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Drilling Fluids for Drilling Wells at the Bovanenkovo Oil and Gas Condensate Field

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***Abstract** - The effectiveness of using drilling fluids depends on the geological conditions of the object occurrence and technologies used in the opening of productive formations.*
The preservation of the filtration characteristics of the bottom-hole zone of wells and the production of industrial hydrocarbon production rates determine the relevance of the present work.
The purpose of the work is to study the effect of drilling fluids on the filtration characteristics of rocks and to ensure the industrial production rates after conducting works on the opening of productive formations.
The novelty of the work consists in the recommendation of using drilling fluids for drilling wells at the Bovanenkovo oil and gas condensate field.

Keywords - *research, drilling fluid, mineralized solutions, perennially frozen rocks.*

I. INTRODUCTION

In the course of drilling thick clay deposits, characteristic of the deposits of Western Siberia, clay solutions are intensively enriched with a solid phase, which leads to an increase in the density of the drilling fluid. At the same time, as shown by studies, an increase in the density of drilling fluid, which causes an increase in repression on the reservoir, leads to an expansion of the component penetration zone of the solution into the reservoir and, accordingly, negatively affects the production characteristics of wells [1]. Considering the above, it is recommended to use solutions with a low content of solid phase for opening layers. The density of the drilling fluid from the moment of opening the productive layers and until completing of cementing the production column should be minimal according to the current reservoir pressure and ensuring at the same time trouble-free drilling of the borehole.

Drilling fluids must meet three important requirements: they should be:

i) easy to prepare,
ii) not too expensive,
iii) environmentally friendly.

Complex drilling fluids play multiple functions simultaneously. They are designed to clean the well, keep the drilled cuttings suspended, prevent the collapse of the good walls, ensure the tightness of the walls, and form an impermeable crust near the bottom-hole zone of the well [2].

The choice of drilling fluid mainly depends on the type of formation and the depth of the borehole. Various types of drilling fluids are commonly used, namely, water, bentonite solution, lubricating-cooling fluid, and polymers (both water-based and drilling fluid-based).

Water is a freely available liquid that is mainly used in drilling. It has very good cooling properties and performs as a moderate lubricant and vibration dampener.

Bentonite weighting agent increases viscosity and improves downhole cleaning. It forms a culmination crust on the borehole walls and thus prevents the collapse of the borehole. Bentonite drilling fluid has gel-forming properties and can keep the cuttings suspended in case of the termination of the circulation.

Polymers have properties similar to bentonite drilling fluids. The only drawback is that the circulation must be carried out during the entire drilling period. Otherwise, the cuttings will quickly settle on the face and cause tool sticking [3].

The task consists in selecting chemicals for the treatment of drilling fluid that causes minimal deterioration of reservoir properties.

To ensure the stability of the borehole walls in the perennially frozen rocks (PFR) for high-quality fastening of the borehole by reducing heat exchange and time spent on deepening for elongated descent, it is proposed to use drilling fluids with increased pseudo-plastic properties.

When surface hole drilling, it is proposed to use a mineralized carbamide solution, a drilling solution based on PKR-M, a solution based on sodium formate. Solutions should have high inhibitory properties, increased viscosity from 50 to 60 stokes, and low filtration ranging from 4 to 5 cm^3/30 min.

When drilling for the production casing string and the tailpipe, solutions, having used for surface hole drilling, are used after being cleaned of excess solid phase, cuttings, processed with polymers, and weighted with additives.

In a good construction cycle, the opening of a productive reservoir is one of the main and complex processes. The quality of this stage largely influences the assessment of the prospects of a new field and the flush production in producing wells.

When the well is completed, the possibility of using drilling fluid and the opening mode, which minimally reduces the reservoir properties of the productive reservoir, manifests itself. In this case, an effective option is opening a productive reservoir in equilibrium mode when the pressure at the bottom hole of the drilled well is close to the reservoir pressure or slightly exceeds it.

The second option is to open a productive reservoir during the depression when the bottom-hole pressure is lower than the reservoir pressure. This allows ensuring the preservation of the natural properties of the productive reservoir.

II. MATERIALS AND METHODS

This work was carried out at the Center for Advanced Research and Innovative Developments of the Tyumen Industrial University (Tyumen, Russia) in September-December 2020.

