Use of methods for water suppression in the Severo-Orekhovskoe field

V F Dyagilev1, T V Dyagileva 2
1 Tyumen Industrial University, Nizhnevartovsk branch, 628616, Tyumen Region, Khanty-Mansiysk autonomous district - Yugra, Nizhnevartovsk, Western industrial hub, Panel 20, Lenina St., 2/P, Bld 9, Office 107
2 Tyumen Industrial University, 38, Volodarsky St., Tyumen, 625000, Russia

E-mail: glibazval.dyagilev@yandex.ru

Abstract. The subject of the study is the use of methods for water suppression in the productive stratum of the Severo-Orekhovskoe field. Based on the results' analysis of the use of water suppression methods in the Western Siberia fields, recommendations were developed for the application of these methods in the Severo-Orekhovskoe field. It is shown that only technologies based on gel- and sediment-forming compositions having selective operation in layer-by-layer inhomogeneous stratum meet the conditions of productive strata of the Severo-Orekhovskoe field for all boundary parameters of application. During the study of the specifics of the field-geologic conditions of the Severo-Orekhovskoe field, effective water-shutoff compounds and technologies based on them were proposed: for strata A2-1, A1-3 - gel-forming compounds ACC-1, TSS-1, and "Geopan". The reagents proposed for use for water suppression operations have a selective effect in layer-by-layer inhomogeneous permeability stratum and have a good filtration in low-permeability reservoirs. The efficiency of using the water suppression technology based on the thermotropic reagent "RV-3P-1" for high-temperature strata BV, JV. It is established that relatively low temperature conditions expand, on the one hand, the range of water suppression technologies. For technologies based on acrylamide polymers (injection of cross-linked polymer compounds, visco-elastic compounds, concentrated polymer compounds, Temposkrin polymer-gel system, etc.), the only limitation is the low permeability of productive strata AB1-2, AB1-3.

1. Introduction
Based on the generalization and analysis of scientific and technical literature on the water suppression technology, we can classify isolation methods into non-selective and selective. This separation is determined by the technological, physicochemical, and mechanical properties of the material.

2. Literature Review
Identification of effective methods of using hydrocarbon resources is the research task of the modern scientific community (Etminan et. al., 2017) [1], which is reflected in the discussions of domestic (Vakhrushev et. al., 2016 [2], Surguchev and Sharbatova, 1988 [3]) and foreign scientists (Lei Wang et. al., 2017 [4], Xian’e et. al., 2017 [5], Wang and Sheng, 2017 [6]), focused on the search and development of methods for predicting the technological efficiency of production and assessment of oil reserves. The study relevance of the existing methodology for the development of natural resources of oil and gas complexes (Seigman et. al., 2010 [7], Report, 1999-2014, 2015 [8]) is undeniable. The
availability of modern methods and principles for assessing the current state of oil reserves in the Northern territories of the Russian Federation demonstrates the need to review and re-evaluate existing methods for predicting oil reserves production. This focuses on updating existing methods for predicting the technological efficiency of production and assessment of oil reserves.

3. Methods

Non-selective isolation methods (NSIM) – are methods using materials that, regardless of the medium's saturation with oil, water, and gas, form a screen that does not break down over time in reservoir conditions. The main requirements for NSIM are the exact identification of the treated watered interval and exclusion of reducing the permeability of the productive oil-saturated part of the stratum. For this purpose, cement, foam cements, polymer cements, technical devices such as drillable packers and overlapping devices are mainly used [9].

Selective isolation methods (SIM) are those methods where materials are used that are injected into the entire perforated part of the stratum. In this case, the resulting sediment, gel, or hardening substance increases the filtration resistance only in the water-saturated part of the stratum, and there is no plugging of the stratum’s oil part. The selective effect of chemicals is based on the difference of physico-chemical qualities of stratum fluids (oil and water) and physico-geological features of the formation’s structure [9].

4. Results and discussion

For productive strata characterized by high layer-by-layer inhomogeneity, it is preferable to use selective technologies for water suppression with the formation of temporary screens – “soft technologies”.

