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Comprehensive justification of the Tyumen suite development system

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Abstract. The article objectives are developing hard-to-recover reservoirs and how to maximize oil production by formulating effective solutions for putting hard-to-recover reserves.

US_2 is planned to be put into development in 2022 and contains 52% of the initial reserves of the entire field. US2 reservoir complicated by low permeability 0.6 mD, saturated intervals are 9.8 m.

The main method of developing hard-to-recover reserves in Western Siberia fields is horizontal drilling with multi-stage hydraulic fracturing. As a matter of course, well designs were analyzed with different lengths of horizontal shaft and with a different number of hydraulic fracturing ports. Calculations of starting flow rates and production profiles for various well options for a typical well have been performed. The optimal solution was evaluated using the complex parameter NPV and cumulative production.

Keywords: hard-to-recover reservoirs, efficient development, drilling, methodology, low-permeability reservoirs

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Комплексное обоснование системы разработки тюменской свиты

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Аннотация. Целью статьи является максимизация добычи нефти путем формирования эффективных решений по вводу в разработку трудноизвлекаемых запасов месторождения Т.

Основную часть трудноизвлекаемых запасов (52 %) занимает пласт $ЮС_2$, ввод которого в разработку запланирован на 2022 год. $ЮС_2$ характеризуется низкой проницаемостью 0,6 мД, нефтенасыщенная толщина составляет 9,8 м.

Основным методом разработки трудноизвлекаемых запасов месторождений Западной Сибири является горизонтальное бурение с многостадийным гидроразрывом пласта. В статье проводится анализ конструкций скважин с разной длиной горизонтального ствола и с разным количеством портов ГРП. Выполнены расчеты стартовых дебитов и профилей добычи для различных вариантов скважин для типовой скважины. Оценка оптимального решения проводилась с использованием комплексного критерия NPV и накопленной добычи.

Ключевые слова: трудноизвлекаемые запасы, эффективная разработка, бурение, методика, низкопроницаемый коллектор

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Introduction

Currently, the issue of developing hard-to-recover reservoirs is becoming more and more topical. A few of recoverable oil reservoirs in Russia (over 65%) are relating to low-permeability reservoirs. Therefore, the efficient development of hard-to-recover reserves is one of the most important objects of oil and gas companies. The Tyumen suite has great potential, but traditional methods are ineffective for the development of such complicated reservoirs [1, 2].

The article objective is to maximize oil production by formulating effective solutions for putting hard-to-recover reservoirs into development using the example of the US_2 reservoir of the T. field.

Object and research methods

The T. field is located in the Tyumen region, on the border of the Khanty-Mansiysk and Surgut regions. The commercial oil and gas content of the field is confined to oil reservoirs: AS_1, AS_4, $AS_{6\text{-}2}$, US_0, US_2, US_4 and US_{10}. The layers of the Tyumen suite (US_2, US_4 and US_{10}) are characterized by low permeability values and classified as hard-to-recover reservoirs [3]. These formations contain over 60% of the initial reserves of the entire field. The main part of hard-to-recover reservoirs (52%) is occupied by the US_2 layer of the T. field, which is planned to be put into development in 2022 (Tab. 1).

Table 1

Hard-to-recover reservoirs properties

	Hard-to-recover reserves (Kd = 0.2)	US_2		US_4		US_{10}	
Permeability, mD	≤ 2	✓	**0.6**	✓	0.2	✓	1.7
Saturated intervals, m	≤ 10	✓	**9.8**	✓	5.9	✓	9.8

The current design solution is an in-line system with a well spacing 800 m. All wells are horizontal with multistage hydraulic fracturing, horizontal wells with a length of 800 m, at each 4^{th} stage of hydraulic fracturing.

Effectiveness of the existing design solutions of the reservoir US_2 was assessed. During the pilot period, 3 wells were drilled (including 2 horizontal wells with a length of 500 m, 5 hydraulic fracturing stages). According at a rough guess of decline rates in oil flowrate, there is a significant excess relative to the design ones (plan -22 %, actual -70 %) (Fig.1). The sharp deviation of the predicted rates from the actual ones is due to the lack of response to injection at the current well spacing.

