Techniques for optimization of gas extraction from production wells annulus

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Abstract. The article experimentally establishes the regularities of the separated gas pressure growth in the annulus depending on geological and technical characteristics of producing wells; it obtains an experimental dependence for calculating the period of stabilization of the gas pressure in the annulus when the pressure is equal to the pressure in the discharge manifold of the well.

1. Introduction

One of the ways to increase the efficiency of oil field development is to intensify oil production from wells [1–8]. It is known that to increase the flow rate of wells operated by traditional mechanized methods, various technologies and technical means are used to reduce the gas pressure in the annulus [9]. Ejectors that are installed in the tubing string above the liquid level or directly at the wellhead are used for forced pumping of gas from the annular space of the well into the flow header [10]. There are also technologies for pumping gas with the help of additional plungers installed on the rod string, as well as an overhead compressor driven by the balance beam of the pumping unit [11].

The experience of using the technology of forced pumping of gas from the annulus showed that the flow rate of one well increases on average by more than 2.7 t / day [12].

To calculate the parameters of gas compression from the annulus to the reservoir, it is necessary to have data on the volumes of gas supplied from the pump intake to the annulus of the well per unit of time.

For the experimental determination of these volumes, it is necessary to measure the dynamics of the gas pressure in the annulus after the pressure is reduced to atmospheric value. In this case, the pumping unit must continue to operate continuously in order to avoid violations of the conditions for gas extraction from oil and its separation at the pump intake.

The dynamics of changes in the gas pressure in the annulus ultimately makes it possible to determine the amount of gas separated at the pump intake and supplied to the annulus, which will be described below.

2. Materials and methods

The essence of the experiment is to pump out gas from the annular space to a pressure corresponding to atmospheric pressure, followed by turning off this compressor and periodically recording the pressure in the annular space for a period sufficient for its stabilization.
The simplest and most accessible method for constructing a pressure dynamics curve is its periodic registration after the pump is started up and brought into operation. In the initial period after killing, the downhole pumping unit pumps out fluid from the annulus. Further on, the dynamic fluid level is stabilized. During the period before and after the stabilization of the pumping mode, periodic beating of the dynamic level and recording of the change in gas pressure in the annular space over time are performed.

3. Results and Discussion

Figure 1 shows the obtained curves of gas pressure dynamics in the annular space of wells No. 740 and No. 716 of the Chutyrsko-Kiengopskoye field. In well No. 740 (curve 1), already after 12 hours, the gas pressure stabilized, which equaled the pressure in the reservoir (about 1.45 MPa).

At the same time, full stabilization of gas pressure in well No. 716 (curve 2) did not occur. The reason for this was the higher dynamic fluid level (852 m) in well No. 716 compared to well No. 740 (462 m), despite approximately the same gas-oil ratio (about 6.5 m³/t) and oil flow rates of wells (6.0 and 5.2 m³/day).

Along with the indicated volume of the well filled with gas, the pressure dynamics are influenced by the gas-oil ratio, the pressure at the pump intake and the conditions for the separation of the free gas phase.

Therefore, the gas flow rate entering the annulus above the pump will be proportional to the value:

\[
Q_g = (G_f - G_{left}) \frac{Z \cdot P_W}{P_O T_O} Q_{oil} \delta, \quad \text{m}^3/\text{day},
\]

where \(G_f\) is the gas factor, m³/m³; \(Z\) is the gas constant; \(P_O, T_O\) — pressure and temperature, equal to 0.1 MPa and 273 K, respectively; \(T_W\) — fluid temperature at the pump intake, K; \(Q_{oil}\) — well oil production rate, m³/day; \(\delta\) — gas separation coefficient.

The \(G_{left}\) value in (1) is determined from the curve of one-time oil degassing.

As an example, Figure 2 shows the curves obtained for fields in Western Siberia. In this figure, at a given pressure value, the amount of gas released from oil is determined, and the residual amount of \(G_{left}\) gas is determined from it.
Figure 2. Differential degassing curves for oils: gas content, m$^3$/m$^3$, pressure MPa

Considering that during the period of reaching the gas pressure, some changes occur at the pump intake, it is permissible to take its average value as the calculated value of the $G_{left}$ coefficient. The $G_{left}$ value can also be calculated by the ratio:

$$G_{left} = G_f \left( \frac{P_{pr} - 0.1}{P_{sat} - 0.1} \right). \quad (2)$$

If we take $V_a$ – as the volume of the annular space above the dynamic level, then the change in the ratio $V_a/V_g$ in time will characterize the rate of filling this space with gas and increasing pressure in it.

Similarly, if we denote $P_a$ - the current pressure in the annulus, and $P_r$ - pressure in the reservoir, then the change in the $P_a/P_r$ ratio per unit time will show the intensity of the gas pressure growth above the dynamic level.

In this case, the $P_a/P_r$ ratio will depend on the volume of gas $V_g$ entering the annulus.

Thus, the parameters $P_a/P_r$ and $V/V_a$ are related in a certain way.

The amount of gas entering the annulus per day is calculated:

$$V_g = Q_g \cdot t, \text{ m}^3, \quad (3)$$

where $t$ is time, days.

