Proposals for the adjustment of design solutions in the formation of a strategy for the effective operation of oil wells

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Abstract. The article considers the features of well pattern infilling as one of the effective ways to enhance oil recovery. A brief description of the field N is given. Analysis of how the well pattern infilling enabled to enhance oil recovery in the reservoir of this field. The influence of well placement density on oil recovery is analyzed. It is proposed to evaluate the degree of influence of each infill well on oil recovery. The performance of each infill well is considered in comparison with the performance of adjacent wells in the same production row or cell, i.e. with close parameters of productive reservoirs and the same type of development conditions.

1 Introduction

As fields are developed, there is a change in the structure of oil reserves. Thus, at a late stage of development, the share of hard-to-recover reserves and the ones initially confined to unproductive objects and zones starts growing.

The efficiency of oil production in such conditions decreases, which requires adjustment of well operation modes. This kind of adjustment can be carried out through the planning and subsequent implementation of a set of geological and technical measures for the stock of injection and production wells. Thus, it is the correct choice of the methods for enhancing oil recovery depending on the conditions of a particular field that significantly affects the effectiveness of these methods. Therefore, the development of innovative geological, technical, organizational and technological solutions aimed to increase the efficiency of complex deposits development under the conditions of the financial and economic situation that has currently developed in Tatarstan, is becoming a pressing issue at the current stage of development of the fuel and energy complex of the Russian Federation.

At the moment, there are very few proven methods of influencing the deposits with hard-to-recover reserves. This is due to the unresolved issues related to the choice of the

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optimal density of the well grid, as well as the methods of opening reservoirs in the process of drilling wells and their subsequent operation. Therefore, it is necessary to determine the most efficient well operation modes and select the optimal grid density value for such production facilities. In PAO “Tatneft”, the construction of wells on a compacted grid does not mean drilling traditional wells, but drilling tight wells. The diameter of the production string of such wells varies from 102 mm to 114 mm. Drilling tight wells in comparison with wells of traditional design allows reducing material costs by an average of 58%.

A small number of wells were drilled in the field under consideration as part of the infill well pattern program, which impedes a detailed analysis of the results of well pattern infilling by drilling. In this regard, the analysis resulted in design decisions aimed to compact the well grid by drilling tight wells (well performance indicators) on the sediments of the Vereisk-Bashkir object of the neighboring field under consideration.

Infill drilling of tight wells and their commissioning leads to an increase in the rate of decline in oil production from the old well stock. At the same time, the rate of decline in production for the tight well is greater than for the old fund. Concurrently, the oil reserves involved in the development of single wells differ by ten times and, respectively, amount to 1.6 and 17.4 thousand tons for the field under consideration. Therefore, when developing a deposit in a natural mode with the wells drilled to infilling, the deposits involve the reserves of fractured zones, there is an interference of wells, and the economic indicators of development worsen [1-8].

2 Methods and materials

In total, 206 tight wells drilled in this field with accordance to the project on well pattern infilling were analyzed. The wells have been worked for 2-17 months from the date of their commissioning (106 wells during 2-11 months – 51.5%, 100 wells during 12-17 months – 48.5%). As of February 1, 2018, 107.9 thousand tons of oil and 135.4 thousand tons of liquid were taken by wells. The average monthly oil production was 53.9 tons per month.

16 wells did not reach the design flow rate (7.8% of the drilled stock, the shortfall in flow rate from 2% to 77%). As of February 1, 2018, the wells worked for 3-10 months, while 3.5 thousand tons of oil and 5.4 thousand tons of liquid were taken. The average monthly oil production was 35.8 tons per month. Three wells (1.5% of the drilled well stock) were downgraded to piezometric (28,613, 28,234) and inactive (28,576) due to the decline in production. As of February 1, 2018, 0.2 thousand tons of oil and 1.7 thousand tons of liquid were selected based on them. The average monthly oil production was 5.2 tons per month. A high drop in oil production (51% – 99% of the initial one) is observed in 59 wells (28.6% of the drilled stock).

As of February 1, 2018, the wells worked for 3-17 months, while 25.6 thousand tons of oil and 33.2 thousand tons of liquid were taken. The average monthly oil production was 36.1 tons per month. For six wells (2.9% of the drilled well stock), the initial water cut was more than 12% with its further increase. In 15 wells, there was a sharp increase in the initial water cut by 10-93% (3-5 months – 5 wells, 12-16 months – 10 wells). An analysis of the available reservoir pressure data (93 wells constituting 45.25 of the well stock) showed that nine wells experienced a drop in reservoir pressure. A more detailed study of these wells enables to recommend the transfer to the injection of a working agent to create a reservoir pressure maintenance system. The dynamics of the operating stock of producing wells in the field under consideration is shown in the Figure 1.
It should be noted that during the development of the waterflooding system, the infill injection wells involve three times more reserves compared to the old production fund used at the beginning of the development. Therefore, in modern market conditions, with the widespread introduction of modern technologies in the oil industry, and based on the analysis of the development of experimental areas, it is advisable to drill carbonate objects stage by stage, specifically: first, drill a sparse grid in natural mode (4–5 years), and then to develop the waterflooding system and multiple compaction of the grid with tight wells (including injection), small-diameter borehole gravimeter, sidetrack, horizontal sidetrack, return wells from other objects.

