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JUSTIFICATION OF THE NUMBER OF CONDITIONALLY HORIZONTAL TRUNKS IN A MULTILATERAL WELL CONSIDERING INTERFERENCE USING THE EXAMPLE OF A SMALL AND THICK RESERVOIR OF EXTRA VISCOUS OIL IN TERRIGENOUS RESERVOIRS

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A B S T R A C T

The most common way to exploit deposits of high-viscosity and ultra-viscous oil is through various combinations of thermal development methods. But the geological and physical limitations of this technology are: increased water saturation in the roof of the formation, layered heterogeneity due to the presence of clay and aquiferous lenses, small thickness of the formation - up to 10 m, high vertical and horizontal heterogeneity. The experience of operating ultra-viscous oil deposits in terrigenous reservoirs shows that for the production of reserves, one of the priorities is the use of wells with horizontal termination in combination with thermal methods, however, there are certain geological and physical limitations of the application in the form of a layer thickness of at least 10 m. Based on the results of numerical studies, it can be argued that the assessment of the effectiveness of a multi-hole well with a horizontal end, including the choice of a trajectory, the required number of additional conditionally horizontal shafts with optimal length, should be carried out using hydrodynamic modeling. Since the increase in the number of conditionally horizontal trunks, their proximity to each other, the small lengths of conditionally horizontal trunks, the presence of smooth divorces from each other lead to great interference and thereby reduce the productive characteristics per unit of their length.

Keywords: terrigenous reservoir; vertical directional borehole; multi-hole borehole with horizontal termination; conditionally horizontal trunk; interference between conditionally horizontal trunks; geological and technological model; well drainage area.

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Introduction

Currently, more and more attention is being paid to the extraction of high-viscosity and extra-viscous oil, which is characterized by low oil mobility in the reservoir, which significantly complicates the operation of oil fields, and existing technologies are not widely used due to high capital investments. The most common way to exploit deposits with high-viscosity and ultra-viscous oil is through various combinations of thermal development methods. But the geological and physical limitations of this technology are: increased water saturation in the roof of the formation, layered heterogeneity due to the presence of clay and aquiferous lenses, small thickness of the formation - up to 10 m, high vertical and horizontal heterogeneity. The experience of operating ultra-viscous oil deposits in terrigenous reservoirs shows that for the production of reserves, one of the priorities is the use of horizontal termination wells in combination with thermal methods, however, there are certain geological and physical limitations of the application in the form of a layer thickness of at least 10 m [1-8]. In this regard, one of the suitable technologies for the development of a small-sized and thick deposit of extra-viscous oil in terrigenous deposits is to drill a multi-hole well with a horizontal end (MWH) and cut conditionally horizontal trunks (CHT) in one plane from the main trunk at a certain angle [9-13]. Over the past decade, one of the promising areas for increasing the production of reserves of deposits is the construction of multi-hole wells with horizontal termination (MWH) from an old, already existing well stock or from a previously drilled lateral horizontal shaft. This technology allows for greater coverage of the facility in terms of area while reducing costs, as it allows for the use of previously drilled coal, existing field development infrastructure, and reduced drilling volumes and drilling waste. In the last decade, the popularity of MWH has been growing, when several new CHT are drilled from the main borehole in order to increase the drainage area and seal the well grid [14-20].

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Choosing an object for experiments

In order to conduct experiments to justify cutting the necessary cost-effective amount of coal from the main trunk, taking into account the expected interference between these trunks, we use one of the fields concentrated in the oil and gas bearing zone of the South Tatar oil and gas region of the Volga-Ural oil and gas province to develop a small-sized and thick reservoir of extra-viscous oil in terrigenous reservoirs. At this field, in the Bobrikov deposits of the C1bb formation, one reservoir-type oil deposit has been identified, measuring 0.56×0.81 km, floor height 3.7 m. The average oil-saturated thickness is 1.8 m. Degassed oil is bituminous, ultra-viscous (570.1 MPa·s), high-sulfur (4.18%), highly resinous and paraffin (4.82%).

