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Packer fluid research and development for Bovanenkovo wells

Low-temperature highly icy frozen rocks (up to minus 7.0°C) and productive formations with temperatures up to 55.0°C under high temperature gradient values (3.3°C/100 m) and small depth, in Bovanenkovo oil-gas condensate field, create conditions for heat transfer from the reservoir to the wellhead with subsequent impact on the surrounding permafrost, including their warming and hydrate plugs dehydration with the annular gas showings. For such conditions, wells are needed, equipped according to the packer scheme, with the placement of non-freezing packer fluid in the packer annulus, which provides thermal convection of heat transfer from the formation to the permafrost zone, preventing their thawing and crushing of production strings. To ensure the safe operation of wells in the Bovanenkovo oil-gas condensate field, the most suitable packer fluids are those based on sodium format.

Keywords: Research, packer fluid, saline solutions, permafrost

1.0 Introduction

The works of many domestic and foreign researchers are devoted to the development and study of packer fluid compositions properties, but the peculiarities of the geocryological conditions of the Bovanenkovo oil-gas condensate field (OGCF) and the existing well designs do not allow mechanically transferring known methodological and technological developments to them without improving them and additional studies [1-4].

The presence in the section of the Bovanenkovo oil-gas condensate field of low-temperature high ice frozen rocks (up to minus 7.0°C) and productive formations with temperatures up to 55.0°C in conditions of high values of the temperature gradient (3.3°C/100 m) and shallow depths creates conditions for heat transfer from the reservoir to the wellhead with subsequent impact on the surrounding permafrost rocks (permafrost), including their thawing and hydration plugs loosening with the occurrence of annular gas showings [5-7]. For such conditions, wells are needed, equipped according to the packer scheme with the placement of non-freezing packer fluid in the packer annulus [8-11].

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2.0 Materials and methods

To ensure the flowing operation safety of high-rate gas-oil-saturated formations, the safety rules [12] regulate the packer's use as part of the downhole equipment [13].

The annular space above the packer is filled with packer fluid [14-16]. The specific fluid gravity must be sufficient to balance the pressure on the packer from below; be sufficiently viscoplastic to eliminate heat transfer; have thixotropic properties for additional sealing of threaded joints when fluid penetrates them; have stability (not delaminate) over time; thermal conductivity should be as low as possible; have a low freezing point; the value of the hydrogen index (pH) must be at least 10-12.

Under the conditions of well operation at the Bovanenkovo oil-gas condensate field, the following requirements are imposed on the packer fluid:

- the packer fluid must create the necessary balancing pressure on the packer from above;
- for formations KhM_{1-2} and TP_{1-6} with anomalous coefficient K_a = 1.23, it is recommended to use packer fluid with a density of up to 1350 kg/m^3;
- for TP_{7-11} formations with K_a = 1.05, it is recommended to use packer fluid with a density of up to 1100 kg/m^3;
- be stable over a long time period;
- have a rheological characteristic that limits convective heat transfer from the layers (the packer location zone) to the permafrost zone, composed of highly icy permafrost;
- have a low corrosiveness to maintain the downhole equipment and suspension devices' performance;
- to have a freezing temperature below the temperature of rocks in the permafrost zone (from minus 5°C to minus 7°C) to prevent violation of the production strings integrity in case of reverse freezing [17].

Hydrocarbon-based packer fluids, in addition to their advantages in increasing the sealing properties for the well and enhancing the corrosion inhibiting ability of downhole equipment, have significant disadvantages, for example, aggregate stability determined by the dispersed phase' (gas condensate's) coalescence in the emulsion, which leads to the emulsion stratification, when the packer fluid enters the productive formation, a deterioration of reservoir properties and a drop in the production rate of the fluid may occur, if barite $BaSO_4$ or magnetite Fe_2O_3 are included in the pacer fluid as weighting agents, then after 1-2 months they begin to precipitate, which leads not only to the removal of the backpressure on the packer, but also to the seizure of the tubing by the precipitated weighting agent; therefore, it became necessary to consider the use of a water-based fluid for these purposes [18-20].

