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Effective system for hard-to-recover reserves development of the BS_9^{2-2}ach reservoir of the Achimov formation of the Sorovskoye field

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Abstract. At the moment, hard-to-recover reserves start playing bigger role in oil production all over the world. In Russia, they account for more than 65% of the total proved reserves. Therefore, the effective development of hard-to-recover reserves is one of the most important and promising tasks of oil producing enterprises. The Achimov formation in Western Siberia has large oil production potential, but traditional approaches are not efficient enough to develop such complex reservoirs.

The purpose of the work is the development analysis and the best option selection for the development of oil deposits of hard-to-recover reserves. The article considers various ways to solve the problem. The most promising are the two options – the drilling of multilateral wells and the drilling of horizontal wells with low-volume hydraulic fracturing. As a result of the analysis of the geological structure and calculation on the hydrodynamic model, it is concluded that the most optimal way is to drill multilateral wells. Economic calculations confirm the feasibility and profitability of the project.

Keywords: Achimov formation, hard-to-recover reserves, oil production, multilateral wells, low-permeability reservoir, hydraulic fracturing, horizontal wells, well completion.

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Introduction

Hard-to-recover oil reserves are characterized by relatively unfavorable geological conditions for oil occurrence and (or) its physical properties (concentrated in deposits with low-permeability reservoirs and viscous oil). The cost-effective development of such reserves can only be carried out using methods and technologies that require increased capital investments and operating costs compared to traditionally used methods [1]. In Russia, the share of hard-to-recover oil reserves reaches more than 65% of all proven oil reserves. By 2035, the Ministry of Energy of the Russian Federation expects the share of oil from hard-to-recover reserves in the total volume of oil production to increase from 8% to 17% [1]. Therefore, the effective development of deposits confined to low-permeability reservoirs is one of the most important and promising tasks for oil producing enterprises.

The Achimov formation in Western Siberia has a great potential for oil production – more than 60 billion tonnes [2]. However, traditional methods of oil production do not allow to use it in full. Due to the complex geological structure, low reservoir properties and poor hydrodynamic coupling of the reservoir, the Achimov deposits are often referred to as hard-to-recover reserves. As a result, the effective development of such deposits requires the search for alternative approaches and new technologies.

PJSC Rosneft Oil Company has experience in developing fields complicated by hard-to-recover reserves at the Sorovskoye field, which is being developed in the conditions of low-permeability deposits of the Achimov formation. The Sorovskoye field was discovered in 2002; the commercial oil content of the field is confined to deposits of the Neocomian, Achimov, Upper Jurassic and Middle Jurassic oil-bearing complexes. The field is at the first stage of development, which is characterized by a rapid increase in production. The development of the field is carried out with the maintenance of reservoir pressure.

The aim of the work is to maximize oil production by determining the optimal type of well completion for drilling the Achimov deposits of the Sorovskoye field. The object of research is the BS_9^{2-2}ach reservoir. The reservoir was put into development in 2019 and contains 30% of the reserves of the entire oilfield. The BS_9^{2-2}ach reservoir is represented by fundoform deposits of the clinoform complex. The Achimov deposits were formed at the foot of the shelf during sediment sliding down the slope. Accordingly, sandy-silty rocks have a complex lenticular structure. The porosity and permeability properties of the studied deposits drastically change within small areas, both laterally and vertically. The main volume of the deposit is occupied by the oil-water zone (93%). This formation is the main one for stabilizing field production in conditions of depletion of reserves of the main development objects. The reservoir is characterized by low permeability (1.8 mD) and high stratification factor (16 units). Reservoir oil reserves are put on the state balance sheet as hard-to-recover.

Analysis of complicating factors of drilling

Based on the results of drilling and launching the first production wells with large-volume multi-stage hydraulic fracturing, the conceptual model of the field was refined. According to the new concept, the BS_9^{2-2}ach reservoir is represented by two units – the upper one (h = 20 meters) is characterized by an increased oil saturation factor, compared to the lower one (h = 28 meters). Both units are represented by high stratification factor. The main complicating factor of development is the high risk of fracture of hydraulic fracturing breakthrough under the oil-water contact (OWC). On average, in wells that have opened the lower unit, the start-up water cut is 20% higher than in wells with drilling only through the top pack.

