Technologies for the Effective Operation of Wells with Horizontal End with Signs of Premature Flooding

Z.S. Idiyatullina, I.N. Khakimzyanov, D.T. Kiyamova
Tatar Oil Research and Design Institute (TatNIPIneft) PJSC Tatneft, Bugulma, Russia

Abstract. The paper presents technology for the efficient operation of wells with horizontal end with signs of premature flooding. When using the well with horizontal end in carbonate reservoirs within 3-5 years there is water breakthrough in nominally horizontal shaft. Therefore, when constructing these wells it is necessary to provide technology for consistent shutdown of sites. The use of innovative computer technologies, in particular geological and technological simulation, shows the effectiveness of this technology for the well with horizontal end. The paper concludes that technology of consistent shutdown of sites with nominally horizontal shafts increases oil production while reducing fluid production.

Keywords: well with horizontal end, geological and technological model, recovery factor, filtration flow line, development options, nominally horizontal shaft

DOI: 10.18599/grs.18.1.6

For citation: Idiyatullina Z.S., Khakimzyanov I.N., Kiyamova D.T. Technologies for the Effective Operation of Wells with Horizontal End with Signs of Premature Flooding. *Georesursy* [Georesources]. 2016. V. 18. No. 1. Pp. 33-38. DOI: 10.18599/grs.18.1.6

Introduction

The well with a horizontal end in its physical nature can increase the area of completion, and has significant potential for flooding of products during operation, especially in carbonate reservoirs. Nominally horizontal shaft in the process of wiring crosses on the way a lot of cracks and fracture zones. Some of them can extend over long distances and connect the oil-bearing and water-bearing layers. Therefore, flooding in the well with horizontal end can occur spontaneously without any stimulation. In the company PJSC Tatneft it occurs on average within 3-5 years and leads ultimately to a significant reduction of the current oil production in the well with horizontal end (Khakimzyanov et al., 2011).

To date, there are no effective point methods of water isolation in the well with horizontal end that isolate watered segment or segments of nominally horizontal shaft. General isolation technologies on water isolation in the vertical and directional wells have their own characteristics and are ineffective. They apply conventional (simple) isolation materials such as cement. When drilling these materials may spread to nominally horizontal shaft and solidify n the form of a wedge (whipstock), which may lead to complications during repair, and there is risk of “loss” of nominally horizontal shaft.

For the purpose of isolation of flooded areas, in recent years the Republic of Tatarstan began to use widely oil-water-swellable packers. Swellable packer is a casing with arranged thereon swellable elastomer of special composition which swells by absorption of fluid in the well, blocking annulus in any open or cased shafts.

In recent years, innovative computer technologies have rapidly developed in order to improve the efficiency of oil field development. In particular, geological process modeling allows making an assessment of projected activities and technologies prior to their mass introduction into production (Khakimzyanov et al. 2014).

Formulation of the problem

With a view to increase the efficiency of oil displacement by water in the carbonate sediments we proposed the technology of sweep increase by displacing agent at the expense of sequential development of the whole nominally horizontal shaft, reducing watering in the well with horizontal end and consistent cut-off of shaft sections. In order to study the process of displacement using this technology we performed geological and technological modeling of the hypothetical oil deposit development (Fig. 1).

Oil reservoir with carbonate reservoir is drilled by vertical wells (No. 1,2,4,5) and wells with horizontal end (No. 3G) on a triangular grid with spacing 300x300 m. In order to maintain reservoir pressure at the primary level a vertical injection well (No. 6n) is drilled. Nominally horizontal shaft of the well No. 3G is marked in the middle of the deposit, 10 m from the oil-water contact (Fig. 1). At the same time at equal intervals from nominally horizontal shaft it is planned to place isolation elements or packers.

In the future, the efficiency of packer will be judged by additional oil production in the deposits as well as by the extraction from individual wells, including the well with horizontal end No.3.

In order to simulate this technology using packer, we divide nominally horizontal shaft of the well with horizontal end No. 3G into 4 sites for five computational cells in each (Fig. 1). In the process of forecasting of calculated technological parameters, water cut will be monitored at each site.

We considered four options for forecast calculations:

- 1 Option envisages the development of oil deposits to achieve a final water cut for the whole deposit equal to 98%;
- 2 Option is the closure of perforated interval (the first site) at the time of achieving water cut 98% in the well 3G;
- 3 Option is the closure of perforated interval (the second site) at the time of achieving water cut 98% in the well 3G;
- 4 Option is the closure of perforated interval (the third site) at the time of achieving water cut 98% in the well 3G;

Analysis of the results for the whole reservoir

According to the results of forecast calculations for the 1st option we see that the water cut of 98% in the first site will be achieved by June 2018, in the second site – September 2020 and the third – October 2025 (Fig. 2).

