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EXPERIMENTAL-INDUSTRIAL TESTS OF THE IMPACT OF WATER–GAS (HBV) TECHNOLOGY IN COMBINATION WITH THICKENED WATER IN KALAMKAS FIELD

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Abstract

It is well known that viscous oil displacement process is optimized with thickened water injection. For example to form thickened water a high molecular weight polyacrylamide (PAM) dilute in water with a concentration of 0.05-0.1%. The process is carried out until 20% of the formation pore volume injected, afterwards pushed with ordinary water, which results in a stable displacement, close to piston-like displacement (the water fingering become more homogenous). The absence of a gas component in thickened water injection technology makes displacement of viscous oil relatively less efficient. Thus advisable to combine SWAG injection with thickened water technology.

Keywords:
Simultaneously water
Alternative gas;
Water injection;
Thickened water;
Polyacrylamide (P_{am});
Oil displacement;
Pore volume.

Nowadays, the number of mature oilfields rapidly increases and EOR ranking becomes more critical tool for engineers. Comparison and analysis of a wide range technologies and techniques turn into intense procedure [1-3].

In oil and gas exploration, various methods are used to displace the products of hydrocarbons from productive formation by treating them with water, aqueous solutions of various agents (surfactants, polymers, acids, and alkalis), gases (hydrocarbon, carbon dioxide, inert), or water–gas mixtures [4-8].

The «KazNIPIoilgas» project of the Scientific Research Institute of JSC reveals that water–gas technology (HBV) is considered a promising direction in enhancing oil recovery [9,10]. Under the project «VNIIoil» the JSC researched a variety of issues for several years, including filtration studies on the core, to enhance the development of oil and gas fields using HBV. It recommended an optimal ratio of the gas to the water phase in reservoirs in the range 0.2–0.4 [11,12].

Recent years have witnessed the commercialization of HBV technology and its deployment to oil and gas fields in the Russian Federation. This has proven to be effective in certain geological and economic conditions [13]. An advantage of HBV technology is that it allows the use of the associated gas in cases where other methods of its use would be unprofitable.

Experimental-industrial work on impact of water–gas (HBV) technology in Kalamkas field

In 2008, on behalf of JSC Mangystauoilgas, the JSC under project KazSRPIoilgas compiled the «Refined project on the development of Kalamkas field» [14] The project envisaged the development of the field using water–gas impact (HBV). However, HBV technology had not been used in deposits in the Republic of Kazakhstan (RK) and, in particular, at the Kalamkas field; therefore, the Central Committee of the RK required the verification of this technology in an experimental section of the Kalamkas field. According to the requirements of the Central Committee, JSC «KazSRPIoilgaz along with JSC Mangystauoilgas developed HBV in the pilot section of the field to justify its full-scale implementation.

Within the framework of this work, a pilot site in the eastern part of the Yu-1S horizon was selected, and a three-dimensional (3D) geological and hydrodynamic model of the experimental site was constructed and tested at wells in the experimental site. A computer simulation of the processes was executed under two variants of development: Option 1, basic, providing for further development of the operational object under the given system; and Option 2, providing for the development of an operational facility with the implementation of HBV technology [15].

To evaluate the effectiveness of HBV technology, the institute VSRIoil was involved in this research. The results of filtration studies on the core material confirmed the effectiveness of this technology, and

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an optimal ratio of the gas to the water phase in the range 0.2–0.5 was recommended [16].

While assessing forecast options for the implementation of HBV, optimizing the recommended gas-to-water phase ratio within narrower limits has been proposed in light of certain considerations. It is known, for example, that the profile of oil displacement in the reservoir by a working agent with density in reservoir conditions is not equal to the density of oil. In reservoir conditions as a rule, it is formed not vertically but, depending on the density of the displacing agent, gravitates toward the lower or upper formation of the reservoir [17]. The HBV process seems to be most effective (approaching piston displacement) in the case where a water–gas mixture is used as a displacing working agent, with density equal to the density of displaced oil ϱorv, in reservoir conditions, i.e., the condition [18]

$$\rho_{HBV_N} = \rho_{orv},\ \mathrm{kg/m^3} \tag{1}$$

provided by the following:

