IMPROVING THE OPERATIONAL EFFICIENCY OF OIL WELLS BY ELECTRICAL PROCESSING BOTTOM-HOLE ZONE

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Abstract. *One of the main problems of the oil industry is incomplete (as a rule, no more than 40%) oil production by primary methods from an oil reservoir. For some oil reservoirs containing reserves of high-viscosity oil, no more than 10–15% can be recovered due to the reservoir's own potential energy. Subsequently, in order to increase the efficiency of the oil reservoir, the oil reservoir is additionally affected by secondary methods. The main ones are associated with the displacement of oil by injection into the formation through additional injector wells of various aqueous solutions, which allow increasing oil production by another 15–20% [1].*

Keywords: *pipe - cement – rock, technological mode, gas wells, permissible.*

ПОВЫШЕНИЕ ЭКСПЛУАТАЦИОННОЙ ЭФФЕКТИВНОСТИ НЕФТИ СКВАЖИНЫ ПО ЭЛЕКТРИЧЕСКОЙ ОБРАБОТКЕ ПРИЗЕМНОЙ ЗОНЫ

Аннотация. *Одной из основных проблем нефтяной отрасли является неполная (как правило, не более 40%) добыча нефти первичными способами из нефтяного пласта. Для некоторых нефтяных пластов, содержащих запасы высоковязкой нефти, за счет собственной потенциальной энергии пласта может быть извлечено не более 10–15 %. В последующем с целью повышения эффективности нефтяного пласта на нефтяной пласт дополнительно воздействуют вторичными методами. Основные из них связаны с вытеснением нефти закачкой в пласт через дополнительные нагнетательные скважины различных водных растворов, позволяющих увеличить добычу нефти еще на 15–20 % [1].*

Ключевые слова: *труба – цемент – порода, технологический режим, газовые скважины, допустимый.*

INTRODUCTION

In oil reservoirs, oil saturates the voids, cracks, and caverns between the solid fractions of the rock that make up the oil-bearing reservoirs. Most oil fields are located in sedimentary rocks, which are good oil reservoirs. In the productive zone of the formation, in addition to oil, there is also bound water. In most reservoirs, it is 20-30% of the pore space volume [2]. Throughout the world, there are a large number of abandoned or mothballed reservoirs, which still have a sufficient amount of oil. An increase in oil recovery of only 1% is equivalent to the discovery of a new field.

MATERIALS AND METHODS

Physically and chemically, oil is a mixture of carbohydrates and organic compounds. The density of oil is 820–950 kg/m3, the electrical conductivity varies over a wide range of 10–6–10–14 S/m, and the electrokinetic potential is usually 40–150 mV [3]. In addition to hydraulic methods, the possibilities of secondary impact on the reservoir by various physical fields - thermal, ultrasonic, magnetic, high-frequency, electromagnetic, as well as their combinations are being studied [1]. Along with traditional secondary methods for increasing the efficiency of oil reservoirs, methods based both on the electrical treatment of the reservoirs as a whole, and the bottom hole zone immediately adjacent to the oil well [4].

Analysis of known technical solutions. The performed analysis of literature and patent information allows us to identify the following methods and methods of electrical treatment of oil reservoirs. The use of direct, alternating, and high-frequency current for heating the oil reservoir and creating electrophoresis phenomena. In the presence of layers with quartz sand, when passing a high-frequency current, a piezoelectric effect occurs, that is, fluctuations in quartz sand and, accordingly, an increased release of oil from it [5]. Impact on the area near the production well with a unipolar electric current before the start of operation. A positive result is achieved due to a complex of electrokinetic effects. At the same time, the increased permeability of the reservoir remains even after the termination of the electric current [6].

The impact on the area near the production well with electric current to heat this area to a temperature that excludes the boiling of pore moisture [7]. The use of the combined electroosmotic and thermal action of direct electric current to create a mineralized channel in an oil-bearing formation, for which, after connecting the wells to a power source, a mineralized liquid is supplied to the cathode well, and the current value is limited by the boiling point of the mineralized liquid [8]. Using the phenomenon of electrophoresis, in which the positive pole of the power source is connected to the production well, and the negative pole is connected to the additional electrode [9]. Bypassing an alternating electric current below the bottom-hole zone, the soil is heated to 130–1500 C, and the formed temperature front displaces oil in the direction of the production well [10].