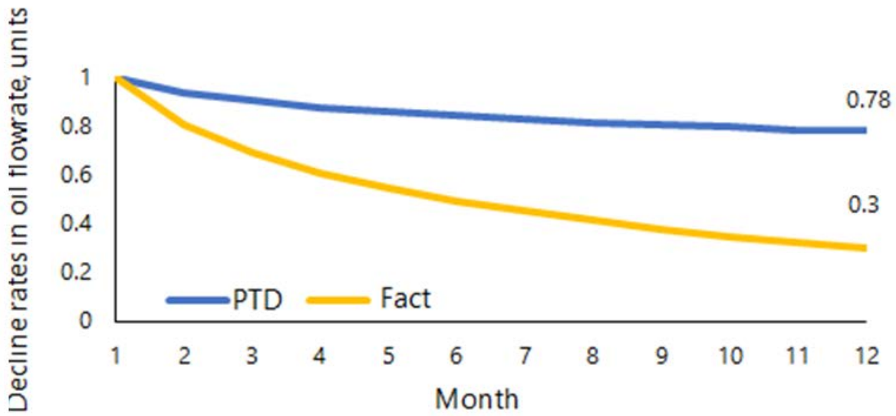

Fig. 1. ***Decline rates in oil flowrates***

In addition, based on the results of drilling and pilot testing, the geological concept was refined - the permeability increased by 15% and became 0.6 mD.

Taking into account the high rates of decline, a methodology has been prepared to substantiate the optimal system for the development of objects complicated by low permeability (Fig. 2). The main method of developing hard-to-recover reservoirs in Western Siberia fields is horizontal drilling with multi-stage hydraulic fracturing [2, 4-6].

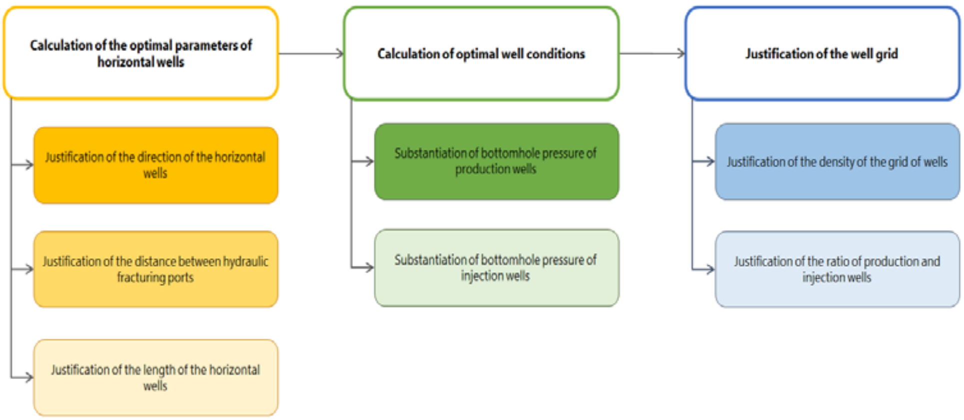

Fig. 2. ***Methodology for substantiating the development system***

As a matter of course, well designs were analyzed with different lengths of horizontal shaft and with a different number of hydraulic fracturing ports [7-9]. Calculations of starting flow rates and production profiles for various well options for a typical well have been performed. The optimal solution was evaluated using the complex parameter NPV and cumulative production.

Results and discussion

Based on the results of the analysis of well indicators for similar fields, it is recommended to take the direction of the designed horizontal wells in the azimuth of 165º-345º (along the stress) [10-13]. Based on the results of calculations, for Lgs 800-1300 m, the optimal distance between hydraulic fracturing ports is 90-120 m, and for Lgs 1300-1700 m, the optimal distance between hydraulic fracturing ports is 130-160 m (Fig. 3).

