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Features of operation of a watered gas well with a plunger lift

Roman Kondrat*

Doctor of Technical Sciences, Professor
Ivano-Frankivsk National Technical University of Oil and Gas
76019, 15 Karpatska Str., Ivano-Frankivsk, Ukraine
https://orcid.org/0000-0002-9653-2567

Nataliia Dremliukh

PhD in Technical Sciences, Associate Professor
Ivano-Frankivsk National Technical University of Oil and Gas
76019, 15 Karpatska Str., Ivano-Frankivsk, Ukraine
https://orcid.org/0000-0002-6991-0227

Liliia Matiishyn

PhD in Technical Sciences, Associate Professor
Ivano-Frankivsk National Technical University of Oil and Gas
76019, 15 Karpatska Str., Ivano-Frankivsk, Ukraine
https://orcid.org/0000-0002-8529-4807

Abstract. To obtain high values of the current gas production and the final coefficient of gas extraction from deposits under the water-pressure regime, it is necessary to ensure complete and continuous removal of liquid from the bottom hole to the surface. An effective method of intensifying the operation of watered gas wells and extending the period of their natural flow is the use of a plunger lift. The purpose of the study was to substantiate the area of effective use of a plunger lift to intensify the removal of fluid from watered gas wells using the reservoir gas's own energy depending on the value of the water factor. The tasks were solved by conducting research on a hypothetical (model) watered gas well using mathematical modelling methods. The proposed mathematical model of the plunger lift operation has been tested for the conditions of a hypothetical gas well at different values of the water factor from 0 to 125 L/thousand m^3. For the well under consideration, the area of effective application of the plunger lift is limited to the values of the water factor of 12-41 L/thousand m^3. According to the research results, the maximum value of the width of the gap between the plunger body and the wall of the tubing, which should not exceed 0.0025 m, is substantiated. The developed mathematical model of the plunger lift operation in a watered gas well, which includes the choice of the area of its effective application and the maximum value of the gap width between the plunger body and the tubing wall, makes it possible to ensure stable operation of watered gas wells with increased gas production due to the use of reservoir gas's own energy and to extend the wells' flowing period. As a result, in practice, the current gas production and the final coefficient of gas extraction from the field are increased

Keywords: productivity; water factor; mechanised operation; minimum required gas flow rate; effective application area; gap width

Introduction

When gas fields are operated under water pressure, there is an increase in well water cut, which negatively affects gas production. As the water factor increases and reservoir energy decreases, fields use a variety of methods to remove water from the well and maintain productivity, including physical, chemical and mechanical methods. The use of a plunger lift is highly efficient because of its simple design and maintenance. The use of a plunger lift increases the

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*Corresponding author

time of active gushing of wells, which are characterised by a significant amount of liquid in the extracted products, and in the case of periodic gas lifts, it helps to reduce the need for additional gas to lift the liquid from the bottom hole to the surface. Therefore, further research into the operation of a watered gas well with a plunger lift deserves attention.

As noted by such scientists as J.J. Marques De Jesus & G. Simonelli (2018) and S. Rajvanshi *et al*. (2023), in gas wells, tubing of a smaller diameter is installed to maintain the inflow of reservoir fluids, or a gas lift method of operation is used. However, neither reducing the diameter of the tubing nor using a gas lift is a permanent solution to the problem of operating watered wells, as the gas velocity first increases to carry the fluid out of the bottom hole, and then at some point the gas velocity decreases again to an insufficient level, and the fluid will not be carried out of the well.

The plunger lift is one of the most common and effective methods of removing fluid from the well under certain conditions, which is also described by T. Nguyen (2020) and Z. Nurkas (2020). The experience of operating plunger lifts and their availability is a big challenge for the Ukrainian industry. In Pakistan, pilot projects are being effectively implemented to help build experience and competence in the general application of plunger lifts in the industry. They are used in wells with a high water factor value, in wells without a packer, and in wells with a packer. Since packer wells cannot use annular gas as a source of energy, the plunger lift depends solely on the energy of the formation gas coming from the bottom of the plunger. Packer wells require special approaches for effective production management.