The results of forecast calculations for the fourth options are shown in Figure 3 in the form of cumulative production dynamics of oil, fluid and oil recovery.

From the analysis of the results for the whole reservoir we can see that by sequentially cutting off sites of nominally horizontal well as they reach their water cut of 98%, it is possible to achieve a gain in cumulative oil production and reduction in accumulated fluid production or water cut. For example, the closure of the first site will increase oil production by 7.5 thousand tons (1.5%) and will reduce the fluid production by 784.2 thousand tons (-8.8%), section 2 – by 11,0 thousand tons (2.3%) and 1340.5 thousand tons (-15.1%), section 3 – 12.1 thousand tons (2.5%) and 1709.1 thousand tons (-19.3%), respectively.

Figure 4a-c shows dependence graphs of cumulative oil production, liquid and water cut for the whole deposit from the operating sites of the well with horizontal end.

Fig. 4a shows that with the reduction of operating sites (with each closure of one site) there is an increase in the accumulated oil production logarithmically with high coefficient of determination $R^2 = 0.9772$. As we mentioned above, with each new cutting off one of the sites, there is also a reduction in the accumulated fluid production on a logarithmic dependence with a high coefficient of determination $R^2 = 0.9986$ (Fig. 4b). Fig. 4c shows that every closure of the next site leads also to a decrease in water content in the whole deposit on a linear dependence with a high coefficient of determination $R^2 = 0.9989$. And if the closure of the first site reduces the water cut to 0.14%, then when disconnecting three sites decrease will be 0.4%.

In order to assess the significance of the sequential closure of working intervals we introduce the value characterizing deviation from the basic option in the shares:

$$\varepsilon = (Q^t_{тек} - Q^t_{баз}) / Q^t_{баз}, \qquad (1)$$

where $Q^t_{тек}$ – current cumulative oil production, $Q^t_{баз}$ – basic cumulative production (in this case, without disconnecting intervals of nominally horizontal shaft).

Figure 5 shows the dynamics in accumulated growth of oil production due to a consistent closure of operating intervals. Comparison of the results shows that the relative effect is higher for the closure of 1 to 3 sites (intervals) of the operating length of nominally horizontal shaft.

