Using new grouting materials during repair and insulation works

R R Kadyrov¹, V V Mukhametshin², L S Kuleshova¹, I Sh Mingulov¹

¹ Ufa State Petroleum Technological University, Branch of the University in the City of Oktyabrsky, 54a, Devonskaya St., Oktyabrsky, Republic of Bashkortostan, 452607, Russian Federation
² Ufa State Petroleum Technological University, 1, Kosmonavtov st., Ufa, Republic of Bashkortostan, 450062, Russian Federation

E-mail: vv@of.ugntu.ru

Abstract. The paper presents the results of using new materials during repair and insulation works (RIW) in the conditions of Tataria fields and assesses the possibility of their application for the fields of other regions. The proposed new RIW technologies enable to increase oil recovery, reduce the water cut of the manufactured products, and intensify the oil production process. The article discusses the use of vinyl polymer VITAM and organosilicon compounds.

1. Introduction
At present, most of the oil fields in Russia and, in particular, the Republic of Tatarstan are at a late stage of development, and are characterized by a decrease in the level of oil production and an increase in the water cut of the manufactured products [1–6]. The reduction of the water cut of the manufactured products and the intensification of oil production is facilitated by carrying out repair and isolation works (RIW) using polymeric materials, high-viscosity oil, aluminum salts, etc., since the widespread use of coarse grouting compositions based on cement is not effective enough. The article presents the results of field trials with the use of some developed RIW technologies over the past decade. The essence of the developed technologies and the conditions for their application are stated.

2. Materials and methods
The technology for limiting the inflow of water using a vinyl polymer is based on the injection of the reagent VITAM being structured in the formation waters of both calcium chloride and sodium chloride types.

To date, on the territory of the West Siberian oil and gas province there have been discovered about 600 liquid and gaseous hydrocarbon deposits including more than 15 unique and 200 large and medium ones. The value of the working oil flow rates at them ranges from units to 100 m³/day. As a rule, hydrocarbon deposits confined to the Cretaceous deposits are multilayer. In productive sandy-clayey sediments, a predominantly pore-type reservoir is developed [7, 8].

Geological and physical characteristics of a number of fields, where it is planned to carry out repair and isolation works are as follows:
- the coefficient of permeability of the watered formation is 5-136 μm²;
- occurrence depth is 1432-3302 m;
- injectivity of water-cut layers is 70-132 m³/day;
- initial reservoir pressure in productive formations is 15-33 MPa;
- formation waters are represented by hydrocarbonate, calcium chloride, magnesium chloride mineralization with a density of 1010 kg/m³;
- reservoir temperature in the treatment zone is 70-180°C.

All the difficulties at the wells of the group of gas condensate fields in the north of the Tyumen region such as Urengoyskoye and Yamburgskoye are manifested in full and are caused by water inflows that are not associated with the development of hydrocarbon reserves.

The gas-dynamic calculations have shown that after withdrawing 70% of gas reserves from the fields, intensive watering of wells begins (pulling water to the bottom of the wells and overlapping filters) [9]. The major part of the Russian gas is recovered from these fields and the restoration of working capacity on them is extremely important for the Russian economy, which have determined the choice of the objects for using the developed technologies of grouting slurries and blocking fluids in relation to the geological conditions of the Urengoyskoye and Yamburgskoye fields.

The geological section of the deposits in lithological terms is basically similar. Reservoirs type is terrigenous. They are represented by alternating sandstones, siltstones with clay deposits. Sandstones are medium-grained with clay, more often carbonate, cement. The depths of the productive horizons are different. The presence of rocks with low positive and negative temperatures is clearly traced (in some areas their thickness reaches 1,000-1,200 m). High-permeability reservoirs with low pore pressures are everywhere. They are most often manifested in the intervals of the Pokur Formation and the gas-saturated Cenomanian horizon. These features of the geological structure to a certain extent complicate the processes of well cementing and separation of productive horizons, and require the use of special oil well cements.