The use of a plunger lift for watered gas wells is an intermediate option between the traditional fountain method and the gas lift (pump) method of operation, as described by M. Burns (2018). The use of a plunger lift in combination with a gas lift allows for increased production, reduced operating costs and more efficient use of reservoir energy in fields. The combination of gas-lift and plunger technologies provides oil and gas operators with opportunities to optimise production from the initial stage of development, which is characterised by high initial fluid flow rates, to the completion of fields for depletion, according to B. Cope & D. Gilmore (2023).

A typical plunger lift model consists of tubing with shock absorbers at both ends and a plunger between them. The plunger is available in two versions: with a gap between its body and the inner surface of the tubing or with a sealing plug. During well operation, the plunger cycles through the tubing string, moving up and down, lifting fluid from the well with each upward movement. Many types of plungers have been proposed, which differ in the design of the plunger body and valve assembly; in particular, the study by Z. Nurkas & K. Khabibuyev (2020), which examined the latest innovations in Kazakhstan.

The scope of effective use of plunger lifts for water removal from watered gas wells is limited by the water factor (water flow rate). At low water factors, when water is carried out of the bottom hole by the formation gas flow, there is no need to equip the well with a plunger lift. With high water factors, the reservoir gas energy is insufficient for both well flow and plunger lift operation. There is no data in the technical literature on the selection of the area of effective use of the plunger lift for the operation of watered gas wells depending on the water factor, which served as the basis for additional research. The purpose of the study was to substantiate the methodology for selecting the scope of effective use of a plunger lift for the operation of watered gas wells depending on the value of the water factor.

Materials and Methods

A study to substantiate the method of choosing the scope of effective use of a plunger lift for the operation of watered gas wells, depending on the value of the water factor, was performed for the conditions of a hypothetical (model) gas well for the following data: the depth of the production well (the depth of lowering of tubing pipes) is 2,300 m; the inner diameter of the production column is 0.146 m; the inner diameter of the tubing is 0.062 m; reservoir pressure is 6.2 MPa; well pressure is 4.4 MPa; the relative density of the gas is 0.6; reservoir water density is 1,028 kg/m^3; coefficients of filtration resistances of the bottom-hole zone of the formation: A = 0.25 (MPa^2 × day/thousand m^3; B = 19 × 10^{-4} (MPa × day/thousand m^3)^2; the width of the gap between the plunger body and the tubing is 0.002 m. The parameters of well operation when only gas enters the face, determined from the joint solution of the binomial formula for gas inflow to the bottom of the well and the formula for gas flow to the tubing using the work dependencies for constant well pressure (4.4 MPa), are: gas flow rate – 30.1 thousand m^3/day, downhole pressure – 5.4 MPa. In the studies, gas enters the well from a gas-bearing formation, and water enters from a watered formation. The study was performed at a constant value of the wellhead pressure (4.4 MPa) and under conditions of changes in the water factor indicators (10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 125 L/thousand m^3).

To determine the lower limit of the water factor, from which it is economically feasible to use a plunger lift in watered gas wells, the gas flow rate from the formation was calculated for different values of the water factor, and the minimum required gas flow rate was established to ensure the removal of fluid from the bottom hole. The calculation of reservoir gas flow rate was carried out on the basis of solving a combined problem, which includes a binomial formula for gas inflow to the well and a formula that takes into account additional pressure losses in the tubing when moving a two-phase flow according to a certain method (Lea & Nickens, 2004; Matkivskyi & Khaidarova, 2021). The minimum required gas flow rate is determined by the formula given (Kondrat & Matiishyn, 2022). This relationship was derived from statistical analysis of data obtained during the operation of watered wells in a particular field:

$$q_{mr} = 2{,}213 \times d_{in}^{1.94} \times q_l^{0.22} \times \sqrt{\frac{P_{dh} \times \rho_l}{\bar{\rho}_g \times Z_{dh} \times T_{dh}}}, \qquad (1)$$

