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Increase in Intake Capacity by Dynamic Operation of Injection Wells

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The method of pumping water to compensate for fluid withdrawals from an oil formation in order to maintain formation pressure has long established itself as an effective technology and is widely used at oil and gas fields. At the same time, field operator is often faced with the problem of reduction in the intake capacity of injection wells, which may be caused by various complications arising in the near-wellbore area due to a violation of water treatment technology or other factors. This problem is typical for reservoirs with low permeability values, which leads to a decrease in the performance indicators of the formation pressure maintenance system.

In order to counter contamination of the bottomhole zone of the well, as a rule, injection of specialized acid compositions for the purpose of cleaning is used. To increase the effectiveness of this procedure, the authors of the article propose to discharge the injection well at the maximum permissible speeds. This event will allow primary cleaning of the bottomhole zone of the formation from moving particles clogging the pore space, and reduce formation pressure in the vicinity of the injection well, which will subsequently improve the intake capacity of the well during treatment with acid compositions. The decrease in formation pressure in the bottomhole zone of the well also has a positive effect on the radius of acid penetration into the formation.

The proposed approach has been successfully tested on a number of injection wells at one of «Gazprom Neft» enterprises. The results of pilot operations showed an increase in the quality of cleaning the bottomhole zone of the formation and an increase in the intake capacity of injection wells with subsequent preservation of intake dynamics.

Key words**:** dynamic operation; discharge; intake reduction; energy-efficiency; inject well operation; oil-water emulsions

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Introduction. The problem of reducing the intake capacity of injection wells during their operation is not new and is especially widespread in conditions of low permeability reservoirs (the absolute permeability is less than 3 mD). The reasons can be both technological and geological in nature. If it is almost impossible to influence geological factors, then technological ones should be minimized. These include contamination of the bottomhole zone of the well with suspended particles, oil products, precipitated insoluble salts, etc. [1, 5].

This article is devoted to the method of increasing the intake capacity of an injection well by short-term discharge at maximum speeds with subsequent bottomhole zone treatment (BHZT) with an acid composition. This approach has several advantages, one of which is a decrease in pressure in the near-wellbore zone, which contributes to the injection of acid composition at lower pressure, additional cleaning of the bottomhole zone due to the removal of suspended particles at high flow rates during discharge, as well as the possibility of sampling fluid for laboratory research.

The injection well discharge method is well known and has been widely used previously [2]. A characteristic feature of the operations was dynamic discharge at speeds of not more than 8 m^3/h, which corresponds to a flow rate of 192 m^3/day. A distinctive feature of the work described in this article is that discharge is carried out at the highest possible speeds (up to 1800 m^3/day) and is combined with an acid treatment.

Course of the work. To test the proposed method, four injection wells were selected in the southern part of the Priobskoye field. The choice was due to the technological possibility to carry out planned operations in the wells, as well as geological conditions. Wells are located in the deep-water part of the formation, characterized by permeability average values of 1.5-2 mD.

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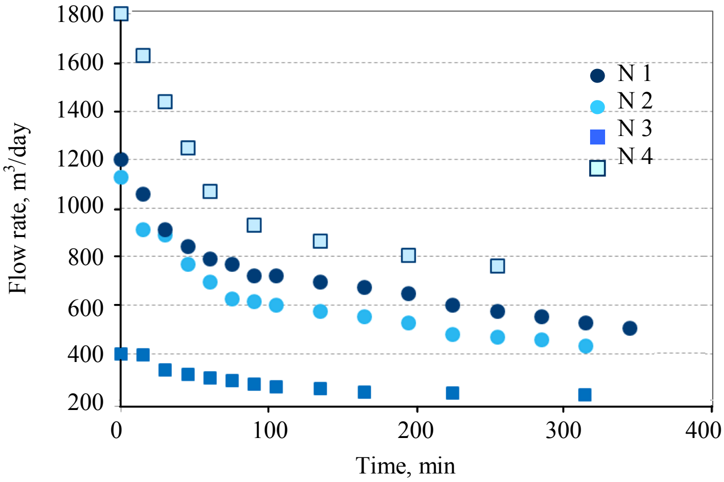

Fig.1. Well flow rate during discharge
N 1-4 – well numbers

The course of work was as follows. The injection well, which has been in operation until the last moment, has been stopped and immediately put into discharge state with a choke of maximum diameter. In the process of discharge, with a frequency of once every half hour, sampling of the outcoming liquid was carried out through a slit sampler installed on a horizontal section of the pipe. Further, these samples were transferred to the laboratory for a detailed analysis, namely, measuring the concentration of suspended particles (CSP), assessing the distribution of particle sizes using a system of different sized filters, determining the composition of the particles, and also determining the content of oil products (Fig.1). The duration of discharge was determined by the conditions for the removal of mechanical impurities by the flow [3, 4]. For the conditions of the wells considered in the article, the discharge lasted a little more than 5 hours.

In order to evaluate the effect of both the discharge itself and the discharge with the subsequent BHZT separately, it was decided to operate wells N 3 and 4 without acid treatment. At the same time, it was decided to operate wells N 1 and 2 twice, i.e. repeat operation after the effect has ended.

