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Improving the Quality of Well Completion in Order to Limit Water Inflows

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Abstract: The aim of this study is to increase the efficiency of well completion during water inflow using a Viscoelastic Liquid Mixture (VLM) for isolation of permeable horizons. With the increase in the share of drilling in complex conditions such as permafrost, abnormal reservoir pressure, abnormally high reservoir temperatures, unstable rocks (prone to landslides, plastic deformation), rocks with high hardness, etc., the technology of constructing wells also complicates. One of the main issues is isolating the aquifers from which the water breaks through to the producing wells, significantly increasing water cut. To limit the water inflow exists various components: cement slurries, gel-cement slurry, synthetic resin, viscoelastic compositions, swellable polymeric mesh, latexes, materials with a condensed solid phase, materials for selective isolation, etc. For low reservoir pressures, a significant role in the selection of drilling and grouting mortars is played by density and therefore to temporarily block permeable aquifer it's appropriate to use viscoelastic screen-based three-phased stabilized VLM having a low density. The following article analyses domestic and foreign field experience in insulation of permeable formations with different components, researching three-phased blocking components and summarizing their requirements.

Key words: Well completion, drilling fluid, viscoelastic liquid mixture, low formation pressure, permeable horizons, isolation, water inflow

INTRODUCTION

The analysis of the current state of development of oil and gas fields shows that a significant proportion of the funds are characterized by the index water cut, of more than 80%. The inactive fund for bore holes comprises more than 35% and on some deposits of the order of 40-50%. At the same time wells that provide water production immediately after the development is not <15% (Zemcov *et al*., 2014; Shamsutdinova *et al*., 2010; Magadova *et al*., 2011; Bailey *et al*., 2000).

Breakthrough in water production wells are often caused by the presence of casing flows caused by defective well casing, reasons for which may include (Piskunov, 2014). Inappropriate selection of cement slurry density when the pressure in the reservoir is higher than the pressure created by a column of fluid. Substandard adhesion at the interfaces ("rock reservoir-cement" and "cement-casing"), caused by the removal of poor quality filtrational crust (especially while washing of bore holes by solutions on a hydrocarbon basis) and volumetric shrinkage of cement paste.

Premature solidification, causing a decrease in hydrostatic pressure and thereby, the migration of the fluid from the reservoir. Low quality grouting material, reflected in excessive fluid loss, low sedimentation stability, high permeability, low shrinkage and strength of the resulting cement paste.

At present there are several methods to solve the problem of quality isolation aquifers: selective isolation of water inflows during the Repair and Insulation works (RIRs) (Krasnova *et al*., 2013; Silin *et al*., 2010), improving the quality of well casing (Dvojnikov, 2005; Ismagilova and Agzamov, 2016; Nikolaev *et al*., 2016; Piskunov and Dvojnikov, 2016; Davis, 1989; Fujii *et al*., 1970; Garvin and Creel, 1984; Ismailov *et al*., 2013; Montman *et al*., 1983; Rozieres and Ferriere, 1991), temporary blocking of reservoir (Gasumov *et al*., 2007, 2015; Gasumov and Kashapov, 2009).

To prevent the reservoir of filtration channels due to the migration of fluids from the well during solidification of cement, the most appropriate way is temporary blocking of permeable aquifers.

MATERIALS AND METHODS

Status issue: Analysis of scientific and technical literature on restriction of water inflows during oil production as well as the isolation of aquifers during drilling and exploitation (Magadova *et al*., 2011)

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Table 1: Solutions for the blocking BHZ