where q_{mr} – minimum required gas flow rate, thousand m^3/day; q_l – the flow rate of liquid (water), which was determined as the product of the water factor and the flow rate of reservoir gas for this factor, m^3/day; P_{dh} – downhole pressure, MPa; T_{dh} – downhole temperature, K; d_{in} – inner diameter of tubing, m; ρ_l – liquid density by P_{dh} and T_{dh}, kg/m^3; $\bar{\rho}_g$ – relative gas density; Z_{dh} – gas compressibility coefficient by P_{dh} and T_{dh}. To lift the plunger, a certain amount of gas is required, which includes the volume of gas to create the required pressure in the tubing below the plunger, as well as the volume of gas passing through the gap between the plunger and the inner surface of the tubing:

$$V_g = 10^{-5} \times L \times f_{pl} \times P_g + q_{los} \frac{L}{W_{pl}}, \tag{2}$$

where V_g – volume amount of gas for lifting the plunger, m^3; L – tubing length from the mouth to the lower shock absorber, m; f_{pl} – cross-sectional area of the plunger lift, m^2; P_g – gas pressure under the plunger, which is necessary to lift the plunger with a column of liquid above it, Pa; q_{los} – gas losses from under the plunger through the gap between the plunger and the tubing wall, m^3/s; W_{pl} – plunger lifting speed, m/s. The rate of rise of the plunger is determined by the formula:

$$W_{pl} = 50 \times \sqrt[3]{s\sqrt{\frac{10^3}{h_l \times \rho_l}}}, \tag{3}$$

where h_l – height of the liquid column above the lower shock absorber, m; ρ_l – liquid density, kg/m^3; S – width of the gap between the plunger and the tubing wall, m. The height of the liquid column above the lower shock absorber is determined by the formula:

$$h_l = \frac{P_a}{\rho_l \times g}, \tag{4}$$

where P_a – pressure of the gas-liquid mixture in the tubing at the level of the lower shock absorber, Pa. The pressure of the gas-liquid mixture in the tubing at the level of the lower shock absorber is determined by the formula:

$$P_a = P_{dh} - h_e \rho_l g, \tag{5}$$

where h_e the distance from the elevator shoe to the lower shock absorber (taken equal to 25-50 m). It was taken that h_e = 25 m in the calculations. Gas loss from under the plunger through the gap between the plunger and the tubing wall is determined by the formula:

$$q_{los} = 271.96 \times d_{in} \times S \times \sqrt{P_g}. \tag{6}$$

The gas pressure under the plunger, which is required to lift the plunger with a column of liquid above it, is calculated using the formula:

$$P_g = h_l \rho_l g + \lambda \frac{h_l W_{pl} \rho_l}{2 d_{in}} + P_{wh} + P_{fr} + P_w, \tag{7}$$

where λ – coefficient of hydraulic resistance (0.025 was taken in the calculations); P_{wh} – pressure at the wellhead, Pa; P_{fr} – pressure expended to overcome the friction of the plunger, Pa; P_w – pressure expended to overcome the weight of the plunger, Pa. The pressure expended to overcome the friction of the plunger was calculated to be equal to $P_{fr} = 10^4$ Pa; the pressure expended to overcome the weight of the plunger – $P_w = 2 \times 10^4$ Pa. The amount of gas flowing from the formation during the plunger lift (V_{gp}) is determined by the formula:

$$V_{gp} = q_g(t) \times t, \tag{8}$$

where – gas production rate, m^3/s; t – plunger lifting time, s. The lifting rise time is determined by the formula:

$$t = \frac{H - h_e}{W_{pl}}, \tag{9}$$

where H – well depth, m. The amount of gas entering the tubing (V_{glos}) is calculated using the formula:

$$V_{glos} = V_{gp} \frac{f_{pc}}{F}, \tag{10}$$

where f_{pc} – cross-sectional area of the production column, m^2.

