The Study of Extraction method of Hard-to-Recover Hydrocarbon stocks Using Oilfield Core Material

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Abstract. The displacement of hard-to-recover oil by water has become the most widespread method of crude oil extraction. However, in its implementation, the oil recovery factor is insignificant. Recently for this purpose the technology of water alternation gas injection has become widespread. In this work, the laboratory tests were carried out in conditions of artificial oil stratum using the samples of live oil, water and gas. For the study were used core material samples selected from the well of oil fields. Experiments were conducted using different models of samples and fluids under conditions of maintaining the layer pressure and back pressure with a flow rate of 0.1 ml / min.

1. Introduction
Currently, there are problems of depletion of oil fields. In the total volume of current oil reserves, the share of hard-to-recover reserves has increased. Further development of oil industry is largely due to the development of these reserves. Under these conditions, creation of efficient, reliable and easy-to-maintain innovative equipment and technology acquires special relevance for oil production.

One of the promising areas in the creation of such equipment and technology is the use of water-alternated-gas injection on the oil stratum with a simultaneous increase in oil recovery.

2. The urgency, scientific significance of the issue with a brief review of literature
The main task in the oil and gas fields development is to increase the oil recovery factor. This indicator which characterizes the degree of completeness of the use of natural resources is low and amounts to 0.30–0.32 [1-7]. Recently, to increase the oil recovery factor, the technology of water-alternated-gas injection has become widespread. As a rule, various variants of simultaneous, sequential, and alternate pumping of water and gas are used. The effectiveness of the listed displacement technologies is largely determined by the filtration-capacitive properties of the productive reservoir, the ratio of viscosity of oil displacement agent, as well as the interfacial tension [8–13]. Obviously, effectiveness of application of exposure agent as well as extrusion mode should be based on detailed laboratory studies or pilot tests.

3. Formulation of the problem
Definition of methods and parameters necessary for comparing the efficiency of extraction of hard-to-recover hydrocarbons: displacement by water-alternated-gas injection, by water or gas.
4. The results of experimental studies

The tests were carried out in conditions of artificial oil stratum using live oil and gas. Laboratory tests were conducted using the core material samples taken from oilfieldwell in Western Kazakhstan.

Selection of a sampling point is based on the results of permeability study of full-sized core. The result was obtained after carrying out an express method for measuring the permeability by means of probe permeameter "Petrozond". This desktop device is intended for rapid determination of relative distribution of gas permeability at the studied points over the entire surface of core column. The device allows you to quickly get direct information about the filtration characteristics of samples without violating their integrity.

After drilling out, the samples investigated were sent for extraction as they required cleaning. Extraction of samples was also repeated after the completion of each analysis since the models of samples were reused. Extracting the samples consists in the process of cleaning the pore space of sample from oil, water, and salts [14–20].

The samples were cleaned by means of Soxhlet apparatus under washing with organic solvents. As a solvent, azeotropic mixture of chloroform with methanol and toluene in the ratio 1: 1: 1.5 was used.

Several experiments were performed using different models of samples and fluids. All experiments were also carried out in conditions of artificial oil stratum with maintaining the strata pressure and back pressure with a flow rate of 0.1 ml / min.

All experiments are divided into 4 categories:
1. Model No. 1 - Water displacement at different pressures;
2. Model No. 2 - Water-alternated-gas injection displacement;
3. Model No. 3 - Gas displacement at an angle;
4. Model No. 4 - Water / water-alternated-gas injection displacement when creating a water-cut condition of 40% and current water cut.

After complete cleaning, all samples were dried at a temperature of 65° C in a drying cabinet (DKN 600) to constant weight. In order to reduce the adsorption of atmospheric moisture, all samples were placed in a glass desiccator and transferred for further study of standard analysis (determination of porosity and gas permeability).