This approach enables:

- To commission the field with positive economic indicators due to the commissioning of a larger volume of reserves while drilling the same number of wells.
- To study in detail the geological structure of the object, identify local features, quickly and selectively change the well density and the layout of injection wells among the recovery wells. Minimize the drilling of unproductive and unnecessary wells, as this requires large costs.
- To establish the natural mode of the deposit, that is, to determine the possibility of developing the deposit on sufficiently effective natural modes by conducting hydrodynamic studies.
- To ensure stable oil production for a long time due to the involvement of reserves on account of an increase in the intensity of the development system by compacting the well pattern, increasing the waterflooding intensity, and development objects enlargement.
- To reduce the cost of the project through the use of horizontal sidetracks, horizontal wellbores, gas distribution substations, dual completion and injection and enhanced oil recovery to infill tight wells patterns.

**Fig. 1.** Dynamics of operating stock of producing wells in considered field.
3 Results and Discussion

When implementing a project for infilling well patterns by drilling tight wells, the following risks associated with the geological features and conditions of field development may arise:

- Failure to achieve the initial production rate.
- Opening of a non-reservoir or a water-saturated reservoir.
- High rates of decline in base oil production of tight wells.
- Deterioration of technological parameters of adjacent wells drilled before infilling.

The main possible geological risks that may cause negative phenomena can be as follows:

- Non-confirmation of the deposit geological setting.
- Location of wells in areas with marginal and bottom water.
- Features of difficult-to-recover reservoirs (fracturing, high viscosity, heterogeneity, low-permeability reservoir in injection zones).

The main possible technological risks that may cause negative phenomena are as follows:

- Decrease in reservoir pressure and decrease in well productivity.
- A sharp increase in water cut of wells.
- Inefficiency of the reservoir pressure maintenance system and unproductive injection.
- Non-tightness of the column and perforation, wellbore leakage.
- Blockage at the bottomhole area and possible loss of asphalt, resin, and paraffin deposition in the bottomhole area.
- Lower density of perforations in wells with a small diameter compared to conventional wells.
- Interference of wells and redistribution of filtration flows associated with it after well patterns infilling.

To evaluate the effectiveness of infill drilling using tight wells, it is necessary to consider the above-mentioned geological and technological risks [9-11].

Based on the analysis devoted to the assessment of the involvement of oil reserves using the method of initial production rates, the following conclusions were made. After wells patterns infilling, there is a decrease in fluid and oil production in the stock of wells drilled before compaction (not tight wells). There is a decrease in the average value (and median value) of the liquid rate and a slight change in the water cut in the wells of the tight wells in dynamics after drilling.

For the field under consideration, the total volume of injected water for the last two years is noticeably less than the cumulative fluid production for the same period (compensation is less than 100%). The result of insufficient compensation for withdrawals by injection and a decrease in bottomhole pressure is a decrease in reservoir pressure, in particular, this is even more pronounced in the field under consideration.

A small number of wells were drilled in the field N considered earlier as part of the infill well patterns program, which does not allow a detailed analysis of the results of well patterns infilling by drilling [12]. In this regard, this paper provides the analysis of previously adopted design solutions for infilling well patterns by drilling tight wells (well performance indicators) on the sediments of the Vereisk-Bashkir object of the neighboring field under consideration. The design and actual indicators of the development of wells drilled in the field under consideration with regards to the project on infilling well patterns have been collected and analyzed.
4 Conclusion

For the field under consideration, 206 wells were analyzed with regards to the involvement of oil reserves in tight wells using the method of initial (amplitude) flow rates through the capacity of drilled wells. According to the results of the analysis, the involved oil reserves amounted to 442.8 thousand tons, while the cumulative oil production from tight wells is 93.5 thousand tons. At the same time, residual oil reserves from tight wells amount to 349.3 thousand tons.

This technique is most applicable for objects with a short history. It is not recommended to apply traditional methods of displacement characteristics to them. When carbonate deposits are introduced into development, reservoir pressure decreases regardless of the development of the waterflooding system from the very beginning of development. First of all, reserves of fractured zones with a macrofracture opening of 100 – 300 microns are involved in the development. In this case, the wells are put into operation with an initial low water cut (10 – 15%), corresponding to the initial saturation of the water fractured zones. For reservoirs of the fractured-porous type, after the formation pressure is reduced by 3.1 – 3.5 MPa, matrix blocks are put into operation. At the same time, the reservoir pressure stabilizes at the same level; the water cut increases from the initial level to the initial saturation of the matrix blocks, and the well oil production rate increases (stabilizes). According to the displacement characteristic, it is observed that new reserves are involved in development.

The effect of developing waterflooding system in the form of involving new reserves in the development begins to appear only after the reservoir pressure decreases to the level of the closure pressure of meso-, macro-fractures at optimal bottomhole injection pressures equal to the lateral expansion pressure. However, in this case, the reservoir pressure should not decrease below the critical deformation pressure. When developing a deposit in a natural mode, wells drilled to infill the patterns, like the old fund, involve reserves of fractured zones, wells interfere, and economic development indicators deteriorate. In this regard, two-stage drilling is really feasible due to the presence of significant reserves and a large project well stock for these deposits.

Tight wells drilled for the purpose of infilling the existing wells patterns are put into operation with flow rates and reservoir pressure at the level of current development indicators for the old well stock. The commissioning of new wells leads to an increase in the rate of decline in oil production from the old fund. At the same time, the rate of production decline in the tight wells is greater than in the old wells, since the oil reserves involved in the development per one well differ by dozens of times. Taking into account the decrease in fluid flow rate both in wells drilled before infilling and in tight wells and the tendency for the drawdown to increase, one can assume a deterioration in well productivity, in particular, this is more pronounced in the field under consideration.

Due to the drilled tight wells on the infilled wells patterns, there was an increase in the involved oil reserves. The performed analysis of the involvement of reserves by three methods showed a relatively good precision of results for the considered field.

References