Analysis of the heavy oil production technology effectiveness using natural thermal convection with heat agent recirculation method in reservoirs with varying initial water saturation

V B Osnos¹, V V Kuneevsky¹, V M Larionov¹, E R Saifullin¹, A V Gainetdinov¹, Yu V Vankov², I V Larionova³

¹Kazan Federal University, 18 Kremlyovskaya str., Kazan 420008, Russian Federation
²Kazan State Power Engineering University, 51 Krasnoselskaya str., Kazan 420066, Russian Federation
³Kazan National Research Technical University named after A.N. Tupolev, 10, K.Marx str., Kazan 420111, Russian Federation

E-mail: mr.emilsr@gmail.com

Abstract. The method of natural thermal convection with heat agent recirculation (NTC HAR) in oil reservoirs is described. The analysis of the effectiveness of this method for oil reservoir heating with the values of water saturation from 0 to 0.5 units is conducted. As the test element Ashalchinskoye oil field is taken. CMG STARS software was used for calculations. Dynamics of cumulative production, recovery factor and specific energy consumption per 1 m³ of crude oil produced in the application of the heat exchanger with heat agent in cases of different initial water saturation are defined and presented as graphs.

1. Introduction

In works [1-4] the following technology that uses thermal and gravitational impact on oil-containing layers was proposed.

Heat exchanger in the form of coaxially arranged pipes is entered in oil reservoir. High temperature heat agent moves downhole through a narrow pipe and returns to the surface through a space between the heat exchanger pipes, then the heat agent is heated to initial temperature and again returns to the heat exchanger. It implemented a closed circuit of heat agent flow. It is proposed to use high temperature heat agent which has a temperature range from - 115 °С to + 450 °С. As a result, the heat agent does not penetrate into the formation, and does not change its structure. Closed circuit scheme can significantly reduce the amount of heat agent consumption and avoid additional water saturation of the formation.

Due to natural thermal convection, heat exchanger walls are heated to high temperature. Water and light oil fractions, surrounding the heat exchanger, evaporate. The flow of hot vapor moves up and heats the high-viscosity oil. Over time oil moves to the lower part of the well due to gravity and retrieved to the surface. A mode of natural thermal convection that directs the upward flow of hot steam and the downward flow of heated oil is implemented. Using of one well allows to reach the zone of maximum heating at the oil production area.
These factors suggest that the proposed technology will be more effective than the widely used technology based on steam assisted gravity method of heavy oil extraction.

The aim of the work is assessment of the effectiveness of the proposed technologies for reservoirs with different initial water saturation.

2. Research method
Evaluating the effectiveness of the new technology using in reservoirs with different water saturation was also carried out in the software product CMG STARS by calculation of hydrodynamic and thermal processes occurring in the reservoir.

As the test element site Ashalchinskoye oil field size – 300x100x10 m is taken [5]. The initial water saturation of the productive formation was varied and amounted to 0.5; 0.4; 0.3; 0.2 and 0 units, that is 50%, 40%, 30%, 20% and 0% water production, respectively.

A heat source for heating the reservoir was a heat-exchanger with high temperature heat agent. The heat exchanger 300 m length, an inner diameter of 0.15 m is placed horizontally in the bottom part of the productive formation.

The selection of oil at the level of the reservoir pressure maintenance (0.4 - 1 MPa) started after the preheat phase formation within three months heater capacity of 7 Gcal/h (coolant temperature is 330-335 °C).

3. Calculation results
The obtained results are summarized in graphs with dynamic data (Figures 1-3).

![Figure 1. Dynamics of cumulative oil production in the application of the heat exchanger with HTC based on different initial water saturation](image-url)
The figures 1-3 show that with the increase in the value of the initial water saturation reservoir is produced for a short period of time. Figure 3 shows the energy consumption needed for production of 1 m$^3$ of oil offered by technology. From figure 3 it is clear that at the initial stage in the first three years oil extraction is the most efficient from the formation water saturation 0.4 and 0.3, and is less efficient - 0.5 units, since it takes a lot of energy to warm more water (specific heat of water is about 4.5 times more oil heat capacity), the same high cost oil without water, because a lot of energy spent on reducing the viscosity of crude oil. In further operation from 4 to 11 years the most effective are the options with initial water saturation of 0.2 and 0.3, because they have low water content and viscosity of the oil the temperature above 130 °C, become approximately equal to the viscosity of water.
4. Conclusion
The efficiency of heavy oil production depends on water saturation reservoir. According to the calculations for Ashalchinskoye oil field water saturation optimal values were from 0.2 to 0.3 units. This is due to the fact that under these conditions less heat energy is required for heating the reservoir because the heat capacity of water is about 4.5 times more oil heat capacity. However, oil production without the water saturation is also high-cost, because a lot of energy spent on reducing the viscosity of crude oil.

The work is performed according to the Russian Government Program of Competitive Growth of Kazan Federal University.

References
[1] Ibatullin R R, Kuneevsky V V, Osnos V B, Zaripov A T, Absalyamov R Sh 2013 Oil economy 1 pp 62-64
[2] Kuneevsky V V, Vankov Yu V, Osnos V B, Zaripov A T, Absalyamov R Sh 2012 Nefteservice 4(20) pp 54-56
[3] Kuneevsky V V, Vankov Yu V, Osnos V B, Zaripov A T, Absalyamov 2012 Power Problems 5-6 pp 84-89
[4] Vankov Yu V, Kuneevskiyv V V, Osnos V B 2014 Exposition Oil Gas 7(39) pp 20-26
[5] Ibatullin R R, Kuneevskiyv V V, Osnos V B, Zaripov A T, Absalyamov R SH 2013 Neftyanoe khozyaystvo 1 pp 62-64