Technology of pumping production of high-viscosity oil with injection of coolant to the bottom through hollow rods

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Abstract. The purpose of the study is to develop a pumping unit that allows successful injection of coolant into the bottom of the well through a column of hollow rods, followed by oil extraction from the well without lifting equipment. The scientific novelty of the material is based on the possibility of heating the bottom-hole zone of the formation and simultaneous oil production. The technological process of extracting hard-to-recover oil using the proposed installation is based on the following operations: withdrawal of the intake into the annulus, descent of the pump shank into the horizontal shaft; steam injection to the shank and its movement within the bottom-hole zone of the formation - warming up of the near-well area; commissioning of the well with a specially selected technological mode of operation of deep-pumping equipment. The field results of testing the steam injection technology at well No. 3777 of Novo-Sheshminskaya Square are reflected, which showed the fundamental possibility of its application for the successful development of high-viscosity oil deposits. The study also found that for the wide application of the proposed technology, it is necessary to successfully solve a number of tasks, among which the most urgent is the issue of effective thermal insulation of hollow rods in order to minimize heat loss during injection of a special substance. Further development of the proposed technology of pumping production of high-viscosity oil lies in the use of modern materials for the production of underground equipment and improvement of the design of pumping units, aimed at increasing the parameter of the inter-repair period. The proposed technology can be used in the fields of the Volga-Ural oil and gas province, in particular, for example, at the Ashalchinsky field, which will significantly increase the percentage of recoverable reserves characterized as difficult to recover.

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1 Introduction

With an increase in the share of hard-to-recover reserves in the total structure of oil reserves, the solution of issues of searching and using unconventional approaches in the processes of exploitation and development of oil fields becomes particularly important (Lake, 2005). An important aspect of today is to increase the efficiency of the development of high-viscosity oil deposits using heat carriers.

The use of heat carriers in pumping production of high-viscosity oil according to technical and economic parameters is one of the promising directions in the development of hard-to-recover oil reserves. Ultra-viscous oil production technologies are based only on superheated steam heating of the reservoir. The steam-gravity effect is already widely used in the Republics of Tatarstan and Komi. Technologies for the selection of borehole products due to high temperatures require improvement and new developments today. One of these is a rod pumping unit, which allows the injection of coolant into the face through a column of thermally insulated hollow rods, and the products are pumped out by a pump through the inter-tube space in the tubing column.

2 Methods and Materials

The Figures 1 and 2 show the installation diagrams. Two cylinders 5 and 6 of the upper and lower pumps, connected in series by a pipe 4, with plungers 7 and 8, respectively, are lowered into the well 1 with a horizontal section of the trunk on the columns of the tubing 2 and hollow rods 3. The plunger 7 of the upper pump is connected to the plunger 8 of the lower pump by a nozzle 9. Inside the upper plunger 7 is placed the vertical channel 10, inside which the discharge valve 11 of the upper pump is placed. The pipe 10 is connected to the eccentric translators 12 and 13. The translator 12 enters the upper coupling 14, and the translator 13 enters the lower coupling 15.

A suction valve 16 is located in the lower part of the cylinder 5 of the upper pump. Vertical holes 17 and 18 are made in the upper 14 and lower 15 couplings. In addition, side channels 19 and 20 are made in the couplings 14 and 15. The cylinder of the lower pump is connected to the shank 21, lowered into the horizontal section of the borehole. The column of hollow rods 3 at the wellhead passes into a flexible high-pressure hose. The inlet of the translator 12 and 13 into the vertical channel 10 is sealed with cuffs.

The horizontal section can be drilled as the end of a vertical trunk or by drilling a side trunk (Figure 1). In the latter case, the side trunk is drilled with a smaller diameter and cemented into the main trunk.

The essence of the pumping unit operation is as follows.