Numerical experiments

In order to evaluate the selection of the required cost-effective amount of CHT using the RMS software package from Roxar based on a geological and technological model, numerical calculations of technological development indicators for 6 variants were carried out. The schematization of the CHT placement by options and the dynamics of their drilling are shown in figure 1 and in table.

The options included the following geological and technical measures: 1 – drilling from a vertical directional borehole (VDB) of a lateral horizontal shaft with a length of 375 m; 2 – drilling of a lateral CHT_1 with a length of 160 m in one plane at an angle of 45% to the main CHT LHB; 3 – drilling of a lateral CHT1 with a length of 160 m in one plane at an angle of 45% on the left and CHT_1-1 150 m long in the same plane at an angle of 45% on the right to the main CHT_1-1; 4 – drilling of a 160 m long lateral CHT in one plane at an angle of 45% on the left, CHT_1-1 150 m long in one plane at an angle of 45% on the right and CHT_2 200 m long in one plane at an angle of 45% on the left to the main CHT LHB; 5 – drilling of a 160 m long lateral CHT in one plane at an angle of 45% on the left, CHT_1-1 150 m long in one plane at an angle of 45% on the right, CHT_2 200 m long in one plane at an angle of 45% on the left and CHT_2-1 on the right parallel to CHT_1-1 at a distance of 110 m from it to the main CHT_1; 6 – drilling of a 160 m long lateral CHT in one plane at an angle of 45% on the left, CHT_1-1 150 m long in one plane at an angle of 45% on the right, CHT_2 200 m long in one plane at an angle of 45% on the left, CHT_2-1 on the right parallel to CHT_1-1 at a distance of 110 m from it and CHT_3 is 160 m long on the left parallel to CHT_2 at a distance of 110 m from it to the main CHT_2.

Table

Dynamics of drilling additional CHT from the main trunk (LHB - lateral horizontal trunk)

Years	Variants					
	1	2	3	4	5	6
2025	LHB	LHB	LHB	LHB	LHB	LHB
2026	-	CHT_1	CHT_1+ CHT_1-1	CHT_1+ CHT_1-1	CHT_1+ CHT_1-1	CHT_1+ CHT_1-1
2027	-	-	-	CHT_2	CHT_2+ CHT_2-1	CHT_2+ CHT_2-1
2028	-	-	-	-	-	CHT_3

