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AN OVERVIEW OF THE RESULTS OF FIELD STUDIES OF THE EFFECT OF LOWERING THE BOTTOM HOLE PRESSURE BELOW THE SATURATION PRESSURE OF OIL WITH GAS ON THE PRODUCTIVITY OF WELLS

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ABSTRACT

The results of the operation of wells with bottomhole pressures below the saturation pressure of oil with gas are analyzed and summarized. The results of generalization make it possible to substantiate the well operation mode that provides the highest productivity and rational consumption of reservoir energy.

Key words: field, well, flow rate, reservoir, bottomhole, pressure, saturation, productivity, analysis, dynamics, research, hydrodynamics, depression, gas, oil.

INTRODUCTION

In the Republic of Uzbekistan, programs for the development of the oil and gas industry are also being implemented. Based on the program of measures taken in this direction, significant results have been achieved, in particular, within the framework of the program to increase the production of hydrocarbon raw materials, the volume of drilling in exploration and production drilling of wells doubled, which ensured the discovery of new oil and gas fields. The strategy of actions for the further development of the Republic of Uzbekistan, developed by the President of the Republic, defines the tasks of reducing the energy intensity and resource intensity of the economy, widespread introduction of energy-saving technologies in production, increasing labor productivity in the sectors of the economy, as well as continuing the policy of stimulating production to raise the oil and gas industry to a new level of efficiency of hydrocarbon deposits, including research to improve the efficiency of deposits with hard-to-recover reserves.

MAIN BODY

As you know, the saturation pressure of oil with gas, along with the energy characteristics of the oil reservoir. With a decrease in bottom hole pressure below the saturation pressure of oil with gas, the viscosity and shrinkage of oil increases, while the presence of free gas leads to a decrease in the phase permeability for oil, as a result of which the productivity index of the well decreases. As a result, despite the vast experience and high advances in technology and technology of oil production, the efficiency of field development under operating conditions with pressures below the saturation pressure of oil with gas is very low, and well rates are often below the level of profitable ones.

The final oil recovery factor of the fields developed under the dissolved gas regime rarely exceeds 15-20%.

In this regard, increasing the efficiency of the development of oil fields in such conditions seems to be one of the urgent tasks of oil production.

Field studies of the effect of lowering reservoir and bottom hole pressures of wells below the saturation pressure of oil with gas on the productivity ratio of wells and the final oil recovery have been carried out at many fields in different countries. These studies can be conditionally divided into two groups: 1) based on the analysis and generalization of the dynamics of development indicators; 2) based on the results of well testing.

RESULTS AND DISCUSSION

In work [1] E.P Gudkov, M.Sh. Mirzaev and Yu.Kh. Shiryaev for geological and physical conditions of development of fields in the Perm region of Russia studied the issue of the permissible degree of reduction of reservoir and bottom hole pressures below the oil saturation pressure. In most of the 18 fields, the values of the initial reservoir pressures and saturation pressures are close to each other. In this regard, the development of fields at reduced reservoir and bottomhole pressures (below the bubble point pressure) was objectively inevitable, especially in the initial period, due to the difficulties of their timely construction, the lack of water and gas sources for injection into the reservoir, with high drawdowns in the reservoir.

On the example of analyzing the dynamics of the development indicators of the Yarino-Kamennolozhskoye field, the possible boundaries of the distribution of the dissolved gas regime in the reservoir are established. The following dependences of the maximum values of pressures in different parts of the reservoir on the saturation pressure have been established:

in the active selection zone

$$Ppl \geq 0{,}8 \cdot Ppump, \quad (1)$$

within the oil-bearing contour

$$Ppl = Ppump \quad (2)$$

on the discharge line

$$Ppl = (1{,}2 \div 1{,}25) \cdot Ppump, \quad (3)$$

in the area of bottomhole operation of wells

$$Pbot \geq 0{,}6 \cdot Ppump \quad (4)$$

The GOR value at which the oil production rate does not decrease and the bottom hole pressure value providing this GOR value were used as criteria defining the limit of the allowable pressure drop in the reservoir below the bubble point pressure.