After lowering the rod installation with a shank 21 into a well 1 with a horizontal section and putting it into operation, a coolant (steam) is supplied to the column of hollow rods 3. Steam from the column of rods 3 through the channel 17 of the coupling 14, a concentric cavity formed by a vertical pipe 10 and a plunger 7, through the channel 18 in the coupling 15 and a branch pipe 9 enters the shank 21. After exiting the shank 21, partially or completely condensed steam will move back through the annular space and enter the intake valve 16 and then through the vertical pipe 8 and the valve 11 be pumped through the hollow column of the tubing 2 to the surface. The flexible sleeve allows the coolant to be pumped into the hollow rods during their reciprocating motion. As the bottom-hole formation zone is heated by steam, oil will begin to flow into the horizontal wellbore, which, mixing with steam condensate, will be pumped to the surface by a pump. The performance of the rod installation is determined by the pumping speed, the feed ratio of the upper pump and the difference in the cross-sectional areas of the plungers 7 and 8.

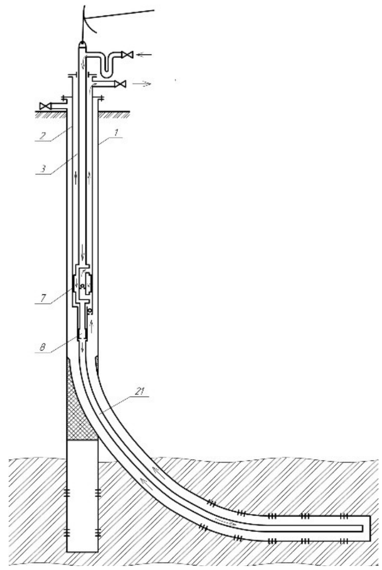

Fig. 1. Coolant injection scheme: 1 – horizontal section of the borehole; 2 – tubing; 3 – hollow rods; 7 – plunger; 8 – plunger of the lower pump. *A source:* "Compiled by the authors".

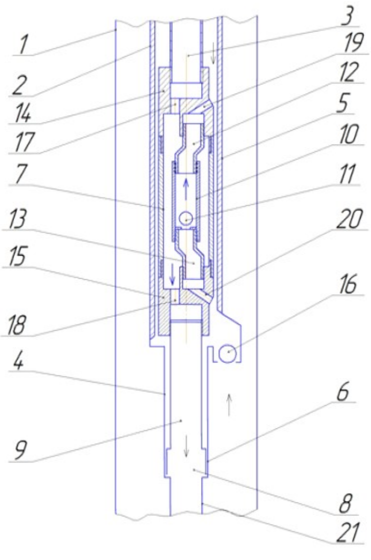

Fig. 2. Diagram of the rod pump: 1– horizontal section of the borehole; 2 – tubing; 3 - hollow rods; 4 – pipe; 5 – cylinder of the upper pump; 6 – cylinder of the lower pump;7 – plunger of the upper pump;8 – plunger of the lower pump; 9 – branch pipe; 10 – vertical pipe channel; 11 – discharge valve; 12, 13 – eccentric adapters; 14, 15 – couplings; 16– suction valve; 17, 18 – vertical channels; 19, 20 – side channels; 21 – shank. *A source:* "Compiled by the authors".

The mineralization of the extracted water varies in the range of 9-20 mg/l. Based on the mineralization of reservoir water, it is possible to predict the possibility of precipitation of the components of the enzyme complex, and select the necessary additives for it [9].

The results of the analysis of the extracted water and oil showed the presence of microorganisms in it in significant quantities. The enzyme component is a product of biological origin and can be biodegradable, so the presence of microorganisms will affect the effect of the enzyme complex. As a result, the addition of a bacterial inhibitor to the enzyme complex is necessary.

Enzyme activity may decrease in reservoir conditions (high mineralization and temperature). The protein nature of enzymes makes them very sensitive to increased concentrations of salts in water, especially calcium and magnesium ions. To prevent this phenomenon, the inclusion of chelated compounds (EDTA) is necessary to limit the influence of metal ions. The stability of the properties of enzymes in seawater at a temperature of 140 ° C at various concentrations of EDTA is determined by two parameters - surface tension and turbidity of the solution during thermal testing [10-11].

