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A MECHANISM FOR PUMPING WATER INTO SMALL OIL FIELDS

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A B S T R A C T

Waterflooding was first applied in the Fergana oil fields in 1952, when pilot water injection was started into the peripheral part of the V+VI horizon reservoir of the Yuzhny Alamishik field. The positive effect of the pilot injection, expressed in a certain increase in the flow rate of wells in terms of oil and liquid, gave grounds to start industrial waterflooding of these horizons in 1953.
In 1954, waterflooding was started along the VIII horizon of the Khojaabad field and the VII horizon of the Yuzhny Alamishik field. In the first years of the introduction of artificial waterflooding methods, the greatest preference was given to systems for injecting water into the peripheral parts of the reservoirs. However, the process of development and operation of these systems in Fergana faced serious difficulties, mainly due to the poor hydrodynamic connection between the peripheral and oil parts of the reservoir.

K E Y W O R D S

Oil field, Waterflooding, Development system, Oil recovery factor, Reservoir pressure, Well grid, Injection well, Multilayer object, Production regulation, Fergana

Introduction

In the first years of the introduction of artificial waterflooding methods, the greatest preference was given to systems for injecting water into the peripheral parts of the reservoirs. However, the process of development and operation of these systems in Fergana faced serious difficulties, mainly due to the poor hydrodynamic connection between the peripheral and oil parts of the reservoir.
For this, as well as for a number of other objective reasons, by the beginning of 1960, peripheral waterflooding at many fields in Fergana began to be gradually supplemented or completely replaced by various intra-contour waterflooding systems. This made it possible to dramatically increase the efficiency of waterflooding and thereby gave grounds for its wider introduction at other Fergana facilities.
Artificial waterflooding methods were particularly intensively introduced at the Fergana fields in the period 1960-1968. During this period, industrial water injection was mastered at the Andijan (III horizon), Yuzhny Alamishik (KKS and III horizons), Khojaabad (III and VII horizons), Severny Sokh

(VIII horizon), Chongara-Galcha (IV horizon), Maili-Su-IV (V and VII horizons), Izbaskent (V and IX horizons) and a number of other fields.

By the end of 1968, 20 development facilities at eight fields were covered by peripheral, intra-contour and combined types of waterflooding only by the former Uzbekneft production association. The annual volume of water injection was more than 3.2 million m3. Along with the above listed traditional waterflooding systems, for the first time in the former USSR, such a combined method of impact was industrially mastered, in which peripheral waterflooding of the reservoir and the transfer of high-pressure gas to its arch part were simultaneously carried out. This method of influence was used in the development of the VIII horizon of the Severny Sokh field and the IV horizon of the Chongara-Galcha field (Galcha area).

Waterflooding and high-pressure gas transfer allowed the Uzbekneft association to produce an additional 200,000 tons of oil in 1968 alone.

Artificial waterflooding was also effectively carried out at the fields of the former Kyrgyzneft association, where by this time ten out of 13 developed oil reservoirs were covered by waterflooding.

A great deal of work on the introduction of waterflooding was carried out during this period by the teams of the Institute of Geology and Exploration of Oil and Gas Fields (IGEOF), the Department of Development and Operation of Oil and Gas Fields of the Tashkent Polytechnic Institute, the central research laboratories of the former Fergananeft, Andizhanneft oil field administrations and the Kyrgyzneft association.

A significant contribution to the solution of problems related to the development of waterflooding at the Fergana fields was made by the works of P.K.Azimov, G.A.Alijanov, A.D.Djumagulov, M.R.Ibragimov, A.M.Khutorov, S.N.Nazarov, A.R.Mukhiddinov, A.A.Tomchani, Kh.M.Turgunov, A.V.Mavlyanov and others. Many issues of waterflooding technology were solved by the engineering and technical workers of the fields, including V.P.Akulov, A.M.Akramov, Z.V.Lyashevich, A.Kh.Khojimatov, L.I.Kalandarov, N.R.Rakhimov, I.N.Khristenko and others.

