Investigation of the influence of water-gas exposure modes on the efficiency of oil displacement

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Abstract. The purpose of the work is to analyze the efficiency of oil displacement by various agents, such as water and gas, in different modes. The methods and technologies used to increase oil recovery are considered, as well as the influence of various parameters on the efficiency of the process.The authors describe in more detail the method of water-gas exposure (VGV) using pumping-ejector systems (PES) to provide a triple effect on oil reservoirs by simultaneous or alternate injection of water and gas. Theoretical and experimental methods were used to conduct the study. The study and analysis of scientific sources on the issue of evaluating the effectiveness of oil displacement became the first stage of the study. Then laboratory tests were carried out to assess the effectiveness of oil displacement by various agents. Based on the results of the work done, it was concluded that the degree of influence of wetting processes on the final result of displacement is an extremely important factor. The uniqueness of this article lies in the study of the possibilities of using multithreaded ejectors to increase the efficiency of extraction of hydrocarbones.

1 Introduction

In the field of exploitation of hydrocarbon resources, one of the main tasks is to increase the oil recovery coefficient. Currently, this indicator in Russian oil production is still low, ranging from 0.30 to 0.32. Therefore, the introduction of innovative approaches, such as the impact of water and gas on the reservoir, becomes especially important.

There are many different techniques for using water and gas in wells, including their simultaneous, sequential or alternating use. Each of these methods has its own field of application, depending on the conditions at the field.

The effectiveness of such strategies primarily depends on the filtration and capacitance properties of the reservoir pore space, as well as on the viscosity and interfacial tension between the displacing agent and the extracted oil. In order to optimize the displacement

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processes and select the most appropriate impact on the formation, comprehensive research is necessary, including both laboratory analyses and field tests. The work is aimed at studying various wetting conditions and modes of water-gas injection in order to optimize oil production processes. The significance of this study is beyond doubt, as it allows for more complete use of natural oil resources and increases the efficiency of the industry.

2 Methods and materials

Theoretical and experimental methods were used to conduct the study. Theoretical methods include the analysis of scientific literature [1-11], generalization and systematization of information, as well as modeling of displacement processes. Experimental methods include conducting laboratory studies, analyzing data obtained from experiments, and evaluating the effectiveness of various displacement methods.

The study and analysis of scientific sources on the issue of evaluating the effectiveness of oil displacement became the first stage of the study. The works of domestic and foreign authors devoted to the issues of oil displacement from the reservoir, the use of various displacing agents, as well as methods for increasing the oil recovery coefficient were studied.

Then laboratory studies were conducted to evaluate the effectiveness of oil displacement by various agents. Samples of reservoir oil, water and gas were used, as well as various displacement technologies, including injection of gas, polymer solutions and thermal agents.

According to the results of laboratory studies, data on oil displacement coefficients for various agents and operating modes were obtained. These data were processed and analyzed using statistical methods [12].

3 Results and Discussion

The method of water and gas exposure (VGV) uses pumping and ejector systems (PES) to provide a triple effect on oil reservoirs by simultaneous or alternate injection of water and gas. The purpose of this process is to increase the coefficients of coverage and displacement of the reservoir, which in turn contributes to an increase in the volume of extracted oil. This is especially important for fields with high viscosity oil.

The improvement of the technology of well construction with the help of PES allows solving problems related to hydrate formation and eliminating the risk of gas breakthrough into production nodes due to the synchronization of gas and water input. In addition, the use of PES allows the use of both dry and enriched gas as a working agent, which increases the flexibility of the method and the efficiency of the oil displacement process from the reservoir.

An additional advantage of the PES, which is important for a complete understanding of the method, is the minimization of operating and capital costs compared to more traditional technologies such as compression or booster equipment. PES not only help to reduce costs due to durable and cost-effective components, but also have increased reliability in operation.

The oil field as a whole, individual well clusters, as well as individual wells can be treated with the help of PES, which demonstrates the scale and versatility of the introduction of this technology in the process of water and gas exposure, in order to utilize associated petroleum gas and maintain the required level of reservoir pressure [13].

The water and gas impact in the context of exploration and development of deposits is closely related to technologies aimed at improving the efficiency of mining. One of these

approaches is the PES method, which involves the use of high-quality equipment available on the market. This opens up prospects for the widespread introduction of this method in order to increase the efficiency of field operation. In this regard, issues related to jet machines are being discussed, including their lower prevalence compared to pumps and compressors that are commonly used, despite their ability to provide the necessary pressure to move liquids and gases.