Selective materials can be used in the form of water-swelling polymers, emulsions, organosilicon compounds, sediment-forming compositions, and anhydrous grouting mortar. Water-swelling polymers are pumped as a suspension in an inert fluid, at a time of water contact, they swell, increasing in volume by 100-300 times, thereby displacing water and increasing the resistance to its movement. Emulsions are used in the wells development in the oil-saturated interval, as a result of their application, the viscosity of the blocking screen decreases. Organosilicon compounds interact with water, resulting in a durable gel. Sediment-forming compositions mixed with formation water form a sediment (10–50% volume), plugging the watered interval. Finally, anhydrous hydrocarbon-based grouting mortars, at a time of water contact in the stratum, form a high-strength impermeable stone, while no stone is formed in the oil zone.

By chemical nature, reagents for water isolation and elimination of behind-the-casing flows are divided into three groups. The first group consists of compositions based on organic materials: viscoelastic mud and cross-linked polymer compositions based on polyacrylimide; water-swelling polymers; "Hpan" and "Givpan" polymers; oxyethyl- and carboxymethylcellulose; compositions based on organic formaldehyde resins.

The second group includes compositions based on organoelemental compounds: organosilicon (AKOR, AKOR-2, AKOR-4, AKOR-BN, product 119-204, Water-repelling organosilicon liquid-11); organoaluminum; organotitanium, etc.

The third group is represented by reagents based on inorganic materials and includes cements, silicates (liquid glass – hydrochloric acid, silicate-alkaline solutions, silinom) and aluminosilicates (nepheline, zeolite-containing component, aluminum salts (chloride, aluminum sulfate, potassium alum with alkalai), reagents "Galka", "Thermogel", VIS-1.

Depending on the formation mechanism of water-shutoff masses and the physicochemical principles of influence on the host medium, five groups of selective chemical reagents can be distinguished (figure 2):

- curable - chemical reagents forming, after entering the stratum, a water-shutoff mass, soluble in oil and insoluble in an aqueous medium;
- gel-forming - chemical reagents leading to the formation of spatial gel-like systems with an inorganic or organic solid phase of high degree of dispersion with aqueous or non-aqueous dispersion medium;
- sediment-forming - chemical reagents under formation conditions leading to the setting of insoluble sediment in water-saturated zones;
- hydrophobizators - reagents, the use of which is based on the water-proofing of the rocks surface in the bottom-hole zone, which leads to a decrease in the phase rocks permeability to water and, consequently, to an increase in the filtration resistance for its movement;
- foam systems are formed as a result of the chemical reagents interaction, which allows blocking the path of water movement as a result of gas bubbles sticking to the surface of water supply channels and the filming of colloido-dispersed compounds.

After entering the reservoir, the curing reagents form a water-shutoff mass that is soluble in oil and insoluble in water. Today, synthetic curing reagents are most in demand their consumption per well is minimal, and the use does not require special equipment [10].

Figure 1. Classification of water suppression methods [10]
Figure 2. Classification of water suppression methods according to the mechanism of water-shutoff masses formation

The use of water-shutoff compositions in the sediments of the Severo-Orekhovskoe field is very limited, due to the specifics of the geological and physical conditions of these objects:
- formation temperature (54 °C or more);
- high permeability variability of strata (layer-by-layer heterogeneity);
- low reservoir properties of certain benches of AB, JV 1 strata (the stratum is represented by VI-V collectors (permeability from 0.002 to 0.01 μm²), less often IV (permeability up to 0.1 μm²) classes according to Hanin. As shown by field practice, such parameters exclude or severely restrict the use of PE methods, and cause their low efficiency [9].

For the conditions of the productive strata of the Severo-Orekhovskoe field, only technologies based on gel-and sediment-forming compositions having selective operation in layer-by-layer inhomogeneous stratum correspond to all boundary parameters of application. Relatively low temperature conditions expand, on the one hand, the range of water suppression technologies. For technologies based on acrylamide polymers (injection of cross-linked polymer compounds, visco-elastic compounds, concentrated polymer compounds, Temposkrin polymer-gel system, etc.), the only limitation is the low permeability of productive strata AB1-2, AB1-3 (in some cases).

