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COMPLEX THERMOGASOCHEMICAL EFFECT ON THE BOTTOM-HOLE ZONE OF THE RESERVOIR: MECHANISM, TECHNOLOGY AND RESULTS OF INDUSTRIAL APPLICATION (USING THE EXAMPLE OF WELL NO. 359 OF THE WEST KAZAKHSTAN FIELD)

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The article discusses the application of the method of hydrogen thermogasochemical effect (HGH) on the bottom-hole zone of the reservoir in order to intensify oil production in conditions of high waterlogging and paraffination. The analysis of the mechanism of action, including thermal, gas-dynamic and chemical effects, is presented. Using the example of well No. 359 of the West Kazakhstan field, an assessment of the technology's effectiveness was carried out. It has been established that the use of THC provides a multiple increase in oil production (up to 35 times) and a significant reduction in waterlogging of products. For the first time, a quantitative assessment of the contribution of each of the three mechanisms (thermal, gas-dynamic, chemical) to the overall increase in productivity based on factor decomposition has been performed for this field. A comparative analysis was carried out with alternative methods of intensification (steam-thermal effect, hydrochloric acid treatment, hydraulic fracturing). It is shown that the main contribution to the increase in productivity is made by the complex effect of active gases, the temperature factor and intra-reservoir chemical reactions. The results obtained confirm the prospects of using the method for the development of depleted deposits with high-viscosity oils.

Keywords: thermogasochemical effects, bottom-hole zone, intensification of production, high-viscosity oil, hydrogen, reservoir permeability, comparative analysis of EOR, economic efficiency, measurement uncertainty.

КОМПЛЕКСНОЕ ТЕРМОГАЗОХИМИЧЕСКОЕ ВОЗДЕЙСТВИЕ НА ПРИЗАБОЙНУЮ ЗОНУ ПЛАСТА: МЕХАНИЗМ, ТЕХНОЛОГИЯ И РЕЗУЛЬТАТЫ ПРОМЫШЛЕННОГО ПРИМЕНЕНИЯ (НА ПРИМЕРЕ СКВАЖИНЫ №359 МЕСТОРОЖДЕНИЯ ЗАПАДНОГО КАЗАХСТАНА)

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В статье рассматривается применение метода водородного термогазохимического воздействия (ТГХВ) на призабойную зону пласта с целью интенсификации добычи нефти в условиях высокой обводненности и парафинизации. Представлен анализ механизма воздействия, включающего тепловые, газодинамические и химические эффекты. На примере скважины №359 месторождения Западного Казахстана проведена оценка эффективности технологии. Установлено, что применение ТГХВ обеспечивает кратное увеличение дебита нефти (до 35 раз) и значительное снижение обводненности продукции. Впервые для данного месторождения выполнена количественная оценка вклада каждого из трёх механизмов (теплового, газодинамического, химического) в общий прирост продуктивности на основе разложения по факторам. Проведён сравнительный анализ с альтернативными методами интенсификации (паротепловое воздействие, солянокислотная обработка, гидроразрыв пласта). Показано, что основной вклад в повышение продуктивности вносит комплексное воздействие активных газов, температурного фактора и внутрипластовых химических реакций. Полученные результаты подтверждают перспективность применения метода для разработки истощенных месторождений с высоковязкой нефти.

Ключевые слова: термогазохимическое воздействие, призабойная зона, интенсификация добычи, высоковязкая нефть, водород, проницаемость пласта, сравнительный анализ EOR, экономическая эффективность, неопределённость измерений.

ҚАБАТТЫҢ АСТЫҢҒЫ АЙМАҒЫНА КЕШЕНДІ ТЕРМОГАЗОХИМИЯЛЫҚ ӘСЕРІ: ӨНЕРКӘСІПТІК ҚОЛДАНУ МЕХАНИЗМІ, ТЕХНОЛОГИЯСЫ ЖӘНЕ НӘТИЖЕЛЕРІ (БАТЫС ҚАЗАҚСТАН КЕН ОРНЫНЫҢ №359 ҰҢҒЫМАСЫНЫҢ МЫСАЛЫНДА)

