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THE EFFECT OF WATER-SWELLABLE POLYMER ON WELL DRILLING WITH MUD LOSS

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ОБОСНОВАНИЕ И РАЗРАБОТКА ТЕХНИКО-ТЕХНОЛОГИЧЕСКИХ РЕШЕНИЙ ДЛЯ ПОВЫШЕНИЯ ЭФФЕКТИВНОСТИ БУРЕНИЯ СКВАЖИН В УСЛОВИЯХ ПОГЛОЩЕНИЯ ПРОМЫВОЧНОЙ ЖИДКОСТИ

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well drilling, challenges, circulation loss, elimination of circulation loss, temporary shut-off, cementing, filler, water-swelling polymer, Petrosorb, laboratory studies, rheology, plastic viscosity, dynamic shear stress, pH, structuring.

The purpose of the paper is to increase the effectiveness of prevention and elimination of mud losses using water-swellable polymer Petrosorb applied as an additive to a mud for quick cementing of the formation caused lost circulation. Through the analysis of scientific and technical publications in the field of prevention and elimination of lost circulation it was found that it is helpful to use viscoelastic compositions for quick cementing of the formations caused lost circulation. That allows shut-off absorbing formations temporary by agents that are not widely used in well drilling today. The effect of drilling fluid environment on behavior of water-swellable polymer was studied. Behavior of water-swellable polymer in a water medium with different pH values (in static and dynamic conditions) was determined. The polymer's behavior when the nature of the medium changes (solution mixed with polymer and a formation water model and leaving alone after) was studied. Determination of the behavior of the water-swelling polymer which was a part of drilling mud composition (in static and dynamic conditions). Changes in plastic viscosity and dynamic shear stresses in time were estimated in order to determine the behavior of the water-swelling polymer in a water media and composition of a mud solution. Studies conucted showed that the nature of Petrosorb's swelling significantly depends on the pH of the medium. That can be used to regulate the dynamics of structuring using the varios technological scheme of absorption elimination. Therefore, it is needed to continue bench and industrial studies in specific geological and technical conditions with real drilling muds used as a medium.

Ключевые слова:
бурение скважин, осложнения, поглощение, ликвидация поглощений, временная изоляция, тампонирование, наполнитель, водонабухающий полимер, «Петросорб», лабораторные исследования, реология, пластическая вязкость, динамическое напряжение сдвига, pH, структурообразование.

Целью работы является повышение эффективности профилактики и ликвидации поглощений промывочной жидкости за счет применения водонабухающего полимера «Петросорб», применяемого в качестве добавки в буровой раствор для оперативного тампонирования поглощающего интервала. По результатам анализа научно-технической литературы в области профилактики и ликвидации поглощений получен вывод, что применение вязкоупругих составов для оперативного тампонирования поглощающих интервалов с целью временной изоляции является целесообразным, в том числе за счет реагентов, не имеющих на данный момент широкого применения при бурении скважин. В работе проведено исследование влияния среды бурового раствора на характер поведения водонабухающего полимера, включающее определение характера поведения водонабухающего полимера в водной среде с различным значением pH (в статических и динамических условиях), исследование поведения полимера при изменении характера среды (смешивание раствора с полимером и модели пластовой воды, оставление в покое), определение характера поведения водонабухающего полимера в составе бурового раствора (в статических и динамических условиях). Для определения характера поведения водонабухающего полимера в водной среде и в составе бурового раствора оценивалось изменение пластической вязкости и динамического напряжения сдвига во времени. Проведенные исследования показали, что характер набухания «Петросорба» сильно зависим от pH среды, что можно использовать для регулирования динамики структурообразования при использовании той или иной технологической схемы ликвидации поглощения, поэтому целесообразно проведение дальнейших стендовых и опытно-промышленных исследований в конкретных геолого-технических условиях при использовании в качестве среды конкретные рецептуры буровых технологических жидкостей.

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Introduction

Mud losses while well drilling is one of the main and frequently occurring challenges. Lost mud and other liquids circulation zones of some formations are caused by pores, channels, cracks, voids in rocks through what a well is drilled and (or) low resistance of rocks to the pressure of a well liquid column. As a result, a liquid penetrates into a formation. The measure used to recover the lost circulation is chosen after the category of lost circulation is being determined and is based on economic efficiency and ease of use. Nevertheless, experience of drilling the wells in considered or neighboring fields is of great importance as well [1].