M.S.Surguchev believes that the permeability for water (wetting phase) is determined only by its saturation, and for oil it increases due to an increase in the total saturation of oil and gas with a stationary gas. However, strong degassing of oil in the reservoir becomes unreasonable, since it causes an increase in viscosity by 2-3 times, and this more strongly reduces oil recovery than free gas in a porous medium increases it, while maintaining reservoir pressure at the initial level allows maintaining the viscosity of oil in development process.

The negative consequences of a decrease in reservoir pressure below the bubble point pressure are different for the horizons of the Uzen field with highly paraffinic oil, when oil recovery in the XIII horizon reached only 6.6% with a water cut of 17%, and in the XIV horizon, respectively, 7.4% with a water cut of 17.9% ... In the fields of the Ural- Volga region, developed with an active water drive mode, for the same viscosity ratios of oil and water, the indicated oil recovery values were achieved with a water cut of the product 2-3 times less or practically over an anhydrous period.

However, in fields where the physical properties (viscosity) of oil are little dependent on pressure (such as Shkapovsky), oil recovery with partial degassing of oil and its displacement by water turns out to be higher than with conventional water flooding. The optimal reduction in reservoir pressure is approximately 20% of the bubble point pressure. In this case, an increase in oil recovery is possible by 5-10%.

For fields with abruptly changing physical properties of oil depending on pressure (of the Korobkovsky type), a reasonable decrease in reservoir pressure is 10% of the bubble point pressure.

Studies carried out in the United States have also shown that in hydrophilic formations with a vapor space saturation with gas below the critical (no more than 15-20%), oil recovery of formations during oil displacement by water can increase by 8-10% compared to water flooding at pressures above the bubble point pressure. [2].

V.V.Poplygin, S.V. Galkin and I.S. Davydova established statistical dependences of oil production on indicators for the fields of the Pre-Ural fore deep territory. Ppl/PpumpиPbot/Ppump. [3]. It follows from them that a natural decline in production rates of new wells with a decrease in reservoir and bottom hole pressures below the bubble point pressure. A significant decrease in productivity when operating at bottom hole pressures below the bubble point pressure is explained by the manifestation of deformation processes and a decrease in the phase fluid permeability of reservoirs.

The main feature of this field is that the minimum bottom hole pressure of oil flowing out of production wells is about 13 MPa lower than the saturation pressure of oil with gas. During fountain operation, the bottom hole pressure decreases below the bubble point pressure, which leads to a drop out of oil and the accumulation of solid asphaltene- paraffin particles in the formations near the bottom of the wells, which sharply increase the filtration resistance for oil, a sharp decrease in the productivity of wells for oil, as if the oil viscosity has sharply increased and low-viscosity oil became high-viscosity. In their opinion, these processes are the reason for the low oil recovery of the Talinskoye field.

V.V. Orekhov, E.V. Pitsyura, D.K. Sagitov and M.S. Antonov, based on the analysis of the energy state of the reservoir of the Kolgan object of the Vakhitov oil field, came to the conclusion that when the reservoir pressure decreases below the saturation pressure of oil with gas, practically irreversible processes of gas release in the reservoir, which leads to the loss of a part of mobile oil reserves [7]. They also note that when free gas is released from oil in the reservoir, the oil viscosity will increase, the phase permeability for oil will decrease, and local gas regions will form, cutting off part of the mobile recoverable oil reserves.

According to M.Z.Taziev, M.Sh. Kayumov, A.I.Khisamutdinov and others [8], geological and technical measures to stimulate oil production include not only treatment of bottomhole zones of wells, but also measures to reduce bottomhole and increase reservoir pressures. Therefore, the choice of wells for carrying out geological and technical measures to stimulate oil production should be carried out with a joint consideration of the dependencies characterizing the decrease in well productivity over time by predicting, as well as assessing the state of development and production of oil reserves (reservoir and bottomhole pressures, oil and liquid flow rates , current recoverable oil reserves), which will ultimately determine the effectiveness of geological and technical measures. They distinguish six zones (I-VI) with a different combination of reservoir and bottomhole pressures of wells relative to the oil saturation pressure:

