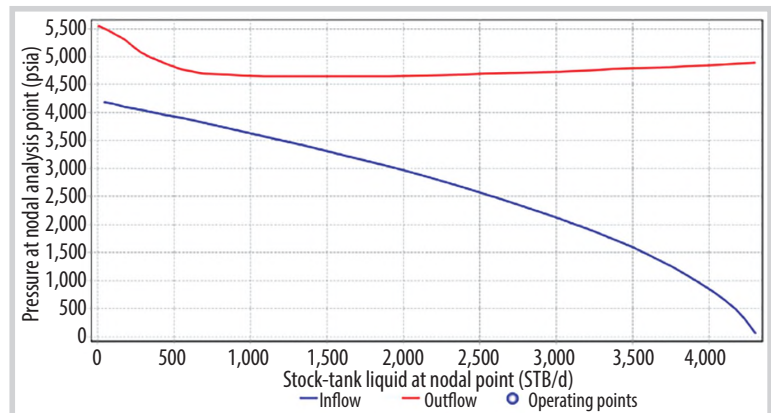| Equipment		Depth (ft)
Christmas tree		0
Casing	Conductor pipe	1,000
	Surface casing	5,000
	Intermediate casing	9,000
	Production casing	11,306
Tubing		11,000
Packer		10,597
Perforation		11,165

Figure 1. *Nodal analysis of the non-eruptive well X.*

Table 3. *Optimal flow with different gas injection rates per day*

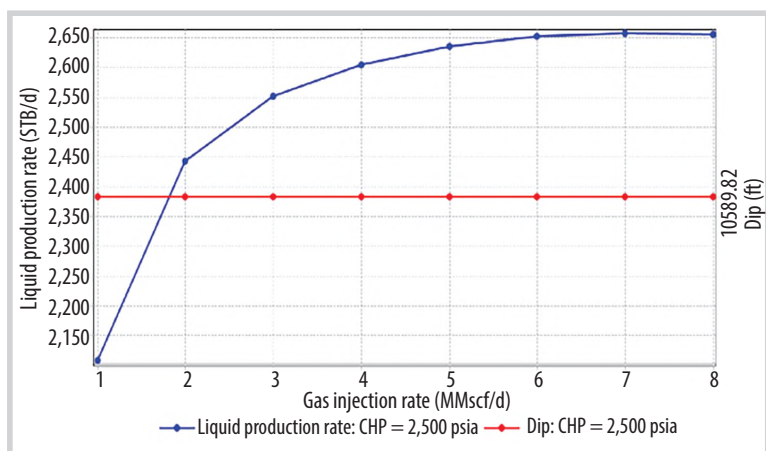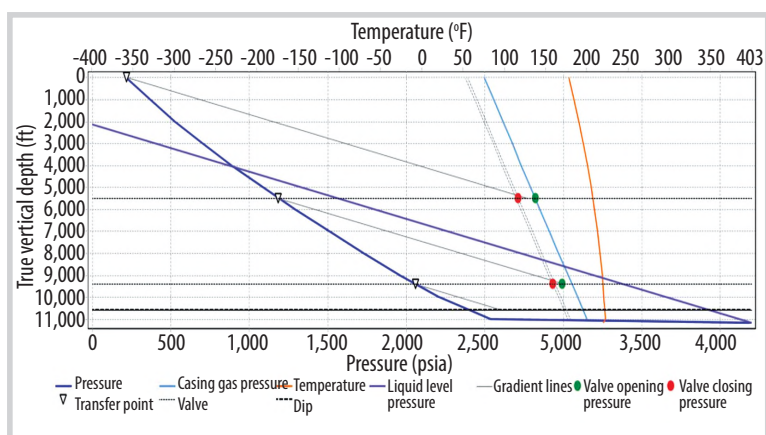| Case	Casing head pressure (psi)	Qgi (MMscf/d)	Ql (STB/d)	DIP (ft)
1	2,500	1	2,107.69	10,589.82
2	2,500	2	2,441.22	10,589.82
3	2,500	3	2,550.61	10,589.82
4	2,500	4	2,604.14	10,589.82
5	2,500	5	2,634.80	10,589.82
6	2,500	6	2,650.82	10,589.82
7	2,500	7	2,656.61	10,589.82
8	2,500	8	2,654.54	10,589.82

Figure 2. Gas-lift performance curve.

