

Use of precipitate formation technology to increase oil recovery under Tarasovskoye field conditions

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Abstract. The article presents data about using the technology of precipitate formation on the basis of sodium sulfate under conditions of the Tarasovskoye field, located in the Yamalo-Nenets Autonomous District. This technology consists in a sequential injection into the formation of sodium sulfate and calcium chloride, which leads to the formation of a precipitate of calcium sulfate, which eventually blocks flushed zones and water-saturated zones, thereby enabling intensification of oil-saturated areas development. Injection of precipitation systems was carried out in injection well № 775, the focus of which includes 6 producing wells. The daily production rate of the test production wells after the event has increased more than 2 times. In addition, the authors noted the positive results of changes in formation characteristics: a decrease in permeability, pressure conductivity factor and hydraulic conductivity in a water-saturated zone.

1. Introduction

In Russia, one of the most common stimulation methods of intensifying oil production is to maintain reservoir pressure (MRP) by the injection of water, and, as a consequence, their development is conducted with high water cut indices. In case of Tarasovskoye field, the operation of more than 60 % of active well stock is carried out with water; about 11.7 % of the well stock are characterized by limiting water cut; many highly watered wells are inactive. In this case, the coefficients of oil withdrawal and sweep efficiency are at the low level.

All this leads to a reduction of the rate of the oil fields development, as well as to an increase in both economic and technical costs of oil production.

To solve the above-mentioned problems, improved, technological and cheaper stimulation methods of influencing the formations both in the laboratory and in the field are searched.

One of the most of promising methods for solving tasks in Tarasovskoye field is application of technologies of precipitate formation based on sodium sulphate [1].

2. Materials and methods

Before carrying out the work, materials on the technical condition of the casing string were examined in order to confirm their integrity and the absence of overflows to the overlying formations.

Delivery of reagent, the preparation of the working solution and injection are carried out using the following equipment and machines:



- ACN-10 (4 pcs.);
- CA-320 (2 pcs.);
- the capacity for preparation and storage solutions.

Sodium sulphate in a commodity form is brought to the well and the ready-made working solution is prepared by diluting it with water from the FPM (formation-pressure maintenance) system. Preparation and injection of working solutions are carried out in injection wells according to individual work plans in one or several cycles.

After the work is done, the injection mode is set, the injectivity of the well is determined at the working pressure of the injection. An act is drawn up for the work performed, indicating the actual data, taking into account each cycle. The well is connected to the water conduit.

Technology involves injection of the following working substances into the formation:

- sodium sulfate solution with a water-repellent agent;
- buffer volume of technical water;
- calcium chloride solution;
- buffer volume of technical water.

The volume of working substances is calculated by the individual characteristics of the production facility. Average reagent consumption per 250 m³ of technical water is as follows: Na₂SO₄ – 24 tons, CaCl₂ – 18 tons, water-repellent agent – 6 tons [2, 3].

In addition, the delivery of equipment and chemical reagents to the site of work, as well as the conditions, time and duration of their implementation, were assessed, [6-8].

The recommended injection volumes and composition of solutions per 1 m of the formation thickness and by cycles are presented in Tables 1, 2.

Table 1. Recommended injection volumes and composition of solutions per 1 m of the formation thickness

Parameter	1 st rim	2 nd rim	3 rd rim	4 th rim
Injection volume of technical water, m ³	60	70	40	80
Concentration of Na ₂ SO ₄ , ton	28.1	-	-	-
Concentration of CaCl ₂ , ton	-	-	18	-
Concentration of water-repellent, ton	6	-	-	-
Injection time, day	2			

Table 2. Recommended injection volumes and composition of solutions by cycles

Parameter	1 st cycle	2 nd cycle	3 rd cycle	4 th cycle
Injection volume of technical water, m ³	85	62.5	62.5	62.5
Concentration of Na ₂ SO ₄ , ton	15	-	-	-
Concentration of CaCl ₂ , ton	-	-	18.7	-
Concentration of water-repellent, ton	0.025	-	-	-
Injection time, day	2			

3. Content, technologies and evaluation of their effectiveness

The technologies of precipitate formation allow aligning with the injective profile of injection wells to increase sweep efficiency by regulating the characteristics of oil recovery and oil displacement. The essence of the technology consists in the sequential injecting of a solution of sodium sulfate and calcium chloride into the formation.

During the reaction of sodium sulfate with calcium chloride, which is contained in the mineralized water and the solution which is pumped into the injection wells, calcium sulfate precipitate is formed. These reactions upon exposure of high temperatures in the formation are more intense [9].

This sequence of injection of solutions is justified by the following. Sodium sulfate, which is injected into the formation, reacts with mineralized water, causing a slow precipitation of high

dispersion of calcium sulfate. Isolation of the solid phase in the injected solution results in an increase of filtration resistance and reducing the filtration rate of water. Then, the buffer volume of water and calcium chloride are injected, in the process of dissemination of which its reaction with sodium sulfate takes place, and a massive precipitate calcium sulfate, affecting the decline in the relative permeability of rocks in the water and redistribution of filtration flows, is formed [10].

Advantages of this technology consist in the following:

- enhancing oil recovery from the formation is achieved by blocking the flushed zone and water-saturated zones with insoluble precipitate calcium sulfate and a subsequent increase in development intensity;
- the reaction of sodium sulfate with mineralized water leads to blocking zones that are flushed with water and, consequently, to the improvement of the water flooding of oil-saturated zones;
- injection of reagents does not require specialized equipment;
- the method is simple to use and excludes such negative effects as salt deposits on the working surfaces of equipment, corrosion, etc;
- the reagent is thermostable, which implies its use in deep-lying formations.