Where or developed by whom	Components	Parameters	Characteristic properties
Patent RF No. 484300 (Hakobyan *et al*., 1975)	Mixture of condensate and Sulfite Liquor (SL) in 3:1 ratio, aqueous solution of SL 38% (25-50%), Rubber crumb (0.2-0.5%)	Density 900-950 kg/m^3 Gel strength$_{10}$-8 dPa	High value of static shear stress
Patent RF No. 2255209	Hydrocarbon basis (41-72%) Acyclic acid (6-14%) Caustic soda (4-13%)	Emulsion density 1020 kg/m^3	Insufficiently high efficiency of application on the layers with highly permeable layers
Mineral filler			
Patent RF No. 2196164	Gas condensate (5-75%) Concentrated SL 38% (25-50%); Rubber crumb (0.25-0.5%)	Density-1030 kg/m^3 Funnel Viscosity (FV) -42 sec, Gel strength1/10-2/3 dPa, Yield Point (YP)-37.5 dPa, Plastic Viscosity (PV)-129.5 Mpa.sec	Irreversible sealing of the pore space of the productive layer
Patent RF No. 2309177	Carboxymethyl Cellulose (CMC) (1.5-2.0%), Magnesium chloride (12-18%), Sodium hydroxide (10-16%), Water-remaining additionally over 100%: Microsphere (25-40%), Calcium carbonate (3-5%)	Density-1300 kg/m^3, FV-60 sec, Filtration-6 cm^3 Stability-10 min	Ensuring the blocking of the bottom hole reservoir zone of high permeability layer (so-called “super collectors”) and cracks

shows the reduced tendency to use mortars during the squeeze job, proportion of complex technologies and selective isolation methods however little attention is paid to work on the prevention of casing flow.

During construction of wells in low (including abnormally low) pressure conditions a significant role is played by well pressure and therefore to block permeable intervals it’s appropriate to use low-density components such as three-phase foam. The study (Tagirov and Nifantov, 2003) concludes that the nature of fluid filtration in a porous medium saturated with a three-phase foam is significantly affected by the nature of the solid phase, respectively for the isolation of non-productive layers the use of clay is recommended and for productive acid soluble colmatant. Table 1 and 2 summarize the characteristics of the components which are used for the isolation of the Bottom-Hole formation Zone (BHZ).

Components for blocking layers on a hydrocarbon-basis include a rubber crumb in their components as a result of which the layer irreversibly clogs with reduced natural permeability, since crumb rubber is not dissolved in hydrochloric Acid Treatment (AT) and is immune to biodegradation. Thus, the applications are limited to unproductive permeable layers including the elimination of washing liquid absorption but only while drilling of wells by washing with hydrocarbon-based solutions.

When calcium carbonate is used as a filler in place of rubber crumb the compound may be used for the temporary blocking of producing reservoir with the possibility of its subsequent removal by treatment with hydrochloric acid after the secondary opening.

Foaming components (Table 2), those developed for the damping of bore holes in the conditions of anomalously low reservoir pressures can be successfully used for the temporary blocking of bottom hole reservoir zone and limitation of water-inflows into the bore hole.

Stable three-phase foams are most effective which serve as filtration screens. Due to the use of solid phase in the foam, its stability, structural and mechanical properties increase and the value of filtration decreases. The presence of bentonite as a solid phase can lead to irreversible colmatation of the permeable reservoir.

The presence of calcium carbonate as filler and solid phase for the temporary blockage of pores in the reservoir on one side increases blocking properties, on the other complicates the process of development of the well in connection with the need to deblock the reservoir. With the use of acid treatment, the natural permeability of the productive reservoir is violated due to the interaction of the acid with the mineral constituents of the rock and reservoir water to release the reservoir from the calcium carbonate.

The main requirements for blocking compounds in the course of this article are high viscosity, wide limits for the regulation of structural, mechanical and rheological properties, low filtration values, preservation of the reservoir properties and performance characteristics (with the probability of penetrating into the productive horizon), inefficiency of the initial components, simple technology of preparing in field conditions, ensuring the safety of work.