There are several classifications of lost circulation, and therefore, methods of screening the measures for their prevention and elimination. The criteria are as follows: intensity of lost circulation and lost circulation coefficients, intake capacity, specific intake and fracture opening. According to the intake capacity of a permeable zone, a measure is chosen to eliminate the loss. A filler is chosen according to dimensions of channels that a liquid flows through [2]. Here, all known classifications have either regional or industrial significance and, therefore, for other conditions they play more an informational role in screening for measures that can be used approximately in a specific case.

That is not a simple task to establish laws when lost circulation occur and select effective measures for their prevention and elimination because there is a large number of factors that cause this phenomenon. In general, a circulation is recovered by minimizing the hydrostatic pressure on well walls by making the mud more light [3-10], sealing the lost-circulation zone by plugging the channels (including using the sealers) with special additives, pastes, cement slurries [11-15], and more rare by use of profile overlap or lowering the intermediate column [16, 17]. Measures for recovering the circulation are shown in Fig.1.

In order to reduce the time to recover the circulation it is expedient to use temporary isolation of permeable zones. In order to do that, fillers wash-over is used quite often as well as injection of viscoelastic compositions, non-hardening plugging mixtures, quick-setting compounds [1, 3, 4, 18-33]. Development of water-swellable polymer compositions for quick sealing of a formation is one of the topical areas [34].

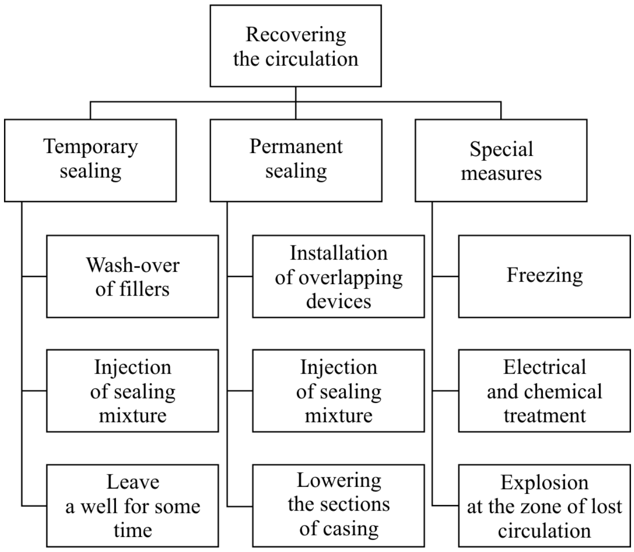

Fig. 1. Measures for recovering the circulation

Selection of a specific measure depends largely on economic efficiency. With the same effect, the choice is made for economic reasons.

Research methodology

In order to develop a composition for temporary sealing of lost-circulation zones the research methodology is proposed below [35, 36].

Stage I. Study of the influence of drilling fluids on water-swellable polymer behavior:

1) determination of the behavior of water-swellable polymer in a water medium with different pH values (in static and dynamic conditions);

2) study of the polymer behavior when the nature of medium changes (mixing of a solution with polymer and formation water model, leaving alone);

3) determination of the behavior of a water-swellable polymer in a mud composition (under static and dynamic conditions).

Stage II. Study of the behavior of a water-swellable polymer in a porous medium:

1) development of the physical model of lost-circulation formation;

2) saturation of the bulk model with a solution of a water-swellable polymer of various properties;

3) determination of the permeability coefficient of a bulk model of a formation over the polymer solution [37].

There is an important characteristic when plugging composition is pumped into the lost-circulation zone such as a composition of a solution, or its mobility, a time-dependent parameter. Rheological properties such as plastic viscosity and dynamic shear stress (DSS), which over time should not grow are mobility indicators for drilling fluids. In order to determine the behavior of water-swellable polymer in a water medium and composition of a drilling mud, the change in plastic viscosity and dynamic shear stress in time were evaluated. The following time intervals were selected for the study:

1) 0-36 minutes (with an interval of 2 minutes) – the time from the moment of preparation of the solution to its injection into the lost-circulation zone (at the depth of 3800 m);

2) 36 minutes after preparation – the moment of penetration of the composition into the lost-circulation zone and interaction with the formation fluid;

3) after 15 minutes of rest (51 minutes after preparation) – time being in the reservoir;

4) a day after the preparation – imitation of the composition stay in the formation.

Rheological parameters were measured on the six-speed Fann 35SA rotary viscometer with constant mixing at the first time interval (simulation of the composition movement along a drill string). In the study of water solutions of the polymer, rheological parameters were not measured after 24 hours.

