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An Environmental Study on Reorganizing the Reservoir Pressure Maintenance System for Western Siberia Oil Fields

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Abstract

This study includes an environmental and social baseline of the oil sector in the region, an analysis of the potential key environmental and social issues, with which an assessment of impacts was made. The authors studied the key geological and physical parameters of productive formations. The authors found out that one of the main problems of the development system of the considered oil field is associated with the AV_{1-3} formation, which is characterized by worsened energy state and low recovery factor. The authors designed the reorganization of the reservoir pressure maintenance (RPM) system at the pilot site of the facility AV_{1-3} as a solution to the problem. This decision will allow increasing the sweep efficiency of the reservoir by waterflooding, and as a result – it will increase the oil recovery factor and remaining recoverable reserves.

Keywords: field development, water flooding, reservoir pressure maintenance, injection profile, environmental impact

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INTRODUCTION

Mature oil fields are used to characterize by significant decreases in reservoir pressure within the bottom hole formation zone. This point negatively affects the energy characteristics of the reservoirs and, ultimately, the oil recovery factor. As a rule, this case is also complicated by the heterogeneity of the reservoir properties, which leads to advanced watering some interlayers relative to others, as well as to the uneven development of recoverable reserves.

Over the years, waterflooding has been the most widely used secondary oil recovery method after the exhaustion of the primary depletion energy of the reservoir (Oyebimpe 2010, Precious et al. 2017, Terry et al. 2013). Since a significant number of prominent oil fields are mature fields and the number of new discoveries per year is decreasing, it becomes more imperative to use secondary oil recovery processes (Nwaozo 2006).

RPM systems of Matisova (2014) are becoming increasingly important due to many unique oilfields are in the final stage of the development. There are up-to-date RPM systems, or, more precisely, the new technologies used to maintain the reservoir pressure that make it possible to increase oil recovery.

Renshi et al. (2016) describes that water injection can be used to compensate the pressure depletion during oil production. Influences of artificial controllable factors (e.g. well ratio of injection to production and total well number) on equilibrium were particularly analyzed using field data. It was found out that the influences were mainly reflected as the location move of equilibrium point with factor change. Then the reservoir pressure maintenance system was especially introduced to reveal the variation law of liquid rate and oil rate with the rising of water cut. It was also found that, even if the reservoir pressure kept constant, oil rate still inevitably declined.

Zakharova et al. (2016) stated that issues related to solving RPM problems in the development of oil deposits are complex and multifaceted. Reasoning from this, the most relevant goals and objectives are associated with improving the effectiveness of RPM systems through developing and implementing a set of measures to optimize the reservoir flooding of productive formations and developing targeted or tailored technologies to enhance oil recovery.

According to Strekalov et al. (2015), the most effective management of structurally complex systems requires the use of the model system that mimics the behavior of real or projected hydraulic systems with

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arbitrary structure and technical indicators that make up their items.

The work presents a review of history matching and oil field development optimization techniques with a focus on optimization algorithms. Authors state no single optimization method is found to be universally superior. Combined well placement and well control optimization techniques are also thoroughly reviewed. The selection of the type, number, and placement of wells to achieve optimum reservoir drainage (Zitha et al. 2011) requires detailed knowledge of reservoir geology, which is unique for every oil field.

Precious et al. (2017) presented a research revealed that pressure maintenance/increment is more effective when there is water injection into zones of the reservoir, for waterflood operations involving the use of vertical injectors, higher water production was observed because water is expected to flow more conveniently in the upward direction due to gravity rather than laterally and with horizontal injectors, higher cumulative production was achieved especially for cases where water is injected into the same zones from which oil is produced.

Meshioye, Mackay and Chukuwezi (2010) conducted a research in which waterflooding has been controlled by smart injector well technology to help optimize or increase the net present value of the field. The optimization procedure was carried out on three different case studies of commingled reservoir having different layer characteristics. A setup optimization procedure was applied, where the rate allocation method was used in each zone of the smart injector well. The major drawback of their work was that the layers were not discretized to incorporate the effect of vertical communication and gravity within the layers.