The desire to ensure effective impact on formations using gas-liquid mixtures is due to the difficulties in which it is required to generate pressure for injection of mixtures. The difficulty of exposure is increased due to the high supply pressure of the components, which is not always feasible in the field.

The jet device, being innovative and reversible in the context of fluid movement, acts on the basis of the energy of the flows interacting during their mixing. The working fluid, passing through the narrowing nozzle, gains speed, while its pressure decreases, transforming in the receiving chamber as a result of contact with the pumped fluid, the pressure of which is noticeably lower. Subsequent mixing takes place in the mixing chamber, which leads to an energy exchange between the components. This energy exchange, starting from the conversion of velocity into pressure and ending with the stabilization of the flow in the diffuser, not only emphasizes the importance of the fundamental design of the devices, but also reveals their potential in the context of an industrial strategy for field development.

The combination of jet devices with pumping systems, especially with electric centrifugal pumps (ECP), is a powerful tool for controlling fluid flows. It should be noted that both land-based and underwater systems are equally capable of using the potential of pumping and ejector systems (PES) to solve a wide range of tasks. This versatile model provides the basis for a number of operations, including mixing, transportation and processing of liquid, gas and multiphase media [14-16].

This article will consider systems that increase oil production using the method of exposure to a water-gas mixture (WGM) together with a pump (PES model) (Figure 1).

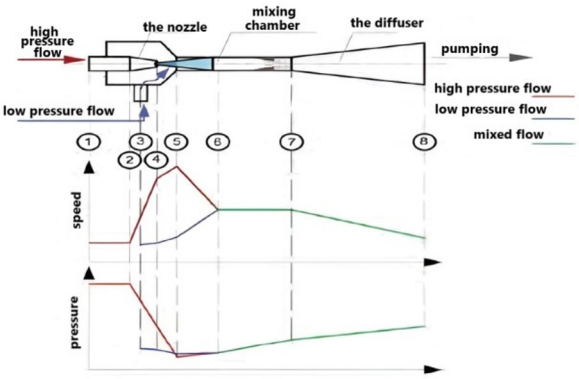

Fig. 1. The design and principle of operation of the inkjet equipment.

A series of experiments were conducted on experimental measuring equipment in order to evaluate the efficiency of hydrocarbon extraction under the influence of hydro- and gas-dynamic operations. The study included an assessment of the oil ejection factor, under conditions of variability of water and gas effects, namely: asynchronous injection of gas followed by water and vice versa; synchronous injection of both media; as well as a change in the supply of displacing agents (Figures 2-3).

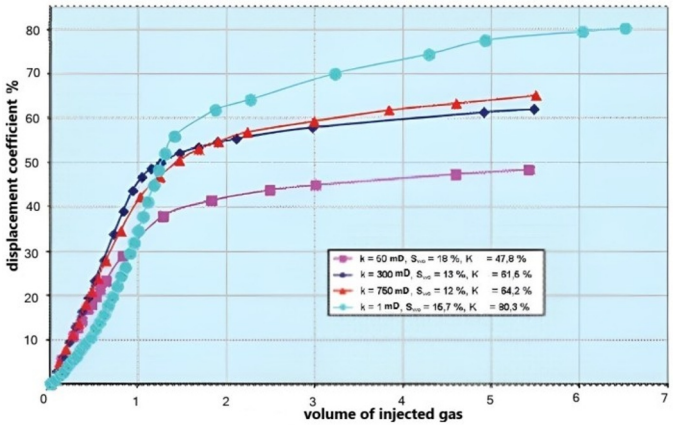

Fig. 2. The efficiency of separating oil from gas through a separation process using gas exposure.