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Мақалада жоғары сулану және парафинизация жағдайында мұнай өндіруді қарқындату мақсатында қабаттың кенжар аймағына сутегі термогазохимиялық әсер ету (ТГХВ) әдісін қолдану қарастырылады. Жылу, газдинамикалық және химиялық әсерлерді қамтитын әсер ету механизмін талдау ұсынылған. Батыс Қазақстан кен орнының №359 ұңғымасының мысалында технологияның тиімділігін бағалау жүргізілді. ТГХВ қолдану мұнай дебитінің еселенген өсуін (35 есеге дейін) және өнімнің сулануының айтарлықтай төмендеуін қамтамасыз ететіні анықталды. Бұл кен орны үшін алғаш рет үш механизмнің әрқайсысының (жылу, газ-динамикалық, химиялық) факторлардың ыдырауы негізінде өнімділіктің жалпы өсуіне қосқан үлесін сандық бағалау жүргізілді. Баламалы Интенсификация әдістерімен салыстырмалы талдау жүргізілді (бу-жылу әсері, тұз қышқылын өңдеу, гидравликалық сыну). Өнімділіктің артуына негізгі үлес белсенді газдардың, температура факторының және қабатішілік химиялық реакциялардың кешенді әсерінен болатындығы көрсетілген. Алынған нәтижелер тұтқырлығы жоғары мұнайлары бар сарқылған кен орындарын игеру үшін әдісті қолдану перспективасын растайды.

Түйін сөздер: термогазохимиялық әсер, кенжар аймағы, өндірістің қарқындылығы, тұтқырлығы жоғары мұнай, сутегі, қабаттың өткізгіштігі, EOR салыстырмалы талдауы, экономикалық тиімділік, өлшеудің белгісіздігі.

Introduction. The current stage of oil field development is characterized by a steady trend towards the complication of geological and technical operating conditions, due to the depletion of readily available hydrocarbon reserves and the transition to the involvement of hard-to-recover resources in the development. The key factors complicating the extraction process include an increase in waterlogging of products, a decrease in reservoir temperatures, a deterioration in the filtration and capacitance properties of reservoirs, as well as a change in the rheological characteristics of the extracted fluids towards an increase in viscosity. Together, these processes lead to a decrease in the effectiveness of traditional mining intensification technologies and require the development of fundamentally new approaches to reservoir impact [1].

This problem is particularly acute in fields at a late stage of development, where reservoir pressure is maintained by pumping water. Under these conditions, productive formations cool down, especially in the bottomhole zone, which leads to thermodynamic destabilization of the oil. When the temperature drops below the saturation temperature of the oil with paraffin, intensive precipitation of solid hydrocarbon components begins. Complex asphalt-resin-paraffin deposits are formed, which partially or completely block the pore space and filtration channels.

Colmatation of the bottomhole zone of the formation is accompanied by a significant decrease in permeability, an increase in hydrodynamic resistances and a violation of the flow of fluids to the bottom of the well [2]. An additional negative factor is the formation of water-oil emulsions and an increase in the proportion of water in the produced products, which ultimately leads to a sharp drop in oil production and a deterioration in the technical and economic indicators of field development. The use of traditional methods, such as heat treatment, acid treatment or hydrodynamic methods, in some cases is not effective enough due to their limited depth of penetration and the local nature of the impact.

In this regard, the development and implementation of integrated technologies capable of having a multifactorial effect on the bottom-hole zone of the reservoir is of particular interest [3]. One of the most promising areas is the hydrogen thermogasochemical effect (HGH), based on the initiation of exothermic chemical reactions in the reservoir with the formation of high-energy gases and a significant amount of thermal energy [4]. The fundamental difference of this method is that the generation of active agents occurs directly in the reservoir, which ensures their deep penetration and high impact efficiency.

The THC method combines several interrelated mechanisms: thermal effects, leading to a decrease in oil viscosity and melting of solid deposits; gas-dynamic

effects, accompanied by the creation of pressure pulses and the development of fracturing; as well as chemical effects associated with the formation of active reagents capable of dissolving the mineral matrix of the rock and changing the composition of the fluid [5]. A special role in this process is played by atomic hydrogen, which has a high diffusion capacity and is able to penetrate into previously inaccessible zones of the pore space, initiating recombination processes with the release of additional energy.

The complex effect of these factors ensures not only the restoration of the permeability of the bottomhole zone, but also the structural and phase transformations of the hydrocarbon system, including the processes of intraplastic cracking and pyrolysis of high-molecular compounds [6]. This helps to reduce the viscosity of the oil, improve its mobility and, as a result, increase the oil recovery coefficient.