- gas consumption, in reservoir conditions, determined by the equation

$$Q_{rv\ HBVrv} = \frac{Q_{smv\ HBVrv}\left(\rho_{wrv} - \rho_{grv}\right)}{\left(\rho_{wrv} - \rho_{grv}\right)}\ ,\ \mathrm{kg/m^3} \tag{2.1}$$

Eq. (2) is derived by the solution with respect to $Q_{rvHBVrv}$ of the equation

$$\rho_{HBVrv} = \frac{\left(\rho_{grv}\, Q_{rv\ HBVrv} + \rho_{wrv}\, Q_{wrv\ HBVrv}\right)}{Q_{sm\ v\ HBVrv}},\ \mathrm{kg/m^3}\ \text{and} \tag{3}$$

- the flow of water, in reservoir conditions, determined by the equation

$$Q_{wrv\ HBVrv} = (Q_{smrv\ HBVrv} - Q_{rv\ HBVrv}),\ \mathrm{m^3/day} \tag{4}$$

where $Q_{sm\ v\ rv}$ - is the flow rate of the gas–water mixture during the implementation of HBV. In reservoir conditions, it is taken to be equal to the volume of water injected into the injection well using conventional flooding technology in compensation mode ($Q_{wv\ comp}$), based on the initial data. ρ_{grv} is the density of gas. In reservoir conditions, it is derived from the initial data. ϱwrv is the density of water that, in reservoir conditions, is determined from the equation

$$\rho_{wrv} = \rho_w\ /\ B_{grv}\ ,\quad \mathrm{kg/m^3} \tag{5}$$

where ρ_w is the density of water that is taken from the initial data; ʙwrv is the coefficient of the volumetric expansion of water that, in reservoir conditions, admits $B_{grv} \approx 1.0$; and ϱorv is the density of oil based on initial data in reservoir conditions, or determined from the equation

$$\rho_{\mathrm{orv}} = \frac{\rho_{\mathrm{o}}}{\mathrm{B}_{\mathrm{wrv}}}\ ,\quad \mathrm{kg/m^3} \tag{6}$$

In the above, ʙwrv is the coefficient of volumetric expansion of oil that is taken from initial data in reservoir conditions. Alternatively, it is determined in the laboratory according to a known nomogram:

$$B_{grv}=1+3.05\times10^{-3}G_{fv}\ \text{при}\ G_{fv}\leq400\ \mathrm{m^3/m^3} \tag{7.1}$$

$$B_{grv}=1+3.05\times10^{-3}(G_{fv}-58)\ \text{by}\ G_{fv}>400\ \mathrm{m^3/m^3} \tag{7.2}$$

where ρ_o the density of oil and G_{fv} is the gas factor from initial data.

However, HBV technology, as applied to conditions at the Kalamkas field, required determining the nature of the displacement front in the formation as a function of the ratio of mobility of the displaced to the displacing agents under specific conditions. The movement of the water–oil contact became unstable with respect to the viscosities of oil and the displacing agent in reservoir conditions, exceeding the limits recommended by the condition [19]

$$7 \leq \bar{\mu}(\bar{\mu} = \mu_{orw}\ /\ \mu_{wrv}) \leq 13 \tag{8}$$

where $\bar{\mu}_{rv}$ is relative viscosity, $\bar{\mu}_{rv}$ =μorv/$\mu_{w\ thickened\ rv}$; μ_{orv} is the viscosity of oil in reservoir conditions; and $\mu_{w\ thickened\ rv}$ is the viscosity of thickened water in reservoir conditions.

The nature of the water–oil contact during the development of viscous instability was obtained from the results of filtration studies on the core [20].

Thus, if, in the implementation of HBV technology the ratio of the viscosity of oil to that of the water–gas mixture in reservoir conditions is in the range

$$7 > \bar{\mu}\left(\bar{\mu} = \frac{\mu_{\mathrm{orv}}}{\mu_{\mathrm{wrv}}}\right) > 13 \tag{9}$$

the HBV process is unstable. This leads to a faster breakthrough in the water and gas mixture to the production wells, an increase in the rate of water production, the extraction of significant amounts of water along with oil, irrational gas consumption, and a reduction in the final oil recovery coefficient (ORC).