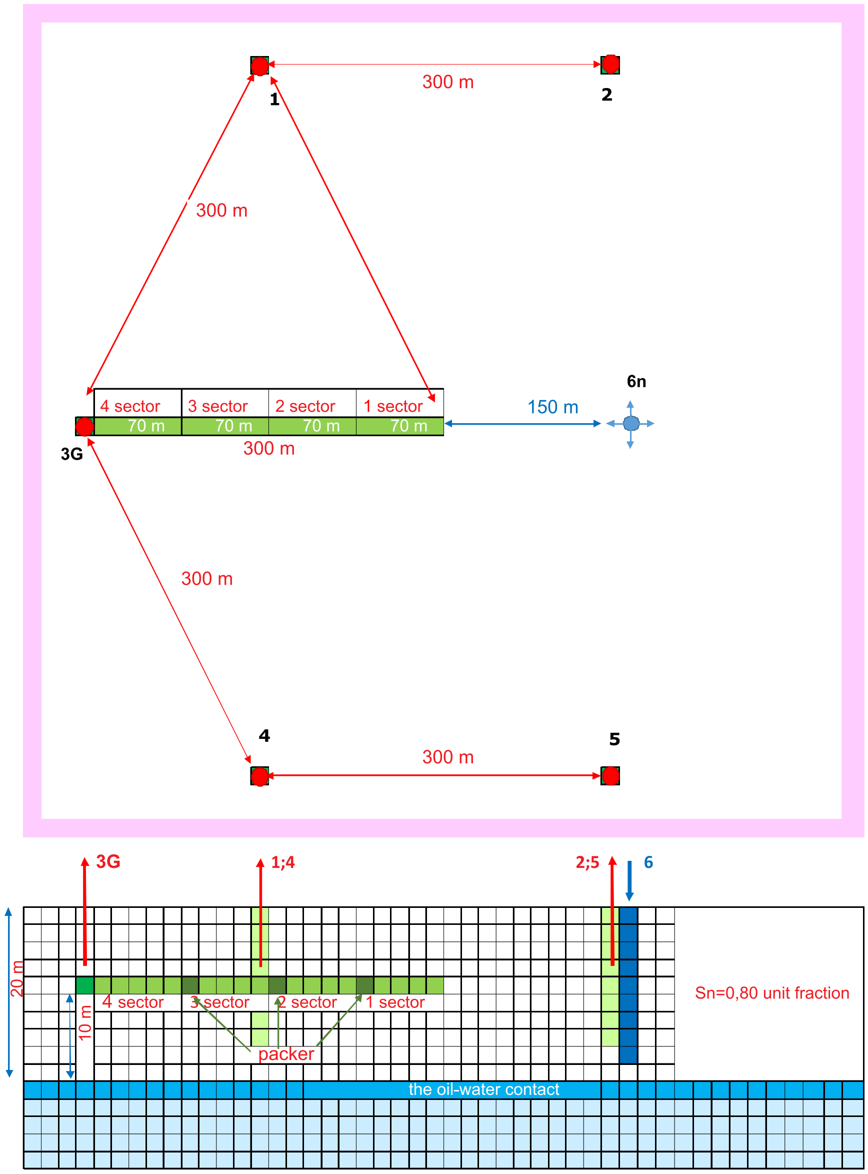

Fig. 1. Scheme of oil deposit and wells location in the element.

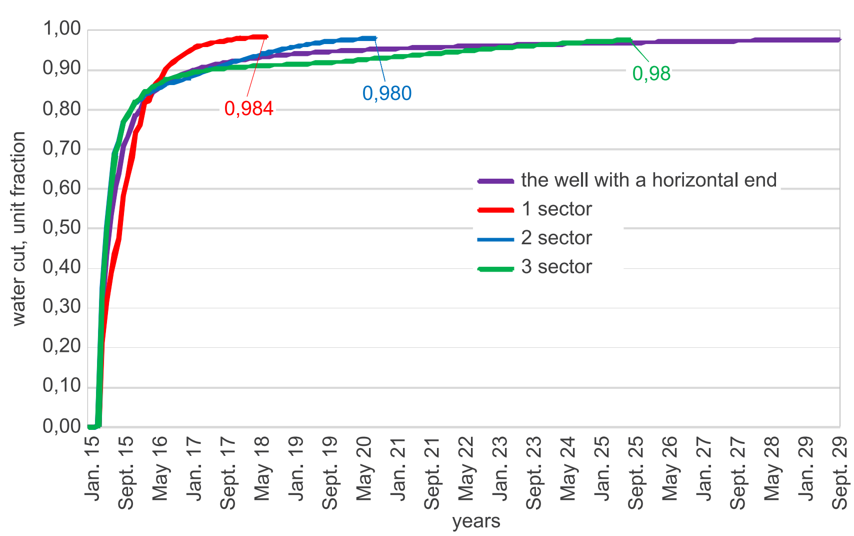

Fig. 2. Dynamics of water cut in well with horizontal end on sites of nominally horizontal shaft.

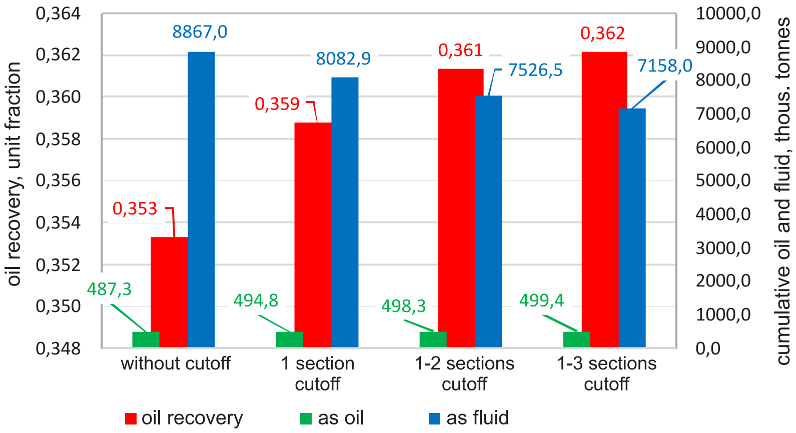

Fig. 3. Dynamics of cumulative production of oil, liquid and oil recovery for options with sequential cutting off sites of nominally horizontal shaft.

Analysis of the results for the well with horizontal end

Let us consider in more detail the impact of cutting off sites of nominally horizontal shaft on the performance of well with horizontal end itself in each of the options. For this purpose we determine the share of each site in the cumulative production for the whole well with horizontal end according to the results of forecast calculations. Figure 6 a-c shows graphs of cumulative production share of each site.