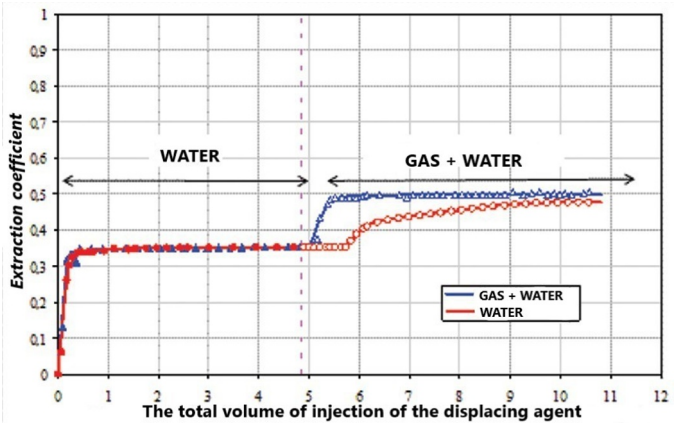

Fig. 3. Change in the oil recovery coefficient.

Based on the results of the work performed, it can be concluded that the degree of influence of wetting processes on the final result of displacement is an extremely important factor that determines the effectiveness and economic feasibility of using various methods of oil and gas extraction.

Wetting of rock and fluid surfaces directly affects the processes of adsorption, capillary pressure, surface tension and the formation of new phase interfaces. In general, the better the fluid wets the rock surface, the higher the probability of it displacing other fluids and, accordingly, the more efficient extraction of hydrocarbons from the formation. To optimize the processes of displacement and increase the recovery rate of hydrocarbons, it is necessary to take into account many factors, including the type of rock, fluid properties, characteristics of reservoir conditions and production technologies. An important aspect is also the development of new methods and technologies that allow you to control the wetting processes and increase the efficiency of displacement.

The designed station, which is a node for injecting a water-gas emulsion into a geological formation, solves the problem of efficient use of associated petroleum gas. The jet device mounted on the supply to the injection equipment inspires the liquid at a pressure varying between 11 and 19 MPa. Mixing of water and the gas supplied in parallel leads to the generation of a homogeneous mixture, which is sent through a pump system for subsequent introduction into the tank. An illustrative diagram demonstrating the technical sequence of operations at this station is presented below (Figure 4).

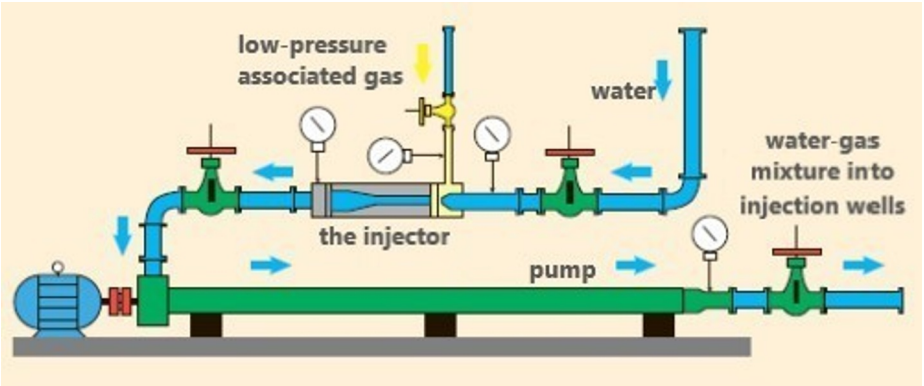

Fig. 4. The scheme of the technological station for the implementation of water and gas exposure.

An innovation and feature in this area is the modular construction of stations (Figure 5), which allows them to be quickly installed in mining sites. In addition, modularity ensures the convenience of dismantling and transporting equipment to new operating sites.

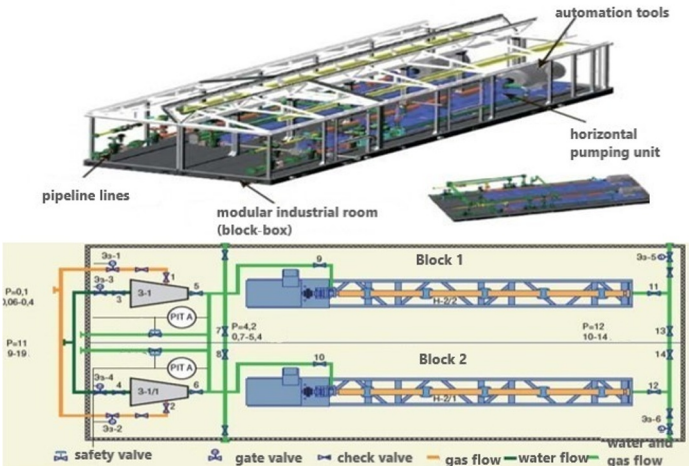

Fig. 5. A modular station for the implementation of water and gas effects on the reservoir.