To optimize the process of displacement of viscous oil into the reservoir, an aqueous solution of thickened water is pumped—for example, in the form of an aqueous solution of a highly soluble polyacrylamide (PAA) with high molecular weight in water with a concentration of 0.05%–0.1%. The process is carried out until a rim is formed in the productive plate, which is approximately 20% of the pore volume of the formation. It is then pushed with ordinary water, which results in a steady displacement close to piston displacement (the length of the instability of the languages is very small) [21].

According to the results of industrial introduction, oil expansion by thickened water is effective; however, its implementation to the recommended wide range of boundary conditions of the interrelation of oil and water $\left(7 \leq \bar{\mu} \leq 13\right)$—determined by Eq. (8)—requires optimization. A method has been proposed to optimize the oil/water relationship in reservoir conditions [22].

However, in the displacement of oil by thickened water, the absence of a gas component in the working agent renders the displacement of viscous oil less efficient. It is thus advisable to combine HBV with the use of thickened water.

Observation of the boundary conditions of the ratio of the viscosity of oil to that of the water–gas mixture in reservoir conditions is recommended as defined by Eq. (8) for sustainable oil displacement by the working agent, and can be achieved by exposing the formation to a water–gas mixture in which thickened water is used as aqueous phase.

Thus, to increase the efficiency of the development of a productive reservoir of oil and gas, and increase the final ORC, improving HBV technology is proposed with the following:

- the ratio of the injected volume of gas to that of water in the water–gas mixture in reservoir conditions within the recommended limits of K_{HBVrv}= 0.2–0.5[2.6] determined by the formula

$$K_{HBVrv}=Q_{g\ v\ HBVrv}/Q_{e\ v\ HBVrv} \tag{10}$$

- giving the front displacement of the vertical profile by pumping into the water–gas mixture in reservoir conditions at a density equal to that of oil in the reservoir, according to the condition determined by Eq. (1) [18]

$$\rho_{WGMrv}=\rho_{wrv},\ \text{kg/m}^3$$

- by providing the flow rate of the water–gas mixture ($Q_{WGM\ v\ rv}$) in the flow:

Gas, in reservoir conditions, determined by Eq. (2.1)

$$Q_{\text{gv HBVrv}}=\frac{Q_{\text{m v HBVrv}}\left(\rho_{\text{w thickened rv}}-\rho_{\text{orv}}\right)}{\left(\rho_{\text{w thickened rv}}-\rho_{\text{grv}}\right)},\ \text{kg/m}^3 \quad (2.2)$$

Water, in reservoir conditions, determined by Eq. (4)

$$Q_{wv\ HBVrv}=(Q_{m\ v\ HBVrv}-Q_{gv\ HBVrv}),\quad \text{m}^3/\text{day}$$

where $\rho_{wthickenedrv}$ is the density of thickened water in reservoir conditions that admits an equal density of ordinary water, i.e., $\rho_{wthickenedrv}=\rho_w$; ρ_{orv} and ρ_{grv} are the densities of oil and gas in reservoir conditions determined by initial data; and $Q_{m\ v\ rv}$ is the water–gas mixture rate pumped into the reservoir, determined by

$$Q_{m\ v\ HBVrv}=Q_{wv\ comp.rv},\quad \text{m}^3/\text{day} \tag{11}$$

where $Q_{wv\ comp.}$ is the volume of water pumped into the well in the compensation mode using conventional flooding technology in reservoir conditions, and is determined from initial data;

- ensuring the stability of the front for the displacement of the water–gas mixture (HCV) to ensure that its viscosity is within the limits recommended by the ratio of the viscosity of its constituent oil to that of the water–gas mixture in reservoir conditions corresponding to the boundary conditions in Eq. (8) [9]:

$$7\le\mu\left(\mu=\frac{\mu_{orv}}{\mu_{wrv}}\right)\le 13$$

- ensuring the optimal viscosity of HBV ($\mu_{HBV\ rv}$) corresponding to the maximum volume of oil $\sum Q_o$, the maximum HBV extracted from the reservoir for the entire period of its development by the HCV rim, followed by its normal water flow determined by plotting the functional dependence of the HCVs of different viscosities on the corresponding volumes of oil displaced for the entire period of development;
- ensuring the optimal value of viscosity for the HCV corresponding to the boundary conditions according to the ratio in Eq. (8) and the maximum volume of oil $\Sigma Q_{o\ HBV\ \max}$ extracted from the production reservoir for the entire period of its development by the HCV rim with its subsequent advancement by ordinary water; further, ensuring the correspondence between this value and the viscosity of thickened water, which is determined by solving the equation proposed by Einstein