3 Results and Discussion

During the operation of the installation, the dynamic liquid level in the well is maintained with the expectation of providing depression to the productive reservoir, by changing the operating mode of the installation or the flow rate of the injected steam (Khalimov, Klimushin & Ferdman,1987).

The advantage of the developed installation is the reduction of heat loss into the well and the surrounding space when pumping coolant into a column of hollow rods. Reducing heat loss in the borehole space due to the injection of coolant into the column of hollow rods provides a greater flow of oil into the well, increases the efficiency of the process as a whole (Verevkin & Diyashev,1982).

In addition, the installation allows the coolant to be delivered using a shank to the bottom of a side bore of a smaller diameter, placing the pump itself in a vertical section of the main borehole.

The most effective mode of operation of the described installation is periodic. The coolant is pumped during the shutdown of the pump in order to warm up the bottom-hole zone of the formation. After injection, the pump is switched on and a long-term selection of heated oil is carried out. After cooling the product to a certain temperature, the injection is repeated. Steam generated by a mobile steam power plant is used as a coolant (Muslimov, 2009).

The technological process of extracting hard-to-recover oil using such a pumping unit is as follows:

- The pump intake is withdrawn into the annular space. The pump shank is lowered into the horizontal section of the well.
- During the shutdown of the pump, steam is injected into the column of hollow rods, which enters the shank through a concentric channel in the plunger and then into the horizontal well bore.
- The movement of steam and condensate to the bottom is accompanied by heating of the bottom-hole zone of the formation and filtration of oil into the wellbore. After warming up the pump, the pump is started up.
- A mixture of oil and steam condensate enters the pump and is pumped to the surface through a column of tubing.
- Oil production is carried out with the maintenance of a dynamic liquid level and depression on the reservoir by selecting the technological mode of operation of the pump and the flow rate of the coolant.
- In order to preserve heat, the inner surface of the hollow rods has a 4 mm thick propylene layer.

The advantages of the pumping unit are as follows:

- The possibility of regulating the daily supply of the installation by changing the diameter of the plunger of the telescopic connector of the installation;
- Reduction of heat loss to the borehole space by an average of 80 % when applying coolant to the face;
- Complete prevention of paraffin deposits in the lift during the extraction of paraffin-containing oil;
- Production of an installation based on mass-produced rod pumping equipment at enterprises of the Russian Federation.

Well No. 3777 (Tournaisky tier, Novo-Sheshminskaya Square) was selected by the customer to test the pumping unit. Pumping equipment for heavy oil production was lowered into the well to a depth of 1130 m. With the help of a lifting unit, the pump was paced at a stroke length of 2.5 m for 2 hours and 20 minutes at a load of 7 tons. According to field data, the viscosity of the extracted liquid was 1.5–2.0 Pa * s. After the specified period, the reservoir products began to flow into the discharge manifold (Dubinskiy, Andreev, Mukhametshin, Kuleshova & Mingulov, 2020).

For greater clarity, the extracted products were briefly drained into an open container. After that, the pumping of the liquid by the lifting unit was stopped, and the polished hollow rod at the mouth was suspended from the head of the rocking machine balancer. However, due to the high values of the maximum load on the rods due to the high viscosity, the cable suspension broke off. Subsequently, the rope suspension was replaced. Further operation of the well was suspended due to the high concentration of mercaptans in the produced oil. The lifting of the equipment also showed a partial melting of the polypropylene thermal insulation in the upper sections of the hollow rods due to the high temperature.

Thus, the tests showed the fundamental possibility of using a column of hollow rods to pump coolant into the bottom-hole zone of the formation.

4 Conclusion

- A pumping unit has been developed that provides injection of coolant to the bottom of the well through a column of hollow rods, followed by oil extraction from the well without lifting equipment.
- Tests of the steam injection technology at square No. 3777 Novosheshminskaya Square showed the fundamental possibility of using the technology on deposits of high-viscosity oil
- The wide application of the technology requires the improvement of the thermal insulation of hollow rods.

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