In subsequent years, V.N.Charushnikov, F.T.Adylov and others carried out a great deal of work on summarizing the experience of developing and waterflooding the Fergana oil fields, and are currently being carried out by N.V.Sipachev, E.K.Irmatov, B.Sh.Akramov, A.G.Posevich, A.Kh.Agzamov, O.A.Kayumov and others.

Currently, almost all Fergana oil fields are in the late and final stages of development. Artificial waterflooding methods cover about 90% of the objects under development, from which more than 80% of the total annual oil production in Fergana is extracted.

The expected ultimate oil recovery factor for waterflooded facilities varies widely - from 25-40% to 60-70%, and sometimes even higher.

Thus, it can be concluded that almost all waterflooding systems known to date have been tested at the Fergana fields.

Waterflooding will remain the main method of development in the coming years.

Ways to improve development systems. The oil field being developed, especially a large one, is a very complex system. Its main elements are reserves with all the diversity of their natural physical and geological features and technical and technological means of development and impact, including production and injection wells, technical means for oil production and water injection, collection and treatment of all well products, and control means.

Obviously, the main condition for rational development is the correct combination of all these main elements of the system.

Recommendations for development that are not tied to specific geological and physical conditions become meaningless. The features of specific fields and reservoirs are extremely diverse, but the main, defining ones include the size of the field, specific reserves per unit area, type of reservoir, permeability, reservoir stratification, oil viscosity, pressure, and regime.

An important and to a certain extent generalizing indicator for sand reservoirs is the ratio of permeability to viscosity.

It is these features that we will use when considering ways to further improve waterflooding development methods.

Improving methods should ensure:

- increase in the rate of oil production from explored reserves with the general goal of meeting the needs of the national economy;
- all-round increase in the final oil recovery, i.e. maximum use of natural resources;
- improving the economic efficiency of costs for the development of the oil production industry.

These are, of course, general and well-known provisions, but now it is worth recalling them, since we cannot be completely satisfied with the state and practical results of the application of waterflooding development methods.

On the density of production well grids. This problem is one of the most difficult in the technology of oil field development. The complexity is due to the fact that, along with the grid density, the development indicators are also affected by the width of the strips, the distance of the first rows from the injection line, the pressure drop, etc. For a long time, in order to search for optimal solutions, grids were used in a wide range - mainly from 64 to 16 ha/well in fields with different characteristics and in different combinations with other development elements.

Grids of the order of 60-40 ha are accepted for reservoirs in terrigenous monolithic formations with very favorable geological and physical characteristics of reservoirs, as well as at great depths of formations, when drilling a large number of wells is economically inexpedient. In the latter case, rare grids must be combined with active impact on the reservoirs - with cutting into narrow strips or with the use of areal and selective waterflooding.

Grids of the order of 30-16 ha are used in the development of reservoirs characterized by average values of reservoir and fluid parameters and significant heterogeneity of reservoirs.

The densest grids - less than 16 ha/well - are used in the development of reservoirs with high oil viscosity, sharp heterogeneity of reservoirs, as well as reservoirs that require limiting fluid withdrawal from wells [5, 8].

The problem of choosing optimal well grids for certain conditions has not been solved.

On the pressure drop between the injection line and the production zone. Creating high pressure drops is one of the conditions for obtaining high development rates. In all possible cases, it is advisable to reduce the bottomhole pressure in production wells by 20-30% below the saturation pressure. It is also advisable to increase the pressure on the injection lines above the initial reservoir pressure, especially with reduced reservoir productivity. For low-permeability terrigenous formations, a water injection pressure of 150-180 kgf/cm² should be used.

From the very beginning of the field operation, it is necessary to correctly justify the value of the injection pressure and build waterflooding facilities for this pressure, avoiding major reconstruction work.

Some caution in choosing the injection pressure is needed when developing reservoirs associated with carbonate reservoirs. Cases of very rapid waterflooding of wells have been noted due to the movement of water along fractures. Since carbonate reservoirs have a very diverse structure of the porous medium, the permissible injection pressure must be established for each specific reservoir based on the results of pilot-industrial water injection into wells that have undergone acid treatment.