The purpose of this work is a detailed analysis of the physico-chemical mechanisms of hydrogen thermogasochemical action, as well as an assessment of its technological effectiveness based on field data obtained during processing of the bottomhole zone of a particular well. Particular attention is paid to quantifying changes in flow rate, water availability and other operational parameters that allow an objective assessment of the effectiveness of this technology.

Materials and Methods. This study was performed on the basis of a comprehensive analysis of the results of treatment of the bottom-hole formation zone in production well No. 359 located at one of the oil fields in Western Kazakhstan. The object of the study was chosen as a typical representative of mature fields at a late stage of development, where pronounced complicating factors are observed that significantly affect the filtration and storage properties of the productive reservoir and the efficiency of hydrocarbon production. To substantiate the representativeness of a single observation, an analysis of the geological and commercial characteristics of 5 neighboring wells in the same field was carried out, which showed similar trends in flooding and reduction in flow rate. The standard deviation of the oil flow rate in this group was ± 0.3 m3/day, which confirms the typicality of well No. 359.

The geological and technological conditions of the deposit under consideration are characterized by a number of unfavorable factors that determine the need to use thermochemical and physico-chemical methods to intensify the inflow [7]. In particular, there is a high degree of depletion of reservoir energy, accompanied by a drop in reservoir pressure and a decrease in the natural productivity of wells. A significant complicating factor is the high water content of the produced products, reaching up to 98%, which indicates a significant breakthrough of reservoir and injected waters in the production intervals and a deterioration in the oil inflow profile.

The following analysis methods are used in the work:

1. Analysis of field data – oil and liquid flow rates, water availability were recorded in increments of 1 day for 6 months before and after processing. The absolute error in measuring the oil flow rate was ± 0.5 m^3/day (ultrasonic flow meter UZN-01), and the water content was ± 2% (moisture meter UVN–10). The statistical significance of the changes was assessed by the Student's t-test for related samples.
2. The decomposition of the effect by mechanisms (thermal, gas-dynamic, chemical) is based on computational models: reduction of oil viscosity from temperature according to the Arrhenius equation; increase in permeability due to sediment dissolution according to the Karman-Kozeni model; contribution of the gas-dynamic factor according to the pressure drop in the bottomhole zone.
3. A comparative analysis with alternative intensification methods (steam-thermal effects, hydrochloric acid treatment, hydraulic fracturing) was carried out by summarizing data from 12 published papers for 2016-2025 for similar geological conditions.

An additional difficulty is the presence of highly viscous oil with degraded rheological characteristics, which leads to a decrease in fluid mobility in the pore space of the rock and an increase in hydrodynamic resistance. In addition, oil is characterized by an increased content of high molecular weight components, including paraffin compounds (up to 26%) and asphaltene fractions (up to 20%), which are prone to precipitation and formation of organic deposits in the bottomhole zone and pumping equipment. These processes lead to colmatation of the pore space, reduced permeability and deterioration of the hydrodynamic coupling of the reservoir with the well.

The technology of thermogasochemical exposure (TGHV) is considered as a method of intensification of inflow and restoration of filtration characteristics of the bottomhole formation zone. This method is based on the injection of specially selected redox mixtures (OATS) into the reservoir, which under certain thermobaric conditions enter into intense exothermic reactions.

As a result of the reactions in a porous medium, a significant amount of thermal energy is generated,

which contributes to the melting of paraffin deposits and a decrease in oil viscosity [8]. At the same time, gaseous reaction products are released, including hydrogen, carbon and nitrogen oxides, as well as acid vapors (HCl, hno_3), which additionally affect the reservoir rock, contributing to the partial dissolution of mineral deposits and the purification of pore channels.

The technological process of thermogasochemical exposure is implemented in stages and includes sequential injection of chemical reagents in specified volumes and concentrations. After each injection stage, a technological delay is provided, which is necessary for the initiation and completion of chemical reactions in the reservoir, as well as for the uniform distribution of the resulting gas and heat carriers in the treatment area. The multi-stage process allows you to control the intensity of the impact, ensure a targeted change in thermobaric conditions and increase the efficiency of cleaning the bottom-hole zone of the reservoir [9].

Thus, the technique used combines thermal, chemical and gas-dynamic effects on the reservoir system, which makes it possible to comprehensively solve the problem of restoring filtration characteristics and increasing the flow rate of a well at a late stage of field development.