At all stages of the displacement experiment, all work was carried out under industrial conditions with maintaining reservoir and back pressure. The feed pump operated in two modes: maintaining reservoir pressure or maintaining a constant flow rate. In our case, the feed pump operated in the mode of constant maintenance of the flow rate — 0.1 ml / min. The receiving pump used to create a back pressure worked in the constant pressure mode. During the experiments, the pressure in receiving pump rose stepwise to a level above the saturation pressure. Registration of changes in the pressure profile was made by a set of pressure sensors installed in the filtration unit and by the pressure sensor of pumps.

At all stages of the study, measures were taken to create the conditions for maintaining the preset temperature (from plus 5 to minus 50°C). The unit with the oil sample worked in the temperature maintenance mode. Before entering the sample, the incoming fluids were heated by filtration unit. All underwater pipes were sealed by heat-insulating material.

Prior to the main experiments to determine the displacement factor, preliminary tests were carried out: determination of water permeability, determination of porosity by liquid saturation, determination of phase permeabilities in order to select the degree of watering. The research results are summarized in Table 1.
### Table 1. Research results.

| Test N. | Experiment description | Oil displacement by water above saturation pressure | Oil displacement by gas/water (methane more than 85%) | Oil displacement by water-alternated-gas injection from top | Oil displacement by water-alternated-gas injection under watering of 40% |
|---------|------------------------|----------------------------------------------------|----------------------------------------------------|----------------------------------------------------------|--------------------------------------------------------|
| 0.1     | Permeability to water, mD | 0.033 | 0.032 | 0.036 | 0.026 |
|         | Residual water saturation, unit fraction | 0.42 | 0.40 | 0.36 | 0.55 |
|         | Residual oil saturation, unit fraction | 0.28 | 0.20 | 0.28 | 0.20 |
|         | Displacement factor, unit fraction | 0.51 | 0.67 | 0.57 | 0.56 |
| 0.2     | Permeability to water, mD | 0.031 | 0.031 | 0.036 | 0.027 |
|         | Residual water saturation, unit fraction | 0.43 | 0.41 | 0.36 | 0.48 |
|         | Residual oil saturation, unit fraction | 0.32 | 0.47 | 0.31 | 0.25 |
|         | Displacement factor, unit fraction | 0.45 | 0.21 | 0.52 | 0.53 |
| 0.3     | Permeability to water, mD | 0.035 | 0.031 | 0.036 | 0.026 |
|         | Residual water saturation, unit fraction | 0.41 | 0.41 | 0.36 | 0.55 |
|         | Residual oil saturation, unit fraction | 0.28 | 0.27 | 0.28 | 0.20 |
|         | Displacement factor, unit fraction | 0.53 | 0.55 | 0.57 | 0.56 |
| 0.4     | Permeability to water, mD | 0.033 | 0.031 | 0.036 | 0.026 |
|         | Residual water saturation, unit fraction | 0.40 | 0.40 | 0.36 | 0.55 |
|         | Residual oil saturation, unit fraction | 0.49 | 0.49 | 0.28 | 0.28 |
|         | Displacement factor, unit fraction | 0.18 | 0.18 | 0.28 | 0.28 |
5. Conclusion
According to the laboratory tests, the maximum displacement factor is manifested when oil is displaced by water-alternated-gas injection (methane content 85%), the value of which is 0.670 unit fraction. The rate of displacement of oil by water-alternated-gas injection (methane content 95%) is 0.550. The rate of gas displacement with a methane content of 85% and 95% is 0.211 and 0.181 unit fraction, respectively. In the rest of the experiments, water-alternated-gas injection (methane 85%) was used. Displacement factor readings vary from 0.518 to 0.557 unit fraction. The obtained values are similar to the values of the experiment carried out on the second model for displacement of oil by water-alternated-gas injection (methane 85%) and ranges from 0.518 to 0.557 unit fraction which suggests that the effect of feeding method or the watering level is insignificant.

If we conditionally take the displacement coefficient of 0.527 unit fraction by water at stratum pressure as the base coefficient, then the growth of displacement bywater-alternated-gas injection (85% methane) is 14.3%, by water-alternated-gas injection (95% methane) is 2.3%. When displaced by 95% methane and 85% methane, the dropis - 31.6% and -34.6%, respectively.

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