During the discharge, samples of the liquid coming out of the well were taken. In all wells except N 3, a high content of oil products and mechanical impurities was observed (Fig.2).

Samples of well N 3 were not contaminated with oil products and, in comparison with others, looked relatively clean (Fig.3). The reason is that, due to the technological problems that have

a *b* *c* *d*

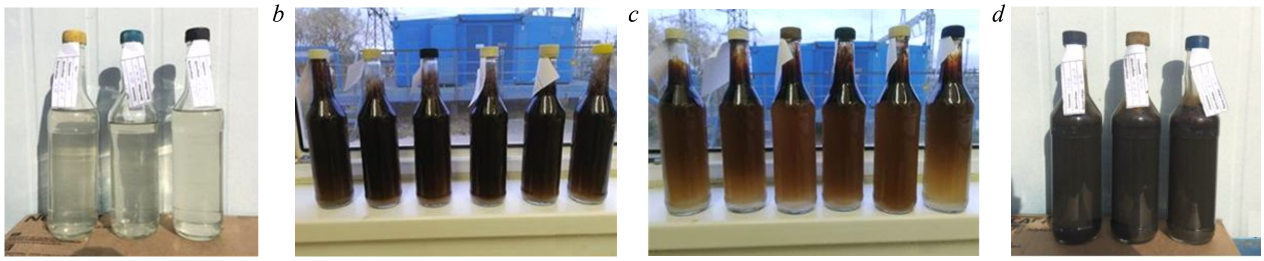

Fig.2. Set of liquid samples taken during well operation:
a – injected water; *b* – well N 1 in dynamics; *c* – well N 2 in dynamics; *d* – well N 4

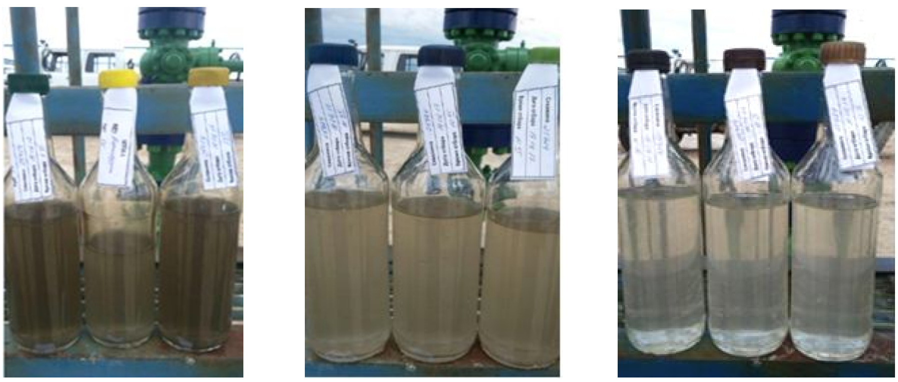

Fig.3. Liquid samples taken during operation of well N 3

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arisen, discharge was carried out at much lower speeds, and this was not enough to clean the bottomhole zone of the well from the bridging agent (polluting the bottomhole zone). Therefore, there is a certain critical production rate, with an increase in which the bottomhole zone is cleaned. More detailed information on determining the critical discharge parameters can be found in [3, 7, 8, 10], in which there are good computations for further study.

In the process of studying the material composition of the samples taken, microscopic studies, x-ray diffraction and x-ray phase analyzes were carried out. In the results obtained, a high content of oil emulsion, as well as about 40 % of mechanical impurities, which are iron compounds, are noteworthy. This suggests that it is worth paying attention to the condition of the piping system, treatment of water for formation pressure maintaining (FPM), and also to determine the base cause of the high content of oil emulsion in the samples. Active work is underway in this direction with the oil-extracting community, the results of which will be published later.

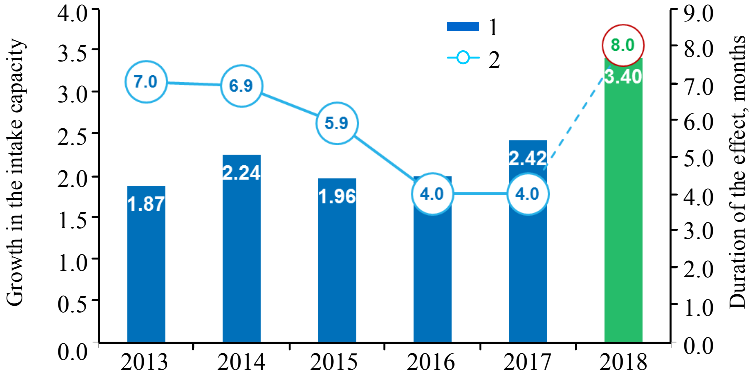

Fig.4. Effectiveness of BHZT in injection wells of Priobskoye field in dynamics.
In 2018, the efficiency after operation was shown
1 – growth in the intake capacity; 2 – duration of the effect, months