RESULTS

Controlling the permeability of the bottom-hole zone adjacent to the producing well by the pulsed current. An increase in permeability is achieved due to the mechanical destruction of cementing substances in thin capillaries, which limit the filtration rate [11]. The impact on the bottom-hole zone of a production well with an electric bipolar pulsed current with an amplitude of up to 3000A with a duty cycle of 1–3 pulses and a steepness of the trailing edge of the pulse of 10–150 MLS. A positive effect is achieved not only due to electrokinetic and thermodynamic effects, but also due to the resonant properties of the oil-bearing formation [12]. By creating between the anode electrode and the production well (cathode) a DC voltage of 150–450 V and a current density of 0.1–10 A/cm2, chemical, and ion-plasma processes are caused, as a result of which hydrogen and alkali are released on the casing (cathode), contributing to a decrease in the surface tension of the oil film and the dissolution of residual petroleum bitumen [13].

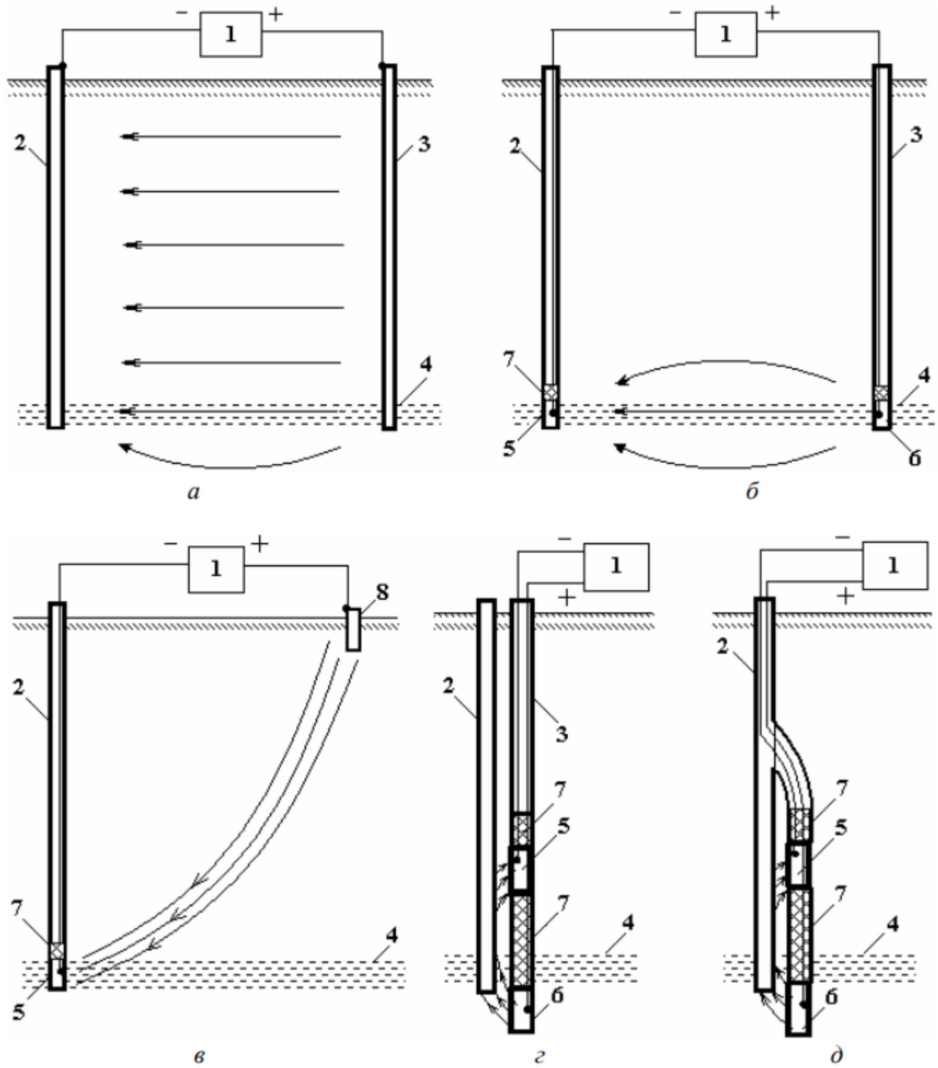
The combined action of direct and alternating current with an amplitude ensures the initiation of redox reactions in oil to decompose polycyclic compounds contained in it into compounds with low molecular weight and hydrogenation of oil [14]. The combined action of direct electric current and anodes supplied to perforated electrodes under a pressure of 1.5–5 atm of an electrolyte solution (aqueous solution of NaCl or inorganic acids) [15]. This method allows you to perform electroosmotic displacement of oil in the direction of the production (cathode) well in oil reservoirs with low water saturation. The performed analysis shows the variety of methods and methods of electrical processing. Each of them requires an additional study of the effectiveness and practical feasibility, which, naturally, cannot be done within the framework of one article. Therefore, in the future, we will restrict ourselves to methods based on the use of electroosmotic forces that arise in capillary porous media when exposed to a constant electric field. In some cases, these methods can be more effective than hydraulic ones.