Zone I: wells in this zone have reservoir and bottomhole pressures below the saturation pressure of oil with gas and are not recommended for BHT formation, since an increase in well productivity will lead to a further accelerated drop in reservoir pressure, oil degassing, and a decrease in final oil recovery (geological and technical measures are required to increase reservoir pressure);

II second zone: wells have reservoir pressure higher than the saturation pressure of oil with gas, but lower than the average reservoir pressure in general over the area, and the bottomhole pressure is lower than the pressure of oil saturation with gas; these wells can be recommended for BHT formation only if an increase in production rates for them will not lead to a drop in reservoir pressure, otherwise, prior to BHT formation, geological and technical measures are required to maintain reservoir pressure;

III zone: reservoir pressure in wells in this zone is higher than the average over the area, and bottomhole pressure is lower than the saturation pressure of oil with gas; wells in this zone are provided with a reservoir pressure maintenance system and are recommended for water isolation works (VIR) and BHT of reservoirs;

IV, V and VI zones: wells in these zones have bottom hole pressures higher than the oil saturation pressure (there is a reserve for lowering bottom hole pressure) and are recommended for VIR and BHT of formations.

When studying the effect of lowering the bottom hole pressure below the oil saturation pressure on the productivity index, a special place is occupied by the results of hydrodynamic studies (HDT), since only in this method the actual productivity of wells is determined [9].

A decrease in the productivity index of wells with a decrease in bottom hole pressure below the bubble point pressure, according to IT Mishchenko and AT Kondratyuk, occurs as follows [10]. Gas released from oil at low contents does not move in a porous medium, that is, its phase permeability is zero.

With a greater decrease in the bottom hole pressure, starting from a certain gas content, the gas begins to move in a porous medium. In this case, with an increase in the gas content, the phase permeability for gas increases, and for liquid, it decreases. Accordingly, the fluid productivity of the well will decrease.

A decrease in well production at a certain bottom hole pressure, lower bubble point pressure and lower than the minimum allowable pressure, is associated with the formation of large zones of oil degassing in the reservoir around the well. At certain ratios Pbot / Ppump and Ppump / Ppl, the size of the degassing zones reaches hundreds of meters, that is, comparable to the distances between the wells. Under such conditions, the degassing zones around the wells merge, and the corresponding part of the formation goes over to drainage in the dissolved gas mode.

An indicator of development in the mode of dissolved gas can be the discrepancy between the gas saturation of oil G and the gas factor Gf. Figure 1 shows the change in the gas factor over time for one of the depletion regimes - the dissolved gas regime [10].