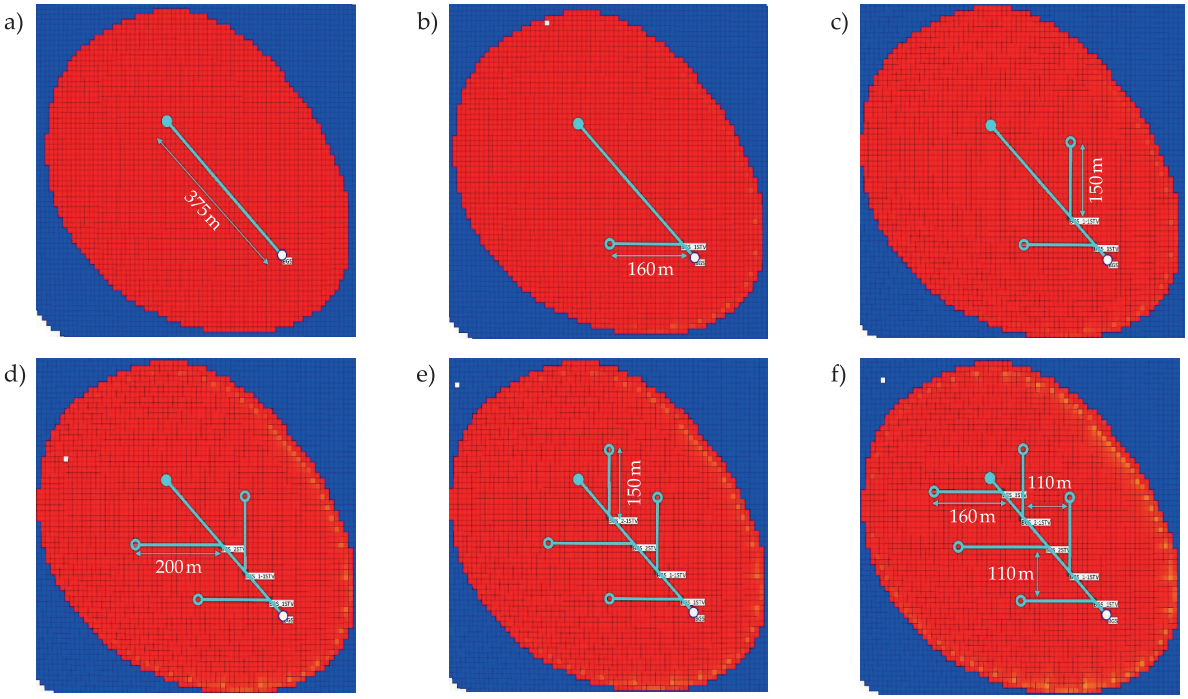

Fig. 1. Schematization of the CHT placement according to the development options: a) 1, b) 2, c) 3, d) 4, e) 5, f) 6

Results of numerical experiments

Based on the analysis of the results of numerical calculations of technological indicators for all variants, it was found that over the forecast period of development (until 2080), the oil recovery coefficient ranges from 0.248 to 0.299 units (fig. 2). From the dynamics of ORC shown in figure 2 for all variants, it can be seen that over the established development period (until 2080), the ORC value for option 1 will be 0.248 shares of units, for option 2 (+1CHT) – 0.256 shares of units, for option 3 (+2CHT) – 0.266 shares of units, for option 4 (+3CHT) – 0.280 shares of units, for option 5 (+4CHT) – 0.288 shares units. and for option 6 (+5CHT) – 0.299% units.

It is well known that the main advantage of the MWH is the organization of the maximum contact area with the productive reservoir, which leads to an increase in the drainage area of the well [21-29]. From the analysis of the positive and negative aspects of the MWH drilling technology obtained from both foreign and domestic practice, it is possible to draw an important conclusion that drilling additional small-length wells may not always lead to an increase in the productive characteristics of the well. This is mainly caused by the existing drilling technology and leads to a large mutual influence of the CHT. According to the analysis, it can also be noted that an increase in the number of CHT does not lead to a noticeable increase in ORC due to the increasing interference between closely located CHT [30-49]. In this regard, based on the results of numerical calculations of technological indicators, we will plot the dynamics of changes in the ORC according to the CHT for all development options (fig. 3).

From the dynamics of the ORC change in the CHT shown in figure 3, obtained as a result of modeling using specialized software, it can be seen that over the projected development period (until 2080), the value of the ORC for the main UGC under the option without drilling additional UGC is 0.248 fractions of a unit, commissioning in 2027 of one additional CHT_1 (option 2) will reduce to 0.209% of units, commissioning in 2027 of two additional CHT_1 and CHT_1-1 (option 3) - up to 0.166% units, commissioning in 2027 CHT_1, CHT_1-1 and in 2028 one additional CHT_2 (option 4) - up to 0.133% units, commissioning in 2027 CHT_1, CHT_1-1 and in 2028 two additional CHT_2, CHT_2-1 (option 5) - up to 0.104 units, and put into operation in 2027 CHT_1, CHT_1-1, in 2028 CHT_2, CHT_2-1 and in 2029 one additional CHT_3 (option 6) - up to 0.0859 units (table).