Results and Discussion

Studies on the operation of a watered gas well with a plunger lift have shown its high efficiency. The research results are shown in Figure 1 as dependences (obtained by formula (1) of the reservoir gas flow rate q_r (curve 1) and the minimum required gas flow rate q_{mr} (curve 2) from the water factor F_w. According to the research results, with an increase in the water factor, the flow rate of reservoir gas decreases (curve 1) from 30.1 thousand m^3/day in the absence of water in reservoir products up to 18.8 thousand m^3/day for water factor 125 L/thousand m^3 (water flow rate 2.35 m^3/day), and the minimum required gas flow rate increases (curve 2) and reaches a value of 47.2 thousand m^3/day for water factor 125 L/thousand m^3. If the water factor does not exceed 12 L/thousand m^3 (which corresponds to a water flow rate of up to 0.31 m^3/day), the well operates efficiently, using the energy of the extracted gas to remove water. With higher water factors, additional measures must be taken to effectively remove water from the well. The value of the water factor of 12 L/thousand m^3 can be considered as the minimum indicator for using a plunger lift. It should also be noted that in Figure 1, the right part of the gas flow rate curve is "conditional", because with water factors above 12 L/thousand m^3, the well is usually not operated.

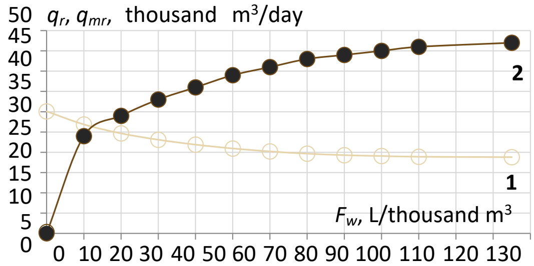

Figure 1. Reservoir gas flow rate dependencies q_r (1) and the minimum required gas flow rate q_{mr} (2) from the water factor F_w

Source: created by the authors

To determine the maximum possible use of a plunger lift in a particular well, it is necessary to calculate how much gas is required to lift the plunger, taking into account different water factor values (or water flow rates). The volume of gas that naturally escapes from the formation during the time it takes to lift the plunger must also be taken into account. For a plunger lift unit to operate without surface gas, the amount of gas flowing from the formation into the tubing during the plunger lift must be greater than the amount of gas required to lift the plunger. Figure 2 shows the dependence of the required amount of gas for lifting the plunger V_g (curve 1) and the actual amount of gas coming out of the reservoir during the lifting of the plunger V_{gp} (curve 2) from the water factor F_{wl}.

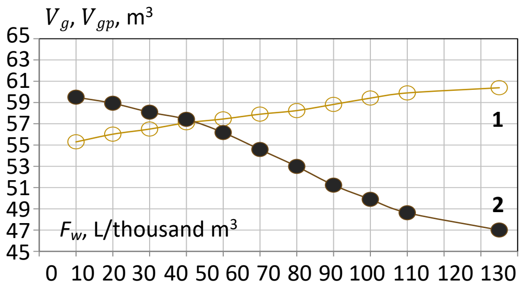

Figure 2. Dependences of the required amount of gas for lifting the plunger V_g (1) and the actual amount of gas coming from the reservoir V_{gp} (2) from the water factor F_w

Source: created by the authors

According to the results of research, with an increase in the water factor, the required amount of gas for lifting the plunger increases from 55.3 m³ (with a water factor of 10 L/thousand m³) up to 60.4 m³ (with a water factor of 125 L/thousand m³) and the amount of gas coming from the reservoir decreases from 59.5 m³ up to 47 m³. The plunger lift operates without gas supplied from the surface to the water factor value of 41 L/thousand m³ (accounts receivable 0.9 m³/day). At higher water factors, the use of a plunger lift is not feasible, as less gas flows from the reservoir than is required to lift the plunger. Thus, for the conditions of the well under study, the range of effective use of the plunger lift is within the range of changes in the water factor of 12-41 L/thousand m³. For the water factor value of 41 L/thousand m³, the effect on the required amount of gas for lifting the plunger is studied V_g and the actual amount of gas coming from the reservoir V_{gp}, the width of the gap between the plunger body and the tubing wall, which varied in the range of 0.001-0.005 m. The relevant dependencies are shown in Figure 3.

