Use of gelling compositions to prevent salt deposition

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Abstract. The main source of salt release is water produced in conjunction with oil. Improving the efficiency of oil production is currently mainly achieved by preventing deposits of inorganic salts during well operation. Of the currently known methods of controlling scaling, the method of preventing deposits using gel-forming components is the most efficient. There are various compositions of gelling compositions to solve this problem. For example, mixtures based on hydrochloric acid, nepheline, high alumina cement, etc. However, these compositions also have some drawbacks. Due to the rapid neutralization of acid, the composition quickly loses its properties. In addition, difficulties may arise when dosing the chemical component and preparing the composition. The formation of the gel directly in the reservoir conditions allows you to create a zone (screen) with increased filtration resistance and exclude inter-reservoir flows, pulling bottom water and fight against scaling. In order for the oil production process to be the most effective, it is very important to choose the optimal option for preventing scaling, taking into account the features of the operation of wells in specific fields.

1. Introduction
The main task of developing any field is the maximum possible production of oil and gas at a low level of technological and economic costs per unit of production. In the process of developing and operating oil wells in the field of oil fields, formation or injected water will form inevitably. Salt sediments are formed precisely as a result of flooding of produced products. Thus, the problem of salt deposition inevitably arises in the process of oil production. In this case, salt deposition can occur at any stage of field development. The process of scaling is directly related to the supersaturation of the aqueous medium with difficulty decomposable salt compounds. This process occurs as a result of changes in the physicochemical state of the oil production system. So, the changes affect the temperature regimes, gas evolution, pressure, etc. If an excessive amount of salts is deposited in the bottom-hole zone of the reservoir, oil producing wells contribute to a significant decrease in their productivity, as well as to an increase in the skin factor. In addition, increased salt levels in wells can lead to a complete disruption of their work. In turn, high costs for repair work will be required. Well pressure can be controlled by various methods. The choice of method depends on the conditions, the availability of technical equipment, and also on the features of the development of deposits. Prevention of increased salt deposition is carried out using physical, technological and chemical methods. Physicochemical exposure technologies are also used to eliminate the effects of water flooding and increase the production of hard-to-recover oil reserves. As we have already said, salt
deposition helps to reduce the productivity of oil wells. The formation of salts occurs as a result of technogenic and natural phenomena [1]. Water that is extracted with oil is oversaturated with sparingly soluble salts. This process occurs as a result of changes in the physicochemical state of the oil production system. In this case, salt deposits are a process of crystallization of masses from supersaturated solutions in the presence of oil elements, a gas phase, and mechanical mixtures, which affect the degree of accumulation intensity, as well as the properties and nature of precipitation. One of the effective methods to reduce the water cut of produced oil is to treat the bottom-hole zone of wells with polymer and gelling solutions [2].

The composition for determining the gelation time was prepared by dissolving the zeolite in the composition of hydrochloric acid, with constant stirring for 15–20 min. After the solution was completely dissolved, mixing was completed [3].

Description of the process: hermetically sealed ampoules with the prepared solution were placed in a thermostat and observed how the gelation process occurs. Observations showed that the higher the concentration of zeolite and hydrochloric acid, the shorter the gelation time of the composition. But in order to apply this method in practice, it is necessary that the gelation time increases, since this will allow this composition to penetrate as deep as possible into the reservoir. Therefore, we can say that by changing the parameters of the content of silicon and aluminum oxides, hydrochloric acid and a gelation rate regulator, one can obtain various variants of these compositions with gelling properties. And this, in turn, is an important factor, since the deposits do not have the same geological and physical characteristics, and this suggests that different versions of such compositions with gel-forming properties are therefore needed.

Experimental data show that the composition can be used to control the permeability of high-temperature formations, as well as during insulation work during the overhaul of wells.

In highly permeable cores, the structuring of the gel occurs throughout the pore space, as a result of which the channels are completely blocked by a structured gelling composition. In a low-permeability sample, a smaller amount of gel is filtered, while some of the pores remain unfilled with a gel-forming composition, which reduces the processing efficiency. The higher the permeability of the rock, the lower the resistance to the breakthrough pressure is the sample [4].