Based on the updated conceptual and geological model, a hydrodynamic model was built, on which a predictive calculation was performed according to the base case (with the design solutions of the current project-technological document (PTD) being preserved). According to the results of the calculation, all project wells were divided into two groups – with normal and increased start-up water cut. The location of the wells of the second group corresponded to the zone dominated by the lower unit, which is characterized by low saturation. Thus, a zone was identified in which large-volume hydraulic fracturing is risky and a revision of design solutions is required (Fig. 1).

Selection of the optimal development method

The work considered various ways to solve the problem of high water cut. The most promising are the two options – the drilling of multilateral wells and the drilling of horizontal wells with low-volume hydraulic fracturing [3, 4]. Both of these options allow us to open the entire section of the reservoir with high stratification factor, provide the required development control and significantly increase the productivity of the well in low-permeability reservoirs.

Fig. 1. Identification of risk zones by starting water cut of the BS_9^{2-2}ach reservoir of the Achimov formation

Based on the literature review [3–6], a block diagram was drawn up for choosing the optimal well profile (Fig. 2). The most optimal way is a multi-stage hydraulic for low-permeability reservoirs. However, in conditions of close location of the underlying water, a transition to multilateral wells is recommended. The investigated object is located on the border by the value of the oil-saturated thickness, on the basis of which the two most promising options were identified:

– Horizontal wells with low-volume hydraulic fracturing in the high-risk area;

– Multilateral wells in the high-risk area.

It should be noted that both options provide for the drilling of a low-risk zone with horizontal wells with large-volume multi-stage hydraulic fracturing, in accordance with the approved documentation. The location of wells in the high-risk zone does not change in the plan. Only the profiles of the wells differ.