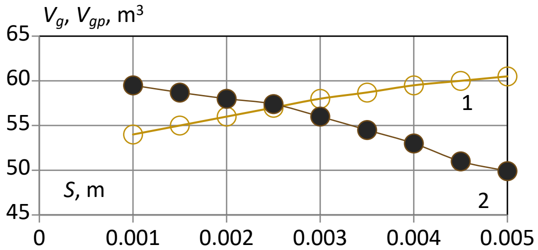

Figure 3. Dependences of the required amount of gas for lifting the plunger V_g (1) and the actual amount of gas coming from the reservoir V_{gp} (2) from the width of the gap between the plunger body and the tubing wall S

Source: created by the authors

The proposed methodology for selecting the scope of effective use of a plunger lift for water removal from watered gas wells depends on the current and forecast values of the water factor. The minimum value (lower limit) of the water factor, starting from which it is advisable to use a plunger lift, is determined by the parameters of the intersection point of the graphical dependencies of the reservoir gas flow rate and the minimum required gas flow rate for water removal from the well on the water factor. The maximum value (upper limit) of the water factor, above which the reservoir gas energy is insufficient for the plunger lift to operate, is determined by the parameters of the intersection point of the graphical dependencies of the required amount of gas to lift the plunger with the water column above it and the actual amount of gas coming from the reservoir during the plunger lift on the water factor. For the conditions of the considered hypothetical (model) well, the scope of effective use of the plunger lift is limited to the values of the water factor of 12-41 L/thousand m³. For a maximum water factor of 41 L/thousand m³, the width of the gap between the plunger body and the tubing wall should not exceed 0.0025 m. At larger gap widths, the amount of gas coming from the formation is less than the required amount of gas to lift the plunger, and the well will not operate.

The mechanised operation of gas and gas condensate wells is effective in water-flooded conditions. Using Schlumberger's PipeSim software, S. Matkivskyi *et al.* (2021) and S. Matkivskyi & L. Khaidarova (2021) performed the studies to optimise the operating conditions of a watered well under conditions of active reservoir water supply to gas-saturated productive horizons. Based on the results obtained, the optimal depth of gas-lift valves from the wellhead was determined, which is 55-58% of the depth of the tubing run. R. Kondrat *et al.* (2017) and R. Kondrat & L. Matiishyn (2022), based on the results of statistical analysis of the calculated data, determined the optimal values of gas lift gas flow rate for different values of the water factor, which ensure maximum well productivity and minimum values of bottomhole pressure.

In addition to gas lift operation, a plunger lift is also successfully used for liquid removal. The plunger lift method has long been successfully implemented at wells in Europe, including in neighbouring Romania. This technology is designed to solve the problem of waterflooding, a very common problem in wells. The cycle time of the plunger as it moves up and down the well depends on various factors such as well pressure, water volume, well depth, etc. There are different types of plungers with different prices, but they all work on the same principle: they rise up the pipe under the action of gas pressure, pushing the liquid out. The main characteristics of the plunger include the time required for one cycle and the speed of its upward movement (Rajvanshi *et al.*, 2023). The frequency of cycles, as well as other factors, affect the service life of the plunger, which is typically designed to last between two and four months before the first inspection. After this period, the equipment should be serviced. The entire process can be monitored remotely using sensors, the data from which is transmitted to a computer via a wireless Internet connection.

The authors, after comparing the calculated results with the actual well loading data, identified systematic errors of empirical models, which prompted the development and implementation of a model that provides higher accuracy in predicting critical flow rates based on actual well flow rates (Rahmati *et al.*, 2022; Olszak *et al.*, 2022). The advantages of implementing plunger lift technology are the simplicity and speed of installation, efficiency and relatively low cost of the system. At the same time, there are limitations to the application of this technology, which are based on the fact that the well must produce a certain gas flow rate in order to push out the plunger and the accumulated fluid. There are also limitations to the implementation of plunger lift technology in terms of depth – they are used mainly in wells up to 3,000 m. The use of a plunger lift made it possible to resume production at the stopped well and reach indicators of 5 m^3/day of oil production and 15 thousand m^3/day gas supply. The installation of the plunger system has reduced capital expenditure by more than 3 times compared to traditional rod and submersible pump systems. The installation of a plunger lift is effective for a long period of well operation by maintaining reservoir energy. If reservoir energy is not sufficient during the operation of watered wells, additional gas injection into the annulus is necessary, according to G.M. Hashmi *et al*. (2016).