The decrease in ORC for the main CHT increases with the commissioning in 2026-2028 of each new additional CHT with a length from 160 m to 200 m, which contribute to the appearance of interference between the main and new additional CHT. The influence of interference on the ORC can be clearly seen from the distribution of oil filtration

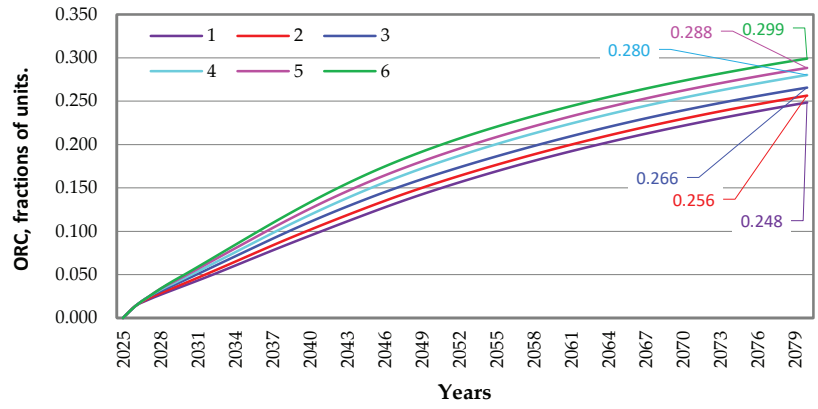

Fig. 2. Dynamics of the oil recovery coefficient by development options

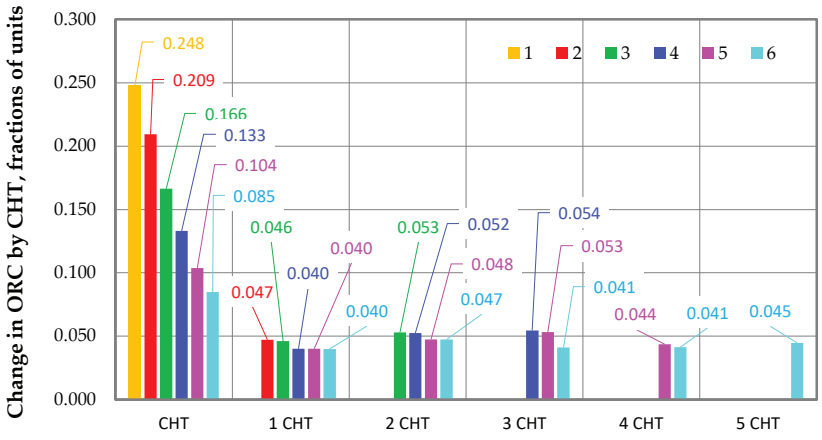

Fig. 3. Dynamics of changes in the ORC of the CHT for all development options

lines between the main and additional CHT by development options at the time of the ORC commissioning (fig. 4a-e). According to option 2 with one UGS_1, the ORC will be 0.047 fractions of units, the commissioning (2027) of the second CHT_1-1 (option 3) led to a decrease in ORC to 0.046 fractions of units, the commissioning of the third CHT_2 (2028) (option 4) - to 0.040 fractions of units, and the commissioning of the fourth CHT_2-1 (2028) and the fifth CHT_3 (2029) (variants 5-6) did not affect the ORC (0.040 fractions of units). The decrease in ORC according to option 2 with one CHT_1 occurred until the commissioning (2028) of the third CHT_2 (from 0.047 fractions of units to 0.040 fractions of units) due to the fact that the first CHT_1 and the second CHT_1-1 are located in the initial part of the main CHT_1, and the fourth CHT_2-1 and the fifth CHT_3 are located at a considerable distance from the first CHT_1 and there is no interference between these CHT (fig. 4b).