$$\mu_{HCV\ rv\ opt}=\mu_{w\ thickened\ rv\ opt}\quad \mu_{HCV\ rv\ opt}\,(1+y\phi_{g\ HCV\ rv}) \tag{12}$$

relative to the viscosity of thickened water

$$\mu_{w\ thickened\ rv\ opt}=\mu_{HCV\ rv\ opt}/(1+y\phi_{g\ HCV\ rv}) \tag{13}$$

- along with the optimal value of the viscosity of thickened water ($\mu_{w\ thickened\ rv\ opt}$), determined by Eq. (12), ensuring the correspondence of this value with the equality of the densities of oil and the displacing agent in reservoir conditions, ($\rho_{HCV\ rv}=\rho_{o\ rv}$), thus transforming Eq. (13) into the following form:

$$\mu_{\text{w thickened rv opt}}=\mu_{\text{HCV rv opt}}\Big/\left(1+Y\frac{\left(\rho_{\text{w thickened rv}}-\rho_{\text{o rv}}\right)}{\left(\rho_{\text{w thickened rv}}-\rho_{\text{g rv}}\right)}\right) \tag{14}$$

where $\mu_{w\ thickened\ rv\ \text{opt}}$ and $\mu_{HCV\ rv\ opt}$ are the optimum viscosities of thickened water and the water–gas mixture (HCV); y is a coefficient recommended at Y= 2.4; and $\varphi_{g\ HCV\ rv}$ is the coefficient of the true volumetric gas content of the water–gas mixture (HCV) in reservoir conditions. To observe the equality of the densities of oil and the displacing agent in formation conditions ($\rho_{HCV\ rv}=\rho_{o\ rv}$) according to the condition in Eq. (1), the value of the true volumetric gas content coefficient ($\varphi_{g\ HCV\ rv}=Q_{gv\ HVB\ rv}/Q_{mixt\ v\ rv}$) is replaced (see Eq. (2.2)) by the corresponding $K_{HVB\ rv}$ (see Eq. (10));

- optimizing oil displacement by the water–gas mixture (HCV) by pumping into the reservoir of the rim of the HCV using the coefficient of the true volumetric gas content ($\rho_{HCV\ rv}=\rho_{o\ rv}$), the value of which, when ($\rho_{HCV\ rv}=\rho_{o\ rv}$) according to Eq. (1), is determined by

$$\varphi_{\text{g HCV rv}}=\frac{\left(\rho_{\text{w thickened rv}}-\rho_{\text{o rv}}\right)}{\left(\rho_{\text{w thickened rv}}-\rho_{\text{g rv}}\right)} \tag{15}$$

The optimal value of HCV viscosity, as expressed by Eq. (12), depends on the optimum value of the viscosity of the thickened water (in the thickening area) as well as on the value of the true volume gas content coefficient ($\varphi_{g\ HCV\ rv}$). Therefore, it is necessary to transform Eq. (13) and, consequently, Einstein's Eq. (12) into Eq. (14) by expressing the value of $\varphi_{g\ HCV\ rv}$ in terms of dependence using Eq. (15). When the condition ensuring the equality of the densities of oil and the working agent is accepted for implementation to reservoir conditions, i.e., the condition ($\rho_{HCVrv}=\rho_{o\ rv}$) by Eq. (1), the value of $\varphi_{g\ HCV\ rv}$ needs to be determined by Eq. (15).

Procedure for the implementation of HBV technology using thickened water as aqueous component

The proposed HBV technology using water as aqueous component was implemented in the following way:

- On the basis of a geological study of the deposit, a geological model of the operational object was constructed and the expediency of implementing HBV technology was preliminarily justified (in terms of formation depth, reservoir pressure and temperature values, volume of oil recovered, oil viscosity in reservoir conditions, presence of hermetic covers of reservoirs, and absence of tectonic disturbances).

