ABSTRACT

To the thesis of the PhD candidate of the specialty 6D070800 – "Petroleum engineering" Turgazinov I. K. with the title "Improving the efficiency of development of oil fields at the last stage of operation with the use of low salinity waterflooding (on the example of South Turgay fields)»

The relevance of the work. It is known that for the development of oil fields, water is pumped into the reservoir from surface or underground sources: first of all, it is necessary to maintain reservoir pressure at the initial level and to compensate for withdrawals by injection, i.e. to maintain well flow rates. In this case, the justification of the choice of the source of water is given insufficient attention. However, as shown by studies of Western and domestic scientists in the injection of highly mineralized waters, there are some technological limitations. So, in particular, it was revealed that during the injection of highly mineralized waters into the reservoirs, due to the incompatibility of the reservoir and the injected water, scaling occurs, resulting in a decrease in the efficiency of waterflooding. This fact has a huge impact on the mode of oil production and oil recovery. To solve this problem, you can apply the injection of low-mineralized water. Low-mineralized water is the source of which are lakes, rivers and shallow beds, and the highly mineralized water in this case is produced water. Studies by Western scientists show that injection of low-mineralized water in certain cases can be used as a method for enhanced oil recovery.

Injection of low-mineralized water is one of the simplest and cheapest methods to increase oil recovery. Since 1990, studies of a number of scientists have revealed the effectiveness and high potential of injection of low-mineralized water into terrigenous and carbonate formations. Laboratory studies with carbonate cores of the North sea deposits have shown that, due to changes in wettability of the rock surface, the efficiency of oil displacement by water during injection of low-mineralized water increases. Multiple studies on the injection of cores with low-mineralized water revealed a decrease in the phase permeability of water, which in turn reduces the water cut of wells and an increase in the rate of oil recovery. In most fields, the formation energy is depleted at the primary and secondary stages of development. As a result, under the land remains a significant proportion of undeveloped oil reserves, even with the injection of different fluids. At the last stage of development, various methods of increasing oil recovery (EOR) are used under certain conditions of the formation and technology. EOR is understood as the injection of various agents into the formation, which under natural conditions do not occur in the formation. But EOR is not limited to the use of the last stage of development of the field, they can be used at the beginning of the Deposit in production. Various technologies, such as mixing and immiscible gas flooding (hydrocarbon gases, carbon dioxide and nitrogen), chemical flooding (surfactants, polymer, alkalis or a mixture thereof), thermal methods (steam injection or intra-layer combustion) and other methods (injection of anaerobic bacteria), enhanced oil recovery are used for oil production.

Water injection has been a traditional way of increasing oil recovery since 1865. The last 10 years, this technology began to be considered in terms of the composition

of the injected water. Thus, a new low-mineralized water injection (LME) technology has emerged that improves displacement by varying wettability in sandstones and carbonate rocks. The popularity of this method lies in the production of light oils, water availability and low investment. The latter advantage is preferable because of the low cost compared to other methods.

The injection of low-mineralized water (LMW) is known in the literature as the, smart flooding in SaudiAramco and modern ion management (AIMSM) of ExxonMobil companies.

Purpose of research. Improving the efficiency of the development of terrigenous reservoirs with low-and high-viscosity oil. Identify the mechanisms during injection of low salinity water. Development of a method for enhanced oil recovery at a late stage with low viscosity and high-viscosity oil using low-salinity water for the Ashchisay and Karabulak fields by conducting laboratory and numerical experiments. Development of a new scheme of the device for obtaining low-salinity water.

The idea of the work is to increase the rate of oil displacement from terrigenous reservoirs with low- and high-viscosity oil due to the use of low-salinity water.

Research objectives

1. Review and analysis of the literature on modern technologies of enhanced oil recovery using low-salinity water.
2. Theoretical justification of the efficiency of injection of LSW to improve oil recovery for fields with low - and high-viscosity oil.
3. Conducting coreflooding studies on a physical reservoir model to determine the oil-displacing ability of the LSW.
4. Justification of the mechanism of oil recovery during injection of low-salinity water.
5. Development of a device for producing low-salinity water.