Any model – whether physical, empirical or AI-based – relies entirely on a high-frequency stream of high-quality data provided by the sensors to derive a conclusion about the current state of flow in the wellbore. External variables such as line pressure can change dramatically within minutes (e.g., due to compressor failure), which in turn can cause the well to fail to lift the plunger and fluid load to the surface, increasing the likelihood of a fluid influx. An automated setpoint optimisation solution that receives high-frequency data can detect such changes in time and take immediate corrective action to eliminate the potential consequences of such pressure spikes in the line. Therefore, scientists have developed algorithms that initially used modern critical flow equations, such as the equation by Z. Wang *et al*. (2017) for calculating critical flow rates. After comparing the calculated results with actual well loading data, they found large systematic errors in empirical models, prompting them to develop and implement a data-based model that provides higher accuracy in predicting critical flow rates based on actual flow rates (Rahmati *et al.*, 2022). Another example is the adaptation of setpoint optimisation algorithms to automatically determine the time of plunger fall. The drop time is usually set based on the general drop rates provided by the plunger manufacturers. These fall rates do not take into account the effects of the density and viscosity of the fluid in the tubing string and can therefore greatly overestimate or underestimate the actual fall time.

The continuous flow plunger lift is not limited to gas well delimitation and is also suitable for wells with higher flow rates. O. Sayman *et al*. (2022) presented wells with a flow rate of more than 500 thousand barrels of oil and 2 million cubic feet of gas per day with 2-7/8 inch outer diameter tubing and two-piece plungers. Typically, higher well flow rates are the upper operating limit for a continuous flow plunger to start operating. Mechanical models of plunger lifts for drop stage vs. multiphase flow help determine when an operator can deploy plungers in their wells (Sayman *et al.*, 2021). If the plunger lift cycles are aimed at reducing wax buildup, the well can be shut-in for extended periods and the plunger can be allowed to drop to the bottom hole spring even at higher flow rates for a limited number of daily plunger lift cycles.

The hybrid use of plunger and gas lift lifts is common in shale wells in North America. The use of a plunger lift in a well with a continuous gas lift can significantly reduce the rate of gas injection while maintaining or improving the production of liquid and gas from the wellbore. The operation of a plunger lift with a continuous gas supply is called a plunger-assisted gas lift (PAGL). A conventional plunger lift with well shut-in for pressure generation by gas injection is called a gas-assisted plunger lift (GAPL). In a PAGL operation, gas injection primarily affects the pressure gradient, fluid retention and velocity profile of the gas along with the tubing. Taking these effects into account by modelling transient or steady-state multiphase flow allows the use of mechanistic falling and rising models for a continuous flow ram. During GAPL operation, the gas lift typically changes the pressure build-up profile and supports the lift of the plunger. Formation inflow and gas injection must be considered simultaneously to determine the casing inlet pressure in traditional mechanical models of plunger lift. D. Pan (2017) used casing, tubing and line pressures to estimate the rate of upward movement.

Many well-known commercial multiphase flow simulators can evaluate the effect of gas lift on the pressure profile for both tubing and annulus. The nodal analysis capabilities are supported by gas lift sensitivity, which helps in the design and optimisation phases. O. Sayman *et al*. (2020) developed mechanistic models on continuous flow plungers for tested 6-inch and 9-inch two-component plungers with steel, cobalt, and tungsten balls. The study showed that each different plunger geometry changes the plunger resistance characteristics, which affect the lowering and lifting stages of the plunger. This article discusses the peculiarities of using a plunger lift for watered gas wells. The main focus was on the analysis of various parameters that affect the efficiency of plunger systems, including gas pressure, water factor, well depth, and others. The difference between the author's study and the above-mentioned researchers is that a new approach to calculating the optimal cycle time and plunger lifting speed was introduced. A methodology has been developed for determining the upper and lower limits of plunger lift use, which allows increasing the efficiency and reliability of well operation.