To select the composition of the water-based packerfluid with a salt content, a set of experimental work was performed, including laboratory studies on the salts solubility and the determination of the maximum possible brines density and on the study of aqueous solutions' characteristics of salts and various concentrations salt mixtures, laboratory studies of the aqueous salts solutions corrosiveness, complex studies of the various polymers' effect on the technological parameters of mineralized solutions, rheological studies of the packer fluids characteristics when heated.

Under laboratory conditions, the value of metal samples'corrosion in salts solutions of sodium chloride (NaCl), potassium chloride (KC_l), format Na (NaCOOH), format K (KCOOH), potassium carbonate (K_2CO_3) 20% concentration by gravimetric – at a temperature of +80° C. The test metal was coupon samples with a size of 30×20×6 mm, cut from carbon steel 32G2-PK (D) – the base metal of production strings.

As a result of laboratory experiments, it was found that at 20% salt content, the lowest corrosion rate of the metal under study is observed in solutions of potassium carbonate, K format, and Na format. The greatest amount of corrosion is observed in solutions of potassium chloride and sodium chloride (Table 1).

Considering the characteristics of aqueous salts solutions, their availability and cost, it is recommended to use Na format as the main component of the packer fluid.

The results of experimental studies to determine the characteristics of aqueous solutions of salts (K format, Na format, sodium chloride, potassium chloride, potassium chloride electrolyte, potassium carbonate) and salt mixtures, the maximum density of brines are shown in Table 2.

To substantiate the dispersion medium of the packer fluid, we studied saline solutions based on Na format and treated with hydroxyethyl cellulose sulfacell 800 [21], a copolymer of polyacrylamide and polyacrylate praestol 2540 [22] and carboxy methyloxypropyl cellulose (CMOPC) [23] including

Table 1: Results of a comparative analysis of the 20% salt content solutions corrosiveness

Name	Corrosion rate Vk, mg/day
Sodium chloride	$231{,}8\cdot10^{-3}$
Potassium chloride	$218{,}6\cdot10^{-3}$
Na format	$195{,}4\cdot10^{-3}$
Potassium carbonate	$174{,}5\cdot10^{-3}$
Format K	$161{,}1\cdot10^{-3}$

Table 2: Characteristics of aqueous solutions of salt mixtures

Mixture composition	Density, kg/m^3	pH	Note
1	2	3	4
20% $CaCl_2$10% NaCl	1258	9,15	After 5-6 days, the crystallization process is observed at room temperature
15% $CaCl_2$15% NaCl	1240	9,40	The process is the same as in the 1st mixture
10% $CaCl_2$20% NaCl	1225	9,50	Sludge formation
30% format Na20% $CaCl_2$	1305	9,54	Complete dissolution does not occur, after 8 hours the crystallization process begins, with an increase in temperature, the mixture dissolves, upon cooling, crystallization occurs again
20% format Na30% $CaCl_2$	1290	9,20	Dissolution is not observed within 16 hours, the crystallization process occurs
25% $CaCl_2$10% NaCl	1280	8,49	After four days, crystals form on the surface of the solution
25% $CaCl_2$10% KCl	1280	7,90	The mixture dissolves partially
10% format Na25% $CaCl_2$	1255	8,74	It dissolves well in water, but after three days a loose sediment forms at the bottom
20% $CaCl_2$15% $MgCl_2$	1265	7,77	After two days, a loose precipitate forms at the bottom, white flakes are noticeable with stirring in the solution
15% $CaCl_2$20% $MgCl_2$	1250	7,66	After two days, a loose sediment forms at the bottom
15% $CaCl_2$10% $MgCl_2$10% NaCl	1260	7,89	Sludge formation after three days

Note: $CaCl_2$ - calcium chloride, $MgCl_2$ - magnesium chloride, NaCl - sodium chloride, format Na - sodium format.