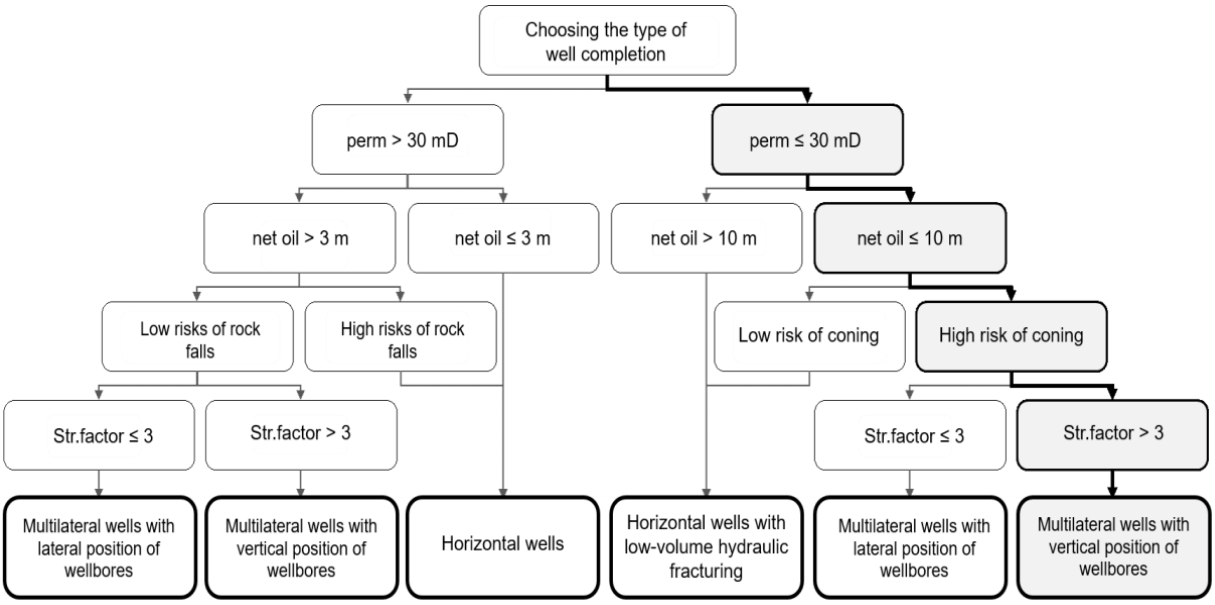


Fig. 2. Block diagram of choosing the type of well completion

Results and discussion

Two variants with different types of completion of wells located in the high-risk zone were calculated on the hydrodynamic model – multilateral wells and horizontal wells with low-volume hydraulic fracturing. The corporate software package RN-KIM was used for the calculation. Due to the absence of the need to simulate the phase state of the fluid, the black oil model was used. The simulation results showed that the "multilateral wells" and "low-volume hydraulic fracturing" options are characterized by comparable dynamics of technological indicators (Fig. 3). On the example of two wells – 1G and 2G, a comparison of start-up flow rates by options is given (Fig. 4). In the base case, there is a high initial water cut due to the close location of the underlying water. With the complexity of the design in the form of multilateral wells or low-volume hydraulic fracturing, an improvement in start-up indicators is observed, and water cut decreases. Over the 40 years of the forecast period, it will be possible to produce 30% more oil compared to the base case.

Plan – an option corresponding to the approved current project document

Basic – an option with the preservation of design solutions, but taking into account changes in the geological basis

MW (Multilateral wells) – an option with placement of multilateral wells in areas of high water content

LVHF (Low-volume hydraulic fracturing) – placement of horizontal wells with low-volume hydraulic fracturing in areas of high water cut

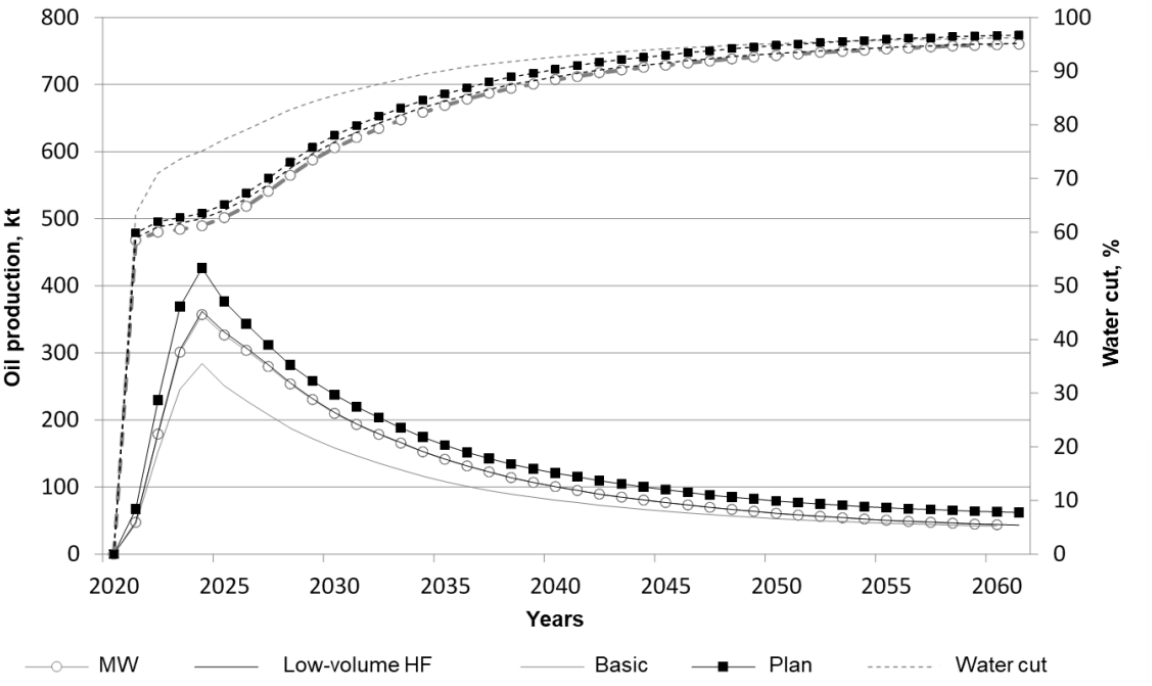
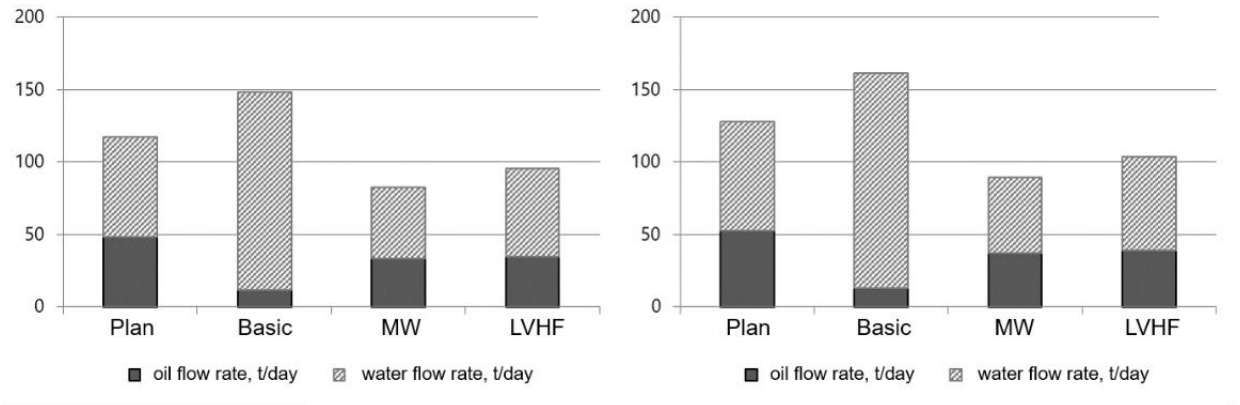