The superabsorbent Petrosorb, which is not currently used for circulation recovery but is promising in this field, is chosen as an agent for study [27, 34, 37]. For the research, a 2 % concentration of Petrosorb was chosen, since in previous studies [37] it was found that the concentration for sealing the lost-circulation zones with the use of a clay solution is equal 1-3 %.

In order to assess the effect of acidity of a medium on the behavior of Petrosorb, water agent solutions with pH 4, 7 and 10 (acidity was regulated by the introduction of citric acid or NaOH) were studied.

Previous studies of Petrosorb [37] have shown its effectiveness in a clay solution, but such a solution is not suitable in a drilling interval for a production column or liner, so it is advisable to study the agent in a biopolymer drilling mud weighted to the required density with barite or calcium carbonate.

Study of Petrosorb in the water environment

Results of study of the effect of medium pH on the character of change in rheology of Petrosorb water solution in time are presented in Fig. 2.

When measuring the plastic viscosity and DSS in neutral and alkaline media after 30 and 26 minutes, respectively, the measurement was impossible because of the limited scale of the Fann 35SA viscometer. So, there was approximation made with a forecast for several periods when constructing the graphical dependencies.

The graphs show that the acidic medium, in which the swelling of Petrosorb particles occurs less intensively over the time, is more suitable than neutral and alkaline media having similar values. The second ones are not so suitable for delivery of polymers to lost-circulation zones at great depths, since swelling of particles and thickening of the solution occurs in a fairly short time (up to 25 minutes on average).

Then the change in plastic viscosity and DSS was studied at the moment of penetration of the solution into the lost-circulation zone and mixing with formation water. Composition and properties of reservoir water can have a significant effect on qualitative and quantitative indicators of work during well drilling, fixing and cementing oil and gas wells, as well as their subsequent operation. There is in well section water of different mineralization, hardness, pH, density, composition (ionic, bacteriological or microbiological) can occur under specific mining and geological conditions. Mineralization of water of oil fields varies from several hundred g/m^3 in fresh water to 300 kg/m^3 in concentrated brines [38, 39].

Since at the moment of mixing of mud with water produced the quantity of mud is much larger, we choose the ratio 3×1 respectively. The Fig. 3*a* shows the characteristics of solutions at four main time points:

1) at the time of addition of Petrosorb to the receiving tanks,

2) upon reaching the bottom of a well before penetrating into the lost-circulation formation,

3) at the moment of interaction with a formation fluid (for two pH values),

4) after staying in a reservoir at rest for 15 minutes.

Dynamics is positive in both cases; particles swell, increasing rheological parameters, thereby isolating the lost-circulation zone.

However, when the alkaline solution interacts with neutral or acidic formation water, the parameters decrease but are stable and sufficient to eliminate the liquid penetration (Fig. 3*b*).

Study of Petrosorb in a drilling mud

At the interval of well drilling production string and tail, the use of clay solutions is limited in order to reduce the plugging of the productive formation, so biopolymer drilling muds are often used. Since it is necessary to ensure the injection of the solution to a greater depth, it is advisable to consider a solution of various acidity (from acidic to alkaline), which can not be achieved with the use of carbonate weighting agents, so we investigate the biopolymer solution weighted by barite. According to the chart of combined pressures, a solution with density of 1160 kg/m^3 is chosen.

Similar to the water solution, rheological parameters are more stable before penetration of the drilling fluid into the lost-circulation zone in the acidic medium (pH is adjusted to 4.08 citric acid) than in the alkaline solution (12.7 is the initial pH of the biopolymer solution). The dependence is shown in Fig. 4.

Since the formation water at depths of more than 1000 meters is rarely neutral, we will analyze two cases:

1) an acid mud penetrates into the lost-circulation formations with alkaline formation water;

2) an alkaline drilling mud penetrates into the lost-circulation formations with acidic formation water.

The analysis is performed similar to the study of water solutions of the polymer, but another time interval is added – after a day of rest of solutions (simulating the presence of a composition in the formation).

