Mining of Mineral Deposits
Volume 17 (2023), Issue 1, 101-107

https://doi.org/10.33271/mining17.01.101

Optimization of gas recycling technique in development of gas-condensate fields

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Abstract

Purpose. The research purpose is to increase the efficiency of development of gas condensate fields with a high condensate yield in the reservoir gas and to develop optimal ways of increasing their hydrocarbon recovery.

Methods. The effectiveness of the implementation of reservoir pressure maintenance technologies using dry gas for the development of gas condensate fields with a high condensate yield in the reservoir gas is studied on the basis of a heterogeneous 3D model using the Schlumberger Eclipse and Petrel software packages. The technological indicators of the development of gas-condensate reservoir are studied for different pressure values at the beginning of the dry gas injection. Calculations were made for pressures at the beginning of injection at the level of: 1.0 P_{init}; 0.8 P_{init}; 0.6 P_{init}; 0.4 P_{init}; 0.2 P_{init}.

Findings. It has been determined that when the dry gas is injected into a gas-condensate reservoir, reservoir pressure is maintained at a significantly higher level than it is in the case of depletion. This ensures stable operation of production wells over a longer period of the reservoir development. According to the research results, it should be noted that in the case of implementation of the reservoir pressure maintenance technology, a part of the precipitated condensate is transferred to the gas phase, which makes it necessary to extract it together with the reservoir gas. Based on the modeling results, the ultimate condensate recovery factor have been calculated. The calculation results indicate that in the case of the cycling process implementation, the ultimate condensate recovery factor of the gas-condensate reservoir increases by 7.26% compared to depletion development.

Originality. Based on the calculation data analysis, the optimal pressure value at the beginning of dry gas injection into a gas-condensate reservoir has been determined, which is 0.842 P_{init}.

Practical implications. The use of the conducted research results will optimize the development system of gas-condensate fields with high initial condensate yield in the reservoir gas and increase the efficiency of development the explored hydrocarbon reserves in the conditions of a significant shortage of hydrocarbon raw materials in Ukraine. The conducted research results indicate the high technological efficiency of the reservoir pressure maintenance technology using dry gas.

Keywords: *3D modeling, deposit, retrograde condensation, hydrocarbon recovery, technologies, cycling process*

1. Introduction

The oil and gas industry of Ukraine plays an important role in the energy sector of the country. Currently, the main hydrocarbon production in Ukraine to meet the needs of the population and industry is provided from gas-condensate fields. However, most of such fields are mined based on natural regimes of reservoir energy depletion and are characterized by low extraction efficiency of explored hydrocarbon reserves.

The complexity of hydrocarbons production under such conditions is caused by the fact that when the reservoir pressure drops below the pressure at the beginning of condensation, condensate precipitates in the reservoir. This leads to its accumulation in the bottomhole zone and a decrease in gas phase permeability and, consequently, the productivity of wells. Thus, there are complications in the operation of production wells due to the condensate accumulation at the face, when the gas-liquid flow rate is below the critical one [1], [2].

The results of industrial experience in the development of gas-condensate fields indicate that under depletion development, not high ultimate hydrocarbon recovery are usually achieved. Gas recovery factors are on average 70-85 %, while condensate recovery factors are 13-40% [3]-[5].

To increase the hydrocarbon recovery from depleted oil-gas fields, it becomes necessary to implement modern secondary and tertiary development technologies. The feasibility of implementing such technologies is determined by the complexity of the field geological structure, the productive reservoir depths, the residual hydrocarbon reserves and a payback period for additional capital investments [6], [7].

A promising direction for increasing the hydrocarbon recovery from gas-condensate fields with a high condensate content in the reservoir gas may be to displace them with hydrocarbon and non-hydrocarbon gases (nitrogen, carbon dioxide, flue gases, a mixture of various gases, etc.), as well as the implementation of water-gas repression technologies (successive injection of liquid and gaseous agents) [8]-[10]. The most common technology for the development of gas-condensate fields, which provides high ultimate condensate

Received: 16 March 2022. Accepted: 5 March 2023. Available online: 30 March 2023

Mining of Mineral Deposits. ISSN 2415-3443 (Online) | ISSN 2415-3435 (Print)

recovery factors compared to depletion development, is the cycling process [11].