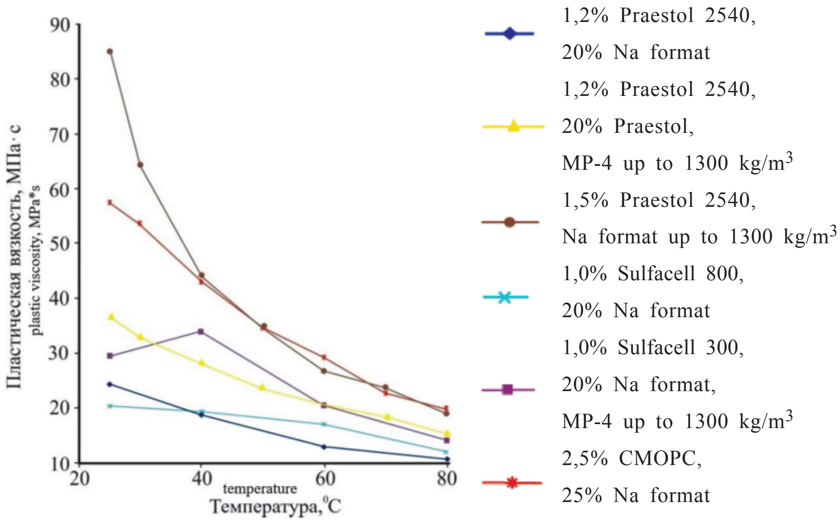

Fig.1 Change in plastic viscosity depending on temperature

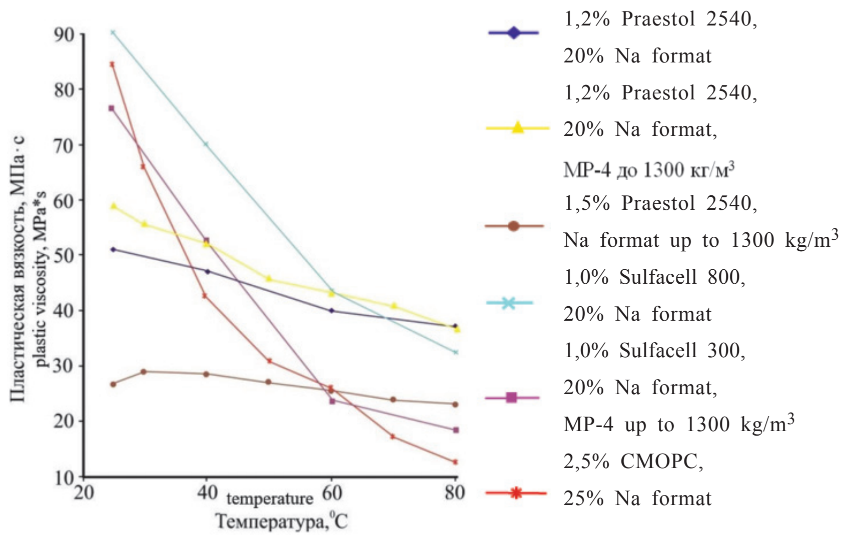

Fig.2 Change in dynamic shear stress depending on temperature

those weighted with finely dispersed marble powder (MP-4) [24]. Technological indicators of the investigated solutions and their composition are presented in Table 3.

To experimentally evaluate the temperature effect on the rheological characteristics of the packer fluid based on Na format, the prepared solutions were tested on a rotary viscometer in the temperature range from 25ºC to 80ºC.

The change in the plastic viscosity of the dynamic shear stress (F) as a function of temperature (T) is shown in Figs.1 and 2.