According to option 3 with two CHT_1 and CHT_1-1, the ORC will be 0.053 fractions of units, the commissioning (2028) of the third CHT_2 (option 4) led to a decrease in ORC to 0.052 fractions of units, the fourth (2028) CHT_2-1 (option 5) - to 0.048 fractions of units. and the fifth (2029) CHT_3 (option 6) - up to 0.047 units. The ORC according to option 3 with two ORC_1 and CHT_1-1 decreases slightly from the commissioning of CHT_2, CHT_2-1 and CHT_3 (from 0.053 fractions of units to 0.047 fractions of units), due to the fact that these CHT_2, CHT_2-1, CHT_3 are located at a great distance from the second CHT_1-1 and between them the interference is minimal (fig. 4b). According to option 4 with three CHT_1, CHT_1-1 and CHT_2, the ORC will be 0.054 fractions of units, the commissioning (2028) of the fourth CHT_2-1 (option 5) led to a decrease in ORC to 0.053 fractions of units. and the fifth CHT_3 (2029) (option 6) - up to 0.041 units. The decrease in ORC according to option 4 with three CHT_1, CHT_1-1 and CHT_2 becomes insignificant after the commissioning (2028) of the fourth CHT_2-1, but the commissioning (2029) of the fifth CHT_3 leads to a decrease in ORC to 0.041 fractions of units, due to the fact that the fifth CHT_3 is on the same side with CHT_2 relative to the main CHT, as well as at a distance of 160 m from the third CHT_2, and intense interference prevails between them (fig. 4). According to option 5 with four CHT_1, CHT_1-1, CHT_2 and CHT_2-1, the ORC will be 0.044 fractions of units. and after commissioning (2029), the fifth CHT_3 (option 6) is reduced to 0.041 units. The decrease in ORC according to option 5 with four CHT_1, CHT_1-1, CHT_2 and CHT_2-1 becomes insignificant after the fifth CHT_3 is put into operation (2029), due to the fact that the fourth CHT_2-1 is located in the opposite direction from the fifth CHT_3 and interference between these CHT_3 is minimal (fig. 4d). According to option 6 with five additional CHT, the ORC will be 0.045 units. (fig. 4e). As can be seen from figures 4a-e, additional CHT drilled from the main CHT, due to the interference between them, take away part of the inflow of the main trunk, but at the same time the total flow rate of the MWH increases. When using several CHT, their interference also increases, most significantly in the area of their connection. Visually analyzing the filtration lines of the oil flow between the main and additional CHT (fig. 4a-e), we can say that the size of the drainage sections of each CHT, and accordingly the size of the oil reserves drained by these CHT, depends mainly on the width of the liquid flow in this CHT. From the experience of developing a research object and its analogues, it is known that the width of the fluid flow into each reservoir is proportional to its discharge, i.e. the entire width of the fluid flow in the reservoir is divided between the main and additional