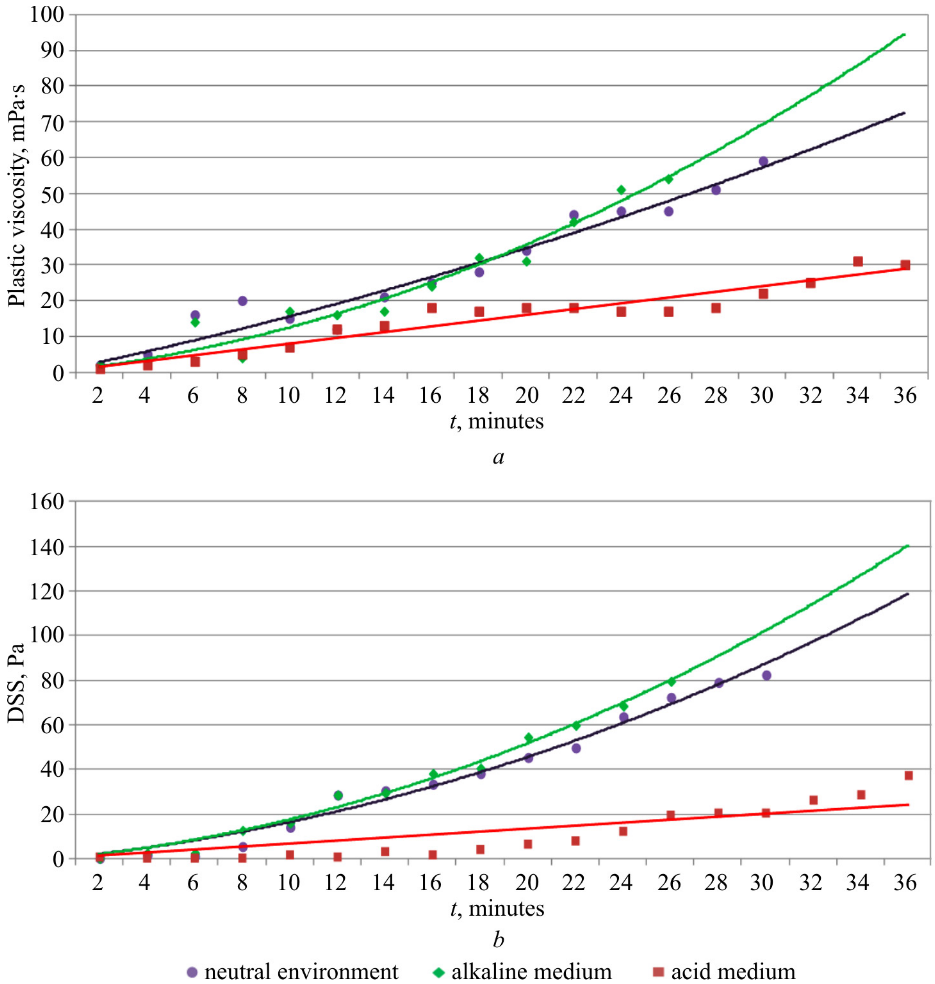

Fig. 2. Dependence: *a* – plastic viscosity; *b* – DSS from the time of Petrosorb water solutions of different pH