The research object concerns revealing the effect of mineralized drilling fluids on the filtration characteristics of the bottom-hole zone and preparing recommendations for the use of mineralized drilling fluids for drilling wells of the Bovanenkovo OGCF.

To develop formulations of fluids for opening productive formations that provide flow rates close to potential, primarily, it is necessary to conduct a study to determine the degree of influence of their filtrates on the return permeability [4].

Until these data are received, all proposals for the initial opening of productive layers are just advisory.

For the primary opening, it is advisable to use drilling fluids that ensure the preservation of reservoir properties of productive formations. The total solid phase content in the solution is maintained at a low level to prevent contamination of the reservoir and increase hydraulic efficiency [5].

The main criteria by which drilling fluids are chosen are the stability of the borehole, which depends on cleaning the well from cuttings, control over the wellbore safety, and maximum preservation of natural reservoir properties when opening productive horizons [6].

To ensure the stability of the good walls for high-quality fastening of the borehole by reducing heat exchange and time spent on deepening for elongated descent, it is proposed to use drilling fluids with increased pseudo-plastic properties [7].

The main parameter determining the change in the filtration characteristics is the return permeability.

To determine the permeability of rock samples and the return permeability, core samples with a permeability from 1·10-3 to 1.0 mm2 are used.

For these purposes, the following equipment and materials are used: analytical scales with an accuracy of 0.01 g, rock samples, installation simulating reservoir conditions, and centrifuge.

Drilling fluid filtrates were prepared in laboratory conditions by filtering them employing an OFITE filter press [8].

When determining the permeability, a prepared core sample with a known absolute permeability and residual water saturation after saturation with kerosene is installed in the core holder of the installation designed to study violations of the productive properties of the FDS-350 formation [9]. In the course of simulating reservoir conditions, the sample is saturated with kerosene, and the permeability of the hydrocarbon liquid is determined. The experiment is considered completed if at least three volumes of hydrocarbon liquid pores are pumped through the sample at a steady flow rate and the value of the permeability coefficient is stabilized.

When modeling the penetration process of drilling fluid filtrate into rock samples, the liquid filtrate is injected from the opposite side of the sample at a constant velocity. The hydrocarbon liquid and the filtrate of the drilling fluid are collected in a special measuring burette, where the volumes pumped through the core of liquids are measured. At the final stage of the test, the sample can be maintained for a certain time, corresponding to the idle time of the well with this type of solution at the temperature and pressure of the test. The drilling fluid filtrate is displaced from the core by reverse filtration with a hydrocarbon liquid at a pressure equal to the depression, applied to the reservoir at good stimulation. The amount of liquid passed through the sample varies from 10 to 15 pore volumes. After cleaning the pore space from the remnants of the drilling fluid filtrate, the permeability of the hydrocarbon liquid is determined, and the return permeability is calculated.

III. RESULTS AND DISCUSSION

Compositions of drilling fluids for the primary opening of productive formations at the Bovanenkovskoye field

A. Investigation of the effect of penetration of amide solution filtrate into reservoir rocks

The composition and parameters of the inhibited amide drilling fluid are given in Table 1.

TABLE I. COMPOSITION AND PARAMETERS OF AMIDE DRILLING FLUID

Composition of the solution wt.%	Density, kg/m^3	T, °C	Static Shear Stress, 10s/1m/10m, dPa	F, cm^3/30 min	H, mm	η, mPa·s	τ_0, dPa	n	K, Pa·s	φ, FSK*	pH
PBMB g/p……....3.0 PATS-V…...……0.4 PATS-N………...0.5 Resin polymer….1.2 FKHLS…………0.4 Polyecol B ……..1.0 SMEG………….1.2 Defoamer …..….0.2 MP-4 …………35.0	1,240	55	14/14/14	2.8	0.3	31	137.7	0.62	0.83	0.30	8.5

*FilterShearCoefficient

Experiments on pumping the filtrate of an inhibited amide solution were carried out using four core samples of the Bovanenkovo OGCF. The results of the experiments are shown in Table 2.