Conclusions

The article summarises the peculiarities of operating a watered gas well with a plunger lift and presents the following conclusions. The influence of the water factor on pressure losses in tubing during the movement of a two-phase gas-liquid flow, the gas flow rate coming from the formation and the minimum required gas flow rate for bringing fluid from the bottom hole to the surface were estimated. A mathematical model has been developed to determine the area of effective use of a plunger lift for removing fluid from the bottomhole of watered gas wells, which depends on the current value of the water factor. The minimum value (lower limit) of the water factor, starting from which it is advisable to use a plunger lift for the operation of a watered gas well, is established. The maximum value (upper limit) of the water factor, above which the energy of reservoir gas is insufficient for the operation of the plunger lift, is substantiated. The model well was tested using a plunger lift at different values of the water factor from 0 to 125 L/thousand m^3.

The scope of effective application of the plunger lift is established, which is limited to the values of the water factor in the range from 12 L/thousand m^3 up to 41 L/thousand m^3. For the maximum value of the water factor, which is 41 L/thousand m^3, the width of the gap between the plunger body and the tubing wall should not exceed 0.0025 m. With a wider gap width, the loss of gas coming from the formation through the gap increases, and the amount of gas remaining becomes less than the required amount of gas to lift the plunger and the well will not operate. It has been established that the efficiency of using a plunger lift for the operation of watered gas wells is influenced not only by the value of the water factor but also by the width of the gap between the plunger body and the wall of the tubing. The proposed methodology for selecting the area of effective use of a plunger lift has been tested for a hypothetical (model) gas well for different values of the water factor (water flow rate). It is advisable to calculate the parameters of the foam packer plunger and compare it with a conventional plunger in further studies.

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None.

Conflict of Interest

None.

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Особливості експлуатації обводненої газової свердловини плунжерним ліфтом

Роман Кондрат

Доктор технічних наук, професор
Івано-Франківський національний технічний університет нафти і газу
76019, вул. Карпатська, 15, м. Івано-Франківськ, Україна
https://orcid.org/0000-0002-9653-2567

Наталія Дремлюх

Кандидат технічних наук, доцент
Івано-Франківський національний технічний університет нафти і газу
76019, вул. Карпатська, 15, м. Івано-Франківськ, Україна
https://orcid.org/0000-0002-6991-0227

Лілія Матіїшин

Кандидат технічних наук, доцент
Івано-Франківський національний технічний університет нафти і газу
76019, вул. Карпатська, 15, м. Івано-Франківськ, Україна
https://orcid.org/0000-0002-8529-4807

Анотація. Для отримання високих значень поточного видобутку газу і кінцевого коефіцієнта газовилучення з родовищ за водонапірного режиму необхідно забезпечити повне і безперервне винесення рідини з вибою на поверхню. Ефективним методом інтенсифікації роботи обводнених газових свердловин і продовження періоду їх природного фонтанування є застосування плунжерного піднімача. Мета дослідження – обґрунтування області ефективного застосування плунжерного піднімача для інтенсифікації винесення рідини з обводнених газових свердловин із використанням власної енергії пластового газу залежно від величини водного фактора. Поставлені завдання вирішувалися шляхом проведення досліджень на гіпотетичній (модельній) обводненій газовій свердловині з використанням методів математичного моделювання. Запропонована математична модель роботи плунжерного піднімача апробована для умов гіпотетичної газової свердловини за різних значень водного фактора від 0 до 125 л/тис.м^3. Для розглянутої свердловини область ефективного застосування плунжерного піднімача обмежується значеннями водного фактора 12-41 л/тис.м^3. Згідно з результатами досліджень обґрунтовано максимальне значення ширину зазору між тілом плунжера і стінкою насосно-компресорних труб, яка не повинна перевищувати 0,0025 м. Розроблена математична модель роботи плунжерного піднімача в обводненій газовій свердловині, яка включає вибір області його ефективного застосування і максимального значення ширини зазору між тілом плунжера й стінкою насосно-компресорних труб, дає можливість забезпечити стабільну роботу обводнених газових свердловин із підвищеним дебітом газу завдяки використанню власної енергії пластового газу і продовжити фонтанний період експлуатації свердловин. У результаті на практиці підвищується поточний видобуток газу і кінцевий коефіцієнт газовилучення з родовища

Ключові слова: продуктивність; водний фактор; механізована експлуатація; мінімально необхідний дебіт газу; область ефективного застосування; ширина зазору