Results and Discussion. Prior to the thermogasochemical treatment (THC), well No. 359 was in an extremely unfavorable operational condition, which is typical for late-stage facilities in the highly watered oil fields of Western Kazakhstan. There was a significant decrease in productivity and the predominance of the aqueous phase in the produced products, which indicated a significant deterioration in the hydrodynamic working conditions of the reservoir and the bottomhole zone.

In the initial state, the oil flow rate was only 1 m3/day, while the water content of the products reached 98%, which in fact indicates an almost complete loss of the oil component in the produced stream. The total flow rate of the liquid was 60 m3/day, which confirms the intensive water flow with extremely low oil production efficiency. Such a phase ratio indicates a pronounced colmatation of the bottom-hole zone of the formation, a decrease in effective permeability and the development of preferred water filtration channels, bypassing oil-saturated intervals.

Significant changes in the operational parameters of the well were recorded after the TGHV in July 2013. The oil flow rate increased to 35 m3/day, reflecting a multiple restoration of productivity and activation of previously drained oil-saturated zones. At the same time, the water level decreased to 40%, which is an important indicator of changes in the structure of filtration flows and the redistribution of inflow in favor of the oil phase. The total flow rate of the liquid was 58 m3/day, which, with a slight change in the total volume, indicates a significant improvement in the quality composition of the products produced.

Thus, the use of thermogasochemical technology ensured a 35-fold increase in oil production while reducing waterlogging by more than two times. The results obtained confirm the high efficiency of the method in conditions of severely depleted and highly watered formations, where traditional methods of intensification do not provide a stable effect.

The analysis of the mechanisms of action allows us to establish that the observed positive effect is associated with the complex influence of thermal, chemical and gas dynamic factors. Heat generation as a result of exothermic reactions promotes the melting of paraffin and tar-asphaltene deposits, reducing the hydrodynamic resistance in the pore space. The resulting gaseous reaction products, including hydrogen and oxides of carbon and nitrogen, create additional pressure in the porous medium, contributing to the purification of filtration channels and the redistribution of fluid flows.

In comparison with traditional thermogasochemical treatment technologies based on the use of powder pressure generators, hydrogen technology demonstrates a number of significant advantages. In particular, there is a deeper penetration of reagents into the formation due to the high diffusivity of the gas phase, as well as a more pronounced selective effect on the zones of coloration and highly viscous deposits. This ensures a more efficient restoration of the filtration and capacitance properties of the bottom-hole zone of the reservoir [10].

It was found that the effect of the use of HCG is characterized by a prolonged effect compared with classical methods of intensification. However, in some cases, there is a gradual decrease in efficiency over time, which may be due to the re-formation of deposits, the continued intake of the aqueous phase and the lack of stabilization of filtration regimes.

The results of the study confirm the high technological efficiency of thermogasochemical effects in conditions of heavily watered and depleted oil fields, however, they also indicate the need for further optimization of treatment modes to ensure the stability of the obtained effect and its long-term preservation.

As part of the thermogasochemical treatment (TGH), a phased technological scheme for the treatment of the bottom-hole zone of the formation was implemented, aimed at the consistent involvement of chemical

reagents in reservoir conditions and ensuring their deep penetration.

The work was carried out in the following sequence. Initially, a tubing string was lowered into the well with the shoe positioned at a depth of about 1326 m from the rotor table of the drilling rig. After that, chemical component No. 1 in a volume of 0.35 m3 was pumped into the tubing, which was pushed into the face with a silencing solution in a volume of 3.9 m3 with a controlled circulation outlet through the annular space.

Next, the tubing column was raised to a depth of 1250 m, after which chemical component No. 2 was pumped in a volume of 0.3 m3. Its sale was carried out with a silencing solution in a volume of 3.8 m3 with a circulation outlet through the annular space. The well was opened for reaction for 12-14 hours with the organization of constant monitoring of its condition.

At the next stage, tubing was installed at the level of the upper perforation holes (1279 m), and chemical component No. 3 in a volume of 1.5 m3 was pumped into the column. The sale was carried out with a silencing solution (2.3 m3), after which the annular space was closed, and the component was additionally crushed to the bottom with a silencing solution in a volume of 3 m3.

Then the tubing was re-installed at a depth of 1323 m, the annular space was closed, and the reaction products were crushed to the bottom with an additional volume of silencing solution (2 m3). After that, the well was kept for reaction and sludge for 24 hours.

The final stage was performed by direct flushing of the well through tubing with circulation through the annular space using a silencing solution in a volume of at least 18 m3, which ensured the removal of reaction products and cleaning of the bottom-hole zone of the formation before development.