Figure 3. Shaft gas lift design.

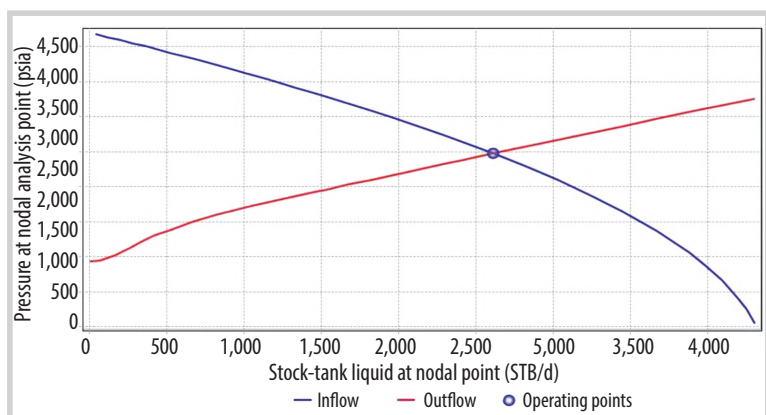*Figure 4. Diagnosis of gas-lift.*

Table 4. Comparison of oil flow rates before and after completion

Before completion		After completion	
Oil flow	P_{wf}	Oil flow	P_{wf}
0 STB/d	4,200 psi	1,400 STB/d	3,163 psi

Table 5. Results of the pressure variation at the wellhead

Wellhead pressure (psi)	Downhole pressure (psi)	Q (STB/d)
50	2,329	2,776
150	2,687	2,687
350	2,474	2,474

3.1. Nodal and sensitivity analyses

Figure 1 shows the evolution of the inflow performance relationship (IPR) and vertical lift performance relationship (VPR) curves of the studied well X.

Figure 1 shows that the operating point does not exist. The well has lost all its natural energy with regard to the distancing of the curves. This reflects the non-eruptive nature of well X and, hence, the need to activate this well by the gas-lift method to make it a producer again. The development of a gas-lift passes through the stages established in [20]. The gas-lift response generates the maximum depth of gas injection into the production tube, and the maximum gas flow necessary to produce maximum oil at the surface. The variation in flow rates and the gas-lift performance curve are shown in Table 3 and Figure 2, respectively.

In Figure 2, the result of the simulations of the response of the well to a gas injection calculates the maximum gas injection pressure casinghead pressure (CHP) = 2,500 psi, and gives the maximum injection depth of 10,590 ft and an optimal injection rate of 3 million standard ft^3 per day (MMscf/d). Table 3 gives a summary of the scenarios carried out for up to eight cases. The optimum gas injection point in the well is calculated according to the height, the pressure, the temperature, and the absolute open flow of the well at the moment when the pressure at the well bottom is higher than tank pressure as shown in Figure 3.

Figure 3, in addition to the first valve placed at 10,590 ft, two other valves will be placed above it to maximise production at the respective depths of 9,402 ft and 5,488 ft. With the installation of the new gas-lift equipment in well X, a depression in the well can therefore be created, until the pressure in the reservoir again becomes higher than the pressure recorded at the bottom of the well. From this moment, well X will be able to deliver a manageable oil flow to the surface. Gas-lift performance results are shown in Figure 4 and Table 4, respectively.

In Figure 4, the meeting point of the IPR/VLP curves gives, after installation of the gas-lift device, a production pressure at the bottom of the well of 2,500 psi for an approximate flow rate of 2,600 standard barrels per day (STB/d). This aspect follows a pattern similar to that of the study [21] on optimisation using smart pump gas-lifts. In Table 4, the production rate does not correspond to that desired by the company, which is 2,600 standard barrels per day, hence it is necessary to optimise this well using sensitivity analyses.

The fluid outlet pressure at the wellhead and the gas injection rate will be analysed. Reservoir pressure is the key to ensuring reservoir production [6]. When a well is put into production, the flow gradually drops with the pressure. The wellhead pressure sensitivity analysis yielded the results summarised in Table 5.