Approach to the development of water-oil zones. In the first period of waterflooding application, it was assumed that water-oil zones may not be drilled and that peripheral waterflooding in all cases will ensure the displacement of oil to production wells drilled in the inner oil-bearing contour.

Without drilling or with drilling a relatively small number of wells, water-oil zones of those reservoirs can be developed, the characteristics of which allow efficient use of peripheral waterflooding. This also applies to deposits with an active natural water drive regime.

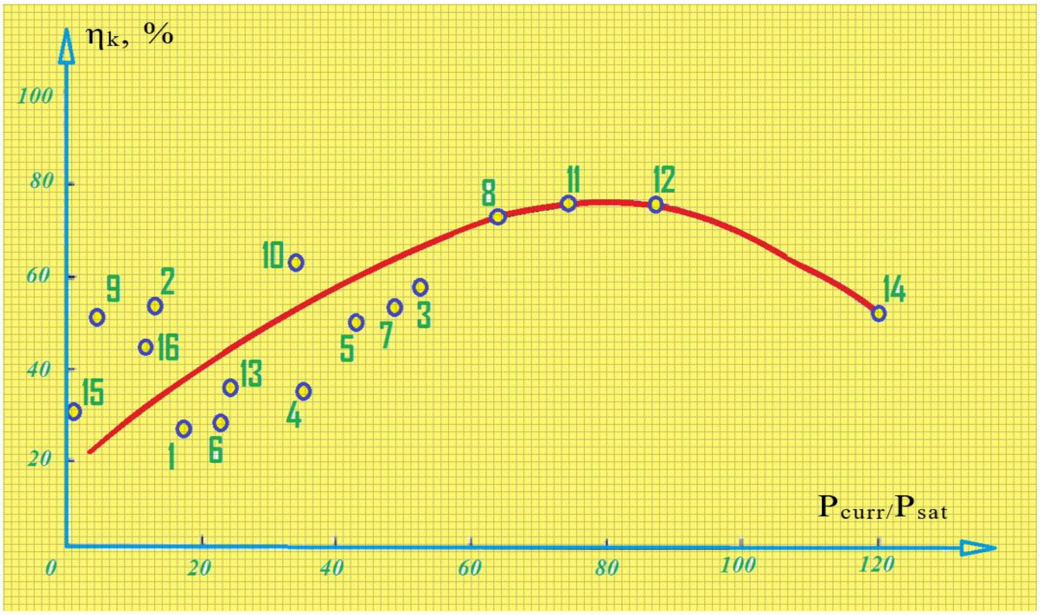

Fig. 1. Dependence of η_k on the current reservoir pressure at which waterflooding was started, expressed as a percentage of the pressure of oil saturation with gas: 1, 2, 3 - Khojaabad field (horizons III, VII, VIII); 4, 5, 6, 7 - Yuzhny Alamishik (I, KKS, III, V+VI+VII); 8 - Boston (III); 9, 10 - Andijan (III subthrust and eastern field); 11 - Chongara-Galcha (IV); 12 - Severny Sokh (VIII); 13-Changyrtash (III); 14-Izbaskent (IX); 15-Nefteabad (II); 16-Kim (VII).

Sequence of Commissioning Injection Wells

Analysis of the $\eta=f(P_{curr}/P_{sat})$ dependence shown in Fig. 1 shows that initiating waterflooding after the value of P_{curr}/P_{sat} exceeds 0.6 - 0.8 leads to a certain loss of oil recovery. During the development process in layers with significant zonal and thickness heterogeneity, the rates of reservoir pressure decline vary across different sections. Therefore, by the time waterflooding commences, the bottomhole pressure in wells located in different reservoir sections can be either higher or lower than the optimal value $(P_{curr}/P_{sat})_{opt}$. In reservoir zones where the pressure is less than $(P_{curr}/P_{sat})_{opt}$, there is a risk of losing some amount of oil. This adverse effect can be mitigated by strategically sequencing the commissioning of injection wells .

