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INFLUENCE OF CONNECTING A NEW GAS PIPELINE TO THE OPERATING GAS PIPELINE ON THE FLOW RATE OF PRODUCTION WELLS

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ABSTRACT
In some cases, it is necessary to connect new line to the pipeline. From this point of view, in the presented work, serious changes occurring in the pipeline as a result of connecting a new gas pipeline to the operating gas pipeline are investigated. The changes occurring in the pipeline are transmitted to the formations, which causes a violation of the stable operation of the wells in the initial period. After a certain period of time, the dynamic processes formed in the system as a result of changes in the transport line become stationary. From this point of view, it is of great practical importance to consider the stationary state of the processes occurring in the system. Therefore, in the presented work, as a result of the addition of a new line to the pipeline, the change in the production of gas wells in stationary regime conditions is studied. The effect of these changes on the operating mode of the wells, the effect on the change in production of operational wells is studied. Taking into account the interaction of the layer-pipeline system, a mathematical model of the movement process of gas and gas-liquid mixture is established, using the equations of motion and continuity, the resulting system of related differential equations is solved. With the help of the obtained formulas, the pressure drop and production reduction for each well are calculated during the connection of the new line. Numerical calculations are performed using various practical values of system parameters and the obtained results are analyzed.

KEYWORDS:
Production;
Layer;
Pressure;
Pipeline;
Stationary state;
Gas-liquid mixture;
Motion and continuity equation.

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Introduction

The rapid development of modern methods and technologies of field development, the operation and drilling of oil and gas wells, the interaction between the layer and the transmission line create new problems, the solution of which is carried out on the basis of the development of methods of flow mechanics of oil, gas and their mixture in porous medium, pipelines.

All this requires the development of solution models that take into account the real conditions of the processes, the extraction and transportation of oil, gas, condensate, their interaction in the lay-transport line system, and the construction and solution of equations describing the actions.

Changes in the pipelines during the transportation of oil and gas affect wells, their production and other parameters.

In some cases, it is necessary to connect new pipelines to the operating gas pipeline. At this time, the operating modes of the wells change. It is of great practical importance to study how this change will affect their production. It should be noted that the study of how the changes in the transport lines will affect the working mode of the layer is related to the systematic study of this process [1-8]. That is, it is related to the solution of the related equations obtained by building the integral model of the process. At this time, filtration in the layer and motion of liquid - gas and their mixture in risers and transmission lines should be studied together.

The works of many scientists have been devoted to these problems:

Mirzajanzadeh A. X., Abasov M. T., Slezkin N. A., Teletov S. G., Kutateladze S. S., Wallis G., Barenblatt G. I., Entov V. M., Jeltov Yu. P. and others.

Despite the fact that a large number of works have been dedicated to the study of the problems of the oil and gas extraction process, there is still a great need to mathematically model, research and study these problems, taking into account the nonlinear effects, the joint movement of oil, gas and oil-gas mixture in the pipeline, and it remains an urgent issue.

Problem statement and methods for solving it

After a certain period of time, dynamic processes formed in the system as a result of changes in the pipeline become stationary. Considering the stationary state of the processes occurring in the system has greater practical importance. Therefore, in the presented

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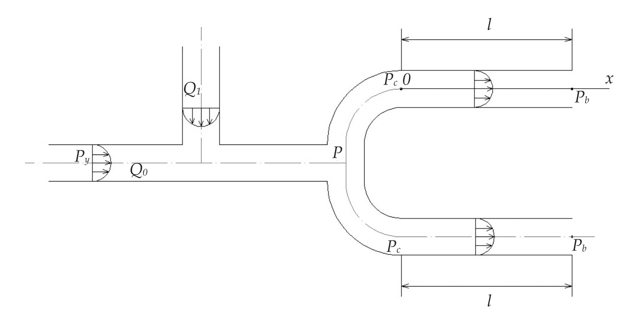

Fig. 1. Scheme of the transmission system

work, as a result of the connection of additional new line to the pipeline, the change in the production of gas wells in stationary regime conditions is studied.

A new gas pipeline is connected to the operating gas pipeline. As a result of the connection of a new line, the pressure increases, which in turn affects the operation of the wells. To study the effect of the gas line to be connected on the production of wells, let's look at the motion of gas in the pipeline (fig. 1).

Let's take the origin of the coordinate axis at the connection point of the line and direct it in the direction of movement along the pipe.