- Based on the results of the geological model, a hydrodynamic model of the same operational facility was constructed; further, preliminary clarifications of the feasibility of implementing HBV (for the residual volume of recovered oil, heterogeneity of permeability of the reservoir, and states of the producing and injection wells) were made.
- Based on the results of the geological and hydrodynamic modeling or other known calculation methods, considering the stratified- and zonal-inhomogeneous formation scheme for the entire lifecycle of the operational facility, the following were determined:
  - volume of oil displaced by injection of ordinary water $\Sigma Q_{o\,1}$ (basic version);
  - different values of the ratio of the viscosity of oil to that of the water–gas mixture (thickened water $\mu_{w\ thickened\ rv}$) in reservoir conditions, ranging from actual to recommended values within the limits of the condition in Eq. (8), presented in the form

    $7 \leq \mu_{HCV\ thickened\ rv}\ (\mu_{HCV\ thickened\ rv} = \mu_{o\ rv}/\mu_{HCV\ thickened\ rv}) \leq 13$

and, within the limits of these ratios, the corresponding values of the viscosity of the thickened water–gas mixture: the solution of the inequality in Eq. (8) with respect to $\mu_{\mathrm{HCV\ thickened}\ rv\ n}$

$$\frac{\mu_{\mathrm{o\ rv}}}{7} \geq \mu_{\mathrm{HCV\ thickened\ rv}} = \frac{\mu_{\mathrm{o\ rv}}}{13} \qquad (16)$$

The results are summarized the results in table 1.

- The volumes of oil (f.e:, $\Sigma Q_{o.g\ recov.1}$ approved., approved by ЦКР RK), $\Sigma Q_{o.g\ recov.2}$, $\Sigma Q_{o.g\ recov.3}$,…, $\Sigma Q_{o.g\ recov.\ n}$, recovered for the entire period of development of the operational object were calculated based on the results of geological and hydrodynamic modeling or using other known calculation methods. This considered the -stratified and zonal-inhomogeneous formation scheme from the actual viscosity of water in reservoir conditions at different values of the viscosity of the working agent, which was determined within boundary limits by Eq. (8) $\mu_{w\ rv\ 1}$ ($\mu_{HCV\ thickened\ rv\ 2}$, $\mu_{HCV\ thickened\ rv\ 3}$, …, $\mu_{HCV\ thickened\ rv\ n}$).
- The functional dependence of the values of the viscosity of water $\mu_{w\ rv}$ (thickened water–gas mixture $\mu_{w\ thickened\ rv\ n}$), in reservoir conditions was graphically determined within the limits recommended by Eq. (8), from the corresponding total volumes of recovered oil for the entire period of development of the reservoir $\Sigma Q_{o.g\ recov.1}$ approved, $\Sigma Q_{o.g\ recov.2}$, $\Sigma Q_{o.g\ recov.3}$, …,$\Sigma Q_{o.g\ recov.\ n}$ in the form of a functional curve $\mu_{w\ rv\ (\mu w\ thickened\ rv}) = f\Sigma Q_{o.g\ recov.n}$, presented as an example in figure 1.
- From the graphical representation of functional dependence $\mu_{\mathrm{w\ rv}}$ ($\mu_{\mathrm{HCV\ thickened\ rv}}$) = $f\Sigma \mathrm{Q}_{\mathrm{o.g\ recov.n}}$ the optimum value of the viscosity of the working agent (ordinary water $\mu_{\mathrm{w\ rv\ or}}$ the thickened water–gas mixture $\mu_{\mathrm{HCV\ thickened\ rv}}$) was determined, which provided the maximum total volume of recoverable oil for the entire period of development of the reservoir (fig.1).
- was determined by the optimal value of the viscosity of the working agent (ordinary water $\mu_{\mathrm{w\ rv\ or}}$ thickened water–gas mixture $\mu_{HCV\ rv\ opt}$) in reservoir conditions, and the optimum value of the viscosity of thickened water, in reservoir conditions ($\mu_{\mathrm{w\ thickened\ rv}}$), by solving Eq. (12) with respect to this quantity by Eq. (13):
- It was ensured that the densities of the displaced oil and the displacing working agent were identical in reservoir conditions ($\rho_{o\ rv} = \rho_{HCV\ rv}$), according to the condition in Eq. (1), by calculating the viscosity of the liquid component of the displacement agent (HCV) by Eq. (14):

$$\mu_{\mathrm{w\ thickened\ rv\ opt}} = \frac{\mu_{\mathrm{HCV\ rv\ opt}}}{1 + Y\dfrac{\left(\rho_{\mathrm{w\ thickened\ rv}} - \rho_{\mathrm{o\ rv}}\right)}{\left(\rho_{\mathrm{w\ thickened\ rv}} - \rho_{\mathrm{g\ rv}}\right)}}$$