Methods for solving the problem. The solution of the tasks was carried out by conducting experimental studies on physical models of the oil reservoir and analyzing the results using computer technology. The use of modern software products for hydrodynamic modeling. Review and analysis of patents for obtaining low-salinity water.

The scientific novelty of the dissertation, for the first time:

1.The dependence of the oil displacement coefficient of the Karabulak field with high-viscosity oil on the pumped volume of water with a salinity of less than 1 g/L is determined;

2.The dependence of oil recovery on the permeability, wettability and mineralogical composition of the rock during the injection of low-salinity water were determined;

3. The dependences of the oil displacement coefficient of the Ashchysay field on the pumped volume of water with a salinity of less than 1 g/L were obtained;

4. A new scheme of the device for producing low-salinity water has been developed (section 6).

Scientific provisions for protection

The results of coreflooding experiments on physical models of reservoirs of the Ashchysay and Karabulak fields using the technology of low-salinity water-flooding (LSW);

2. Conditions of application of low-salinity water-flooding technology (LSW) with enhanced oil recovery of terrigenous reservoirs with low and high-viscosity oil;

3. The mechanism of increasing the displacement coefficient of reservoirs with low-and high-viscosity oil at a late stage of development;

4. Technological calculations for carrying out low-salinity water-flooding at the Ashchysay field;

5. The new scheme of the device for producing low-salinity water.

Practical significance. The possibility of increasing the coefficient of displacement of oil (K_{disp}) from reservoirs with low - and high-viscosity oil with the help of low-mineralized flooding technology (LSW), which can be used in Kazakhstan fields "Karazhanbas", "Kalamkas", "Northern Buzachi", "Zhalgyz Tobe", "Moldabek", "Kenbay", etc., taking into account the mineralogical composition of the rock.

Personal contribution of the author consists:

- In the formulation of research problems and substantiation of methodological approaches to their solution;
- Analysis and synthesis of literature data;
- In the planning, organization and carrying out of experimental researches, processing and generalization of the results;
- In conducting numerical simulations;
- In the development of methods for the introduction of HMB in the field.
- In search and analysis of patents for obtaining low-salinity water.

Approbation of the work. The results obtained in the dissertation work were reported at international scientific conferences and forums:

- At the international Satpayev readings "scientific heritage of Shakhmardan Esenov" (Almaty, 2017);
- XII international scientific and practical conference "Advances in Science and Technology" (Moscow, 2018);
- At the international Satpayev readings "Innovative solutions to traditional problems: engineering and technology" (Almaty, 2018).

Publications. The main provisions of the work are presented in 8 publications, including 3 publications recommended by the KKSON MES. 2 articles in foreign scientific journals with non-zero impact factor included in the Scopus database, "ARPN Journal of Engineering and Applied Sciences" (IF 0.37), "Journal of Engineering and Applied Sciences" (IF 0.35), 3 articles in the proceedings of international conferences. Filed 1 application for a patent for a utility model (registration number 2018/03062, from 28.04.2018).

Structure and scope of work. The thesis contains an introduction, 6 sections, conclusion and list of references. The thesis is presented on 111 pages of computer typing, including 58 figures and 21 tables, a list of 110 items of literature.

Summary of thesis

The introduction substantiates the relevance of the research topic, identifies the main goals and objectives, substantiates scientific novelty, the main protected provisions, practical value and testing of the work.