Oil production increases when wellhead pressure drops. Figure 6 presents the results of well performance as a function of wellhead pressure.

In Figure 5, the curves are obtained for the wellhead pressures of 50, 150 and 350 psi respectively for flow rates of 2,776, 2,687 and 2,474 standard barrels per day. Figure 6 and Table 6 show the results of the gas injection sensitivity analysis.

When the injection rate increases, so does the production rate. Thus, it is wise to increase the injection rate at the surface in order to optimise production. Table 7 and Figure 7 illustrate the optimum values and the optimum productivity curve, respectively.

3.2. Economic evaluation

The optimisation of well X activated by gas-lift (gas injection rate of 3 million standard ft^3 per day) makes it possible to produce at a constant rate for 3 years with a continuous injection of gas, hence it is necessary to make an economic evaluation to know the profitability of this method. The parameters to be taken into consideration are the following: expenses, income and profit. Expenditures are
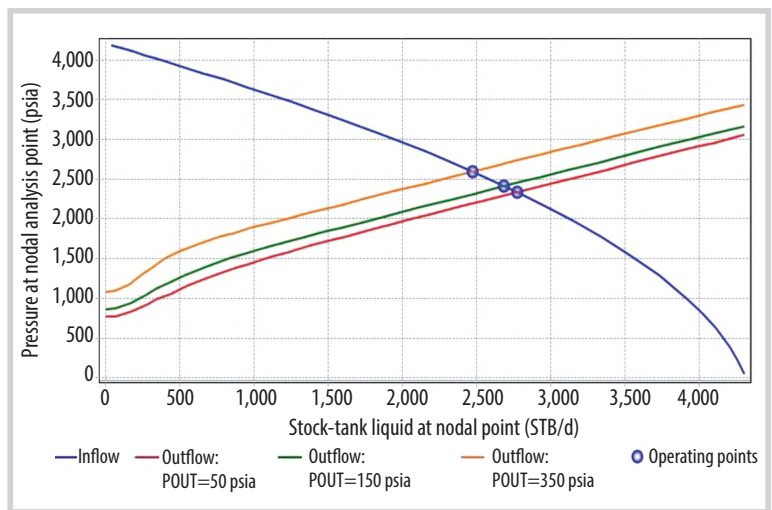

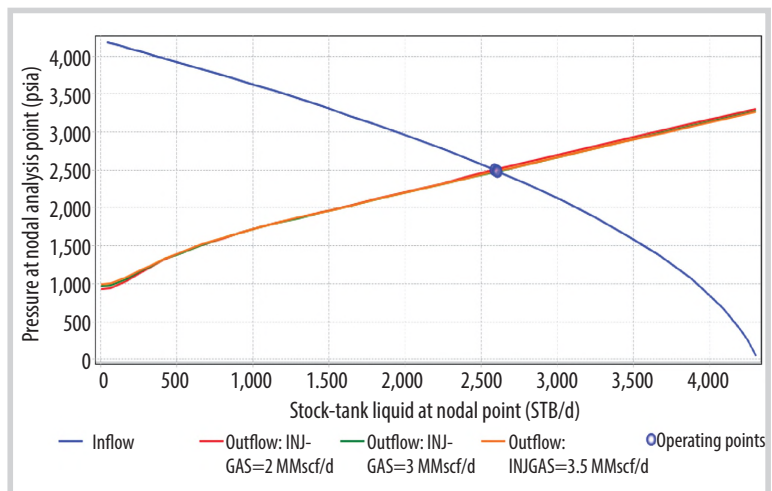*Figure 5.* Operating point as a function of wellhead pressure.
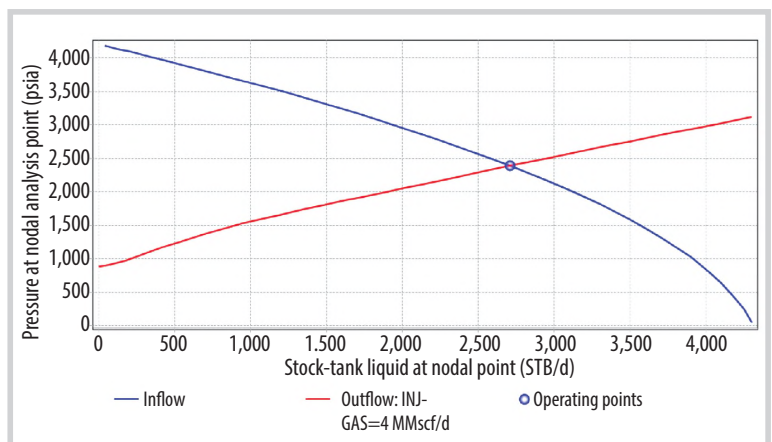