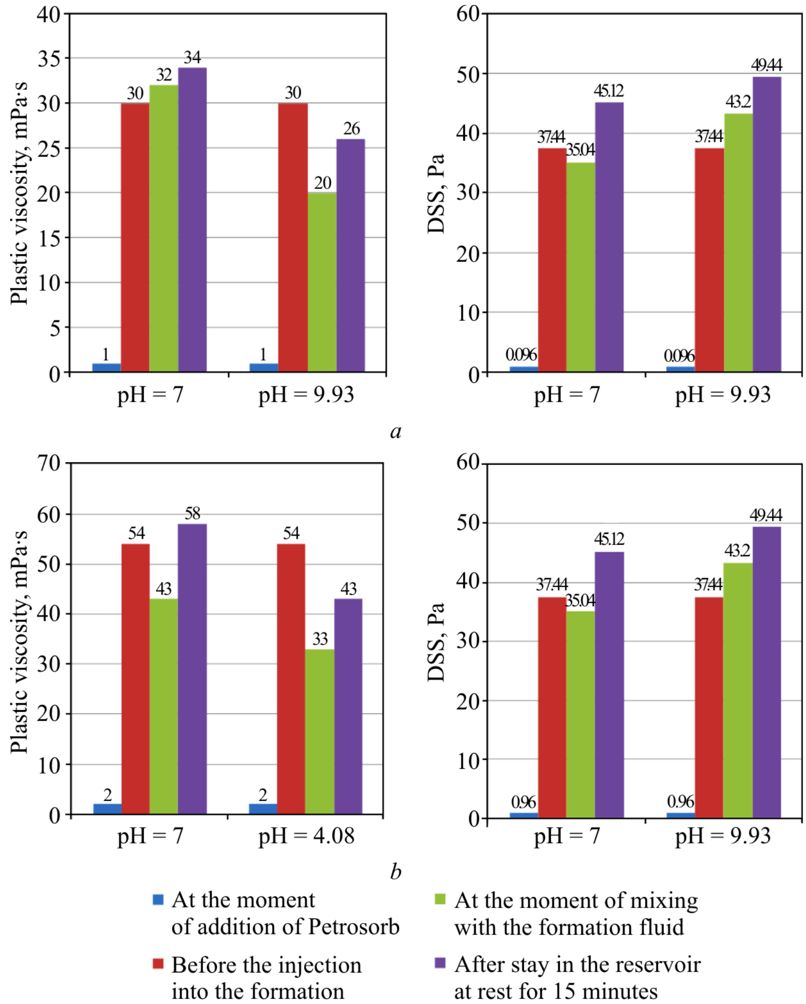

Fig. 3. Change in plastic viscosity and DSS of 2 % water solution of the polymer Petrosorb: *a* – pH = 4.08; *b* – pH = 9.93

The results are shown in Fig. 5.

Before the injection of a 2 % polymer drilling mud into the lost-circulation zone, plastic viscosity and DSS values had fairly good performance. Decrease of these parameters in the initial period of mixing with formation water is caused only by the increase of the liquid phase, while the swelling of Petrosorb particles does not decrease. Over the time, the polymer continues to increase in size, so that the solution in the absorbing formation already has about a day enough rheology to recover the circulation by plugging the voids.

Technology of recovery the circulation using Petrosorb

Several technological schemes can be implemented to eliminate the lost circulation such as leaving at rest and expecting natural sealing of well walls (with a minimum liquid penetration intensity), plugging with viscoelastic compounds through special sealers, plugging individual zones using stepped cement couplings [13, 17, 20, 22, 40]. A technological scheme for plugging a well with the proposed composition, depending on the depth of lost-circulation zones, can be represented by two options [37, 41-43].

1. If the challenge occur at depths of 400-500 meters: addition of the water-swellable polymer Petrosorb into the working mud immediately after circulation is lost and delivery to the lost-circulation zone.

2. If the challenge occur at depths of more than 500 meters it is advisable to use polymer delivery according to the scheme of parallel injection, since swelling speed of polymer particles does not allow the composition to be pumped to the required depth. At the same time with delivery of the composition diesel-bentonite mixture (DBM) + Petrosorb through the drill string fresh water is