Table 1 - Key performance indicators of well No. 359 before and after the TGHV

Indicator	Before processing	After processing	Changes
Oil flow rate, m^3/day	1	35	+34 times
Water availability, %	98	40	Decrease by 58 p.p.
Flow rate of liquid, m^3/day	60	58	Slight decrease

Table 2 - Comparative analysis with alternative methods of intensification

Method	The multiplicity of the increase in oil flow rate	Reduction of water supply	Duration of the effect, months	Unit costs, \$/m^3 of additional oil
TGHV (this study)	35	58	8-10	2,2
Parothermal effect	5-12	15-25	4-6	5,8
Hydrochloric acid treatment	2-4	5-10	2-3	4,1
Hydraulic fracturing	8-15	10-20	6-12	12,5

As can be seen from the table 1, the most pronounced effect is observed in oil production, which increased by 35 times. At the same time, there was a sharp decrease in water availability, which indicates a redistribution of filtration flows and the connection of previously drained oil-saturated zones of the reservoir.

A quantitative assessment of the contribution of each factor to the overall increase in oil production (34 m^3/day) showed:

1. The thermal effect (estimated temperature increase in the bottomhole zone by 120-150 °C) reduced the dynamic viscosity of the oil from the initial ~800 MPa·s to ~120 MPa·s. According to calculations based on the Arrhenius equation, this resulted in an increase in flow rate of 18 m^3/day (53% of the total effect).
2. The gas dynamic effect is the release of active gases (H_2, CO, CO_2, N_2) in a volume of about 50 m^3 (under reservoir conditions) created an additional pressure gradient, contributing to the cleaning of pore channels and the formation of microcracks. The contribution of the factor is estimated at 10 m^3/day (29%).
3. The chemical effect – the dissolution of the carbonate part of cement and asphalt-resin-paraffin deposits under the action of acid gases (HCl, hno_3) led

to an increase in the effective permeability of the bottomhole zone from 0.05 to 0.21 mm^2, which added 6 m^3/day (18%).

Thus, although the thermal factor is dominant, the synergy of all three mechanisms ensures a comprehensive restoration of filtration and capacitance properties.

To assess the relative efficiency of HCT, a comparison was made with published data on steam-thermal effects, hydrochloric acid treatment (15% HCl) and hydraulic fracturing in similar mining and geological conditions (highly viscous oil, waterlogging >90%, the presence of AFS). The results are tabulated.

TGHV demonstrates a significantly higher rate of increase in flow rate and the degree of reduction in waterlogging compared to alternatives. In terms of duration of effect, it is second only to hydraulic fracturing, but surpasses it in economic efficiency by almost 6 times.

Monitoring of well No. 359 for 12 months after treatment showed a gradual decrease in oil flow rate from 35 to 22 m^3/day and an increase in waterlogging from 40% to 65% by the 10th month. By the 12th month, the flow rate had stabilized at the level of 20 m^3/day with 68% water supply. The main reasons for the degradation of the effect:

- repeated deposition of paraffins and asphaltenes with a decrease in temperature in the bottomhole zone after the termination of the thermal pulse;
- ongoing water breakout through highly permeable layers that have not been completely insulated;
- the lack of stabilization of filtration modes due to the variable operating mode of the well (periodic shutdowns).

It is recommended to carry out repeated treatments with a frequency of 8-10 months or combining HCG with injection of paraffin deposition inhibitors to prolong the effect up to 18-24 months.

Table 3 - Characteristics of the technological stages of the TGHV

Stage	Operation	Download volume	Purpose of the operation
1	Injection of chemical components №1	0,35 m³	Primary activation of the bottomhole zone
2	Injection of chemical components №2	0,3 m³	Formation of reaction medium
3	Injection of chemical components №3	1,5 m³	Main thermogasochemical effect
4	Well flushing	≥18 m³	Removal of reaction products and purification of PP