Figure 6. Gas injection rate sensitivity.

Figure 7. Optimal production curve.

Table 6. Gas injection rate sensitivity results

Gas injection rate (MMscf/d)	Oil flow (STB/d)
1	2,420
2	2,570
3	2,600

Table 7. Optimal parameters

Parameters	Values
Pressure (psi)	100
Injection rate (MMscf/d)	3
Optimal diameter (inch)	2.5
Optimal flow (STB/d)	2,718

Table 8. Capital expenditure (CAPEX) and operation expenditure (OPEX)

Parameters	Price in (USD)	Quantity	Total (USD)
Equipment	50,000	1	50,000
Installation	20,000	1	20,000
Taxes	0.15	2,976,210	446,431.5
Water treatment	350,000	3	1,050,000
Service	300,000	6	1,800,000
Price per barrel	10	2,976,210	29,762,100
Cunning cost/2	1,200,000	6	7,200,000
TOTAL			40,328,531.5

a function of capital expenditure (CAPEX) and operation expenditure (OPEX) shown in Table 8.

In Table 8, the revenues amount to USD 223,215,750, which is mainly based on oil production for a net present value (NPV) of USD 182,887,219. At the end of this economic assessment, it appears that the gas-lift activation method is appropriate, because in addition to the fact that it optimises production, it is still profitable. The gas-lift method is more economically advantageous because it is economically profitable by producing 2,718 barrels per day.

4. Conclusion

This paper proposed a design of a continuous gas-lift system, allowing activating and optimising the production of hydrocarbons from a non-eruptive well, while injecting as little gas as possible into the production column. The reservoir, pressure-volume-temperature and well data were used and their importance was clearly perceptible. Also, in order to achieve the defined objectives, an appropriate methodology was developed. The first step was to define and present the data used. The second step was to present a nodal analysis and sensitivity analysis of the non-productive well and the third step was to make an economic evaluation. The gas-lift design facilitated optimal surface oil recovery and a sensitivity analysis helped to optimise surface production. Finally, an economic analysis was developed to determine the profitability of the project. In view of these procedures, it appeared that the nodal analysis of the well before the installation of the gas-lift showed an absolute open flow of 46.7 standard barrel per day. The design of the gas-lift for injecting gas into the well allowed for an injection pressure of 2,500 psi for each valve and a maximum height of the first gas valve set at 10,159 ft. For better recovery of hydrocarbons on the surface, two relay valves must be placed at the respective depths of 9,402 ft and 5,488 ft and the daily injection rate

was 3 million standard cubic feet per day for an available gas quantity of 4 million standard ft^3 per day. An outlet pressure of 100 psi suggested the optimum production flow rate recorded at 2,718 standard barrels per day. The economic analysis revealed a gross profit of USD 182,887,219 after 3 years.

References

[1] Chang Samuel Hsu and Paul R. Robinson, *Petroleum science and technology*, 1st edition. Springer, 2019. DOI: 10.1007/978-3-030-16275-7.

[2] Boyun Guo, William C. Lyons, and Ali Ghalambor, *Petroleum Production Engineering: A computer-assisted approach*. Gulf Professional Publishing, 2007. DOI: 10.1016/B978-0-7506-8270-1.X5000-2.

[3] S. John, Forecasting oil and gas producing for unconventional wells, 2nd edition, Petro. Denver, 2018.