Today, the main material for carrying out RIW is oil well cement and various modified compositions based on it. However, they have a number of disadvantages that lead to low RIW success. This is oil well cement’s low capacity of penetration into the pores and channels of the formation due to a significant excess of the cement particles size in comparison with the size of the pore channels and cracks in the formation. In addition, cement solutions are mainly aqueous solutions, which it is difficult to work with in winter due to their freezing. Polymer materials based on phenolic resins have unregulated setting times at elevated temperatures. Organosilicon AKOR type compounds contain ferric chloride, which is highly corrosive. Monomeric organosilicon compounds such as methylchlorosilane, dimethylchlorosilane, phenyltrichlorosilane require “delicate” handling when preparing work solutions and have difficult-to-control hardening period and short storage period leading to premature hardening in manufacturer’s containers [10–12].

A critical review of the structuring processes of polymers in the pore volume of rocks in the presence of formation fluids has resulted in the following basic requirements for polymeric materials for conducting RIW depending on the geological and technical conditions:

1. Sediment-forming and gel-forming polymeric materials must interact with formation waters; the sizes of the associates formed in the solutions should be sufficient to overlap the pore channels and cracks and be adsorbed on the rock to form near-wall layers in the pore space reducing the phase permeability to water.
2. The oligomers of polymeric materials must be cured on the basis of polycondensation reactions since the degree of their conversion in the pore volume of the formation is higher in comparison with other types of polymerization.
3. Sufficient adhesion to the rock in the presence of formation fluids, the ability to selectively adsorb with respect to hydrophilic minerals with the formation of chemisorption bonds, the ability to withstand the aggressive effects of formation fluids and factors associated with the intensification of development.
3. Results and Discussion

3.1. Vinyl resin applications

According to the technical task developed by the authors, a vinyl polymer has been synthesized. Laboratory and model studies have shown that it compares favorably with polymers based on hydrolyzed polyacrylonitrile (hydrolyzed polyacrylonitrile) in the amount of precipitated sediment, its packing density when exposed to salt solutions and an increase in oil permeability when it enters the oil-saturated part of the formation. In this regard, this reagent has been recommended when carrying out repair and insulation works. Unlike hydrolyzed polyacrylonitrile, whose plugging mass is formed only in the formation waters of the calcium chloride type, the vinyl polymer is structured in both calcium chloride and sodium chloride waters. The structure-forming agents of the vinyl polymer are salts of mono- and polyvalent metals contained in formation waters. When limiting the inflow of desalinated water, artificial mineralization of the watered formation is carried out with aluminum salts (aluminum chloride, polyaluminium chloride, aluminum sulfate and ferrous salts (FeSO4, FeCl2)). The technology is applicable to isolating water of both calcium chloride and sodium chloride mineralization [13-16].

RIW with plugging compounds based on vinyl polymer have determined the conditions under which they are advisable to be carried out:
- reservoir type is terrigenous;
- temperature in the range of RIW is within 5-100°C;
- specific injectivity of wells before treatment is 0.9-3.0 m³/ (h MPa);
- water cut of well production is within 80-99%.

The technology has been successfully handed over to the acceptance committee of PAO “Tatneft” and is being industrially introduced.

The stability of polymer-metal complexes of hydrolyzed polyacrylonitrile and vinyl polymer in formation fluids depending on the nature of the salts contained in the formation waters was assessed. Chlorides of iron, copper, nickel, barium and calcium were chosen as electrolytes for the study. Reservoir fluids were simulated by fresh industrial water, reservoir water of the Devonian horizon D1 and Devonian oil. The storage medium was changed to a fresh one every three days. Periodically, the physical properties of the stored sediments were assessed as follows: the consistency of the mass and its hardness were visually determined, the weight and volume were measured.

The persistence of hydrolyzed polyacrylonitrile sediments obtained by means of salts FeCl₂, CaCl₂, BaCl₂, NiCl₂ can be arranged in the following sequence:

FeCl₂ > NiCl₂ > BaCl₂ > CaCl₂.

The resistance of precipitation for vinyl polymer VITAM has a similar sequence.

When the vinyl polymer is deposited with a solution of calcium chloride, the destruction of the sediment is not observed, but it is unstable in relation to desalinated waters. Thus, when limiting the inflow of desalinated waters by means of hydrolyzed polyacrylonitrile and vinyl polymer, it is recommended to carry out artificial mineralization of the watered formation with aqueous solutions of aluminum or ferrous salts.