Figure 6a shows that the highest cumulative oil production is in site 4 (36.3% of total production), which is the most distant from the injection well number 6n. The smallest oil production is in the first site (17.4%), according to which the water cut will reach the value of 98% by 2018. The share of cumulative oil production from remote areas of the injection well grows logarithmically with a high coefficient of determination $R^2 = 0.996$.

Fig. 6b shows a distribution graph of cumulative oil production share on sites after cutting off the first site. We can see that the missing cumulative oil production for the first site due to its closure is redistributed to the remaining sites. The share of cumulative oil production from remote areas of the injection well increases by 13.9% (1 site) to 39.3% (4 site) on a logarithmic dependence with relatively high coefficient of determination $R^2 = 0.994$.

Distribution graph of cumulative oil production share on sites after cutting off 1 and 2 sites is shown in Fig. 6c. From the figure it can be seen that the missing cumulative oil production of 1 and 2 sites due to their closure is redistributed to the remaining sites. The share of cumulative oil production from remote areas of the injection well increases by 14.5% (1 site) to 42.2% (4 site) on a logarithmic dependence with relatively high coefficient of determination $R^2 = 0.981$.

Fig. 6b shows a distribution graph of cumulative oil production share on sites after cutting off 1, 2 and 3 sites. We can see that the missing cumulative oil production for the 1, 2 and 3 sites due to their closure is redistributed to the remaining sites. The share of cumulative oil production from remote areas of the injection well increases by 15.2 % (1 site) to 43.9% (4 site) on a logarithmic dependence with relatively high coefficient of determination $R^2 = 0.952$.

We use the formula (1) and enter the quantity that characterizes the relative change in the share of each site of the accumulated oil production in comparison with the option without cutting off sites of nominally horizontal shaft. The distribution of relative change in the share of cumulative oil production by sites is shown in Fig. 7.

The figure shows that the sequential closure of each site differently affects the relative change in the share of cumulative oil production. For example, closure of the first site leads to shortage of 20.2% in the accumulated oil at the site, site 2 – to increase of 2.5%, site 3 is unchanged, site 4 – to increase of 8.3% . Closure of 1-2 sites leads to cumulative oil production of 1 and 2 sites by 16.5% and 18.9%, respectively;