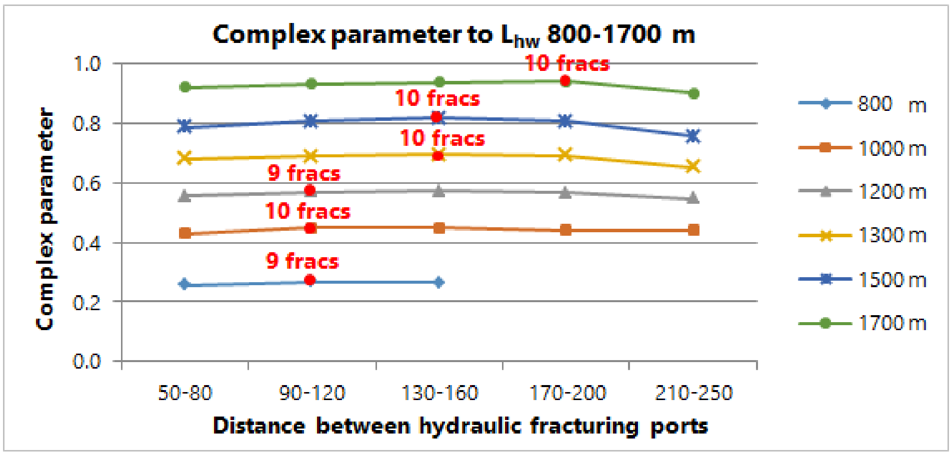

Fig. 3. ***Determination of the optimal number of hydraulic fracturing ports***

Using the complex parameter (1), which takes into account NPV and cumulative production for options with different number of hydraulic fractures and length of horizontal wells, the optimal length of horizontal wells for the US_2 formation was determined as 1500 m [14-15].

$$K = \sqrt{K_{NPV} * K_Q},$$

$$where\ K_{NPV} = \frac{NPV - NPV^*}{NPV^*}, K_Q = \frac{Q - Q^*}{Q^*}. \qquad (1)$$

To determine the ratio of production and injection wells in the US_2 formation the following equation was used (2):

$$\left(\mathrm{P}_{res} - \mathrm{P}_{bh}^{prod}\right) N^{prod} \lambda_{oil} K_{prod}^{GW} =$$

$$\left(\mathrm{P}_{auto\ frac}^{inj} - \mathrm{P}_{res}\right) N^{inj} \lambda_{wat} \begin{Bmatrix} K_{prod}^{GW}\ if\ GW \\ K_{prod}^{DW} if\ DW \end{Bmatrix}. \qquad (2)$$

For the directional well maintain reservoir pressure system, the ratio of production to injection pressure is 1 : 3, for horizontal wells maintain reservoir pressure system, the ratio is 1 : 1 [16-18].

Using a complex parameter, the optimal time for the injection wells flow-back was determined (Fig. 4), which is 3 months.

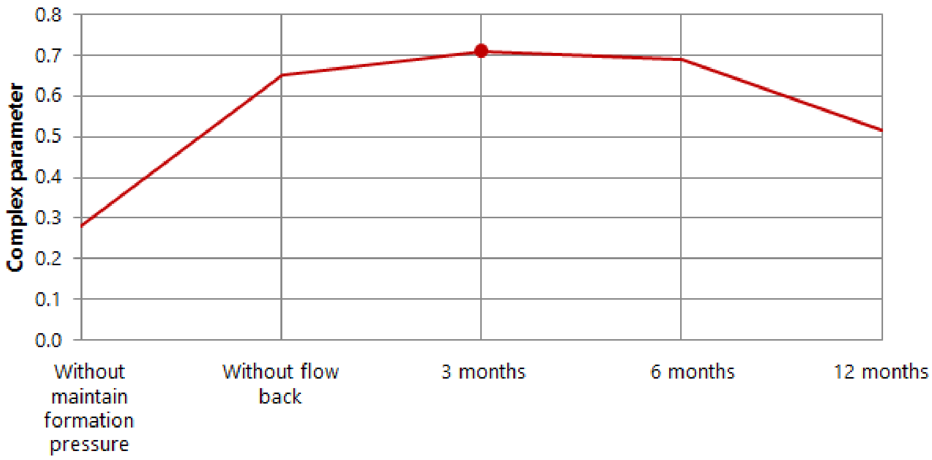

Fig. 4. ***Determination of the optimal time of injection wells development***

To determine the well network, a full-size hydrodynamic model was used, as well as a complex parameter. According to the calculation results, the optimal option is with a grid density of 87 hectares/well and the distance between the rows is 400 m. According to the results of the calculation, the rates of decline are characterized by more optimistic dynamics in comparison with the actual ones (Fig. 5).