Where:

P_{curr} - Current pressure

P_{sat} - Saturation pressure

$_{opt}$ - Optimal

The forecast of zones with $P_{curr}/P_{sat} \approx (P_{curr}/P_{sat})_{opt}$ can be performed in the following sequence:

1. **Initial Reservoir Pressure Determination:** At the initial stage of development, the initial reservoir pressure (Pres.init) is determined for each well.
2. **Pressure Decline Analysis:** Based on the fluid withdrawal rates from the wells, as specified by the process regime, the time it takes for the current reservoir pressure to decline to the $(P_{curr}/P_{sat})_{opt}$ values is determined. This analysis provides the dynamics of the well stock, identifying wells with bottomhole pressure values $\leq (P_{curr}/P_{sat})_{opt}$. This dynamic behavior serves as the basis for converting production wells into injection wells and initiating water injection.

Utilizing the proposed sequence for commissioning injection wells allows for:

1. **Optimized Waterflooding:** Establishing a sequence for activating waterflooding centers based on the depletion of natural reservoir energy in different zones.
2. **Continued Natural Production:** Continuing the operation of a portion of the well stock in natural production mode in zones where $P_{curr}/P_{sat} > (P_{curr}/P_{sat})_{opt}$.

Regulation and intensification of development. The entry of many fields, including large ones, into the late stage requires increased attention to the regulation of development - one of the most important ways to increase the efficiency of the systems used.

In the process of developing a number of fields, the designed systems were radically changed. Sometimes this was done due to the need to increase production rates against those previously envisaged. Often, such measures were taken because the adopted system did not ensure the achievement of the design level of production.

Ways to improve the efficiency of developing multilayer objects. With the use of waterflooding, the allocation of objects of high capacity, often combining layers with significantly different characteristics, is widely practiced.

In this regard, many proposals have been made and are being implemented to improve the operation of multilayer objects. Thus, the admissibility of accelerated production of more productive layers, if they lie below others, is substantiated. The separate injection of water into layers with different permeability through independent injection wells with the simultaneous opening of all layers in production wells, which is used at many fields, has fully justified itself. Several methods of selective isolation of layers have been developed - oil workers have done a lot in this direction. The method of simultaneous-separate operation of layers is being introduced.

All these methods should be widely used in the development of multilayer objects, however, these tools are often used insufficiently thought out and not at a high technical level.

There are still a lot of shortcomings in the application of the simultaneous-separate operation method. The tasks solved by this method are not clearly defined, rational ways to solve them have not been found.

On improving the displacement properties of injected water. The conducted theoretical research and pilot-industrial work have to a certain extent prepared the entry of waterflooding into a new period of development, into a period of increasing its efficiency through the use of physicochemical methods. Work is underway to test in field conditions methods of adding surfactants, carbon dioxide, sulfuric acid, thickeners to the injected water, as well as injecting hot water.

The tests carried out allow us to count on the fact that the use of surfactants in different conditions will increase oil recovery by about 5-10% .

The main task of enterprises and institutions is to carry out all this work accurately, competently and obtain all the necessary data on the effectiveness of the processes. Physicochemical methods in combination with waterflooding belong to the future. The wide scale of waterflooding ensures their wide application on the basis of already created field systems.

In the reports provided for in the program of the meeting, including this report, based on the experience of development, a principled approach to solving a number of basic technological provisions of waterflooding methods has been defined. This should help to ensure that the development systems recommended by design organizations meet the requirements of the national economy as much as possible from the very beginning of the commissioning of new fields and are justified in a differentiated manner, taking into account their geological and physical conditions. It has not yet been possible to achieve this. The projects submitted in recent years do not yet sufficiently meet these requirements. In some areas, preference is given to any one waterflooding system, and it is believed that it is quite effective in almost all geological and physical conditions.

There are cases when, for deposits with identical geological and physical conditions, systems that are significantly different from each other are adopted, and vice versa, for deposits with sharply different characteristics, systems that are close in intensity.

These are just some examples, but they also speak of serious shortcomings and the need to develop a common approach, common criteria for justifying development systems.

Research and design institutes need to accelerate the restructuring of design work on the development of oil fields, make the most of the advantages of integrated design and provide justification for development systems that are most appropriate from a national economic point of view.

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