Impact of production wells operational changes on high-viscosity oil recovery

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Abstract. As light oil reserves are developed, the share of heavy high-viscosity oil (HVO) reserves, which are considered difficult to recover, increases in the total balance of oil reserves. Therefore, the future of the oil industry is inevitably linked to the development of highly viscous heavy oil deposits. Today, according to various estimates, epy reserves of high-viscosity oil and bitumen range from 790 billion tons to 1 trillion tons. This is more than 5 times more than the residual recoverable reserves of low and average viscosity oil. The world experience of developing high-viscosity oil deposits shows that the cost-effective development of most of them is limited due to low efficiency of oil wells and low oil recovery achieved through natural operation mode or flooding. If the first of these problems is successfully solved in recent times by drilling horizontal and multilateral wells, the second one requires the introduction of various technologies to influence the formation (thermal methods, miscible displacement, etc.), which are not always highly efficient. In this work we will consider the impact of changing the operation modes of production wells on the production of high-viscosity oil reserves on the example of the Northern Buzachi field (Republic of Kazakhstan).

1. Introduction
One of the most common geological and technical measures aimed at improving development efficiency is optimization of production well operation modes. At the same time, this type of well interventions means the intensification of oil reserves withdrawal – increase of well fluid flow rate due to the installation of larger pump or change of pump operation parameters. In the conditions of the Northern Buzachi field, the optimization process includes forced fluid withdrawal (FFW). The FFW technology allows creating high pressure gradients with step-by-step increase of production well flow rates (reduction of bottomhole pressure). This leads to intensification of oil production in non-uniform (compartmentalized) watered layers, allows draining unrecovered oil [1, 3, 4]. FFW is particularly important is in the development of non-Newtonian oil deposits, where significant pressure gradients are required to create moving volumes of oil in the reservoir.

2. Materials and Methods
The questions raised were considered on the basis of scientific analysis and synthesis of experience in the development and operation of high-viscosity oil deposits. Processing of initial field information during the efficiency analysis of changing the operation modes of production wells was carried out
using modern methods of statistical information processing [8]. The obtained results were put into practice and the implementation results confirmed their efficiency.

3. Results
The analysis of oil reserves recovery from the first production facility of the seventh block of the Northern Buzachi field shows that the current oil recovery index (ORI) amounted to 0.054 unit fraction. Besides, the current water cut in the field as a whole was 82.3%. The trend of water cut change shows that it is impossible to reach the approved ORI at saturated water cut (Figure 1).

![Figure 1](dependence_of_current_ORI_on_current_water_cut_of_extracted_product.png)

**Figure 1.** Dependence of current ORI on current water cut of extracted product (a) and dynamics of IRR brought into production per one production well (b) of the seventh block of the first operational facility of the Northern Buzachi field.

The dynamics of specific initial recoverable reserves (IRR) brought into production, shown in Figure 1b, indicates a very slow increase in the indicator, despite the fact that during this period the production well stock was increasing and the formation-pressure maintenance system was formed. In other words, further “extensive” development path of the site development system makes it impossible to hope for significant improvement of technological indicators of development.

Thus, in the first production facility of the seventh block of the Northern Buzachi field, the operating development system does not allow achieving the approved values of the oil recovery index. At the same time the extracted product is characterized by high water content, water cut exceeds 82%, which indicates low efficiency of oil recovery.

Let us look at the analysis of changes in technological modes of production well operation.

The results of changes in the process modes of 42 production wells producing liquid from the formations of the first and second production facilities of the Northern Buzachi field were analyzed. The optimization process was limited to changing the reciprocating speed (rpm) of the pump [11, 12]. By way of example, Figure 2 illustrates the changes of well performance indicators as a result of changing the operating conditions of the pumping equipment.
Figure 2. Change of oil flow rate (a) and water content of the extracted product (b) depending on the reciprocating speed. Well No. 1017-1 of the second production facility of the Northern Buzachi field

The analysis of dependencies of technological parameters of well operation (oil flow rate, water cut) on the change of pump operation mode showed that unique dependencies linking these values are absent or not determined by the operation data.

It was determined that a change in the reciprocating speed (rpm) of the pump may result in the following:

1. reduction of water cut and increase of oil flow rate with the increase of the reciprocating speed (rpm) (for example, well 1017-1, May 2013, change of the reciprocating speed (rpm) from 180 to 230, well 1088, August 2013 change of the reciprocating speed (rpm) from 160 to 240).
2. increase of water cut and decrease of oil flow rate with the increase of the reciprocating speed (rpm) (for example, well 1017-1, October 2012 - January 2013, successive increase of the reciprocating speed (rpm)).
3. reduction of water cut and increase of oil flow rate with the reduction of the reciprocating speed (rpm) (for example, well 1017-1, January 2013, change of the reciprocating speed (rpm) from 240 to 180).
4. increase of water cut and reduction of oil flow rate with the reduction of the reciprocating speed (rpm) (for example, well 1088, March 2013, change of the reciprocating speed (rpm) from 180 to 160).

Thus, the impact of optimization on current well development performance is not unambiguous. Therefore, the optimization efficiency was determined based on the displacement characteristic method [2, 5, 6].

Let us consider how production wells reacted to the optimization of their operation modes. Displacement characteristics were built for all wells. In general, the total effect amounted to 14,517 thousand tons of additional oil produced. However, the curve analysis showed that it is not possible to build a correct displacement characteristic for a single well since there is no straight section. This well was not considered in the final value of the optimization effect. With this in mind, the reasonable effect of well optimization taking into account all losses makes 14,397 thousand tons, which is quite significant for this deposit [8, 7]. Of the wells with a reasonable optimization effect, 29 reacted positively with a significant effect value, 3 wells had a minor positive effect, 9 wells had a significant negative effect, 1 well had a minor negative effect, and 1 well could not have the effect determined due to the absence of a straight-line section. The optimization efficiency analysis of operation modes of production wells regarding the development objects shows that the total effect for the wells of the first object is negative. Specific optimization losses of wells of the first object make 17.3 t/(well*month) (Table 1).
Table 1. Distribution of optimization effect across development objects

| Object     | Number of analyzed wells | Total effect, t | Average effect, t/µV | Average duration, month | Specific effect, t/(well*month) |
|------------|--------------------------|----------------|----------------------|-------------------------|---------------------------------|
| Jurassic   | 24                       | -2669          | -111                 | 6.4                     | -17.3                           |
| Cretaceous | 15                       | 15609          | 1041                 | 5.9                     | 176.4                           |
| Combined   | 3                        | 1457           | 486                  | 6                       | 81.0                            |

The main technological effect of the optimization accounts for wells of the second production facility – the specific effect makes 176.4 t/(well*month) (Table 1). It is interesting that the positive effect of optimization is also obtained for joint wells – the specific effect makes 81.0 t/(well*month).

4. Conclusions
The applied optimization of the operation modes of the production wells of the Northern Buzachi field produced a significant technological effect. According to the 42 wells considered, the technological effect amounted to 14397 tons of additional oil produced.

The total effect of optimization of the wells of the first production facility is negative. At the same time out of 24 wells 9 wells have negative effect. For the main and consolidating well stock, the losses are approximately equal. For the horizontal wells of the first object, the effect of optimization is positive.

All considered wells of the second production facility have a positive effect of optimization. At the same time the wells of the consolidating stock have the maximum specific effect.

The ambiguity of the optimization effect for different wells causes the need for theoretical study of the impact of changing the operation mode of the production well on the efficiency of oil production.

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