The volume of the water–gas mixture (HCV) pumped into the production reservoir of the field was determined to create a rim with a volume 20% of the pore volume of the formation according to the formula (it was assumed that the pore volume of the formation was equal to the maximum volume of oil in reservoir conditions extracted over the entire period of its development)

$$\Sigma Q_{mixt.v\ HCV\ rv} = 0.2\Sigma Q_{o.g\ HBV\ max} / \rho_{o\ rv},\ \mathrm{m}^3 \qquad (17)$$

where $\Sigma \mathrm{Q}_{\mathrm{ogHBV\ max}}$ (HCV) is the maximum amount of oil recovered over the entire period of development of the productive reservoir by displacing the optimal viscosity $\mu_{\mathrm{HCV\ rv\ opt}}$ in a volume of 0.2 from the pore volume of the reservoir, and pushing it with ordinary water determined by the curve dependences $\mu_{HCV\ rv} = f\Sigma Q_{og\ recov}$ (fig.1). $\rho_{o\ rv}$ is the density of oil, in reservoir conditions, taken from the initial data.

Table 1

Different values of relative viscosity μ (the ratio of the viscosity of oil $\mu_{\mathrm{o\ rv}}$ to thickened water $\mu_{\mathrm{w\ thickened\ rv}}$) and the corresponding values of viscosities of thickened water μw rv, in reservoir conditions within the limits recommended by the condition in Eq. (8)

With oil viscosity, in reservoir conditions, 17.6 cps, the values of dimensionless viscosity value ($\bar{\mu}$)						
$\bar{\mu}$	25	15	13	11	9	7
Corresponding values of water viscosity $\mu_{\text{в пл}}$ (thickened water $\mu_{\mathrm{w\ thickened\ rv}}$)						
$\mu_{\mathrm{w\ rv}}$ ($\mu_{\text{HCV thickened пл}}$)	0.7	1.173	1.354	1.6	1.95	2.51

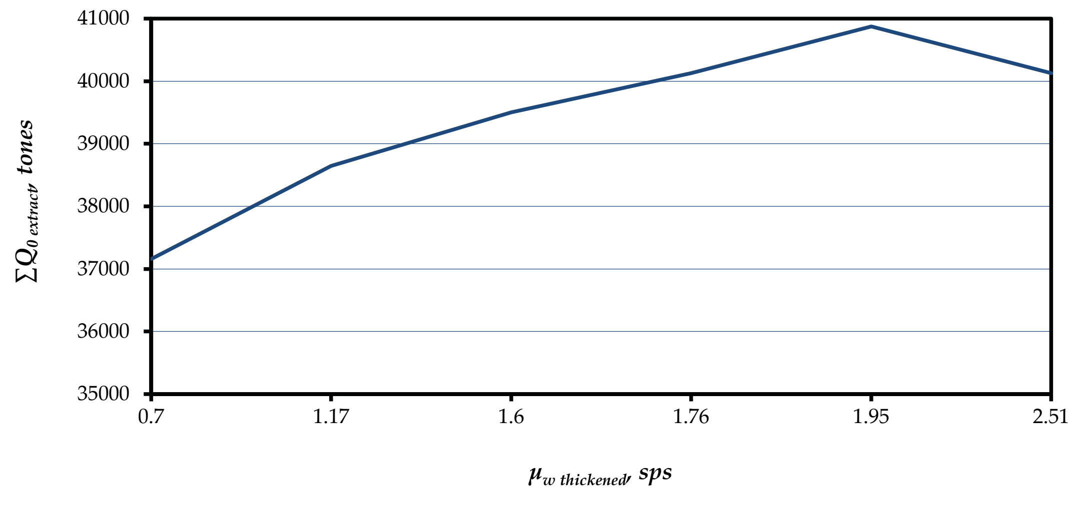

Fig.1. Layer-inhomogeneous reservoir of hypothetical deposit A. The curve of dependence of the volumes of oil extracted from the operational object for the entire period of development using the rim of the water–gas mixture (HCV) of various viscosities