In order to establish such a relationship in several wells in fields with a large scatter of GOR values, using the measurements described above, the curves of the dynamics of dimensionless pressures were plotted as a function of time (Figure 3).

Figure 3 shows that the nature of change of gas pressure in the annulus is approximately the same. With an increase in the value of $V_a/V_{in}$, the period after which the pressure in the annulus reaches the pressure in the reservoir ($P_a/P_r = 1$), decreases.

From a practical point of view, the period of reaching the gas pressure in the annular space of the reservoir pressure is especially interesting. The inverse value of this period (1/1/t$_{set}$), characterizes the intensity of gas inflow and growth of its pressure in the annulus. The value of the pressure in the annulus during its stabilization will correspond to the pressure in the discharge manifold of the well due to the presence of a check valve at its wellhead.
Figure 3. Dependence of the relative value of $P_d/P_r$ on the period of operation of the installation of the downhole sucker rod pump: 1 - well No. 279; 2 - well No. 336; 3 - well No. 740; 4 - well No. 598

Figure 4 shows the dependence of $1/t_{set}$ on the parameter $V_g/V_a$. This dependence is described by the formula:

$$1/t_{set} = 3.63 \times 10^{-3} \left( V_g/V_a \right)^{1.75}$$

(4)

or

$$t_{set} = 3.63 \times 10^{3} \left( \frac{K_{Gf}Q_{oil}V_{o}}{V_{a}} \right)^{-1.75}$$

(5)

Formula (5) makes it possible to calculate the period $t_{set}$, during which the gas pressure in the annular space will reach the pressure in the discharge manifold of the well.

Figure 4. Dependence of the parameter $1/ t_{set}$ on the value $V_g/V_a$
4. Conclusion
1. The regularities of the pressure increase of the separated gas in the annulus were experimentally established depending on the geological and technical characteristics of the wells.
2. The study obtains an experimental dependence for calculating the period of stabilization of the gas pressure in the annulus when the pressure is equal to the pressure in the discharge manifold of the well.

References
[1] Briones M, Zambrano J A and Zerpa C 2002 Study of Gas-Condensate Well Productivity in Santa Barbara Field, Venezuela, by Well Test Analysis SPE Annual Technical Conf. and Exhibition (San Antonio, Texas, 29 September-2 October 2002) p 9, DOI: 10.2118/77538-MS
[2] Mukhametshin V V and Kuleshova L S 2020 On uncertainty level reduction in managing waterflooding of the deposits with hard to extract reserves Bull. of the Tomsk Polytechnic University. Geo Assets Engineering 331(5) 140–146, DOI 10.18799/24131830/2020/5/2644
[3] Yakupov R F and Mukhametshin V Sh 2013 Problem of efficiency of low-productivity carbonate reservoir development on example of Turnaisian stage of Tuymazinskoye field Oil Industry 12 106–110
[4] Kuleshova L S, Mukhametshin V V and Safiullina A R 2019 Applying information technologies in identifying the features of deposit identification under conditions of different oil-and gas provinces. J. of Phys.: Conf. Ser. 1333(7) 072012. DOI: 10.1088/1742-6596/1333/7/072012
[5] Economides J M and Nolte K I 2000 Reservoir stimulation (West Sussex, England: John Wiley and Sons) 856 p
[6] Khuzina L B, Mukhametshin V Sh, Tyncherov K T and Shaikhutdinova A F 2018 On the choice of the oscillators’ installation site Int. J. of Civil Engineering and Technology 9(9) 1952-1959
[7] Akhmetov R T, Mukhametshin V V and Kuleshova L S 2019 Simulation of the absolute permeability based on the capillary pressure curves using the dumbbell model J. of Phys.: Conf. Ser. 1333(3) 032001. DOI: 10.1088/1742-6596/1333/3/032001
[8] Chudinova D Yu, Kotenev Yu A, Sultanov Sh Kh and Mukhametshin V Sh 2018 The neural network for grouping wells of different facies zones of productive layer IOP Conf. Ser.: Earth Env. 194(8) 082008. DOI: 10.1088/1755-1315/194/8/082008
[9] Sevastyanov A, Ivanov A A and Fatkullin A S 2014 Technology of gas removal from oil wells annular area Oilfield Engineering 9 30-31
[10] Topol'nikov A S, Urazakov K R and Molchanova V A 2009 Modeling of Gas Bypass from the Annulus During Operation of Wells with Low Production Rate Complicated by High GOR Scientific-Technical Herald “NK Rosneft” 2 33–37
[11] Mak-Koi C 2004 Gas Compressor Activated by the Walking Beam of a Jack May Be Useful in Various Field Operations Oil and Gas Technologies 3 44–46
[12] Olarte J D, Haldar S, Said R, Ahmed M, Burov A, Stuker J, Kharrat W and Wortmann H 2011 New Approach of Water Shut off Techniques in Open Holes - and World First Applications of Using Fiber Optic Services With Tension-Compression Sub SPE/DGS Saudi Arabia Section Technical Symp. and Exhibition (Al-Khobar, Saudi Arabia, 15-18 May 2011) p 10. DOI: 10.2118/149116-MS