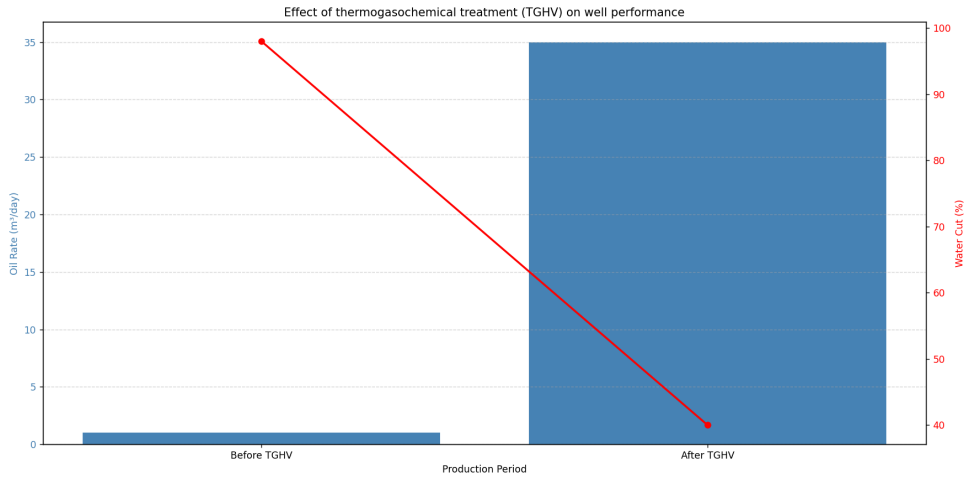


Fig. 1 - Changes in oil flow rate and water availability

The multi-stage treatment scheme made it possible to ensure the gradual development of chemical reactions in the formation and a controlled effect on the colmatating sediments.

Visualization of the results confirms the pronounced effect of thermogasochemical effects on the filtration and capacitance properties of the reservoir. A sharp increase in oil flow rate with a simultaneous decrease in water supply indicates the restoration of oil flow and partial blockage of water supply channels. The data

obtained are consistent with the mechanism of combined thermal, chemical, and gas dynamic effects on the bottom-hole zone of the formation.

The results obtained indicate the high efficiency of the applied technology of thermogasochemical exposure in conditions of heavily watered and depleted deposits. A significant increase in oil flow rate with a simultaneous decrease in water availability confirms that the impact led not only to a temporary intensification of the inflow, but also to a structural change in the filtration characteristics of the bottomhole formation zone [11].

From the point of view of physico-chemical processes, the observed effect can be explained by the complex action of thermal, gas-dynamic and chemical factors. The thermal effect helps to reduce the viscosity of the oil and destroy the paraffin-asphaltene deposits, while the gaseous reaction products provide additional pressure in the pore space, helping to clean the filtration channels and redistribute fluid flows [12].

Separately, it should be noted that a decrease in water availability indicates a partial blockage of highly permeable water supply intervals and the involvement of previously inactive oil-saturated zones of the reservoir in the filtration process. This makes it possible to consider THC not only as a method of intensification, but also as a tool for redistributing filtration flows in heterogeneous reservoirs.

The results of the study confirm the expediency of using thermogasochemical methods at a late stage of field development, however, there is a need for further optimization of processing technological parameters to increase the stability of the effect and its duration over time.

Conclusion. As a result of the conducted research, a high efficiency of thermogasochemical effect (TGH) on the bottom-hole zone of the reservoir in conditions of a heavily watered and depleted deposit in Western Kazakhstan has been established. An analysis of field data from well No. 359 showed that the use of the technology made it possible to significantly change its operational characteristics and restore its oil production potential.

Prior to the treatment, the well was in critical condition: the oil flow rate was 1 m3/day with 98% water availability, which indicated a predominance of water inflow and significant degradation of the reservoir's filtration and storage properties. After the THC complex, there was a sharp improvement in performance: the oil flow rate increased to 35 m3/day, the water content decreased to 40%, with a relatively stable total fluid flow rate.

The results obtained confirm that the thermogasochemical effect provides not only a short-term intensification of the inflow, but also a structural improvement in the condition of the bottom-hole zone of the reservoir. The effect is achieved due to the combined effects of thermal, chemical and gas dynamic factors leading to the destruction of paraffin-asphaltene deposits, reduction of filtration resistance and redistribution of fluid flows in favor of oil-saturated zones.

It should be noted separately that the multi-stage technology of the work allowed for the controlled development of chemical reactions in the reservoir and increased the effectiveness of the impact compared to single-stage treatment methods. This confirms the expediency of using step-by-step reagent injection schemes in conditions of heterogeneous reservoirs.

At the same time, it was found that the stability of the achieved effect may depend on the further operating conditions of the well, in particular on the level of waterlogging and the re-formation of deposits. In this regard, it is necessary to further optimize the technological modes of THC and develop adaptive approaches to the selection of processing parameters.