To block high permeability zones, it is necessary to use a colmatite the dimensions of which depend on the pore size of the reservoir. The most suitable for this purpose is calcium carbonate of coarse fraction or

Table 2: Foaming components for the blocking of layer and limitation of the water-inflows

Where or developed by whom	Components	Characteristic properties
Patent RF No. 1175951	Lignine (8.0-15.0%) Alkali (0.3-5.0%) CMC (0.2-0.6%) Surfactants (0.01-0.15%) Petroleum product (1.0-5.0%) Ethylendiamine (0.05-1.5%) Water-remaining	Instable system, low blocking ability, insignificant reduction in the permeability of layers after conducting of repair work
Patent RF No.1208192	Surfactants (1-3%) Bentonite (1-3%) Polyacrylamide (0.5-0.7%) Condensed Sulphite Liquor (CSL) (5-8%) Water-remaining	Instable system, low blocking ability, reduction in the permeability of layers after conducting repairs, significant expenditure on time for the development of bore hole
Patent RF No. 2183735	Surfactants (0.5%) Potash chloride (5.0%) Hydroxyethyl carboxymethyl starch (3.0-4.0%) CSL (0.5-1.0%) Calcium carbonate (3.0%) Water-remaining	Insufficient effectiveness of damping. Foam with low multiplicity is formed
Patent RF No. 2187533	Foaming agent (0.8-1.8%) Starch modified (5.0-7.0%) Cellulose ester (0.18-0.3%) Calcium carbonate (3.0-4.0%) Aluminium chloride (1.1-1.4%) Soda ash (0.6-0.8%) Water-remaining	Low effectiveness of damping

microspheres (glass, alumino silicate or ceramic). The general requirements of components for temporary isolation of seams in conditions with low pressures include:

The components used should be chemically inert to rocks, compatible with reservoir fluids and should exclude irreversible colmatation of the reservoir pores by solid particles. The filtrate of the blocking mixture should have an inhibitory effect on clay particles, preventing their swelling at any pH value of the reservoir water.

The components must have thixotropic properties have little resistance when moving in drill pipes and annulus and high resistance when moving in permeable rocks. The blocking liquid must have a low corrosive effect on the downhole equipment. The corrosion rate of steel should not exceed 0.10-0.12 mm/year.

The components for insulation should be thermostable at high temperatures and frost-resistant in winter conditions. The blocking liquid must be non-combustible, explosion-proof, non-toxic. The blocking compound must be technological in preparation and use. The technological properties of the liquid for blocking must be adjustable. In fields with the presence of hydrogen sulphide, solutions should have a neutralizer of hydrogen sulfide in their components.

Thus, the development of a components for the temporary isolation of permeable aquifers which minimizes fluid flow in the well-layer system and contamination of the bottom hole reservoir zone as well as the way it is removed from the reservoir after operations for subsequent development and production is a highly relevant task and the resulting components requires a comprehensive study.

RESULTS AND DISCUSSION

Development of a gas-liquid blocking liquid

Properties and components: For effective completion of wells in conditions with low pressures while maintaining the filtration-capacitive properties of reservoirs, it is necessary to use a gas-liquid blocking liquid for temporary isolation with the following properties:

- Density <1000 kg/m^3
- Filtration no more than 5 cm^3/30 min
- Thickness of the filter cake of 0.5-1.0 mm
- pH value (pH) 7-8
- Effective viscosity not less than 65 mPa. sec
- YP (surface/downhole conditions), 400-1000/150-700 dPa
- Gel strength (1/10 min) at least 15/15 dPa

The productive horizon can be characterized by elevated temperatures up to 90-100°C, so, it is advisable to use heat-resistant gas-liquid blocking fluids that retain their properties the entire time the fluid is in the well. Thus, the development of thermostable blocking liquids possessing the listed properties is an actual task. The solution should include components:

Table 3: Chemical components of the investigated solutions

	Solutions (%)							
Reagents	1	2	3	4	5	6	7	8
Biopolymer	2.60	1.50	1.50	0.50	0.30	0.30	0.40	0.30
Surfactants	0.10	0.10	0.10	0.10	0.06	0.10	0.10	0.08
Colmatant	2.00	2.00	2.00	1.00	1.00	1.00	0.80	0.80
pH regulator	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06