Zhai et al. (2016) present a novel methodology to model inter-well connectivity in mature waterfloods and achieve an improved reservoir energy distribution and sweep pattern to maximize production performance by adjusting injection/production strategy on well control level. The method involves a reduced-physics based fast numerical tracer test on each well that yields inter-well connection strength or well allocation factors, and then a data-driven efficiency model on each inter-well connection calibrated automatically from the production/injection history of the reservoir.

This paper focuses on the improvement of the reservoir pressure maintain the system on the example of Western Siberia oil fields.

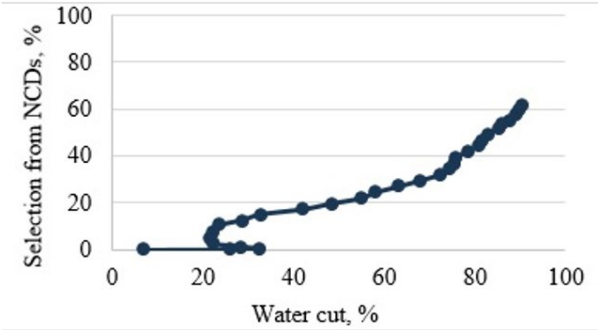

Fig. 1. Dependence «selection from initial recoverable reserves (NCDs) vs water cut»

METHODOLOGY

There are different methods that were used during carrying out of the experiments, the majority of them are: research analysis and generalization of the actual geological and field information, analysis of literary data, numerical modeling of the oil and gas fields development processes with the use of software systems for mathematical simulation and statistical calculation.

The basic laws and representations of reservoir physics, subsurface hydrodynamics and methodological approaches to the concept of effective pore space are used as a theoretical basis.

RESULTS AND DISCUSSIONS

The field is located in Khanty-Mansi Autonomous district. Nowadays the field is at the third development stage, and has almost reached the final stage, the current water cut is 90.5 %.

The main problem of the current development state is the inconsistency of the water cut of the extracted production with the value of producing reserves (**Fig. 1**).

The primary cause of this problem is the advanced watering of the field, due to geological, technical and technological reasons. For the most part, this type of waterflooding is affected by the development object (**Fig. 2**).

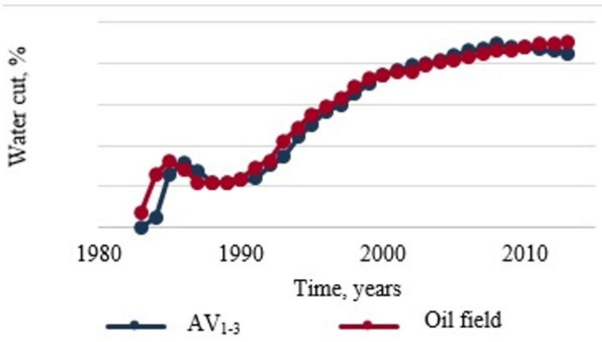

Fig. 2. Dynamic of water cut

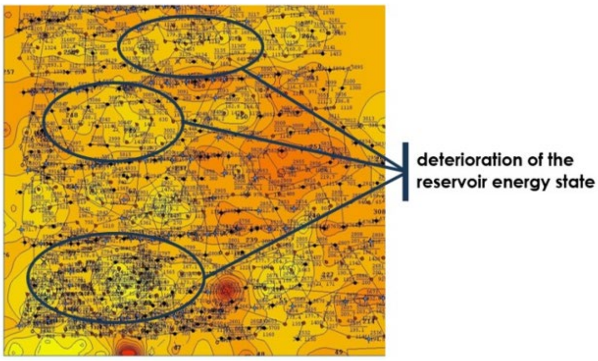

Fig. 3. Extraction from the structural plan

Fig. 4. Extraction from the current inventory map of AV_{1-3}

The object AV_{1-3} is the largest in terms of oil content area and the largest one within considered field development in terms of reserves. It is characterized by a high heterogeneity of reservoir properties. There are 6 sites of geological-field analysis identified within the object AV_{1-3}, each of them is characterized by its own facies group of deposits. inherent only to its geological and physical properties and features of changing the heterogeneity of the reservoir.