The choice of pilot sites and wells for injection of precipitating formulations containing sodium sulfate is based on the results of a complex analysis of the geological and physical characteristics and features of the structure of the reservoir, the features of the lithological and hydrodynamic connection between the interlayers and the wells.

The pilot site of the Tarasovskoye field, selected for the use of the precipitate formation technology, meet the following field and reservoir conditions:

- porous reservoir with stratified and zonal heterogeneity;
- predominantly calcium chloride formation waters;
- water cuttings of well production exceeds 70 %;
- low development of a production facility as a whole;
- porosity factor is more than 0.1;
- average permeability is more than $0.005 \mu\text{m}^2$;
- injectivity of injection wells is more than $100 \text{ m}^3/\text{day}$.

Statistical methods are used with great success to determine the active recoverable oil reserves of the field and to assess the effectiveness of the application of an EOR if the objects or fields are operated under the regime of oil displacement by water.

The selected methods for determining the active recoverable oil reserves and for assessing the efficiency of the application of the EOR were tested based on data on the exploitation of long-developed fields (objects) in Bashkortostan.

The methods of equalizing the initial dependencies are used in processing the actual data for all methods in order to obtain the equations of a straight line. The last rectilinear portion of the dependencies is used for prediction. It is assumed that at a late stage of development, the last rectilinear portion of the displacement characteristic during extrapolation to the final values of water cut and the oil recovery factor yields a correct forecast of the indicators, that is, there will be no more breaks.

Evaluation of the EOR effectiveness was performed by the methods of the following authors, based on the definition of "characteristics of displacement":

- G S Kambarova;
- A M Pirverdyana;
- BashNIPIneft;
- D K Gaysina, E M Timasheva;
- S N Nazarova.

There were no significant differences in the calculations by the mentioned methods described here. They differ only by the method of determining the linear dependence and the definition of cumulative production.

The results of the carrying out of events (an incremental production of oil, decrease of the water

cuttings of well production, etc.) appear only after a long period of time.

Formation characteristics after exposure, as well as evaluation of its influence, are determined by the use of hydrodynamic and geophysical researches in wells [4,5].

To substantiate the optimal parameters of the technological process of impact on the formation and to assess its influence, various hydrodynamic and geophysical studies of wells are also carried out. Hydrodynamic and geophysical studies of wells allow us to evaluate the efficiency of the treatments performed by changing the filtration properties of the formation immediately after the impact.

A common and affordable way to assess the hydrodynamic parameters of a formation and wells is to determine the pressure decline (recovery) curve before and after the impact on the deposit, which are processed using the information technology by the method of "tangentials" in the special program. Their processing allows one to determine the degree of change in the hydraulic conductivity and piezoconductivity of the formation before and after the impact. To do this, a rectilinear section is selected on the transformed curve in coordinates of the "logarithm of time - wellhead pressure", along which the coefficient of permeability, hydroconductivity and piezoconductivity, formation pressure and reduced well radius are calculated.

The authors considered the injection of the sediment-composition, based on sodium sulfate, in injection well № 775 of Tarasovskoye field.

Table 3. Amount of additionally produced oil

Injection date	Incremental production of oil, for each method, ton/year					
	Kambarova	Pirverdyana	BashNIPIneft	Gaysina, Timasheva	Nazarova	Average
03.2014	3919	3177	3526	3833	1747	3240

The pressure recovery method allowed us to determine the coefficient of permeability, pressure conductivity factor and hydraulic conductivity before and after the event in well № 775; the calculation results are presented in Table 4.

Table 4. Results of research of well № 775 by pressure recovery method

Research date	Reservoir characteristics before and after the event		
	permeability, μm^2	pressure conductivity factor, m^2/sec	hydraulic conductivity, $\text{um}^2\cdot\text{m}/(\text{mPa}\cdot\text{sec})$
03.2014	0.043	0.100	0.50
08.2015	0.031	0.072	0.36

As a result of calculations, the daily production rate of wells of focus № 775 will amount to 30 ton/day, will increase by 15.8 ton/day or 2.11 times.

The calculation results of the production rate of wells of focus № 775 are presented in Table 5.

Table 5. Dynamics of production rate of wells before and after event

Well number	Production rate before event,	Production rate after event,	Difference,
	ton/day	ton/day	
160	1.5	4.5	3.0
336	2.9	5.2	2.3
337	2.7	5.5	2.8
356	1.6	4.3	2.7
357	2.4	5.1	2.7

826	3.1	5.4	2.3
Total	14.2	30	15.8

4. Conclusion

The effectiveness of the technology of precipitate formation in Tarasovskoye field was evaluated. Calculations were carried out by the six focuses with the use of five methods, based on the determination of «displacement characteristics». The calculation of the focus of injection well № 775 showed a positive technological effect of incremental production of oil (3240 ton/year). The formation parameters (permeability, pressure conductivity factor and hydraulic conductivity) were calculated before and after injection of the reagents, using hydrodynamic researches of injection well № 775, which made up, respectively, 0.043 and 0.031 μm^2 , 0.100 and 0.072 m^2/sec , 0.50 and 0.36 $\mu\text{m}^2\cdot\text{m}/(\text{mPa}\cdot\text{sec})$. The calculation has proved to be correct and has been confirmed by the actual data by focus № 775. On this basis, it is possible to predict an increase in the production rate by other similar focuses as well.

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