Charniy equations for gas motion in the pipe will be as follows [9].

$$-\frac{\partial P}{\partial x}=\frac{\partial Q}{\partial t}+2aQ \qquad -\frac{\partial P}{\partial t}=c^2\frac{\partial Q}{\partial x} \tag{1}$$

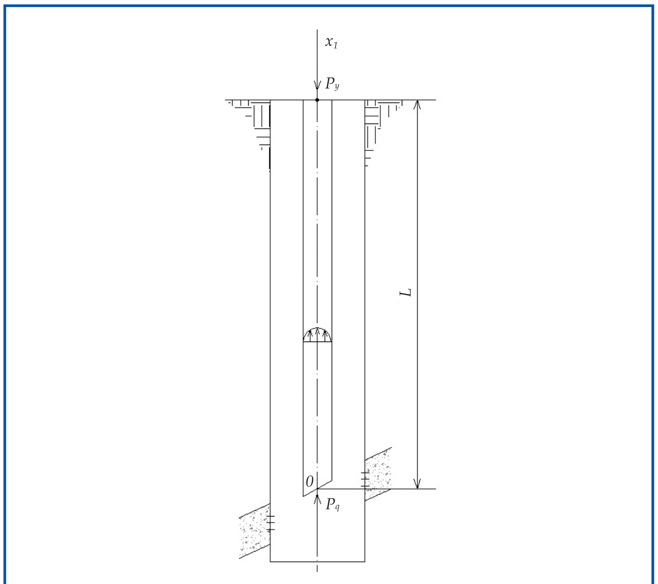

Fig. 2. Scheme of the well

here $Q=\rho V$, ρ – the density of the gas at a given pressure, V – the average speed of the gas flow over the cross-sectional area of the pipeline, x – the coordinate, t – time, P – the pressure of the gas in any cross-sectional area of the pipe, c – the speed of sound propagation in the gas, a – the resistance coefficient.

Let's look at the stationary motion of the gas. Then

$$-\frac{dP}{dx}=2aQ \qquad \frac{dQ}{dx}=0 \tag{2}$$

We get from the second equation of the system (2)

$$Q=const \tag{3}$$

If we integrate the first equation of system (2), we get:

$$P=C-2aQx \tag{4}$$

where C is a constant of integral.

Boundary condition

$$P\big|_{x=0}=P_c \tag{5}$$

Considering the condition (5) in equation (4), the pressure at the outlet of the pipeline:

$$P_b=P_c-2aQl \tag{6}$$

Pressure drop in the pipeline before the new gas pipeline is connected ΔP_0, based on the formula (6), can be calculated as follows

$$\Delta P_0=P_{c_0}-P_{b_0}=2aQ_0l \tag{7}$$

where Q_0 – is the mass flow rate of gas pre-injected by the line. $Q=\rho V_0$, P_{b_0} – the pressure at the outlet, P_{c_0} – the pressure at the inlet, l – the length of the line.

After connecting the new gas line to the transmission line, the pressure drop in the transmission lines ΔP_1 can be found as follows

$$\Delta P_1=P_{c_1}-P_{b_1}=2a(Q_0+Q_1)l \tag{8}$$

where Q_1 is the mass flow rate of the connected gas, P_{c_1} is the pressure at the inlet after connecting the line, P_{b_1} is the pressure at the outlet.

Increase in pressure drop in transmission lines after connecting a new gas line

$$\Delta P=\Delta P_1-\Delta P_0 \tag{9}$$

If we e write expression (8) in equation (9), we get:

$$\Delta P=2alQ_1 \tag{10}$$

Now, let's look at the effect of the pressure increase on the production of the wells as a result of connecting the new gas line to the transmission lines.

For this purpose, let's look at the integral modeling of the process of joint movement of gas in the reservoir and risers.

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x – place the beginning of the arrow at the lower end of the lifting pipeline and direct it upwards (fig. 2).

Then, averaging the gas flow velocity over the cross-sectional area of the pipeline, we get it for the equation of motion.

$$-\frac{dP}{dx_1} = 2aQ + \rho g \tag{11}$$

here g – release is urgent.

As the gas rises through the pipe, its pressure and density change.

If we accept the process as isothermal, we will get it.

$$\rho = \rho_{atm}\frac{P}{P_{atm}} \tag{12}$$

where ρ_{atm} is the density of gas at atmospheric pressure, P_{atm} is the pressure at any cross-sectional area of the lifting pipeline at atmospheric pressure.

If we substitute expression (12) in equation (11), we get

$$-\frac{dP}{dx_1} = 2aQ + \rho_{atm}\frac{g}{P_{atm}}P \tag{13}$$

If we integrate equation (13), we get:

$$P = C_1 e^{-\alpha x} - \frac{2aQP_{atm}}{\rho_{atm} g} \tag{14}$$

where C_1 is a constant of integral.