Electroosmotic effect on the bottom-hole zone of an oil reservoir. The positive effect of using electroosmosis to displace oil with water compared to hydraulic displacement can be observed when the oil reservoir is finely porous. Pore moisture is an aqueous electrolyte solution. In this case, a double electric layer is formed at the boundary of the capillaries, the diffusion part of which, as a rule, consists of positive cation ions. The concentration of cations is higher than that of anions, therefore, during electroosmosis, the resulting moisture flow will be directed from the anode to the cathode. One of the features of electroosmosis, in comparison with conventional hydraulic filtration, is a different dependence of the fluid velocity on the pore radius. In the most general case, two models of the distribution of two liquids (water and oil) in the pore space can be presented. In the first case, water and oil particles alternate with each other in the pore space, in the second case, two liquids are located parallel to the pore surface. Then, in the first case, one speaks of electroosmotic displacement when water enters the oil reservoir from outside, and in the second case, of a joint electroosmotic flow of two liquids under the action of an electric field [4].

The practical implementation of the electroosmotic method requires significant energy costs. The power consumption is determined by the voltage of the DC source and the spreading resistance between the anode and cathode electrodes. On fig. 1 shows possible schemes for creating an electroosmotic flow to the bottom-hole zone of a production well, where 1 is a direct current source, 2 is a production well, 3 is an additional well, 4 is an oil-containing layer, 5 is a cathode electrode, 6 is an anode electrode, 7 is an insulating insert, 8 - additional surface electrode. If a direct current source is connected directly to the upper bases of the wells, then most of the current (respectively, electrical energy) is spent on processing the layers of the earth that do not contain oil (Fig. 1, a). It is more economical to connect the power source to the lower parts of the wells with the latter isolated from the main well (Fig. 1b). The use of a surface anode electrode instead of an auxiliary well (Fig. 1c) leads to a significant increase in the spreading resistance and, as a result, to unreasonably high energy consumption. The minimum energy consumption can be achieved if not the entire oil reservoir is subjected to electrical treatment, but only the bottom-hole zone near the production well. In addition, pumping equipment is located in the production well, so in most cases, it is impossible to lower any electrical cables and electrodes into the lower part of the production well. Thus, the methods of electroosmotic treatment of the bottom-hole zone, presented in Fig. 1, d, e, are the most practically implemented and provide minimal energy consumption. At the same time, due to the significantly lower electrical resistivity metal well (compared to the surrounding soil), the base of the production well will work as a bipolar electrode, resulting in a significant reduction in spreading resistance between the anode and cathode electrodes.

Pic. 1.

Schemes for connecting a DC source to create an electroosmotic flow to the bottom-hole zone of a production well.