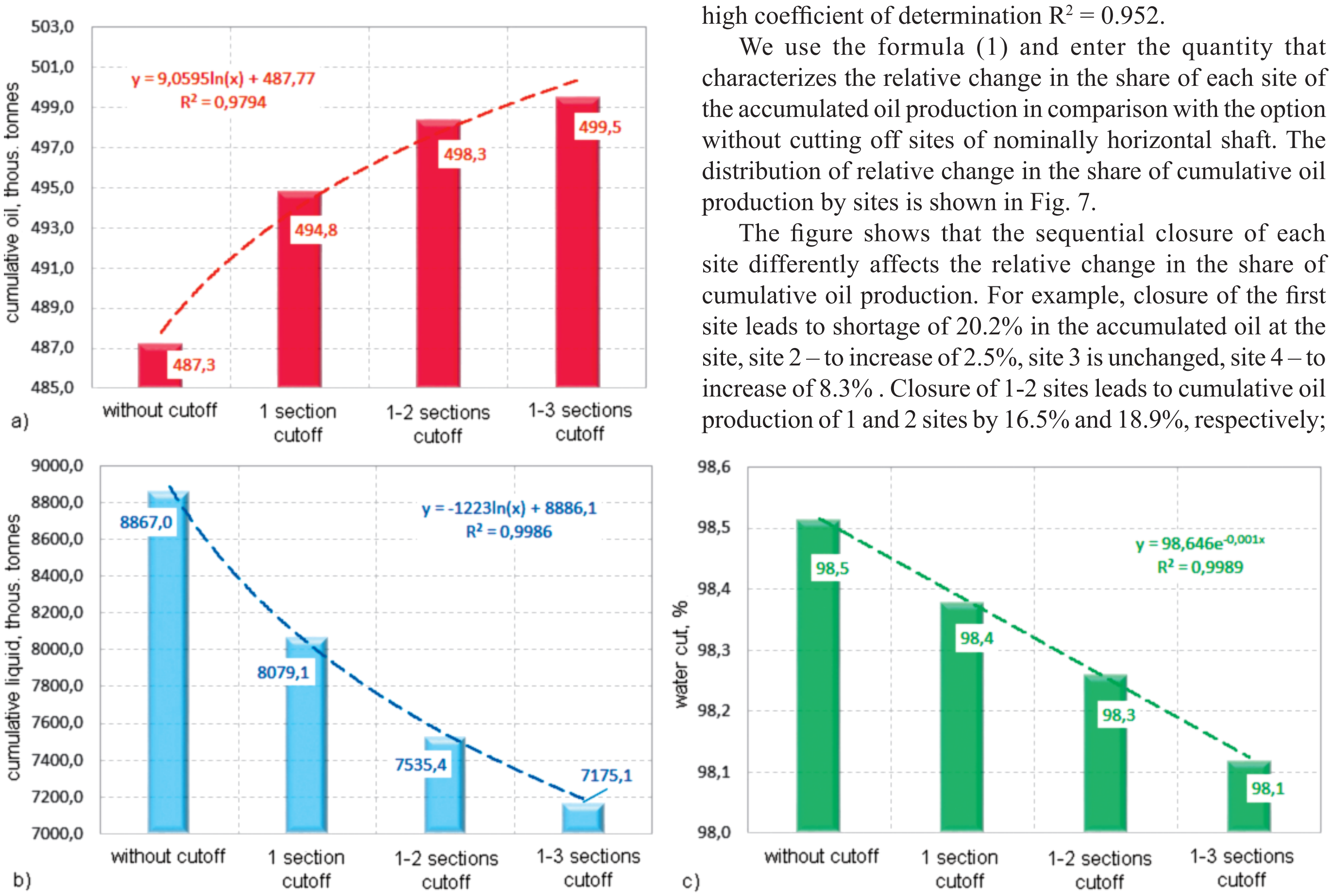

Fig. 4. Dependence of cumulative production of oil (a), liquid (b) and water cut (c) for the whole deposit from the operating sites of nominally horizontal shaft of the well with horizontal end No.3.

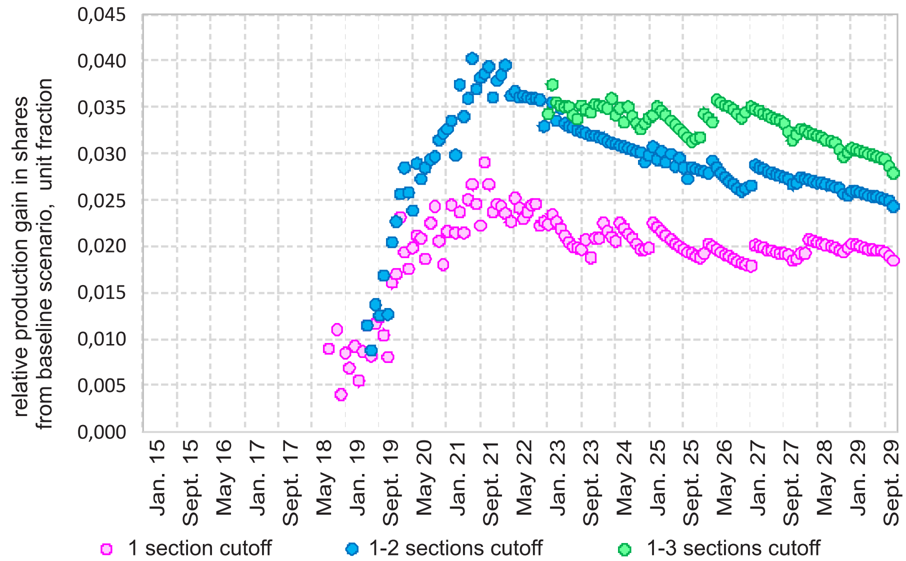

Fig. 5. Growth dynamics of cumulative oil production (in shares of the basic option) by cutting off sites of nominally horizontal shaft. The curves are calculated until the end of the development of the basic scenario.

while there is an increase in 3 and 4 sites by 3.0% and 16.2%, respectively. Closure of 1-3 sites leads to shortage in accumulated oil: in site 1 – by 12.7%, site 2 – by 15.2%, and site 3 – 9.2%. In site 4 there is an increase of 21.1%.

Assessing the impact of cutting off sites of nominally horizontal shaft on the performance of adjacent vertical wells

When arranging the system of development using both vertical wells and wells with horizontal end, it is necessary to pay special attention to the interference between the wells.

Based on the results of forecast calculations we assess the impact of successive closure of sites on the performance of vertical wells, in particular, on their accumulated oil. Fig. 8 shows filtration flow lines of oil to vertical wells and to wells with horizontal end. As seen in Figure 8, wells 1,2 and 4,5 are arranged symmetrically with respect to the injection well No. 6 and well with horizontal end No.3.