The design solutions formed for AV_{1-3} contain the combination of a three-row with a focal flooding system to maintain reservoir pressure.

The current state of the reservoir pressure maintenance system led to the point that in many sections of the exploited object the reservoir pressure

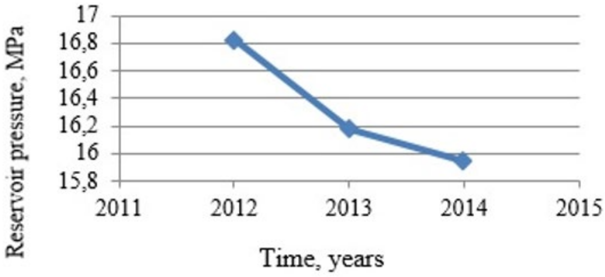

Fig. 5. Dynamic of the reservoir pressure reduction at the considered area

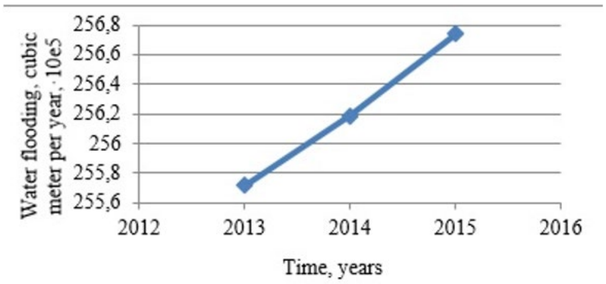

Fig. 6. Dynamic of injecting from GPS-6

decreased by more than 4 MPa in comparison with the initial one (**Fig. 3**).

The lack of effectiveness of the implemented system of RPM is also evidenced by the unevenness of the development of reserves at the facility. In one of the areas with increased values of current mobile stocks, the site most required to optimize the waterflooding system was selected (**Fig. 4**).

For a two-year period oil production in this area fell by 23.32 tons/day, reservoir pressure decreased by 0.7 MPa and is 82% of the initial. At the same time, the amount of injection from the group pumping station (GPS) serving this site increases annually, but they are clearly insufficient to maintain the reservoir pressure at the required level (**Figs. 5**, **6**).

In order to improve the development system on the selected site, the authors suggested to change an in-line block system to a block-closed one. This will make it possible to use previously non-drainage oil reserves, as well as to reduce the volume of pumping through the wells of the main injection lines.

There are 18 production and 16 injection wells in operation at the site. The site belongs to «2b» zone of geological and field analysis (GPA), geological and physical characteristics of which are presented in **Table 1**.

Table 1. Geological and physical characteristics «2b» of the gas-discharge zone

Parameter	Value
Netpay thickness, m	9.9
Permeability, 10^{-3}mkm^2	91.7
Porosity, unit fraction	0.21
Net sand coefficient, unit fraction	0.57
Recovery factor, unit fraction	0.54
Stratification factor, units	3

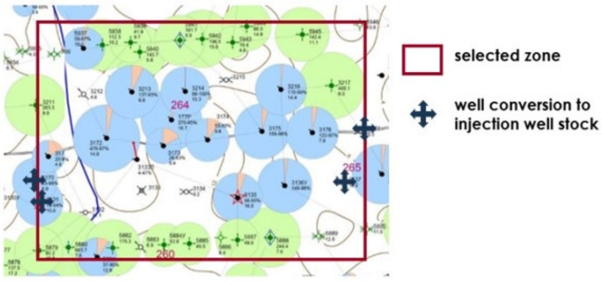

Fig. 7. Extraction from the current selection map with the selected site

The reorganization of the RPM system will be carried out due to the development of injection wells from production and other wells. Wells were selected based on their position in the formation geometry and data on the largest drops in oil and liquid production in the last 2 years. Well-to-well hydrodynamic connectivity was also taken into account. As a result, we selected 2 production wells, 1 piezometric well and 1 inactive wells (**Fig. 7**).