Fig. 3. Comparison of production and water cut indicators of wells in the BS_9^{2-2}ach reservoir



a b

Fig. 4. Comparison of starting flow rates of the wells of the BS_9^{2-2}ach reservoir of the Sorovskoye field selected for calculation on a hydrodynamic model: a – well 1G, b – well 2G

Economic calculations for assessing the financial performance of development options were carried out on the basis of technological calculations performed in the above-mentioned part of this work. To assess the economic model of the project, the discount rate was taken at the level of 20% approved by the Company.

The economic assessment of all three options the option "plan" is calculated in the approved project document) showed that the best economic performance is the option with the replacement of horizontal wells with large-volume hydraulic fracturing in the high-risk zone with multilateral wells. The net present value (NPV) of the multilateral well option is 10% higher than the large-volume fracturing option due to lower capital construction costs. Despite comparable production performance, the low-volume hydraulic fracturing option is characterized by lower economic performance. This is due to the high cost of construction of such wells relative to the multilateral wells.

Sensitivity analysis (Fig. 5) allows us to talk about a fairly high efficiency of technological solutions. The project is more dependent on oil price fluctuations and is fairly resistant to cost increases. A more favorable market situation is a reserve for increasing the efficiency of the project. The project proposed in this paper is cost-effective and expedient and is recommended for practical implementation.