Multithreaded ejectors are an advanced achievement of inkjet technology. This area is considered as a potential basis for the implementation of projects aimed at minimizing energy consumption in the production and transportation processes (Figure 6).

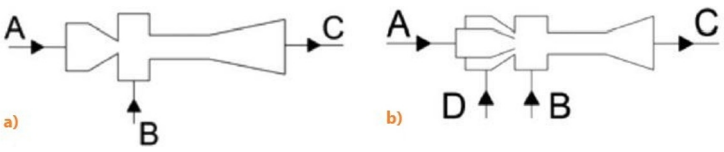

Fig. 6. a) Single-threaded ejector circuit b) Multithreaded ejector circuit.

The features of the operation of multithreaded ejectors consist in the ability to process several flows of the pumped or working medium, each of which has individual initial pressures. Within a single flow, the ejectors work with a pair of “working/pumped media". The versatility of such devices is enhanced by the possibility of transforming the

multithreaded ejector circuit into a single-threaded version when the initial media pressures are equal, which indicates the flexibility of use in various technological conditions.

There is significant potential for the use of multithreaded ejectors in the extraction of hydrocarbones, given their ability to reduce economic and technical costs. These devices, which are an advanced achievement in the field of inkjet technology, have the ability to simultaneously operate several productive layers. The effectiveness of multithreaded ejectors is especially evident in their flexibility in carrying out repair work or adjusting the operating mode without the need for underground well repairs.

Their main advantage is the ability to replace several single-flow systems, which reduces the total number of necessary pipelines and reduces the load on power pumps. The result of such a reduction in the number of components of the hydraulic system is an immediate reduction in the number of equipment, a reduction in cost and an increase in the reliability of the control systems.

Ejectors with the possibility of using multiple streams allow the use of multiphase pumping systems for simultaneous transportation of gas and oil, as well as for the introduction of water and gas effects on the reservoir. Using one such device, it is quite possible to operate two or three reservoirs, which makes it a truly unique and necessary tool for specialists in the field of hydrocarbon production.

Manufacturers, realizing the advantages of using multithreaded ejectors, will undoubtedly see them as promising solutions for the development of the extractive industry. This implies sustained interest and investment in the further development of this kind of technology, leading to process optimization and a gradual reduction in operating costs for mining. In order to increase the hydrocarbon recovery coefficient, the primary importance is attached to detailed laboratory tests of procedural aspects and regime installations, namely, the conditionality of the impact of various agents on the effectiveness of the actions taken. Regarding the increase in the production of hydrocarbon-saturated reservoirs, it is important to emphasize the importance of physical modeling in the context of the application of non-primary methods of reservoir exploitation. Undoubtedly, this acquires strategic importance at the design stage of pilot industrial testing at specific sites of deposits, as well as when forming a strategy for the development of the entire facility aimed at extracting natural hydrocarbon reserves. As a result of the conducted study evaluating the effectiveness of oil displacement by water and gas in various modes, the following results were obtained. It was found that the efficiency of displacement significantly depends on the selected mode and the type of displacement agent used.

The study showed that when using gas for displacement, a higher displacement coefficient is observed compared to water in certain operating modes. This may be due to differences in the interaction between the various components of the oil-water-gas system, as well as changes in physico-chemical properties depending on the experimental conditions.

To increase the efficiency of the oil displacement process, it is necessary to take into account the operating mode and correctly select the displacing agent. Further research in this area can help optimize oil production processes and improve field productivity.

4 Conclusion

In this article, an assessment of the effectiveness of oil displacement by water and gas in various modes was carried out. The study showed that the most promising methods of increasing the oil recovery coefficient are the use of gas methods and the use of multifunctional formulations to increase oil recovery.

It can be concluded that the degree of influence of wetting processes on the final result of displacement is an extremely important factor that determines the effectiveness and

economic feasibility of using various methods of oil and gas extraction.

It was also found that the efficiency of the displacement process depends on a number of factors, including the properties of the formation and fluids, the characteristics of the displacing agents and the technological parameters of the process. To optimize the process, it is necessary to conduct research on specific objects and take into account their individual characteristics.

Thus, evaluating the effectiveness of oil displacement is a complex task that requires taking into account many factors and conducting research at experimental sites.

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