The RIW technology (with the use of the reagent VITAM) is designed to restrict water inflow through the reservoir, install a screen in the OWC zone, eliminate behind-the-casing flows in production wells and is applicable to isolate water of both calcium chloride and sodium chloride mineralization. The industrial production of polymer VITAM was organized at OAO “Norta” (Dzerzhinsk, Nizhny Novgorod Region). More than 45 repairs were carried out in PAO “Tatneft” using the reagent VITAM. The success of the work performed was 75%, the water cut of the produced products decreased by 20-30%. Additional oil production per well operation was 1.5 t/day. Based on the conditions of reagent VITAM application (the interval of RIW is possible within 5-100°C), it can be recommended for fields in Siberia, Ingushetia and other fields with a reservoir temperature of up to 100°C.
3.2. Application of organosilicon compounds

Plugging minerals based on organosilicon compounds have become widely used in the oil fields of the Krasnodar Territory and Siberia. These are compositions containing alkoxysiloxanes (AKOR, VTS-1 and VTS-2), oligoorganooxychlorosiloxanes (product 119-204). However, these compositions have a number of disadvantages: it is preferable to use AKOP at elevated temperatures of the collector since the hardening time is greatly slowed down in the temperature range of 20-30°C. Due to a number of advantages inherent in organosilicon compounds (good filterability into the formation, low freezing point, resistance of the resulting plugging mass to temperature and formation fluids), organosilicon products 119-296T, 119-296I have been developed and implemented at the enterprises of PAO “Tatneft” based on distillation residues of tetraethoxysilane, which are relatively cheap reagents. Distillation residues contain esters of orthosilicic acids. In addition, the orthosilicic acid ester easily forms homogeneous non-segregating mixtures with water. It has been found that the following can be used as homogenizing additives: SAS, neutral cosolvents (methylcarbinol, ketones), active cosolvents (polyglycols, organic acids, etc.). In the process of working with product 119-296T, a high sensitivity of the hardening time of compositions based on these products to temperature and concentration of hydrochloric acid has been noted. Therefore, formulations for the winter and summer seasons have been worked out, formation water of the D1 horizon or a solution of calcium chloride with a density of 1,180 kg/m³ has been used as one of the components for the winter season, and fresh industrial water – for the summer season. When performing RIW with plugging compounds based on an organosilicon product, the following conditions, under which it is advisable to carry out them, have been determined:

- reservoir type is terrigenous;
- temperature in the interval of carrying out RIW is no more than 180°C;
- specific injectivity of wells before treatment is 0.8-2.8 m³/(h MPa);
- water cut of well production is 99%.

The overall success of waterproofing works using the organosilicon product 119-296T for 225 introduced wells was 80%. Additional oil production and limitation of associated water for the analyzed period (385 days) amounted to 655 and 5572 tons per day, respectively.

Thus, the plugging composition based on organosilicon products recommended above is universal, technological and effective for many oil fields in Russia.

4. Conclusion

The developed technologies have been introduced in more than 600 wells, which has proven the promising nature of their application to limit the inflow of formation waters in terrigenous and carbonate reservoirs. The economic effect as a result of the implementation amounted to more than 300 mln. RUB (in 2017 prices), an additional 200 thousand tons of oil was produced and the withdrawal of associated water was reduced by 4 million tons.

References

[1] Andreev V E, Chizhov A P, Chibisov A V and Mukhametshin V Sh 2019 Forecasting the use of enhanced oil recovery methods in oilfields of Bashkortostan IOP Conference Series: Earth and Environmental Science (International Symposium «Earth sciences: history, contemporary issues and prospects») 350(1) 012025 DOI: 10.1088/1755-1315/350/1/012025

[2] Malyarenko A M, Bogdan V A, Kotenev Yu A, Mukhametshin V Sh, Umetbaev V G 2019 Wettability and formation conditions of reservoirs IOP Conference Series: Earth and Environmental Science (IPDME 2019 – International Workshop on Innovations and Prospects of Development of Mining Machinery and Electrical Engineering) 378(1) 012040 DOI: 10.1088/1755-1315/378/1/012040

[3] Khokhlov V I, Galimov Sh S, Devyatikova S G, Kotenev Yu A, Sultanov Sh Kh and Mukhametshin V Sh 2019 Justification of impact and planning of technology efficiency on the basis of limy-emulsion formulation in low-permeability highly-rugged reservoirs of Tyumen deposits IOP Conference Series: Earth and Environmental Science (IPDME 2019 –
[4] Valeev A S, Kotenev Yu A, and Mukhametshin V Sh 2018 Evaluation of Water-Alternating-Gas Efficiency when Using Wide Range of Gas Composition IOP Conference Series: Earth and Environmental Science (IPDME 2018 – International Conference on Innovations and Prospects of Development of Mining Machinery and Electrical Engineering) 194(8) 082042 DOI: 10.1088/1755-1315/194/8/082042