In this connection, the figure shows the same filtration flow lines of oil to the wells 1, 2 and 4, 5 for each option with the sequential closure of sites. It's worth noting that the well 2 and 5 are located in 260 m and wells 1 and 4 number 1 in 410 m from injection well 6.

Let us consider in more detail operating indicators of the technology for wells 1 and 2 in particular, on the accumulate oil, liquid and water content.

Fig. 9 shows the dynamics of change in the accumulated oil and liquid in the adjacent vertical wells for the options with the sequential closure of sites. On Fig. 9a we clearly see that the well 2 exposes the greatest impact and symmetrically located injection wells 6 and 5. These wells are located at a distance of 260 m from the injection well. For example, when using all nominally horizontal shafts without cutting off sites, the cumulative oil production for the vertical wells is as

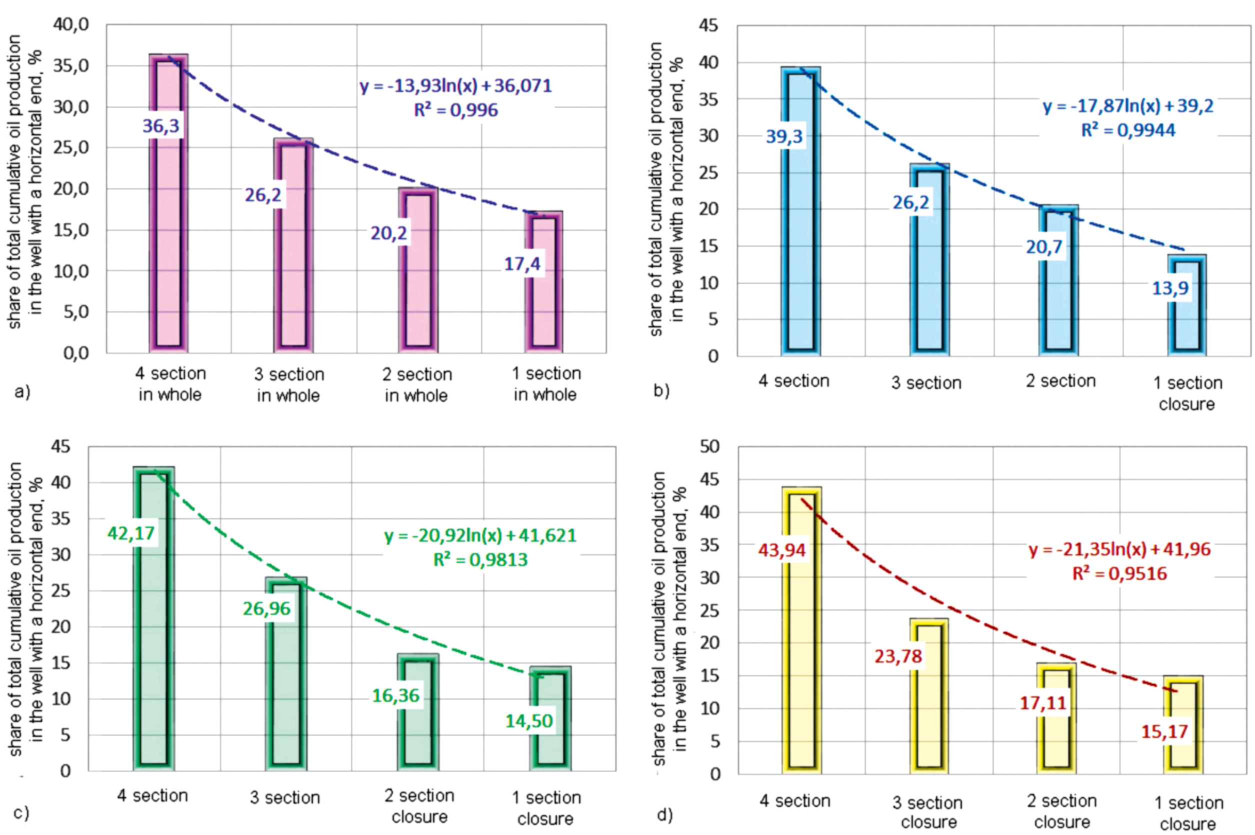

Fig. 6. Dynamics of cumulative oil production share by sites of nominally horizontal shaft in the operation of all sites (a), with closure of one site (b), with closure of 1-2 sites (c), with closure of 1-3 sites (d).