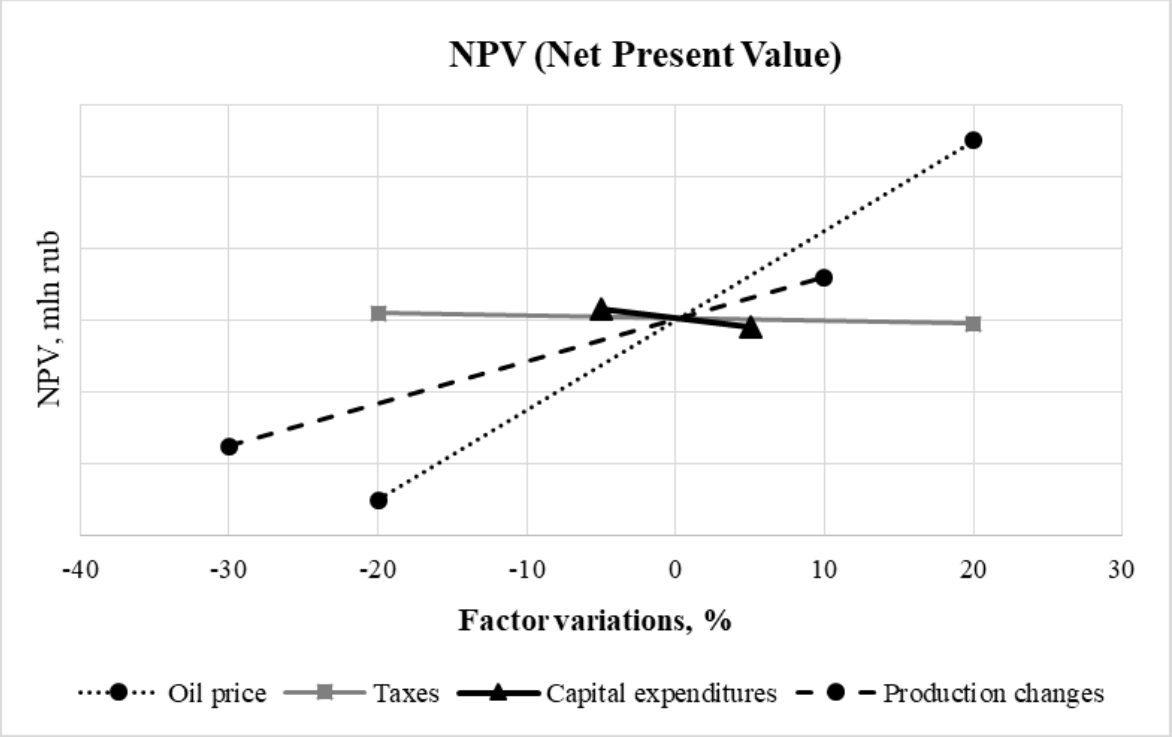


Fig. 5. Project risk sensitivity diagram

Conclusion

Thus, despite the fact that horizontal wells with multi-stage hydraulic fracturing are the traditional solution for choosing a well completion method in the development of hard-to-recover reserves of the Achimov deposits, in conditions of a close location of the underlying waters, the option with the placement of multilateral wells has shown greater efficiency. This design solution made it possible to increase the projected oil production by 30% compared to the base case approved by the current project document. The results of this work can be replicated both in the fields of Western Siberia, the oil content of which is confined to the Achimov suite, and in other objects with similar permeability and contact oil reserves.

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Эффективная система разработки залежи трудноизвлекаемых запасов пласта $БС_9^{2-2}$ач ачимовской толщи Соровского месторождения

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Аннотация. В настоящее время трудноизвлекаемые запасы играют большую роль в нефтяной промышленности во всем мире. В России их доля достигает более 65% от всех доказанных запасов нефти. Поэтому эффективная разработка залежей трудноизвлекаемых запасов – одна из важнейших и перспективных задач нефтедобывающих предприятий. Ачимовская толща в Западной Сибири обладает большим потенциалом, но традиционные подходы недостаточно эффективны для разработки таких сложных коллекторов.

Целью работы является проведение анализа и выбор наилучшего варианта разработки нефтяных месторождений с трудноизвлекаемыми запасами. В статье рассматриваются различные способы решения этой проблемы. Наиболее перспективными являются два варианта: бурение многозабойных скважин и бурение горизонтальных скважин с проведением малообъемного гидроразрыва пласта. В результате анализа геологического строения и расчетов на гидродинамической модели сделан вывод, что наиболее оптимальным способом является бурение многозабойных скважин. Экономические расчеты подтверждают целесообразность и рентабельность проекта.

Ключевые слова: ачимовская толща, трудноизвлекаемые запасы, добыча нефти, многозабойные скважины, низкопроницаемый коллектор, гидроразрыв пласта, горизонтальные скважины, заканчивание скважин.

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