[5] Mukhametshin V Sh, Kotenev Yu A and Sultanov Sh Kh 2018 Assessment of the Need to Stimulate the Development of Hard-to-Recover Reserves in Carbonate Reservoirs IOP Conference Series: Earth and Environmental Science (IPDME 2018 – International Conference on Innovations and Prospects of Development of Mining Machinery and Electrical Engineering) 194(8) 082027 DOI: 10.1088/1755-1315/194/8/082027

[6] Kotenev Yu A, Mukhametshin V Sh, and Sultanov Sh Kh 2018 Energy-efficient technology for recovery of oil reserves with gas injection IOP Conference Series: Earth and Environmental Science (IPDME 2018 – International Conference on Innovations and Prospects of Development of Mining Machinery and Electrical Engineering) 194(8) 082019 DOI: 10.1088/1755-1315/194/8/082019

[7] Chudinova D Yu, Kotenev Yu A, Sultanov Sh Kh, and Mukhametshin V Sh 2018 The neural network for grouping wells of different facies zones of productive layer IOP Conference Series: Earth and Environmental Science (IPDME 2018 – International Conference on Innovations and Prospects of Development of Mining Machinery and Electrical Engineering) 194(8) 082008 DOI: 10.1088/1755-1315/194/8/082008

[8] Yakupov R F, Gimazov A A, Mukhametshin V Sh, and Makaev R I 2018 Analytical method for estimating efficiency of oil recovery technology in case of bottom water-drive reservoir, verified on the hydrodynamic model Oil Industry 6 66-69 DOI: 10.24887/0028-2448-2018-6-66-69

[9] Kadyrov R R, Nizaev R Kh, Yartiev A F, and Mukhametshin V V 2017 A novel water shut-off technique for horizontal wells at fields with hard-to-recover oil reserves Oil Industry 5 44-47 DOI: 10.24887/0028-2448-2017-5-44-47

[10] Mukhametshin V V and Kuleshova L S 2019 Prediction of production well flow rates using survey data IOP Conference Series: Earth and Environmental Science (IPDME 2019 – International Workshop on Innovations and Prospects of Development of Mining Machinery and Electrical Engineering) 378(1) 012114 DOI: 10.1088/1755-1315/378/1/012114

[11] Rogachev M K, and Mukhametshin V V 2018 Control and regulation of the hydrochloric acid treatment of the bottomhole zone based on field-geological data Journal of Mining Institute 231 275-280 DOI: 10.25515/PMI.2018.3.275.

[12] Khisamov R S, Abdurakhmanov G S, Kadyrov R R and Mukhametshin V V 2017 New technology of bottom water shut-off Oil Industry 11 126–128 DOI: 10.24887/0028-2448-2017-11-126-128

[13] Al-Nakhli A R, Bataweel M, Almohsain A, and Al-Badairy H 2017 Breakthrough Polymer Water-Shutoff System Shows Promise for Carbonate Ghawar Field Journal of Petroleum Technology 69(12) 78-79 DOI: 10.2118/1217-0078-JPT

[14] Fuller M J 2017 An Innovative Approach to Gel Breakers for Hydraulic Fracturing Journal of Petroleum Technology 69(3) 48-51 DOI: 10.2118/0317-0048-JPT

[15] Nitin Y V, and Rashmi B B 2010 Pat. 7687571 B2 USA. Int. Cl. C 08 L 23/00, C 08 L 51/00. Swellable elastomer-based apparatus, oilfield elements comprising same, and methods of using same in oilfield applications assignee Schlumberger Technology Corp. No. 12/100,434 field 10.04.08 published 30.03.10 25 p

[16] Song Q Kh, Wang H, Dong W, Bradshaw R, Cui W, and Njoku J 2017 Investigating the Benefits of Rotating-Liner Cementing and Impact Factors Journal of Petroleum Technology 69(5) 3 p DOI: 10.2118/0517-0082-JPT