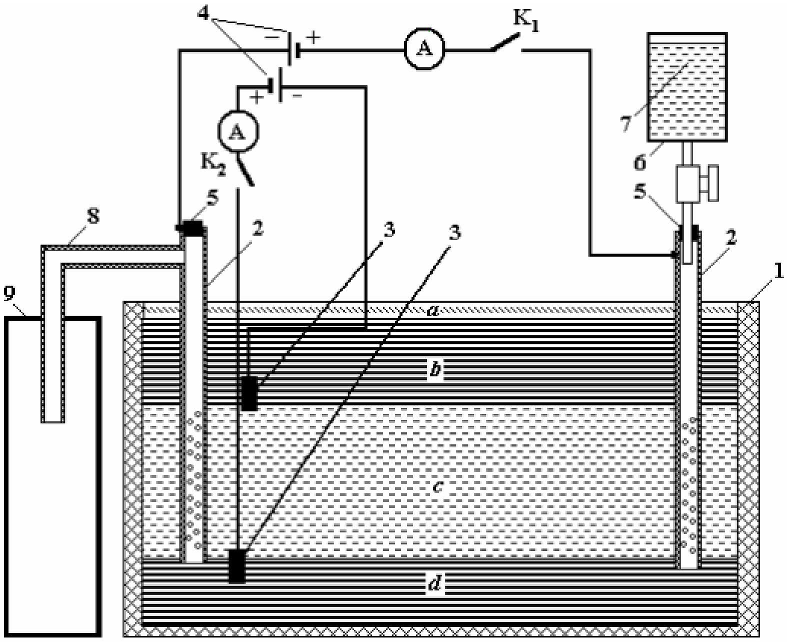
Laboratory experiment. To substantiate the possibility of minimizing energy consumption in the implementation of the electroosmotic method of enhanced oil recovery according to the schemes of Fig. 1d,e a laboratory experiment was performed, the results of which are presented below. The diagram of the laboratory setup is shown in fig. 2. Plastic box 1 contains a 4-layer medium. Layer c - oil-saturated mixture, layers b and d - clay, layer a - paraffin. Layer thicknesses c=15 cm, d=5 cm, b=10 cm, a=1 cm. Perforated metal tubes 2 were spaced 40 cm apart. The anode and cathode electrodes 3, metal cylinders 4 mm in diameter and 10 mm long, are located at a distance of 5 cm from the nearest perforated tube. The perforated tubes in the upper part are closed with insulating plugs 5. From tank 6, 1% sodium chloride solution 7 entered the oil-containing layer. The solution that passed through the oil-containing layer through pipe 8 entered storage tank 9. The laboratory experiment was carried out in three stages. At the first stage, when switches K1 and K2 were switched off, a 1% aqueous solution of NaCl was filtered from tank 6 through perforated tubes 2 through the oil-saturated layer c. At the same time, a similar transparent aqueous solution of NaCl was supplied from pipe 8 to tank 9 for 10 minutes. In the second stage, the key K1 was closed, and a current of 100 mA flowed between the electrodes. After 1.5 minutes after the start of electroosmotic treatment, the oil began to come out. After 35 minutes, the power source was turned off, while the liquid filtration rate decreased by about 10 times, and the oil output completely stopped. Then the power source was turned on again by means of the key K1, and after 2 minutes the filtration rate reached its previous value with the simultaneous release of oil.

DISCUSSION

In the third stage, after a half-hour disconnection of the power source, the voltage was applied by closing switch K2 between additional electrodes 3 installed in the immediate vicinity of the perforated metal tube 2 (switch K1 was in the off state). At the same time, an aqueous 1% NaCl solution was filtered from tank 6. A picture was observed that was completely analogous to the second stage of the laboratory experiment.

Rice. 2.

Scheme of the laboratory setup



Thus, the laboratory experiment confirms the possibility of using electroosmosis to increase the oil yield without using the wells themselves as electrodes [16].

CONCLUSION

1. The use of electroosmotic treatment of both oil reservoirs and the bottom hole zone of the well is most appropriate for finely porous oil-containing layers. In this case, electroosmotic filtration to the production well is more efficient than hydraulic.

2. To minimize energy consumption during electroosmotic treatment, electrodes for creating an electroosmotic flow should be located directly at the production well (in the bottom hole zone). The latter in this case should work as a bipolar electrode.

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