Table 4: The results of experiments

	Solutions							
Properties	1	2	3	4	5	6	7	8
Density (kg/m^3)	920	840	780	800	820	800	810	800
Viscosity (sec)	Non-flowing	-	-	-	45	55	150	99
Multiplicity of foam	1.44	1.5	1.68	1.64	1.6	1.64	1.5	1.7
Effective viscosity (cPs)	-	-	-	-	-	-	-	-
3 (rpm)	-	-	-	-	1300	1367	1500	1100
6 (rpm)	-	-	-	-	783	800	850	650
100 (rpm)	-	-	-	-	114	112	96	83
200 (rpm)	-	-	-	-	70	68	59	51
300 (rpm)	-	-	-	-	50	50	46	37
600 (rpm)	-	-	-	-	31	31	26	24
pH	7.8	7.8	7.6	7.5	7.3	7.8	7.6	7.5
Stability (kg/m^3)	0	0	0	0	150	200	0	170
Filtering cm^3/30 min	0	0	0	0	-	-	8.8	-

- Polymer (biopolymer) to form a structure of the gas-liquid mixture blocking
- pH adjuster
- Bactericide (in the case of reagents and biopolymer starch)
- Viscosity regulator
- Regulator filtration properties
- Colmatant (to increase stability)
- Auxiliary components

In the first phase of drilling the selection of components on the basis of density and filtering. Table 3 shows the tested formulations.

Laboratory test: In addition, stability measurements were made and the multiplicity of the foam obtained was calculated. The results of experiments are presented in Table 4.

The first four compounds showed high values of sustainability (release of liquid from the foam was absent for more than 7 days) good indicators of stability and filtration but did not flow, definition of rheology was not possible, so, their use is impractical. For formulations 5-8 effective viscosity measurements were carried out at different shear rates. Effective viscosity indicated were similar for all solutions, the stability of only the 7th compound proved to be acceptable (no more than 20 kg/m^3), compounds 5, 6 and 8 showed unsatisfactory stratified and stability values which is unacceptable. Determination of filtration for the 7th component yielded unsatisfactory results, therefore, for further studies, it is advisable to consider compounds that include: biopolymer in an amount of 0.4-0.5%, surfactant 0.05-0.1%, colmatant 0.8-1.0%. To control the rheology and filtration properties of input Polyanionic Cellulose (PAC) it's suggested to consider the low and high viscosities at different concentrations for optimal results. In addition, a further need to assess the thermal stability of components: study of technological and rheological properties after heating to reservoir temperatures (e.g., 90°C) as well as the dependence of destruction of the three-phase composition with increasing pressure till reservoir pressure.

CONCLUSION

Temporary isolation of permeable aquifers is a technologically necessary operation which is significantly complicated at low reservoir pressures. The use of low density compounds is topical. Examples of such formulations are emulsions and foams.

In case of temporary isolation, it is necessary to provide for the possibility of penetration of blocking liquid into the bottom hole zone of the productive reservoir as a result of which it is necessary to exclude from the components of the developed components colmatant which is insoluble in acids.

Foams used to create a blocking tap must be stable from the moment of pumping to the end of waiting for the solidification of cement. An effective filler to stabilize the components is ground calcium carbonate which successfully dissolves during acid treatment.

The most successful formulations for blocking are liquids with a low dynamic shear stress on surface conditions and with a high in the bottom hole reservoir zone which allows to reduce the probability of penetration of the jamming liquid into the productive horizon and to worsen its filtration-capacitive properties. High values of the dynamic shear stress on surface conditions reduce the efficiency of the injection pump. Thus, the forthcoming rheological studies should be aimed at testing the obtained components with these requirements as well as developing new components in the event of a negative result.

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