The scope of gel-forming compositions is determined by: gelation time at the preparation temperature, gelation time at the reservoir temperature, gel strength, gel stability in mineralized water, time stability, and the possibility of gel destruction [5].

2. Materials and methods
The technology of gel-forming compositions (GFC) is perspective due to the manufacturability of the solution and its injection into the formation, the relatively low cost of the reagents and their non-toxicity, high strength and stability over time of the gel formed, the ability to break down under the action of an alkaline agent.

Chemical methods for enhancing oil recovery in fields have been used since the mid 70s. During this period, about 15 different technologies were tested, in particular: system treatments using: polymer dispersed systems (PDS); viscoelastic compounds (VEC); gelling compositions (GFC); combined compositions; gelling formulations based on sodium silicate (GFC); precipitating agents based on sodium silicate; sediment-forming on the basis of aluminum chloride and others [6].

In order to achieve increased oil return and at the same time to prevent salt deposition, various methods are used, among which the methods of physicochemical exposure are especially popular. And one of these methods is the use of such chemical compositions that under certain conditions form a gel-like substance, thereby regulating the flow and creating filtration resistance in the bottomhole zone and in the depth of the formation.

The application of this method allows smoothing the injection profile in injection wells, and due to the fact that this silicate-polymer solution at a high temperature of the formation turns into a gel and fills all the cracks and passages, this solution does not allow water to enter the production well.

The selection of the effective composition of the gel-forming components was carried out using the
following reagents:
- zeolite reagent intended for the production of synthetic detergents - white crystalline powder, hazard class 4, produced in accordance with TU 381011366. Chemical composition of the powder: AlO - 28%, SiO₂ - 32–34.4%, NaO - 17.6%, water - 20%;
- hydrochloric acid HCl, produced in accordance with TU 6-01-04689381; density 1110 kg / m³;
- to ensure a high gelation rate, we used AB catamine. The class of this reagent is cationically active surfactants. The substance is obtained compounds of the quaternary ammonium component by condensation of a tertiary amine and benzochloride according to the following formula: (R₁R₂R₃N⁺ - CHCH) CI, where R = alkyl C26518-C18; R₂ = CH; CH₃2537; R = CH; CH32537; R = CH; C33253H. 7

This method is based on the property of silicon and aluminum oxides dissolved in inorganic acids to form a gel-like substance at certain temperatures. This helium substance consists of amorphous positively charged aluminum oxides and negatively charged polysilicic acids, the ratio of which is strictly defined. In order for these oxides to dissolve, an excess of acid is necessary. In the process of gel formation, three-dimensional polymer networks are formed, the process of formation of which continues until half of the total volume is filled with solid microgel. At this stage, the viscosity is characterized as highly viscous, and the sol reaches the “gel point”.

This method is the injection of hydrochloric acid into the reservoir with the addition of a small amount of polymers and a solution of water glass. The interaction of sodium silicate with acids causes the release of silicic acid. As a result of this reaction, a sol is formed, which after some time passes into a gel, which serves as an insulator of water in highly permeable zones of the formation.

In this method, we considered cases of possible precipitation of calcium carbonate from a solution, as the most common type of carbonate scaling, when moving a water-oil stream with a gas phase and in its absence [7].

3. Results and discussions
In the presence of a large amount of salts, the permeability of the formation decreases. The work investigates the effect of inorganic gels based on aluminosilicates (AS) on permeability (and on the change in the volume of scaling).

| The concentration of nepheline, g / 100 ml of acid solution | HCl concentration % | The volume fraction of mineralized water in an acid solution, % | Type of gel formed | Gelation time, h |
|-----------------------------------------------------------|----------------------|---------------------------------------------------------------|-------------------|-----------------|
| 3.0                                                       | 9.5-10               | 50                                                            | Weak              | 25-30           |
| 9.0                                                       | 9                    | 0                                                             | Dense             | 20-25           |

Filtration resistance for water movement is directly related to the presence of gel and residual oil in a porous medium. Filtration of water in a porous medium does not lead to the destruction of weak helium compositions based on aluminosilicates [8].