The first section of the thesis is devoted to a literary review of laboratory and field studies to improve the efficiency of development with the use of low-mineralized flooding for terrigenous and carbonate reservoirs. This Chapter presents the results of laboratory studies and field tests of injection of low-salinity water into oil reservoirs. According to the goal, the research objectives are formulated. Summing up, it should be noted that the injection of low-mineralized water has a positive effect, as has been proven by many studies in this area. The specific mechanisms of oil recovery are still not fully understood and require further research. At the micro level, it can be noted that the rock wettability (change of wetting edge angle), decrease of interphase tension and increase of polar components of oil in injected low-mineralized water, which were adsorbed on the rock surface before injection of HMB, change during injection. It was also proved that electrostatic forces on the rock surface change due to changes in the Zeta potential after injection of low-mineralized water or water with a modified composition. Thus, the charge on the surface of the rock changes, the pH of the medium increases, although the works confirming the above statement are still insufficient.

Also, the literature review showed the absence of theoretical and experimental studies on the use of HMB to displace low-and high-viscosity oils from terrigenous and carbonate reservoirs. Further experimental studies on core flooding are needed to study the possibility of using HMB to displace viscous and high-viscosity oils and to study the mechanisms of oil recovery.

The second section presents theoretical studies on flooding with low-salinity water. The basic equations for modeling low-salinity water flooding are given. The formula for calculating the displacement front and pressure distribution is derived. In this Chapter, the main dependences for the construction of a mathematical model of flooding with low-mineralized water into the reservoir were obtained.

The formula for pressure distribution over the reservoir for injection and production wells is derived.

For the first time the dependence of the front radius of displacement of low-mineralized water on the injection time was obtained, taking into account the oil saturation of the reservoir, which must be found experimentally.

These equations are necessary for the calculation of technological parameters of low-mineralized water injection into terrigenous formations under the current conditions of field development.

According to the obtained formulas, the pressure distribution in the reservoir depends on the pressure at the bottom of the wells and their flow rate (flow rate).

The process of water displacement front affects the flow rate of the injected agent, the injection time.

The third section deals with laboratory studies on the injection of low-salinity water into terrigenous reservoirs with low-and high-viscosity oil. The results of the

study of flooding of LSW are presented. Based on the results of the experiments, the mechanisms of oil recovery of LSW are explained. The problems of numerical simulation of injection of low-salinity water into a formation with high-viscosity oil are also considered. The numerical simulation revealed the advantage of using LSW at the last stage of field development.

1) a set of laboratory and numerical studies on the injection of terrigenous reservoirs with viscous and high-viscosity oil to determine the effectiveness of low-mineralized (HMB) flooding for the conditions of the field "Aschysay" and "Karazhanbas". Modern installations and software were used in the experiments.

2) for the First time a series of filtration experiments were carried out to identify the effectiveness of low-mineralized water for high-viscosity oil in terrigenous rocks. In addition, up to 19% of the oil was extracted in the laboratory.

3) dependences of the pressure gradient on the type of rock and oil at different flow rates were obtained.

4) thus, the use of low-mineralized water deserves attention as a method of increasing oil recovery in order to displace viscous and high-viscosity oils from terrigenous reservoirs, taking into account the composition of the rock containing oil.

In the fourth section, the economic efficiency was calculated for the use of low-mineralized flooding in the Ashchysay field. The income of the state and the company from the introduction of low-salinity water-flooding technologies is calculated. In the technical and economic assessment can be seen that the project is very profitable, as the cost of construction and drilling is covered by large revenues. On the income distribution diagram it can be seen that the income of the state and the investor from this enterprise is about 40 and 60 %, respectively, and is beneficial for both parties, i.e. it makes sense for the state to invest in this project or attract an investor.

According to the results of preliminary calculations, it can be concluded that it makes sense to invest in the development of this field with the injection of low-mineralized water with further high profitability.

The fifth section provides scientific recommendations for the implementation of low-salinity water flooding for the conditions of the Ashchysay field.

The sixth section presents the developed technical solutions for which the applicant received a positive opinion on the grant of a patent. The comparison of technical solutions obtained by the applicant with their prototypes is carried out. The developed device for producing low-salinity water, which has a more advanced design compared to the prototype, providing water production through the use of solar energy, is presented

In conclusion, the main results and conclusions of the thesis are presented.