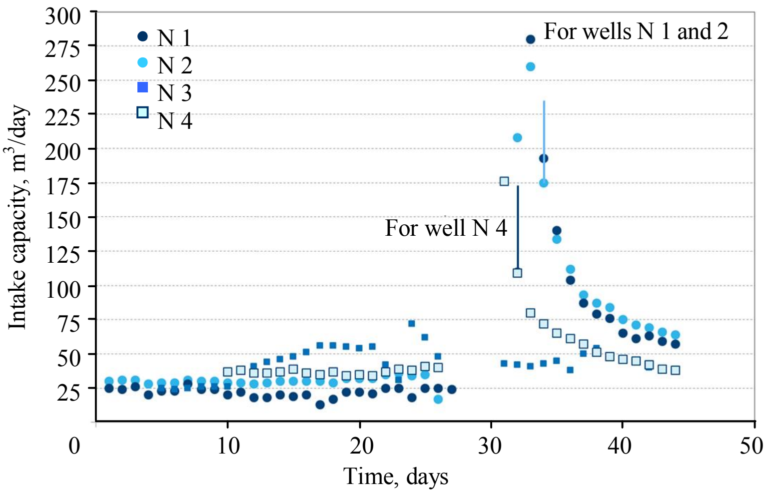

Fig.5. Well operation parameters after injection start

The next stage of the process is the conduction of acid BHZT. In the case of the Priobskoye field, the treatment is carried out with a mixture of hydrochloric and hydrofluoric acids, which is typical for the terrigenous type of reservoir.

For the sake of the experiment, it is also necessary to present the results of the analysis of previously performed BHZT in injection wells of the Priobskoye field without dynamic operation. An analysis of the growth dynamics in the intake capacity is shown in Fig.4.

As can be seen from the histogram (Fig.4), the average increase in the intake capacity of injection wells is 2, and the average duration of the effect over the past two years is 4 months. For comparison, in part of the histogram for 2018, the results obtained after operating injection wells with subsequent BHZT with acid compositions are presented. The rate of increase in the intake capacity was 3.4, and the duration of the effect was about 8 months.

After BHZT, studied wells were immediately transferred to the injection mode. With shut-off intake of about 25-30 m^3/day, the launch parameters of the wells were about 10 times higher. Fig.5 shows the obtained parameters of the working wells after the injection start. It should be recalled that at wells N 1 and 2, BHZT was performed, and wells N 3 and 4 were operated without subsequent acid treatments.

During operation of well N 1, about 160 m^3 of liquid was taken out, well N 2 – about 200 m^3, well N 3 – about 60 m^3, well N 4 – a little less than 150 m^3. The entire taken volume was injected during the first days of the wells functioning in the injection mode (marked by vertical lines in Fig.5). Due to the fact that taken volume is extremely small in order to affect the redistribution of formation pressure in the area of well drainage, the average value of the intake capacity, starting from the moment of replacement, is considered as an increase from operation with the conducted BHZT.

Thus, the average increase in the intake capacity in wells N 1 and 2 after BHZT was 3.4. In well N 3, the production rate was limited; an increase in intake was not obtained. In well N 4, after the operation, BHZT was not carried out, and a twofold increase in the intake capacity was obtained, which reached shut-off values during the month of well function.

Regarding the duration of the effect, it should be noted that during the initial operation with the subsequent BHZT of wells N 1 and 2, a positive effect was observed for about 10 months. The greatest decrease was observed in the first month of exploitation. After repeated operation, it is still too early to make an unambiguous conclusion about the duration, because current well production values are twice as high as shut-off ones and continue to fall. However, even a top-level assessment as a result of regression analysis showed that after treatment the wells reach shut-off values in 7-8 months. Well N 4, operated without acid treatment, had a positive effect for 1 month. Well N 3 showed no increase in intake due to insufficiently high discharge speeds. It is important to note that according to the regulations, well development after BHZT is not carried out, and therefore, all reaction products, including insoluble sediment, remain in the formation, which can cause significant negative consequences for low-permeability reservoirs [6, 9]. This point needs further study and is not considered in the framework of this article.

Results. The results of field-testing of the approach described in the article show that the intake capacity during well operation at the maximum possible discharge speeds with subsequent BHZT is on average 40 % higher than after standard acid treatment of the injection well's bottomhole. Also, the experimental data showed that the duration of the treatment effect is 1.5-2 times higher than with the standard approach.

The authors suggest that conducting dynamic operation before BHZT will contribute to more effective cleaning of the bottomhole zone for the following reasons:

• bottomhole zone is cleaned from mechanical impurities due to high speeds of outcoming liquid;

• pressure in the near-wellbore zone decreases, therefore, a faster injection of the acid composition occurs;

• reagent radius of effect increases, as a result of which the skin factor will decrease.

An analysis of samples taken during operation revealed a significant content of iron compounds. Moreover, in the injected water leaving the pump-compressor station, the iron content was within normal limits. Therefore, it is necessary to pay close attention to the condition of the piping system, as well as to study the possibility of adding special anti-corrosion agents during water treatment process.

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