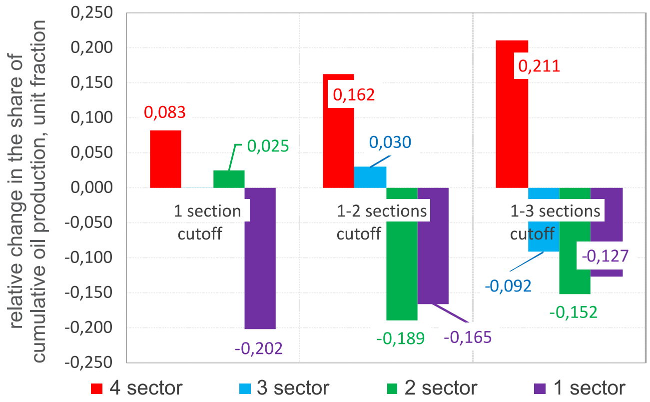

Fig. 7. Distribution of the relative change in the share of cumulative oil production by sites of nominally horizontal shaft.

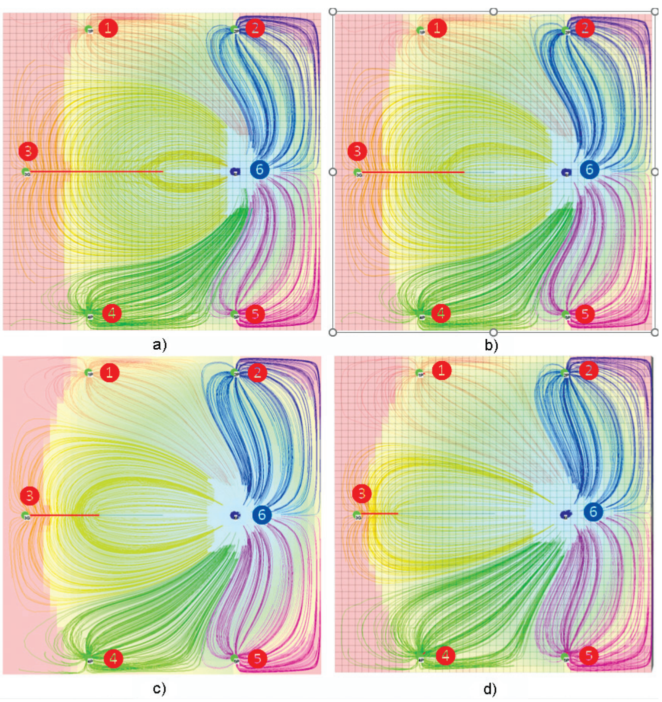

Fig. 8. Filtration oil flow lines to wells of deposit: a) without closure (at the end of development), b) closure of the 1 site, c) closure of 1-2 sites, d) closure of 1-3 sites.

follows: wells 1, 4 – by 68.2 thousand tons, wells 2, 5 – by 69.8 thousand tons.

Closure of the first site leads to equalization of cumulative oil production between wells 1, 4 and 2, 5. Extraction for them is 71.6 tons and 71.7 tons respectively.

When disconnecting sites 1-2, cumulative oil production is redistributed. Well No.1 and symmetrically located injection wells 6 and 5, both located at a distance of 410 m from the injection well, will expose the greatest impact. For example, oil extraction from wells 1,4 amounts to 75.7 thousand tons each, and from wells 2, 5 – 73,1 thousand tons each.

Closure of sites 1-3 leads to more redistribution of cumulative oil production between wells 1, 4 and 2, 5, while the oil extraction reaches the maximum value at 79.0 thousand tons and 74.0 tons respectively.

From the comparison of accumulated fluid production for options with sequential cutting off sites (Fig. 9b) we can notice a different picture. In this case, the well No.2 and symmetrically located well No. 6 and 5 expose the greatest impact. For example, when using whole nominally