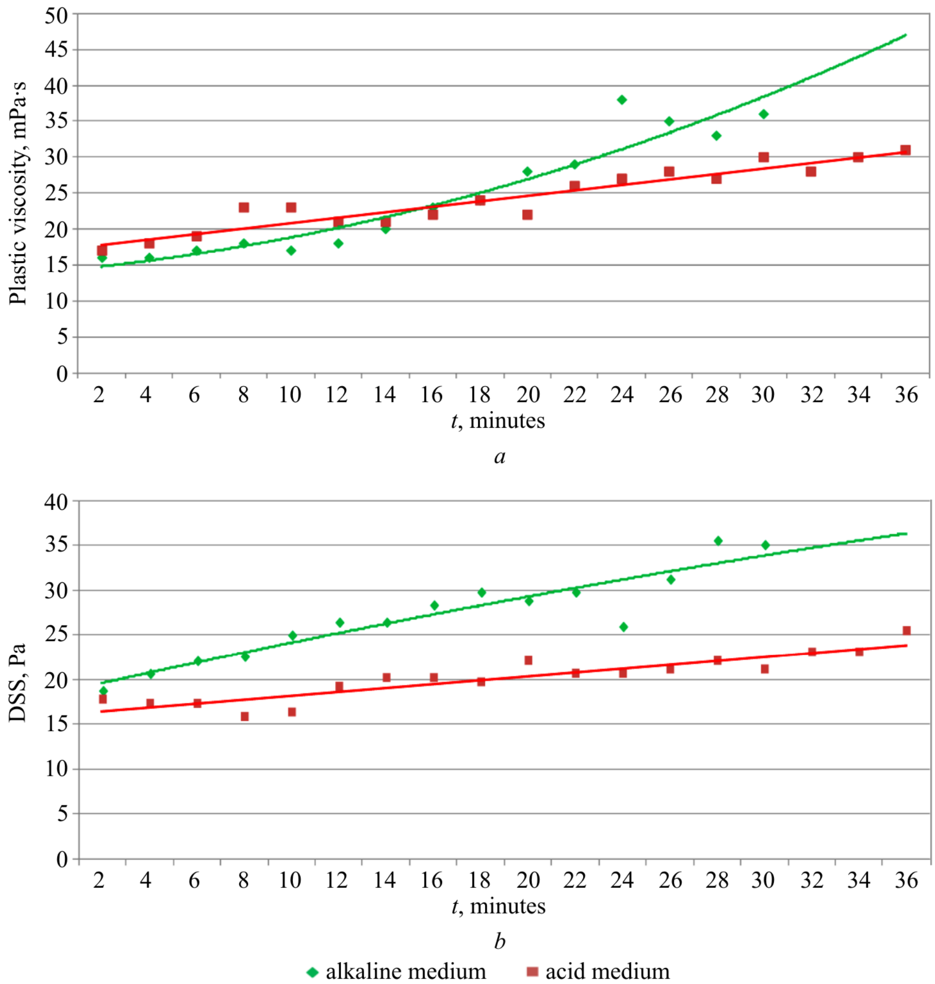

Fig. 4. Dependence: *a* – plastic viscosity; *b* – DSS from the time of a different pH mud with Petrosorb added

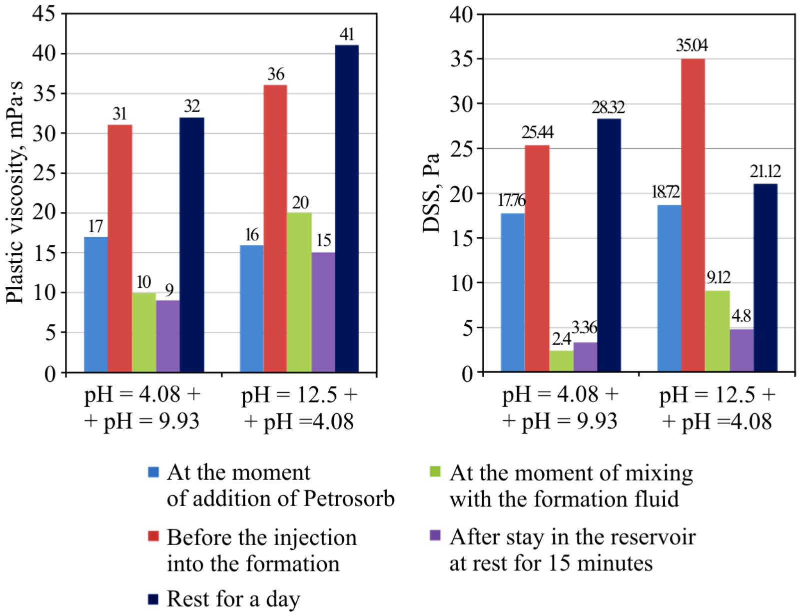

Fig. 5. Change in plastic viscosity and DSS of a 2 % mud (pH = 4.08 and pH = 12.5) with polymer Petrosorb added

pumped through the annular space. Precisely at the lost-circulation zone injected water is mixed and then displaces the DBM from the plugging mixture due to the difference in their densities. When the polymer particles are combined with water they begin to swell actively and precisely at the lost-circulation zone, thereby sealing the permeable formation.

In order to deliver the plugging mixture down to the deep formation directly a plugging tool was designed. A tool descends into the well on drill string and includes a packer element, allows separating lost-circulation zones and rest of the wellbore. That contributes to reducing the cost of plugging material for conducting the sealing jobs [37, 41, 42, 43].

Conclusions and recommendations

Based on laboratory studies conducted and analysis of scientific and technical references from the field of recovery of mud circulation following conclusions were obtained:

1. It is necessary to bring the mud fluid environment to acidic one for pumping at great depths (with no carbonate and acid-soluble rocks in a section), since it produces less intensive swelling of Petrosorb particles, which allows delivering the mixture to the bottom hole in a mobile state for 25-35 mines.
2. When using alkaline solutions, the time (from the moment of adding Petrosorb) to the rational injection is 10-15 minutes.
3. By addition of Petrosorb to drilling muds lost circulation can be recovered as soon as possible with no stops in a drilling process at different depths of lost-circulation zones using various technological injection schemes.

For the moment, the effect of pH on rheology of mixtures has been studied. That is proposed to study the effect of mineralization and formation water composition on technological characteristics of muds with the water-swellable polymer in future. Further studies of the behavior of Petrosorb in various environments and bench studies of the process of circulation recovery will provide an opportunity to conduct a preliminary assessment of the economic effectiveness of the proposed formulations and technologies.

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