The calculation of the additional amount of balance reserves was based on a change in the sweep efficiency after the reorganization of the RPM system. To do it, we used the geological-statistical method, proposed by Revenko, Brilliant and Kuramshin. The calculation showed that, when changing a three-row system to a block-closed one, the final oil recovery factor will increase by 1.2% and this will allow to produce more oil in the future.

The current and accumulated compensation was also calculated on the selected site to assess the efficiency of the RPM system. The optimal compensation for the formation of the AV group is equal to 105 %. The current compensation is as high as 124 %. If at such excess reservoir pressure in a zone of selection does not reach values close to initial, we come to a conclusion that volumes of pumping are distributed unevenly, and the bulk of pumped water is filtered on the limited volume of formation.

Therefore, in order to increase the efficiency of water flooding in the considered area, in addition to the reorganization of the system, it is necessary to apply the

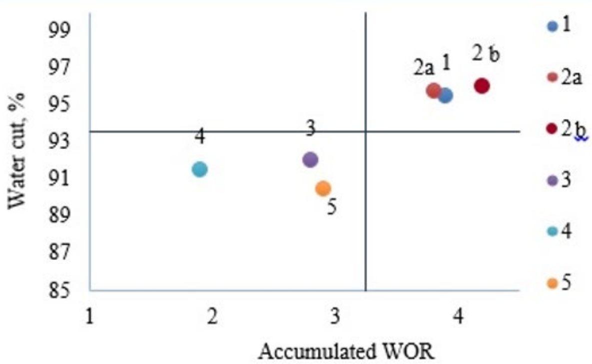

Fig. 8. Water cut vs accumulated WOR

technology of equalization of the injectivity profile. This will lead to containment of water breakthrough from injection to production wells; as well as to stabilize, or to reduce the water cut of production wells that are hydro-dynamically related to the injection wells.

The assumption that it is necessary to apply the technologies of the runway at the site under consideration was confirmed by the constructed nomogram «cross» «water cut - water-oil ratio (WOR)». According to it, the selected site is located in the zone characterized by the highest degree of washing of the filtration channels, as well as by water cut - higher than the object on average, and accordingly - the priority for injecting the runway formulations (**Fig. 8**).

To select the type of pumping agent, the efficiency analysis of the technologies that are already applied in the area AV_{1-3} was carried out. As a result of the analysis, the polymer-gel system Ritin was selected, which showed the highest specific efficiency in the previous year. To inject the composition authors selected a well that has an active hydrodynamic connectivity with 3 production wells, the liquid flow rate of which is more than 150 tons per day.

The calculation of the technological efficiency from the injection of Ritin was carried out according to the method of the Company "Kogalym Scientific Research And Design Institute of Oil" and Federal State Budgetary Educational Institution of Higher Education «Gubkin Russian State University of Oil and Gas» (Lysenko 2003), based on the change in the volume water content of the reservoir depending on difference between the physical properties of oil and the displacement water, as well as the coefficient of increase in the filtration resistance in the injecting area.