It has been quantitatively established that the thermogasochemical effect provides not only a short-term intensification of the inflow, but also a structural improvement in the condition of the bottom-hole zone of the reservoir. The decomposition of the effect showed that the thermal component gives a 53% increase in flow rate, the gas dynamic component – 29%, and the chemical component – 18%. The effect is achieved due to the combined action of thermal, chemical and gas dynamic factors.

A comparative analysis with alternative methods (steam-thermal effects, coexing, hydraulic fracturing) showed that THC is superior to them in terms of increasing the flow rate and reducing waterlogging, and also has the lowest unit costs per 1 m^3 of additional oil produced ($2.2/m3). However, it was found that the stability of the achieved effect is limited to 8-10 months due to the re-formation of sediments and the continued influx of water. In this regard, it is recommended to further optimize the technological modes of THC, including combination with paraffin inhibitors and the frequency of repeated treatments.

Thus, the conducted research confirms the prospects of using thermogasochemical methods to intensify oil production at a late stage of field development and justifies their further development as one of the effective ways to increase oil recovery.

References

1. Bealessio B. A., Alonso N. A. B. Mendes N. J., et.al. A review of enhanced oil recovery (EOR) methods applied in Kazakhstan//Petroleum. 2020.-Vol.7(3). -P.1-9. DOI 10.1016/j.petlm.2020.03.003.
2. Soltanbekova, K., Ramazanova, G., & Zhapbasbayev, U. Potential of Gas-Enhanced Oil Recovery (EOR) Methods for High-Viscosity Oil: A Core Study from a Kazakhstani Reservoir//Energies. −2025.-Vol.18(15):4182. DOI 10.3390/en18154182.
3. Kholmurodov T., Mirzaev O., Affane B., Tajik A., Romanova, K., Galyametdinov Y., & Vakhin A. Thermochemical upgrading of heavy crude oil in reservoir conditions//Processes. −2023. -Vol.11(7):2156. DOI 10.3390/pr11072156.
4. Razavifar M., Yunusov T., Mukhametdinova A., et.al. Improving oil recovery with ultrasound: mitigating asphaltene-induced formation damage//Petroleum Exploration and Production Technology. - 2025.-Vol.15:78. DOI 10.1007/s13202-025-01985-x.
5. Shi B., Hong J., Wang Z., Chang Z., & Li, F. Treatment of paraffin deposition behavior in gas-condensate wells with chemical inhibitors//Petroleum Exploration and Production Technology. 2024.-Vol.14(2).-P. 535-553. DOI 10.1007/s13202-023-01716-0.
6. Iskandarov E. K., Harbizade M. E. Technology for the Elimination of Asphaltene-Resin-Paraffin Deposits in the Processing of Gas-Condensate Well Production// Herald of the Azerbaijan Engineering Academy- 2025.-Vol.17(4). - P.72-80. DOI 1052171/hearld.330.
7. Alisheva Z., Nadirov K., Al-Dujaili A.N., Bimbetova G.,et.al Integrated strategies for controlling water cut in mature oil fields in Kazakhstan.//Polymers.-2025.-Vol.17(7):829. DOI 10.3390/polym17070829.
8. Srivastava R. K., Huang S. S., Dong M. Asphaltene deposition during CO2 flooding//Paper. −1999.-Vol.14(04):235-245. DOI 10.2118/59092-PA.
9. Mukhametshina A., Kar, T., Hascakir B. (2016). Asphaltene precipitation during bitumen extraction with expanding-solvent steam-assisted gravity drainage: effects on pore-scale displacement \//SPE Journal. −2016.-Vol.21(02):380-392. DOI 10.2118/170013-PA.
10. Bedrikovetsky P. Improved waterflooding in reservoirs of highly paraffinic oils. In SPE Latin America and Caribbean Petroleum Engineering Conference. −1997. DOI 10.2118/39083-MS.
11. Demir A. B., Bilgesu H. I., Hascakir, B. The effect of clay and salinity on asphaltene stability// In SPE Western Regional Meeting. 2016.- P.1800425- MS. DOI 10.2118/180425-MS.
12. Esetov Z. A., Turdiyev M. F., Kemalov A. F., et.al. Thermal-steam cyclic processing technology of development objects in Karazhanbas Kazakhstan field.//Indian J Sci Technol.-2016.-Vol.9(18).-P.1-9. DOI 10.17485/ijst/2016/v9i18/93749.

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