Boundary condition

$$P\big|_{x_1=0} = P_{q0} \tag{15}$$

Considering the boundary condition (15) in equation (14), we get:

$$P = \left(P_{q0} + \frac{2aQP_{atm}}{\rho_{atm} g}\right)e^{-\alpha x} - \frac{2aQP_{atm}}{\rho_{atm} g} \tag{16}$$

where $\alpha = \frac{\rho_{atm} g}{P_{atm}}$ (when the liquid-gas mixture moves in the riser pipeline $\alpha = \frac{\rho_{atm} g(1+\varepsilon)}{P_{atm}}$, where $\varepsilon = \frac{m_k + m_{su}}{m_q}$, m_k is the mass of condensate in the mixture, m_{su} is the mass of water, m_q is the mass of gas)

P_y we can find the pressure at the mouth of the well from expression (16).

$$P\big|_{x=L} = P_y \tag{17}$$

If we consider condition (17) in equation (16), we get:

$$P_y = \left(P_q + \frac{2aQP_{atm}}{\rho_{atm} g}\right)e^{-\alpha L} - \frac{2aQP_{atm}}{\rho_{atm} g} \tag{18}$$

From the expression (18), we find:

$$P_q = \left[\frac{2aGP_{atm}\left(1 - e^{-\alpha L}\right)}{gf} + P_y\right]e^{\alpha L} \tag{19}$$

where, $G = \frac{Qf}{\rho_{atm}}$ is the volume of gas coming from each well at the same time, f is the passage area of the riser pipe.

Based on the actual mining data of each well, the wellhead pressure and its debit G, the bottom pressure P_q can be found by the formula (19).

The mass of gas Q_m percolating through the layer and entering the well in a single time is found as follows

$$Q_m = \frac{\rho_{atm}\pi kh}{P_{atm}\mu}\frac{P_k^2 - P_q^2}{\ln\frac{R_k}{r_c}} \tag{20}$$

where, h is the height of the filter, k is the filtration coefficient, μ is the dynamic viscosity of the gas, R_k is the radius of the reservoir contour, r_c is the radius of the well, P_k is the contour pressure.

From the expression (18), we find Q

$$Q = \frac{\left(P_q e^{-\alpha L} - P_y\right)g\rho_{atm}}{2aP_{atm}\left(1 - e^{-\alpha L}\right)} \tag{21}$$

From the continuity conditions: $Q \cdot f = Q_m$, taking into account expressions (20) and (21) we obtain:

$$\frac{\left(P_q e^{-\alpha L} - P_y\right)gf}{2a\left(1 - e^{-\alpha L}\right)} = \frac{\pi kh}{\mu \ln\frac{R_k}{r_c}}\left(P_k^2 - P_q^2\right) \tag{22}$$

By solving this equation, we can find P_q. After connecting the new gas line to the previous lines, the pressure increase ΔP will come on top of P_y, the downhole pressure P_q will be found from the expression (22).

Then, as a result of the connection of the gas line, the well bottom pressure P_q increases, so the efficiency of the well per unit time changes (decreases) and can be found as follows according to the formula (20).

$$Q_{m1} = \frac{\rho_{atm}\pi kh}{P_{atm}\mu}\frac{P_k^2 - P_{q1}^2}{\ln\frac{R_k}{r_c}} \tag{23}$$

P_{q1} is the pressure created at the bottom of the well after the new gas line is connected to the previous lines.

The percentage reduction in well productivity after a new source is connected can be found as follows.

$$\eta = \frac{Q_m - Q_{m1}}{Q_m}\cdot 100\% \tag{24}$$

If we write formula (20) and (23) in expression (24), we get:

$$\eta = \frac{P_{q1}^2 - P_q^2}{P_k^2 - P_q^2}\cdot 100\% \tag{25}$$

By means of the expression (25), it is found how

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much the productivity of a well decreases after connecting a new gas pipeline to the previous lines in each well.

For the field, the decrease in productivity of the wells after connecting the new gas line to the transmission gas pipeline can be found as follows:

$$\eta = \frac{\sum_{i=1}^{n}\eta_i\, Q_i}{\sum_{i=1}^{n} Q_i}\cdot 100\% \qquad (26)$$

where, n is the number of wells, and Q_i is their production.

Also, let's look at the motion of the liquid-gas mixture that filters through the formation and enters the well at the same time.

The mass amount of liquid-gas mixture from the layer can be found by the following formula:

$$G_1 = \pi kh \frac{\rho_{atm}}{\mu_q\, P_{atm}} \frac{P_k^2 - P_c^2}{\ln\frac{R_k}{r_c} - \frac{r_c}{R_k} - 1} \qquad (27)$$

where, μ_q is the dynamic viscosity of the gas-liquid mixture, P_c is the wellbore pressure, P_k is the contour pressure.