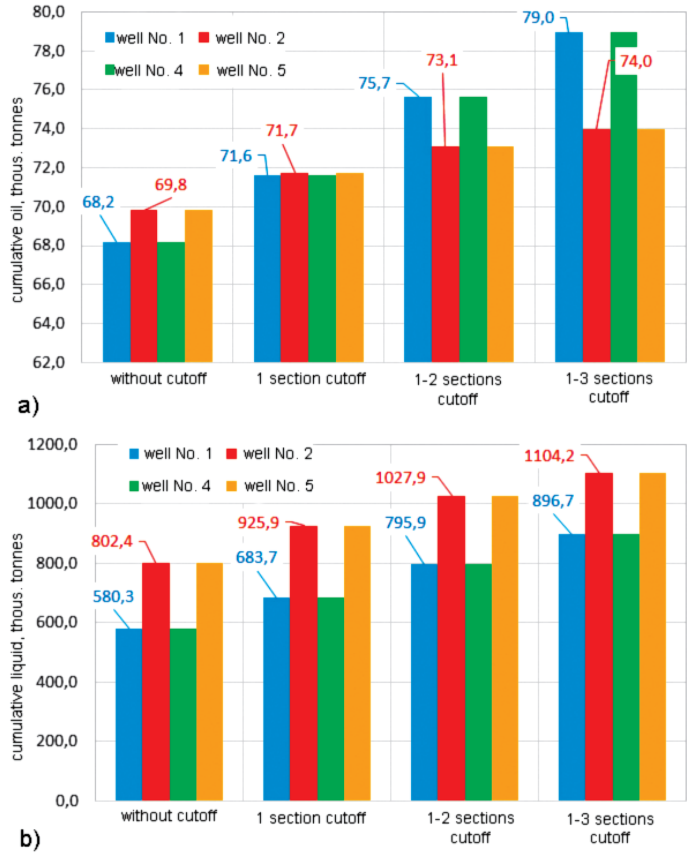

Fig. 9. Dynamics of cumulative production of oil (a) and liquid (b) of adjacent vertical wells for the options with sequential cutting off sites of nominally horizontal shaft.

horizontal shaft without cutting off sites, the accumulated liquid extraction for vertical wells is as follows: wells 1, 4 – by 580.3 tons, wells 2, 5 – by 802.4 thousand tons.

When cutting off the 1 site, difference in cumulative liquid production between wells 1, 4 and 2, 5 increases, production is 683.7 thousand tons and 925.9 thousand tons respectively.

When cutting off sites 1-2, the difference in cumulative liquid production also increases, thereof for wells 1, 4 production is 795.9 thousand tons, and for wells 2, 5 – 1027.9 thousand tons.

Closure of sites 1-3 leads to a further increase in the difference of cumulative liquid production between wells 1, 4 and wells 2, 5, the extraction reaches the maximum value – at 896.7 thousand tons and 1104.2 thousand tons, respectively.

Conclusions

1. When operating wells with horizontal end in carbonate reservoirs, in 3-5 years there is water breakthrough into nominally horizontal shaft. Therefore, when constructing these wells it is necessary to provide the possibility of using technology for subsequent closure of sites.

2. According to the results of computer simulation for oil deposits with a system of vertical (production and injection) wells and wells with horizontal end, we can conclude that the use of technology for subsequent closure of sites of nominally horizontal shaft increases oil production while reducing liquid production.

3. Reduction of operating sites of well with horizontal end (with each closure of one of the sites) leads to an increase in the accumulated oil on a logarithmic dependence with a coefficient

of determination $R^2 = 0.9772$, as well as a reduction of the accumulated liquid production on a logarithmic dependence with a coefficient of determination $R^2 = 0.9986$.

4. With each subsequent closure of one of the sites there is a redistribution of oil production to the site, located closer to the vertical part.

5. From the comparison of cumulative oil production by option with sequential cutting off sites of nominally horizontal shaft we can see that with every closure of one or more sections there is a redistribution of cumulative oil production between vertical wells located at different distances from the injection well.

References

Khakimzyanov I.N., Khisamov R.S. et al. Nauka i praktika primeneniya razvetvlennykh i mnogozaboynykh skvazhin pri razrabotke neftyanykh mestorozhdeniy [Science and practice of branched and multilateral wells to develop oil fields]. 2011. 320 p.

Khakimzyanov I.N., Khisamov R.S. et al. Voprosy optimizatsii i povysheniya effektivnosti ekspluatatsii skvazhin s gorizontal'nym okonchaniem na osnove matematicheskogo modelirovaniya mestorozhdeniy Tatarstana [Problems of optimization and efficiency of well operation with horizontal end on the basis of mathematical modeling of Tatarstan oil fields]. 2014. 240 p.

Information about authors

Zarina S. Idiyatullina – Engineer

Ilgizar N. Khakimzyanov – Head of the Laboratory, Doctor of Science

Dilyara T. Kiyamova – Engineer, PhD

Tatar Oil Research and Design Institute (TatNIPIneft) PJSC Tatneft. Russia, 423230, Republic of Tatarstan, Bugulma, M.Jalil str. 32, e-mail: khakimzyanov@tatnipi.ru

Received December 31, 2015