TABLE II. THE RESULTS OF EXPERIMENTS ON ASSESSING THE EFFECT OF THE PENETRATION OF THE FILTRATE OF THE AMIDE SOLUTION ON THE PERMEABILITY OF SAMPLES

Deposit, well, sample	Gas permeability, $K \cdot 10^{-3}$ μm²	Porosity, %	Residual water saturation, %	Permeability by kerosene, $K \cdot 10^{-3}$ μm²		Return permeability, %
				before test	after test	
Bovanenkovo well 60 – P sample 57315	571.0	29.4	16.8	112.0	93.0	83.0
Bovanenkovo well 95 sample 83340	411.2	27.1	19.8	302.0	275.0	91.0
Bovanenkovo well 53 sample 27517	51.5	26.6	24.7	9.4	10.4	110.0
Bovanenkovo well 100 P sample 83048 (1)	51.1	25.4	30.7	12.0	7.6	63.0

Filtrate of mineralized amide solution was injected into the samples selected for experiments. The obtained results have shown that the return permeability in samples No. 57315 and No. 83340 is sufficiently high, ranging from 83.0 to 91.0% with very close gas permeability. The return permeability in sample No. 83430 exceeded that of sample No. 57315 by 8%, which is associated with the degree of cementation of the sample since the kerosene phase permeability in sample No. 83430 exceeded that of sample No. 57315. In samples with lower permeability up to $51.5 \cdot 10^{-3}$ μm², the return permeability varies from 63.0 to 110.0%. Lower values of return permeability in sample No. 83048 compared to sample No. 27517 are associated with the structure of the pore space by the presence of small pores not involved in the filtration.

B. Investigation of the effect of penetration of drilling fluid filtrate based on sodium formate (HCO_2Na) into reservoir rocks

The composition and parameters of the drilling fluid based on sodium formate are given in Table 3 [10]. Experiments on injection of drilling fluid filtrate based on sodium formate were carried out using four core samples of the Bovanenkovo OGCF. The results of the experiments are shown in Table 4.

TABLE III. COMPOSITION AND PARAMETERS OF DRILLING FLUID BASED ON SODIUM FORMATE

Composition of the solution wt.%	Density, kg/m³	T, °C	Static Shear Stress, 10s/1m/10m, dPa	F, cm³/30 min	H, mm	η, mPa·s	τ_0, dPa	n	φ, FSK*	pH
PBMB g/p………………...3.0 Robus KK……………..….0.2 KREM………..…………..1.2 Sodium formate.. ……..…15.0 SKZH-11…………………..0.3 KSD…………………...…1.5 FK 2000 M…………..…1.0 Defoamer …..………..…..0.1	1,240	55	35/45	3.2	0.2	18	90	0.8	0.30	8.5

*FilterShearCoefficient

TABLE IV. THE RESULTS OF EXPERIMENTS ON ASSESSING THE EFFECT OF THE PENETRATION OF THE DRILLING FLUID FILTRATE BASED ON SODIUM FORMATE ON THE PERMEABILITY OF SAMPLES

Deposit, well, sample	Gas permeability, $K \cdot 10^{-3}$ μm^2	Porosity, %	Residual water saturation, %	Permeability by kerosene, $K \cdot 10^{-3}$ μm^2		Return permeability, %
				before test	after test	
Bovanenkovo well 75- P sample 69136	56.4	28.2	39.5	12.0	5.0	41.4
Bovanenkovo well 100-P sample 81764.1	565.28	31.0	16.6	13.3	13.3	100.0
Bovanenkovo well 58 sample 28202	57.11	26.4	24.7	35.4	17.0	47.0
Bovanenkovo well 100 sample 83061	29.98	23.7	33.1	10.0	5.2	52.0

In this sample collection, the filtrate of mineralized drilling fluid based on sodium formate was injected into four samples No. 69136, 81764.1, 28202, and 83061. The limits of permeability changed from $29.98 \cdot 10^{-3}$до $565.28 \cdot 10^{-3}$ μm. From the entire collection of samples, return permeability was completely reached only in sample No. 81764.1 with a permeability of $565.28 \cdot 10^{-3}$ μm.

The remaining three samples with a permeability value ranged from $29.98 \cdot 10^{-3}$до $57.11 \cdot 10^{-3}$ μm^2 showed a decrease in permeability from 41.4 to 52.0% after injection of solution filtrates. The return permeability was not reached during the simulation of the good development process.