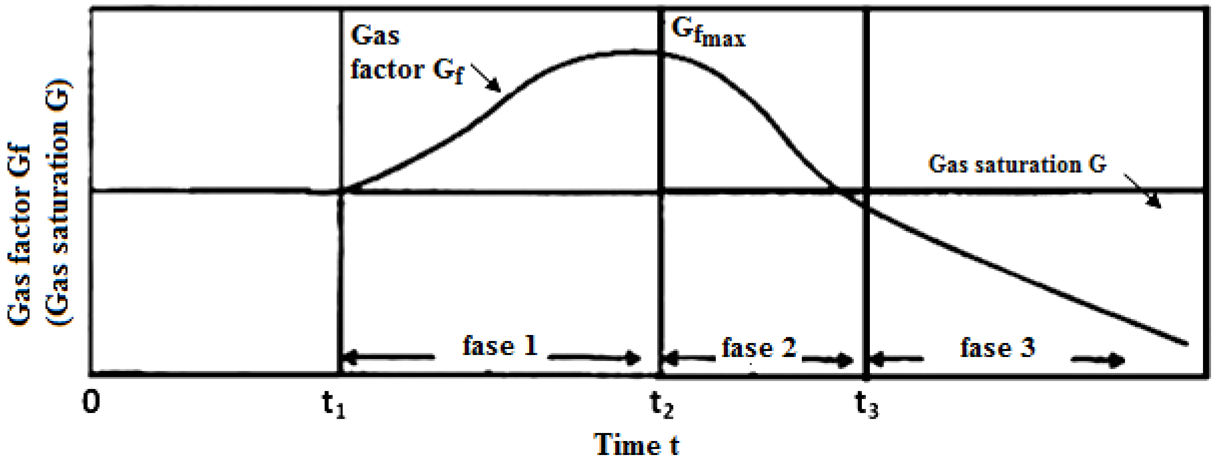

Figure. 1. Change in gas factor with time in the regime of dissolved gas

The constancy of the gas factor and the equality of its gas saturation during the time period 0-t1are characteristic for the displacement mode. The difference in the values of the gas factor and gas saturation is characteristic for the regime of the dissolved gas. Thus during the time t1 - t2 GOR increases to values Gфmax remaining gas saturation of magnitude greater D. In period t2 - t3 is reduced by GOR Gфmax to G. Starting from time t3, gas-oil ratio becomes smaller than the gas saturation. By the nature of the change in the value of the gas factor Gфrelative to the gas saturation Γ, three time phases of the dissolved gas regime can be distinguished: t1 - t2- the first phase; t2 - t3 - second phase; t≥t3is the third phase. It is obvious that these phases are associated not only with the energy state of the development target, but also the production rates of production wells and, ultimately, the total cumulative oil production.

According to the results of studies carried out in [4] on the Bobrikovsk deposits of the Siberian field, the average annual oil production from wells operating with Pbot below Ppump more.

In work [5] VD Lysenko, MM Ivanov, VA Grigoriev and other scientists, the deplorable experience of the development of the Tallinskoye field located within the Ural-Volga region is analyzed, where instead of the potential (design) possible oil recovery 45% the actual oil recovery was equal to 9-11%.

In works devoted to the study of the operation of production wells at bottom hole pressures below the bubble point pressure, there is a curvature of the indicator lines due to the release of free gas in a porous medium. The field studies carried out, especially in recent years, have established a qualitatively new phenomenon associated not only with the curvature of the indicator lines, but also with their bending towards the pressure axis (depression). At the same time, a larger drawdown on the formation (lower bottom hole pressure) corresponds to a lower liquid flow rate up to the transition of the well operation to pure gas. Such indicator lines were obtained at various oil fields: Tuimazinsky and Shkapovsky (Bashkortostan),
Romashkinsky, Bavlinsky, Elabuga and Kontuzlinsky (Tatarstan), Varyogansky, Severo-Varyogansky, Vyngapurovsky, Tarasovsky, Talinsky (Western Siberia) and others. Moreover, similar indicator lines are typical for the Uzen field (Fig. 2).