Resistance filtration using dense gel did not reach 60%. Thus, we concluded that no apparent dehydration of the gel occurred with all the investigated pressure drops and permeabilities. As a result of the transition to water filtration, a small number of particles of the destroyed gel is displaced. This indicates that the dense gel has a stable effect in a porous medium [9].

As a result of our studies, we came to the following conclusions:
- AS gels in a porous medium are destroyed only when exposed to oil at high pressures;
- aluminosilicate gels are destroyed along with their dehydration.

The formation of a three-dimensional gel network occurs as a result of primary cyclic or linear elements of silicic acid sol micelles, microgel particles, and only then macrogel. When using a weak
gel, destruction occurs under the influence of oil bound by the separation of the macrogel into individual particles. The gel loses most of the retained water [10].

The microgel particles are enveloped with oil, which in turn leads to obstacles in the reconstruction of the three-dimensional structure of the macrogel. When using a dense gel, a slight compaction of the helium composition occurs. This result is caused by an increase in pore pressure. The influence of the permeability of the porous medium on the decrease in oil and water permeability was studied using a dense AS gel. As a result of this study, we found that as the permeability of porous structures increases from 0.377 to 2.22 μm$^2$, the maximum and residual resistance conditions for oil and water also begin to increase. Thus, the higher the initial permeability, the correspondingly, the more it decreases under the action of interstitial gel formation (Figure 1).

Similar processes occur under the influence of weak AS gel. An increase in the level of permeability of porous media from 0.377 to 2.22 μm$^2$ does not lead to a special change in the displacement of the gel and water phases during oil filtration [11].

It should also be noted that the initial oil saturation of porous media in all experiments does not depend on the level of permeability of porous media. The residual oil saturation of porous media in this case in the main and auxiliary experiments showed almost the same results. A dense AS gel in a hydrophilic porous medium does not significantly affect the ganglion parameters of residual oil [11].

![Figure 1. The dependence of resistance factors on the permeability of porous media](image)

Our studies have shown that the key parameters that directly affect the results of gel exposure are oil saturation and permeability of porous media. The lower the oil saturation and the higher the permeability, the stronger the gel reduces the permeability.

Solutions containing hydrophilic elements of colloidal size are able to selectively control the permeability of heterogeneous hydrophilic porous media. In particular, polymer gels have this property. The filtration cross section reduces the plugging mass that forms in the center of the pores. This phenomenon is presented in Figure 2 [12].
The formation of the plugging mass occurs under the influence of particles of colloidal size. An increase in the level of permeability of the porous medium and a decrease in oil saturation leads to the formation of grouting mass in the free pore volume.

4. Conclusion
In the framework of this study, we performed the following tasks: we analyzed the effect of inorganic gels of nepheline aluminosilicate on the degree of permeability of porous media. As a result, we found that there are no significant differences in the degree of reduction in oil and water permeabilities. It was shown that the imbalance previously found for crosslinked polymer gels in the degree of decrease in oil and water permeabilities is explained by the competition between the formation of the plugging mass (including gel) on the surface and in the free pore volume, technological solutions for the prevention of salt deposits are proposed. It was established that during the operation of the wells of old fields, their large water cut was revealed, which in most cases leads to the formation of salt deposits on the inner walls of the equipment. This problem is acute during oil production, as equipment deposition decreases due to scaling. The fight against already formed salt deposits is very difficult and unprofitable, therefore, the most optimal method of protecting the internal surfaces of the equipment is to prevent the precipitation of salts. Low viscosity gel-forming solutions based on inorganic reagents are used for waterproofing works in production wells in order to reduce oil water cut, which, in turn, has a significant impact on the amount of scaling.

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