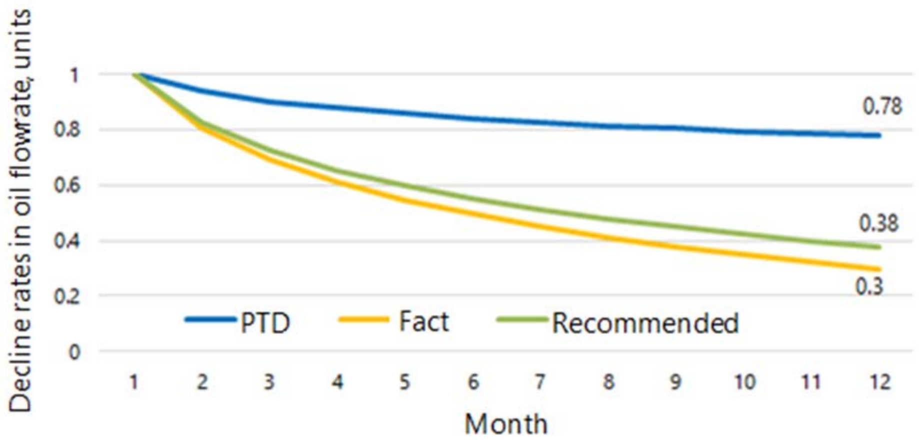

Fig. 5. ***Decline rates in oil flowrates***

Three options were involved in the comparison: "project-technological document" - technological indicators of the current PTD without taking into account the revised geology, "Basic" - solutions of the current project document applied in an updated geological view, "Recommended" - proposed design solutions based on the results of justification. A detailed description of the options is presented in table 2.

The economic evaluation of the three options showed that the recommended option with a horizontal well length of 1500 m, a distance between hydraulic fracturing ports of 150 m and a grid spacing of 400 m is characterized by the best economic indicators (Fig. 6).

Table 2

Comparison of options

Parameter	PTD	Basic	Recommended
Production well completion type	Horizontal well with multifrac		
Injection well completion type			
Horizontal well length, m	800	800	1500
Distance between hydraulic fracturing ports, m	200	200	150
Distance between the rows, m	800	800	400
Well stock, units	90	103	165
Cumulative oil production (40 years), million tons	11.9	11.2	15.7
NPV, units	-	1	1.7

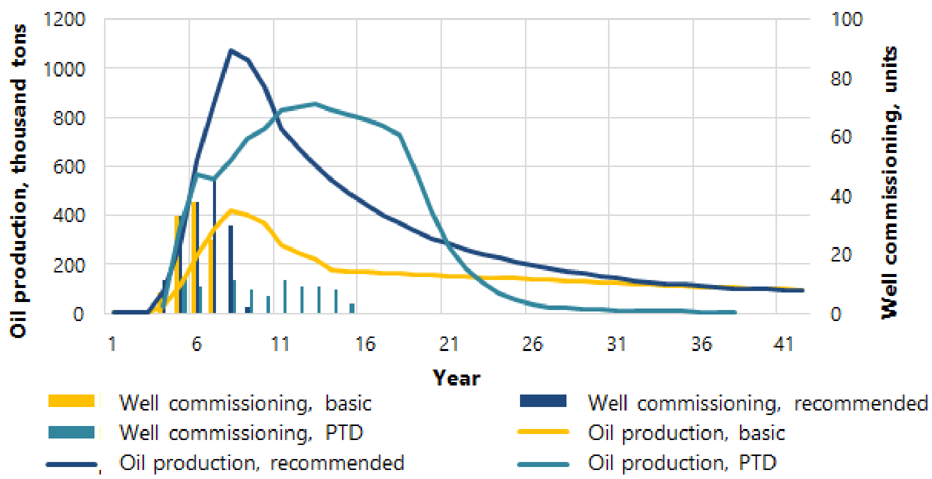

Fig. 6. ***Comparison of starting metric options***

The application of the recommended design solutions will increase the cumulative oil production relative to the base case by 103%, NPV - by 70%.

Conclusion

In reservoirs with low permeability the main method of developing is horizontal drilling with multi-stage hydraulic fracturing [19-20]. In the course of work well designs with different lengths of horizontal shaft and with a different number of hydraulic fracturing ports were determined by complex parameter.

The formulated approaches to substantiating the development system can be replicated in the fields of Western Siberia, the oil-bearing capacity of which is confined to the Tyumen suite.

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