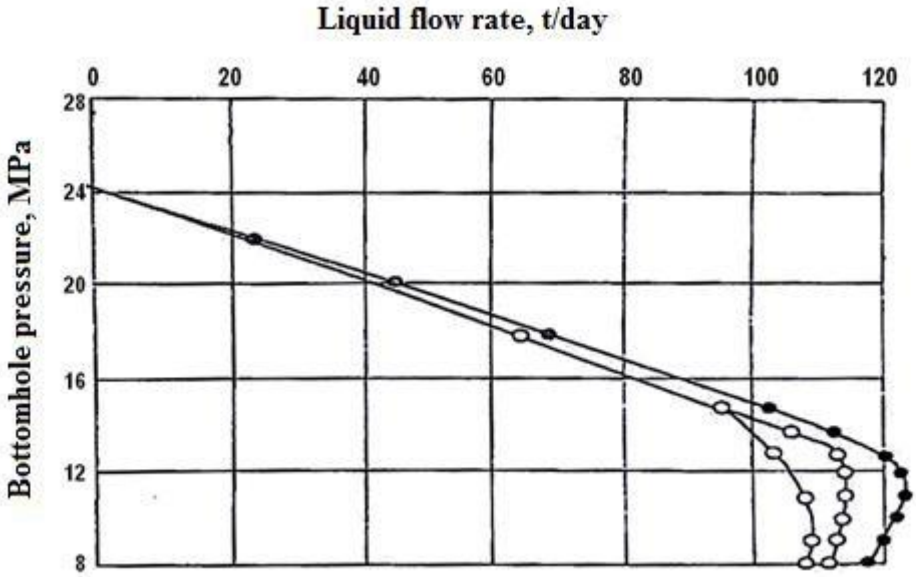

Figure. 2. Indicator lines

The problem of operating wells with bottomhole pressures below the bubble point pressure (especially in fields whose initial reservoir pressure is close to the bubble point pressure, which is the Talinskoye field) has not yet been resolved, because many experts believe that when developing fields with maintaining reservoir pressure by pumping water a significant decrease in bottomhole pressures in producing wells is permissible, since even with nonlinear indicator diagrams, an increase in drawdown leads to an increase in production rates, and oil degassing in the main drained volume does not occur, that is, the main drainage mode is the displacement mode and the transition to the depletion mode is unlikely. Based on this, well operation modes are recommended with the use of appropriate production equipment, which makes it possible to reduce the bottom hole pressure significantly below the bubble point pressure.

As a result of generalizing the results of hydrodynamic testing of wells in the Ural-Povolye and Western Siberia, I.T. Mishchenko and A.T. Kondratyuk suggested a generalized dependence to determine the critical bottom hole pressure in the following form:

$P_{bot.crit} = 3{,}5 + 68{,}33 \cdot 10^{-3} \cdot G_0 \cdot P_{pump}/P_{pl}$ (1)

where, $68{,}33 \cdot 10^{-3}$ is a numerical empirical coefficient having the dimension of MPa · t / m3; G - gas factor, m3/ t.

This dependence can be used in practice when establishing operating modes for production wells, including for the Tallinskoye field.

The critical bottom hole pressure also determines the maximum possible drawdown ΔP_{max}:

$\Delta P_{max} = P_{pl} - P_{bot.crit}$ (2)

or taking into account (1):

$\Delta P_{max} = P_{pl} - 3{,}5 - 68{,}33 \cdot 10^{-3} \cdot G_0 \cdot P_{pump}/P_{pl}$ (3)

At the same time, despite the fact that (1) has a linear character, there are three zones for grouping objects depending on the dependence of Pbot.crit on G0

I-zone of rather heavy oils of the Ural-Volga region with a low gas-oil ratio (gas-oil ratio ranges up to 23 cubic meters / t, and the saturation pressure - from 5.6 to 6.2 MPa);

II-zone of normal Devonian oils of the Ural-Volga region (DI, DII) with an average gas ratio of 30 to 70 cubic meters / t and a saturation pressure of 9-10.1 MPa;

III-zone of light oils from both Devonian deposits (DIV) of the Ural-Volga region, and light oils from fields in Western Siberia with gas (factor from 120 to 300 cubic meters / t and more, saturation pressure from 12.6 to 22.1 MPa.

For the first zone-zone of heavy oils, the value of the critical bottomhole pressure varies in the range from 3.5 to 5 MPa, which is (0.6 ÷ 0.8) · Ppump; for the second zone-zone of normal oils Pb.crit5 ÷ 8 MPa, which is (0.5 ÷ 0.8) Pbot.crit, for the third zone-zone of light oils Pbot.crit8 ÷ 20 MPa, which is (0.4 ÷ 0.1)) Ppump.

Based on the results of hydrodynamic testing of wells, V.D. Lysenko proposes to divide oil deposits into two types. The first type includes those in which the minimum flowing pressure of producing wells with pure oil is higher than the bubble point pressure. The second type is where the minimum bottom hole pressure of oil flowing is lower than the bubble point pressure [9].

In oil deposits of the second type, a decrease in the bottom hole saturating pressure can lead to a catastrophic decrease in the productivity index.

The operation of wells with bottom hole pressure below the bubble point pressure is considered by some specialists as one of the reserves for oil production stimulation. For example, works [11, 12, 13] show a high efficiency of lowering the bottom hole pressure below the bubble point pressure for the geological and physical conditions of the fields in Bashkortostan and Tatarstan. Meanwhile, there are research results [14, 15, 16] indicating the low efficiency and even negative consequences of this method in the fields of Tatarstan.

CONCLUSION

The results obtained will make it possible to establish a well operation mode at fields close in their geological and physical conditions, which ensures the highest productivity and rational consumption of reservoir energy, which will ultimately lead to an increase in the efficiency of reservoir development and an increase in the final oil recovery of reservoirs.

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