During calculating the increase in production rate, the decrease in the action of Ritin in time is also taken

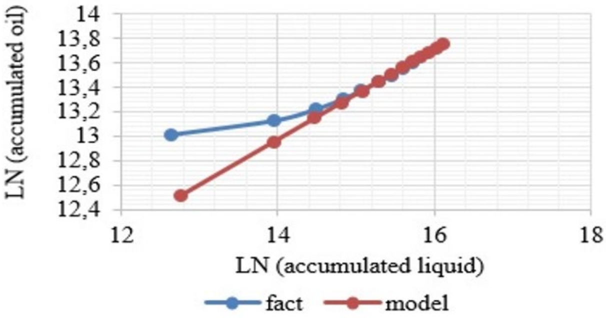

Fig. 9. Waterflooding displacement characteristics by the Abyzbaev method

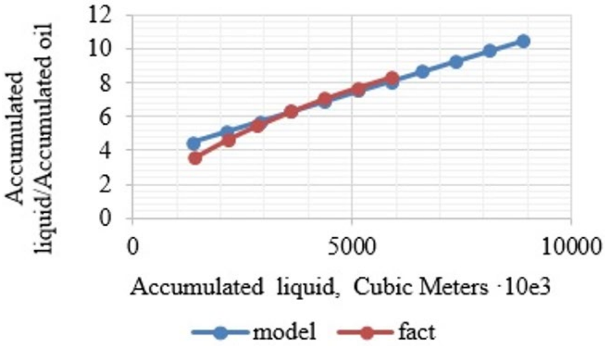

Fig. 10. Waterflooding displacement characteristics by the Nazarov-Sipachev method

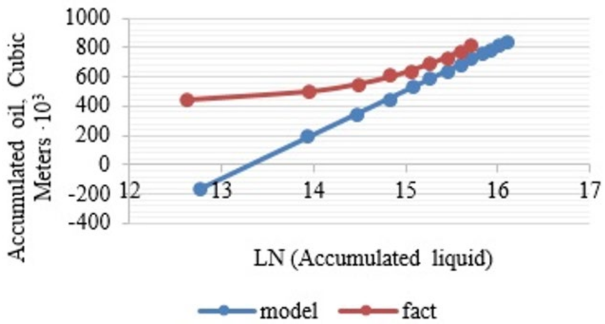

Fig. 11. Displacement characteristics according to the Sazonov method

into account, as well as the annual natural drop in production rate associated with the extraction of recoverable reserves. But in our case, it was necessary to take into account that due to the reorganization of the system, there was an increase in the current recoverable reserves, and accordingly a change in the dynamics of the fall in production. To account these changes, the displacement characteristics were constructed by the Abyzbaev, Nazarov-Sipachev, and Sazonov methods (**Figs. 9**, **10**, **11**) (Savelyev 2008).

The forecast of average annual oil production was obtained on the basis of the average values as the results of the construction of the 3 characteristics.

Thus, taking into account the transition to a block-closed development system, the annual production of three selected wells will increase up to 434 tons of oil per 1 ton of Ritin. At the same time, the average annual water cut will decrease by 12 %.

CONCLUSION

IWACO BV Consultants for Water and Environment was commissioned to undertake a project for the Dutch, German and Russian Greenpeace offices in 2000, to assess the environmental and social impacts of the oil industry in West Siberia. In this article, the authors analyzed the current development system of the oil field in Western Siberia. Due to the energy state analysis, as well as the degree of development of the main development object, a site was chosen for implementing measures to optimize the water flooding system.

The key measures to optimize the water flooding system at the selected site included the transformation of the reservoir pressure maintenance system from the three-row block, formed at the site from the beginning of the development, to the block-closed and organization of measures to equalize injectivity profiles using the Ritin technology.

Specific wells have been justified for transferring them to injection, and also a technological calculation of injection of polymer-gel Ritin composition at one of the injection wells of the site is given.

According to the technological calculation, as a result of the transformation of the reservoir pressure maintenance system, the final oil recovery factor will increase by 1.9 %. In case of success, this will lead to an increase in the current recoverable oil reserves in the area, thereby increasing the effect of the subsequent injection of the polymer-gel composition of Ritin into one of the injection wells. The total technological effect from the proposed measures will amount to 5,996.24 tons of additional oil per year, which makes it possible to recommend them to the oil field.

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