For technologies based on water-soluble polianionites (injection of Givpan polymer with crosslinking agent), inorganic and organic silicon compounds (injection of AKOR, KROS, ETS-40 solutions of water glass — silicate-alkaline effect and other ethylsilicates), the limiting factor for their application is the low average permeability of the rocks of AB 1-3 strata [11].

Suspension or disperse systems have low filtration capacity in collectors with permeability less than (0.02-0.03 μm²).

For the conditions of the field-geologic conditions of the Severo-Orekhovskoe field, effective water-shutoff compounds and technologies based on them were proposed: for strata A2-1, A1-3 - gel-forming compounds ACC-1,
TSS-1, and "Geopan". The reagents proposed for use for water suppression operations have a selective effect in layer-by-layer inhomogeneous permeability stratum and have a good filtration in low-permeability reservoirs.

Technologies based on the proposed reagents are aimed at increasing the oil recovery of terrigenous strata and are intended for:
- restrictions on water inflow to producing wells;
- reducing non-productive injection in the formation-pressure maintenance system;
- alignment of the injection and selection profile;
- elimination of interstratal flows between productive strata in the bore-hole annulus and the contour discharge of injected water into the aquiferous part of strata [12].

Technologies based on thermogel-forming compositions (GFC "RV-3P-1", GFC "GALKA" GFC "METKA" are applicable only in the conditions of highly permeable strata BV6.8, medium permeable strata JV1 (stratum temperature of layers over 80°C). For technologies based on thermogel-forming reagents, the high temperature of the strata is a necessary factor in the formation of an ecologically friendly aluminum hydroxide gel. As field practice shows, cross-linked or gel-forming polymer systems based on known polyacrylimide are not recommended for use in high-temperature strata (they are destructured at a temperature above 75-80 °C); emulsion systems (they are thermally stable for a long time only up to a temperature of 85 °C) [12].

Field-statistical criteria for optimal application of the "Geopan " reagent based technology:
- eff. oil-filled thickness more than 2 m.;
- collector-terrigenous, porous-fractured;
- permeability of productive strata more than 0.01 μm²;
- acceleration not less than 50 m³/day;
- during well treatment oil flow rate is more than 1.5 t/day;
- during complex treatment (injection + reactive producing) the total oil flow rate by element (block) should be more than 3.5 t/day.
- abrupt change (20% or more) in the water cutting of the produced liquid at the source of impact;
- for producing wells, the reservoir pressure is not less than 0.7 hydrostatic pressure;
- availability of residual recoverable reserves.

Criteria for applying the technology based on the "ACC-1" reagent:
- terrigenous heterogeneous reservoir (number of permeable intervals >2);
- carbonate content is not more than 10%;
- permeability from 0.01 μm ² and more.
- the technology works in waters of different mineralization;
- Criteria for successful application of "RV-3P-1" reagent technology:
- Stratum temperature - not less than 70 °C
- Collector - terrigenous.
- Permeability coefficient-not less than 0.05 μm².
- Number of permeable intervals - more than 2.
- Formation water mineralization - without restrictions.
- Water cutting by the source of impact is 50–90 %.

A wide range of process conditions:
- Injected water is used in working solutions;
- high processability (liquid commodity form), use of standard equipment;
- well treatment at temperatures up to -35 °C;
- incorrectly installed gel barrier is eliminated with 0.5 % hydrochloric acid solution;
- reagents are non-toxic, do not violate the ecology.
5. Conclusion
For the field-geologic conditions of the Severo-Orekhovskoe field, effective water-shutoff compounds and technologies based on them are proposed: for strata $A_{2.1}$, $A_{1.3}$ - gel-forming compounds ACC-1, TSS-1, and "Geopan". The reagents proposed for use for water suppression operations have a selective effect in layer-by-layer inhomogeneous permeability stratum and have a good filtration in low-permeability reservoirs. The water suppression technology based on the thermotropic reagent "RV-3P-1" are recommended for high-temperature strata BV, JV.

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