- The optimal concentration of the aqueous solution of the thickening reagent was determined, which corresponded to the optimal value of the viscosity of the thickened water in reservoir conditions ($\mu_{\text{wthickenedrv opt}}$). This was determined by Eq. (14) by using the laboratory results of the effects of the curve of functional dependence of the viscosity of thickened water on the concentration in the solution of the thickening reagent ($\mu_{\text{wthickenedrv}}=f(C_{(\text{reagent thickener})}\%)$, and finding the optimum value of its concentration in the aqueous thickener reagent solution ($C_{(\text{reagent thickener})\ \text{opt}}\%$).
- The optimum consumption of the reagent thickener in the form of dry powder was determined during the pumping of thickened water into the water–gas mixture (HCV), with the creation of a thickened HCV rim with a volume 20% of the pore volume of the reservoir by the formula

$$G_{(\text{reagent thickener})\ \text{opt}} = \frac{1000C_{(\text{reagent thickener})\text{opt}}Q_{\text{wv HBVrv}}}{100 - C_{(\text{reagent thickener})\text{opt}}} \qquad (18)$$

where $\Sigma Q_{wvHBVrv}$ is the volume of water in the water–gas mixture (HCV) pumped into the productive stratum of the oil and gas field when creating an optimal viscosity rim $\mu_{\text{HCVrv opt}}$ with a volume 20% of the pore volume of the reservoir, and determined by Eq. (4) above. $C_{(\text{reagent thickener})\ \text{opt}}$ is the optimal mass concentration of the thickening reagent in the aqueous solution of optimum viscosity, mw thickened rvopt, and is determined by the functional dependence of this value on the viscosity of the thickened water ($\mu_{\text{w thickened rv}}=fC_{\text{reagent-thickener}}$) by plotting the results of laboratory studies.

- The duration of implementation of water–gas impact (HBV) was determined, for which a rim was created, according to the formula

$$T_{year}=\Sigma SQ_{wv\ HCVrv}/N_{well}\ Q_{mixt.v\ HCVrv}\times 365,\ \text{year} \qquad (19)$$

where N_{well} is the number of injection wells taken from the initial data; and $Q_{mixt.vHCV\ rv}$ is the HCV volume in reservoir conditions injected into a well. It was taken from the original data according to the compensation condition in Eq. (11) $Q_{mixt.vHCV\ rv}=Q_{wv\ comp.\ rv}$.

Having determined the parameters of water–gas impact (HBV) using thickened water, we began implementing the process.

MangistauOilGas JSC plans to begin construction of the pilot site at the Kalamkas field to test HBV. It is recommended that thickened water be used as an aqueous component.

Example of implementation of HBV technology using thickened water as liquid component

An approximate scheme for implementing a method to develop a productive reservoir of an oil field using HBV, in which thickened water is used as liquid component, is shown in figure 2.

For the formation and stabilization of a foam-like water–gas mixture of required viscosity in the water flow coming from booster pump 2 to the input to pumping-booster unit 3, feeding for the thickener was provided by means of the block dosing installation (Br-10 type 9) with foaming surfactants (such as alkyl benzene sulfonate; synthetic, anionic, environmentally friendly and biodegradable surfactants, such as sulphonol and proxanol), as defined by the optimal concentration of flow ($C_{(\text{reagent-thickener})\ \text{opt}}$), by plotting the viscosity of the thickened water concentration in a solution of thickener $\mu_{\text{wthickenerrv}}=f(C(\textit{reagent-thickener})\ \%)$ (fig.2).

Having carried out the calculations of the necessary parameters of the process of HBV in accordance with the developed methodology and using the thickened water as aqueous component, implementation was undertaken.