[4] Michael J. Economides and Curtis Boney, "Reservoir stimulation in petroleum production", *Reservoir Stimulation*, 3rd edition. John Wiley & Sons, 2000.

[5] Frank Jahn, Mark Cook, and Mark Graham. *Hydrocarbon exploration and production*, Vol. 55, 2nd edition. Elsevier Science, 2008.

[6] Jonathan Bellarby, "Artificial lift", *Well completion design*, 1st edition. Elsevier Science, 2009.

[7] Saurabh Goswami and Tej Singh Chouhan, "Artificial lift to boost oil production", *International Journal of Engineering Trends and Technology*, Vol. 26, No. 1, 2015. DOI:10.14445/22315381/IJETT-V26P201.

[8] Alan Brodie, Joe Allan, and Atholl Campbell, *"Gas-lift well design"*, Petroleum Technology Company, 2015.

[9] Shahab Ayatollahi, A. Bahadori, and A. Moshfeghian, "Method optimizes Aghajari oil field gas lift", *Oil and Gas Journal*, Vol. 99, No. 21, pp. 47 - 49, 2001.

[10] Ehsan Khamehchi and Mohammad

Reza Mahdiani, *Gas allocation optimization methods in artificial gas-lift, 1st edition*. Springer Briefs in Petroleum Geoscience & Engineering, 2017.

[11] Ali A. Garrouch, Mohammad Al-Dousari, and Zahra Al-Sarraf, "A pragmatic approach for optimizing gas lift operations", *Journal of Petroleum Exploration and Production Technology*, Vol. 10, pp. 197 - 216, 2019. DOI: 10.1007/s13202-019-0733-7.

[12] Asekhame U. Yadua, Kazeem A. Lawal, Stella I. Eyitayo, Oluchikwu M. Okoh, Chinyere C. Obi, and Saka Matemilola, "Performance of a gas-lifted oil production well at steady state", *Journal of Petroleum Exploration and Production Technology*, Vol. 11, pp. 2805 - 2821, 2021.

[13] Mohamed A. H. Elgadban Abdalsadig, Amir Nourian, Ghasem Ghavami Nasr, and Meisam Babaie, "Gas lift optimization using smart gas lift valve", *International Journal of Mechanical and Mechatronics Engineering*, Vol. 10, No. 6, pp. 1162 - 1167, 2016. DOI: 10.5281/zenodo.1125185.

[14] Guy Vachon and Terry Bussear, "Production optimization in ESP completion with intelligent well technology", *SPE Asia Pacific Oil and gas Conference and Exhibition, Jakarta, Indonesia, 5 - 7 April 2005*. DOI: 10.2118/93617-MS.

[15] Gabor Takacs, "A critical comparison of TDH calculation models in manual ESP design procedures", *Journal of Petroleum Science and Engineering*, 2020, DOI:10.1016/j.petrol.2020.108210.

[16] Gabor Takacs, "Evaluation of ten methods used for prediction of pressure drop in oil wells", *Oil Gas European Magazine*, Vol. 2, pp. 44 - 51, 1983.

[17] Abdel BenAmara, "Gas lift - past & future", *SPE Middle East Artificial Lift Conference and Exhibition, Manama, Kingdom of Bahrain, 30 November - 1 December 2016*. DOI: 10.2118/184221-MS.

[18] Fathi Elldakli, "Gas lift system", *Petroleum & Petrochemical Engineering Journal*, Vol. 1, No. 4, pp. 1 - 11, 2017.

[19] Ali Hernandez, *Fundamentals of gas lift engineering: Well design and troubleshooting*, 1st edition. Gulf Professional Publishing, 2016.

[20] E.N. Magdi, "Artificial lift technology, Dubai: advancing performance excellence, 2017.

[21] Badr A. Mohamed, Naoko Ellis, Chang Soo Kim, Xiaotao Bi, and Ahmed El-raie Emam, "Engineered biochar from microwave-assisted catalytic pyrolysis of switchgrass for increasing water-holding capacity and fertility of sandy soil", *Science of the Total Environment*, Vol. 566 - 567, pp. 387 - 397, 2016. DOI: 10.1016/j.scitotenv.2016.04.169.