As a result of the research performed, it is found that the value of the plastic viscosity for all investigated solutions is consistently reduced by 2-3 times. At the same time, the consistency indicator for solutions treated with praestol 2540 practically does not change, unlike other solutions, in which it is significantly reduced (by 8-40 times). The value of the dynamic shear stress (F) also decreases with different intensities. For solutions treated with praestol 2540, this indicator decreases by 1.5-2.0 times, and for solutions with sulfacell 800 and CMOPC it decreases by more than 10 times.

Based on the experimental work results, it is recommended to use a copolymer of polyacrylamide and polyacrylate praestol 2540 as a structure-forming and thickening additive. It is recommended to use Na format as a water-soluble and weighting additive, as well as a frost-resistant packer fluid.

TABLE 3: COMPOSITION AND MAIN TECHNOLOGICAL PARAMETERS OF SOLUTIONS BASED ON NA FORMAT

Solution composition	Main technological parameters							
	ρ, kg/m^3	T, s	Static shear stress$_{1/10}$, dPa	F, sm^3/30 min	η, mPa·s	τ_0, dPa	n	K, Pa·s
1	2	3	4	5	6	7	8	9
1.2% Praestol 2540; 18% Na format; the rest is water	1100	84	34/34	>40	37	122,0	0,68	0,44
1.2% Praestol 2540; 20% Na format; MP-4 up to a density of 1300 kg/m^3; the rest is water	1300	156	48/48	2	52	158,0	0,70	0,53
1.5% Praestol 2540; 45% Na format; the rest is water	1300	122	43/48	17	125	76,5	0,92	0,23
1.0% Sulfacell 800; 20% Na format; the rest is water	1120	175	28/28	6	27	278,0	0,90	-
1.0% Sulfacell 800;2 0% Na format; MP-4 up to a density of 1300 kg/m^3; the rest is water	1300	240	43/43	6	44	433,0	0,42	4,71
2.5% CMOPC; 20% Na format; the rest is water	1175	286	29/34	2	64	413,0	0,53	2,76

Table 4: Technological parameters and composition of the packer fluid for seams PK_9, KhM_{1-2}, TP_{1-6}

The composition of the packer fluid	Concentration, %	Main technological parameters						
		ρ, kg/m³	T, s	Static shear stress, dPa		η, mPa·s	τ_0, dPa	n
				1 min	10 min			
Format Na Praestol 2540	45,0-50, 01,3-1,5	1300-1350	100-140	30-50	30-50	60-90	150-200	0,8-0,9

Table 5 Technological parameters and composition of the packer fluid for TP_{7-11} formations

The composition of the packer fluid	Concentration, %	Main technological parameters						
		ρ, kg/m³	T, s	Staticshearstress, dPa		η, mPa·s	τ_0, dPa	n
				1 min	10 min			
Format Na Praestol 2540	15,0-20, 01,2-1,3	1100-1110	80-100	20-40	25-40	30-50	100-1500	0,6-0,7

The following technology is recommended for the packer fluid preparation. The estimated amount of praestol 2540 is introduced into the processed water. After complete dissolution of the polymer, the packer fluid is treated with sodium format. In the case of packer fluid foaming after Na format adding, it is recommended to treat it with an antifoam agent Sophexil 4248 P [25] in an amount of 0.2-0.3 wt.%.

Technological parameters and compositions of the recommended packer fluids, considering the conditions of their use, are given in Tables 4 and 5.

It can reduce the Na format concentration to 20-25%, followed by weighting to the required density with marble powder of the MP-4 grade with a particle size of no more than 10 microns.

3.0 Conclusions

As a result of the experimental work, the optimal packer fluids composition was selected for the PK_9, KhM_{1-2}, TP_{1-6}, TP_{7-11} formations of the Bovanenkovo oil-gas condensate field. The use of packer fluids during the operation of gas wells will help to reduce emergencies by eliminating the thawing of permafrost in gas wells.

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RECEPTOR MODELLING OF AIR POLLUTANTS FOR SOURCE APPORTIONMENT ON COAL-BASED ANTHROPOGENIC ACTIVITIES

(Continued from page 303)

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