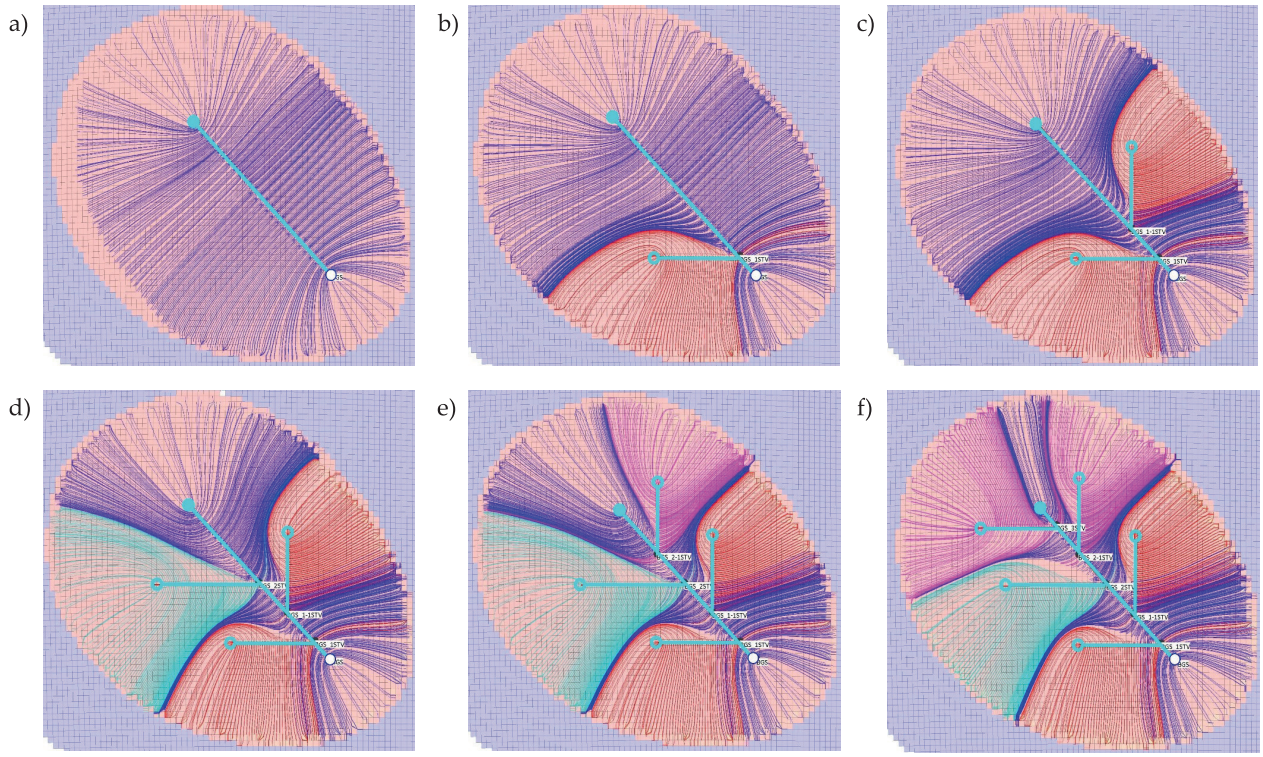

Fig. 4. Distribution of oil filtration flow lines by development options at the time of the CHT commissioning: a) 2 (for 2026), b) 2 (for 2027), c) 3 (for 2027), d) 4 (for 2028), e) 5 (for 2028), f) 6 (for 2029)

reservoirs in proportion to their discharge.

Usually, in an ideal homogeneous reservoir, the entire volume of an oil deposit is divided into separate drainage sections between the exploited coal deposits (fig. 4a-e). Therefore, when any additional CHT is put into operation, the nature of the distribution of drained reserves between CHT will change, and the drainage area of the commissioned CHT itself will be redistributed between neighboring CHT.

Thus, based on the results of the numerical studies carried out, it can be argued that the assessment of the effectiveness of the MWH, including the choice of a trajectory, the required number of additional CHT with the optimal length, should be carried out using hydrodynamic modeling. Since an increase in the number of CHT, their proximity to each other, small CHT lengths, and the presence of smooth CHT separations from each other lead to large interference and thereby reduce the productive characteristics per unit length of the CHT.

Conclusions

1. At facilities where the horizontal termination technology (HTT) with multi-stage hydraulic fracturing (MHF) is ineffective due to low power, MHF drilling is a «gentle» technology for involving oil reserves in operation, since in such cases MHF branches become to a certain extent analogous to multi-zone hydraulic fracturing cracks in the HTT.
2. The intensification of oil extraction in wells through multi-hole drilling and improvement of the degree of reservoir drainage makes it possible to optimize the cost of commissioning small deposits and bushes by eliminating the cost of mobilizing the fleet for drilling and delivery of materials for hydraulic fracturing.
3. The main advantage of the MVHF is the organization of the maximum contact area with the productive reservoir, which leads to an increase in the drainage area of the well. From the analysis of the positive and negative aspects of the MWH drilling technology obtained from both foreign and domestic practice, it is possible to draw an important conclusion that drilling additional small-length wells may not always lead to an increase in the productive characteristics of the well. This is mainly caused by the existing drilling technology and leads to a large mutual influence of the UGC.
4. Based on the results of the numerical studies carried out, it can be argued that the assessment of the effectiveness of the MWH, including the choice of a trajectory, the required number of additional CHT with the optimal length, should be carried out using hydrodynamic modeling. Since an increase in the number of CHT, their proximity to each other, small CHT lengths, and the presence of smooth CHT separations from each other lead to large interference and thereby reduce the productive characteristics per unit length of the CHT.
5. Additional CHT drilled from the main CHT, due to the interference between CHT, take away part of the inflow of the main trunk, but at the same time the total flow rate of the MWH increases. When several CHT are operating, their interference also increases, especially in the area of their connection.

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