The pressure during the movement of the liquid-gas mixture in the riser pipeline is as follows:

$$P = \left[P_c + \frac{2aQ\,P_{atm}}{(1+\varepsilon)\rho_{atm} g}\right] e^{-\alpha L} - \frac{2aQ\,P_{atm}}{(1+\varepsilon)\rho_{atm} g} \qquad (28)$$

$$\alpha = \frac{\rho_{atm}(1+\varepsilon)g}{P_{atm}}$$

where, ε is the mass fraction of water and condensate in gas.

Wellhead pressure P_y:

$$P\big|_{x=l} = P_y \qquad (29)$$

where, L – second row is the discharge depth of the riser pipeline. Considering expression (28) from condition (29), we get:

$$P_y = \left[P_c + \frac{2aQ\,P_{atm}}{(1+\varepsilon)\rho_{atm} g}\right] e^{-\alpha L} - \frac{2aQ\,P_{atm}}{(1+\varepsilon)\rho_q\, g} \qquad (30)$$

From expression (30), wellbore pressure P_c can be found as follows.

$$P_c = \left[\frac{2aG\,P_{atm}\left(1-e^{-\alpha\cdot L}\right)}{gf} + P_y\right]\cdot e^{\alpha\cdot L} \qquad (31)$$

where, G is the productivity of the well (the sum of the volume of gas multiplied by the volume of product from the formation).

The wellbore pressure before the new source is connected is found by expression (31). Then, from the expression (27), we get the following expression for each well based on their given operating modes:

$$\frac{\pi kh}{\mu_q\left(\ln\frac{R_k}{rc} - \frac{r_c}{R_k} - 1\right)} = \frac{G_1\cdot P_{atm}}{\rho_{atm}\cdot\left(P_k^2 - P_c^2\right)} \qquad (32)$$

There G_1 is the mass of the gas-liquid mixture from the reservoir to the bottom of the well.

From the condition of equality of the mass amount of the gas-liquid mixture coming from the layer to the bottom of the well at the same time and the sum of the amount of ash of the gas injected into the well at the same time to the mass amount of the liquid-gas mixture rising through the lifting pipeline at the same time:

$$\frac{\left(P_{c1}\cdot e^{-\alpha L} - P_y\right)(1+\varepsilon)gf}{2a\left(1-e^{-\alpha L}\right)} = \frac{\pi hk\left(P_k^2 - P_{c1}^2\right)}{\mu_q\left(\ln\frac{R_k}{r_c} - \frac{r_c}{R_k} - 1\right)} + V\cdot P_{atm} \qquad (33)$$

After connecting the new line, we will find the value of the pressure P_y at the bottom of the well by writing the quantity obtained for each well from the expression (32) $\frac{\pi hk}{\mu_q\left(\ln\frac{R_k}{r_c} - \frac{r_c}{R_k} - 1\right)}$ instead of in the expression (33). Then, after the new source is connected, the yield of the well is found as:

$$G_1 = \pi kh \frac{\rho_{atm}}{\mu_q\, P_{atm}} \frac{P_k^2 - P_{c1}^2}{\ln\frac{R_k}{rc} - \frac{r_c}{R_k} - 1} \qquad (34)$$

Thus, after the gas well is connected to the line, the loss in the gas lift well is as follows

$$\varepsilon = \frac{G - G_1}{G}\cdot 100\% \qquad (35)$$

If we substitute expressions (27) and (34) in formula (35), we get it

$$\varepsilon = \frac{P_{c1}^2 - P_c^2}{P_k^2 - P_c^2}\cdot 100\% \qquad (36)$$

The variation of gas production in each well is found with the help of formulas (33) and (34).

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Conclusion

Based on the research, we see that the pressure increases as a result of the connection of the new pipeline, which in turn affects the operation of the wells. Using the practical values of the parameters and the received formulas, the production of wells was found for each well separately and for all wells in percentage and m^3/day.

After the new gas pipeline is connected to the system, the pressure increase in the system is calculated by the formula (11), and the productivity of the wells after the new source is connected is found by the formula (35).

Numerical calculations are carried out at different values of practical parameters and the obtained results are analyzed.

After the high-pressure gas line is connected to the system and depending on the amount of injected gas:

When a pressure drop is obtained $\Delta P = 4\, atm$, gas production of wells decreases by 12-13 %; when $\Delta P = 9\text{-}10\, atm$ daily productivity of wells decreases by 28-29.8 %.

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