C. *Investigation of the effect of penetration of drilling fluid filtrate based on PKR-M*

The composition and parameters of the drilling fluid based on PKR-M are given in Table 5 [11].

TABLE V. PARAMETERS OF DRILLING FLUID BASED ON PKR-M

Composition of the solution wt.%	Density, kg/m^3	T, °C	Static Shear Stress, 10s/1m/10m, dPa	F, cm^3/30 min	H, mm	η, mPa·s	τ_0, dPa	n	φ, FSK*	pH
PKR-M ……….. 4.8 KREM-S ……... 0.5 Calciumchloride.. 34	1,240	55	40/60	3.0	0.2	28	125	0.6	0.30	5.5

*FilterShearCoefficient

Experiments on injection of drilling fluid filtrate based on PKR-M were carried out using four core samples of the Bovanenkovo OGCF. The results of the experiments are shown in Table 6.

TABLE VI. RESULTS OF EXPERIMENTS ON ASSESSING THE EFFECT OF PENETRATION OF DRILLING FLUID FILTRATE BASED ON PKR-M ON THE PERMEABILITY OF SAMPLES

Deposit, well, sample	Gas permeability, $K \cdot 10^{-3}$ μm^2	Porosity, %	Residual water saturation, %	Permeability by kerosene, $K \cdot 10^{-3}$ μm^2		Return permeability, %
				before test	after test	
Bovanenkovo, well 75- P sample 69137	37.10	25.5	42.4	11.0	2.3	24.0
Bovanenkovo, well 100-P sample 81756	389.47	29.3	21.8	15.0	13.0	89.0
Bovanenkovo, well 58 sample 28203	39.35	26.1	26.1	7.5	2.7	36.0
Bovanenkovo, well 100-P sample 83051	25.10	24.2	41.7	8.5	4.8	56.0

After pumping the drilling fluid filtrate based on PKR-M, high results were obtained in terms of the return permeability in sample No. 81756 with a permeability of 389.47·10-3 μm2, in which the return permeability reached 89.0%. In samples, No. 69137, 28203, and 83051 with low permeability values ranging from 25.10·10-3 to 39.35·10-3 μm2, the return permeability has lower values ranging from 24. to 56.0%. Such differences in the return permeability values are associated with the increased clay content in tested rocks.

IV. CONCLUSION

A. Evaluation of the penetration of drilling fluid filtrates on samples of reservoir rocks

Laboratory experiments conducted using core samples allowed establishing that when pumping filtrates of drilling fluids, an irreversible deterioration in permeability was observed in some experiments. This concerns samples No. 69136 and 28202, into which a drilling fluid filtrate with sodium formate was injected.

Sample No. 81764.1 with a permeability of $565.3 \cdot 10^{-3}$ μm^2showed a complete restoration of return permeability, which was associated with a low content of gel cement. In the remaining samples, low return permeability is associated with the absence of potassium ions in the drilling fluid filtrate, which has high inhibitory properties. The presence of potassium in the filtrate of drilling fluid allows maintaining the stability of clay minerals composing the cement of reservoir rocks and eliminating the possibility of destruction of the borehole walls.

The experimental part with the injection of an amide solution into filtrate samples is represented by three samples. No. 57315, 83431, 27517, in which the permeability increased from 83.0 to 110.0%. This phenomenon is associated with the hydrophobization of the pore space of reservoir rocks by lubricating and inhibitory additives, such as SMEG, resin polymer, and poliecol. Hydrophobizing agents that are part of the amide solution filtrate give a stable surface wettability due to their contact with the rock and adsorption on the surface. The hydrophobization effect can be achieved using lubricating and inhibitory additives.

Experiments conducted using solution filtrate based on PKR-M showed the lowest values of return permeability recovery. The return permeability was reaching 89.0% only in a sample with a permeability of $389.47 \cdot 10^{-3}$ $\mu m^2$and a low content of residual water, which indicates a low clay content in the sample.

Samples with a permeability from $25.1 \cdot 10^{-3}$ to $37.1 \cdot 10^{-3}$ μm^2have the lowest values of return permeability, which is associated with the high clay content of rocks and the composition of the drilling fluid. The presence of calcium chloride in the fluid composition does not contribute to the stabilization of clay minerals, which leads to uncompensated exchange and weakening of the bonds between the layers of clay minerals and the shedding of the good walls.

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