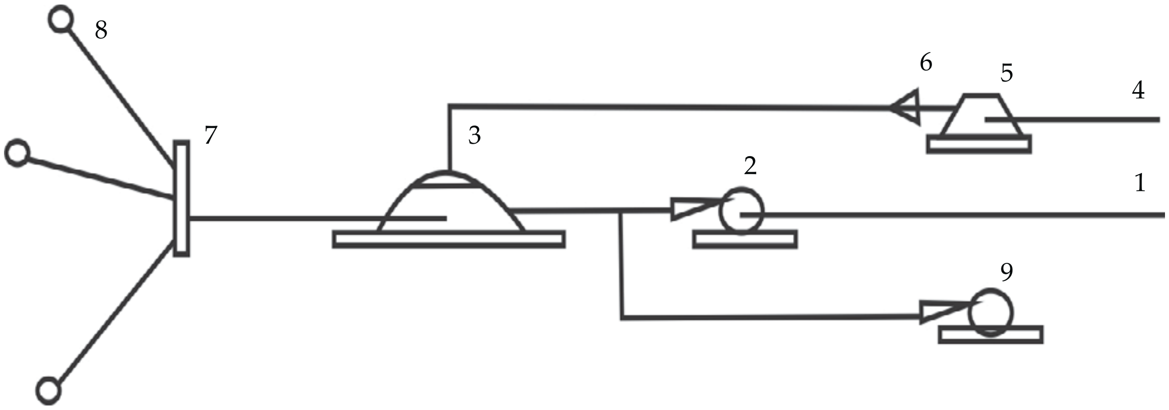

Fig.2. Technological scheme of HBV using a pump booster unit
1 - technical water supply; 2 - support pump; 3 - pump booster unit;
4 - gas pipeline from the gas source; 5 - booster compressor; 6 - pressure regulator;
7 - water distribution unit (VRB); 8 - injection wells; 9 - block batcher type Br-10)

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Опытно-промышленные испытания технологии водогазового воздействия (ВГВ) с применением загущенной воды на месторождении «Каламкас»

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Реферат

Известно, что процесс вытеснения вязкой нефти можно оптимизировать закачкой загущенной воды. Например, для получения загущенной воды высокомолекулярный полиакриламид разбавляют в воде до концентрации 0.05-0.1%. Технология осуществления процесса заключается в закачке оторочки данного состава в объеме 20% от порового пространства пласта, с последующим вытеснением обычной водой. При этом характер вытеснения нефти близок к поршневому и более стабилен по сравнению с заводнением. Отсутствие газовой составляющей в технологии закачки загущенной воды делает вытеснение вязкой нефти относительно менее эффективным. При этом целесообразно сочетать нагнетание ВГС с технологией загущенной воды.

Ключевые слова: водогазовое воздействие; заводнение; загущенная вода; полиакриламид; вытеснение нефти; поровый объем.

«Kalamkas» yatağında qatılaşdırılmış suyun istifadəsilə su-qaz qarışığının vurulması texnologiyasının təcrübi-sənaye sınaqlarının aparılması

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Xülasə

Məlumdur ki, özlü neftin sıxışdırılması prosesini qatılaşdırılmış suyun vurulması ilə optimallaşdırmaq olar. Məsələn, qatılaşdırılmış suyun alınması məqsədilə suda yüksək molekulyar poliakrilamidi 0.05-0.1% qatılığına qədər həll edirlər. Texnologiyaya uyğun olaraq prosesin həyata keçirilməsi zaman tərkibdən ibarət haşiyə layın məsamə fəzasının 20% həcmində laya vurularaq sonradan adi su ilə sıxışdırılır. Bununla yanaşı, neftin sıxışdırılması xarakteri porşenli sıxışdırılmaya yaxındır və suvurma ilə müqayisədə daha sabitdir. Qatılaşdırılmış suyun vurulması texnologiyasında qaz komponentinin olmaması özlü neftin sıxışdırılmasını nisbətən daha az səmərəli edir. Eyni zamanda, su-qaz qarışığının vurulmasını qatılaşdırılmış suyun vurulması texnologiyası ilə birləşdirmək daha məqsədə uyğundur.

Açar sözlər: su-qaz qarışığının vurulması; suyun vurulması; qatılaşdırılmış su; poliakrilamid; neftin sıxışdırılması; məsamə həcmi.