To implement the cycling process, it is necessary to project an optimal system for placing production and injection wells in the gas-bearing area. In the case of the development of anticlinal-type gas-condensate reservoirs, it is recommended to place the injection wells in the central part, and the production wells – on the periphery. The results of numerous studies indicate the technological efficiency of the cycling process technology implementation. By maintaining reservoir pressure using dry gas, the ultimate condensate recovery factors are at the level of 70-90% [12].

The main cycling process disadvantages are significant capital investments, a long period of development, and conservation of hydrocarbon gas reserves during the period of maintaining reservoir pressure. The flooding of gas-condensate reservoirs is usually an ineffective way to increase hydrocarbon recovery, since it leads to blocking of significant natural gas volumes in a porous medium with water, its breakthrough to the well faces and complications during their operation. However, in the case of depleted gas-condensate reservoirs, the implementation of combined technologies with successive injection of liquid agents with their subsequent displacement by gaseous agents (liquid-gas repression) can ensure high efficiency of their additional development [13].

Reservoir pressure maintenance by water injection during the development of gas-condensate reservoirs with a high condensate content in the reservoir gas can be used only at the initial stage of field development with a subsequent transition to the depletion development [14]-[16]. Research results indicate that alternate injection of solutions of surface-active substances (surfactants) and gas is a more effective method for increasing the ultimate condensate recovery factors from gas-condensate fields compared to injection of water or water-gas mixtures. When injecting solutions of surfactant and gas, foam is formed in the porous medium, which makes it possible to more efficiently displace condensate that has precipitated in the bottomhole zone of the reservoir [17].

The implementation of technologies using non-hydrocarbon gases is a rather effective method for increasing the ultimate hydrocarbon recovery. Nitrogen, carbon dioxide, air, flue gases or exhaust gases, as well as their mixtures, are widely used as injection agents. The specificity of the use of a certain type is associated with the reactions occurring when they interact with a hydrocarbon mixture [18]-[20].

When using nitrogen as an injection agent, pressure increases at the beginning of condensation, and at the points of the first contact with the reservoir gas, a small amount of condensate precipitates, which then moves ahead of the displacement front [21].

The use of carbon dioxide to maintain reservoir pressure, on the contrary, helps to reduce pressure at the beginning of condensation, therefore, its injection must be conducted uniformly over the entire gas-bearing area. The carbon dioxide injection into productive reservoirs also leads to a decrease in the interfacial tension at the hydrocarbon-fluid-water interface, an improvement in rock wettability when dissolved in hydrocarbon fluid and water, and ensuring the transition of oil from a film state to a droplet state [22]-[24].

The high efficiency of carbon dioxide injection technology is conditioned by its high solubility in reservoir fluids compared to other gases. When carbon dioxide is dissolved in the condensate, its volume increases, which in turn causes the displacement of the remaining immobile condensate to the production wells [25].

The carbon dioxide injection technology is simple and widely used in the world. However, due to the high compressibility and solubility in water, larger volumes must be injected to maintain pressure compared to nitrogen.

Air is the most available and cheapest non-hydrocarbon agent, but its mixing with natural gas leads to the reservoir of an explosive mixture. Under standard conditions, the ignition of a gas-air mixture is possible at a methane concentration in the air in the range of values from 6.0 to 13.3%. This phenomenon can be avoided by adding an antioxidant to the air, in the field this can be flue or exhaust gases [26].

There are also a number of combined methods based on the sequential or simultaneous supply of displacing agents to increase the hydrocarbon recovery. The expediency of using each of the methods depends on the conditions of development of a particular field [27]-[29].

The effectiveness of technologies for increasing hydrocarbon recovery, when the development of gas-condensate fields with high condensate content, mainly depends on the displacing properties of injection agents. However, the research results indicate that the thermobaric conditions under which technological processes are conducted are also important.

The problem of increasing the efficiency of development of explored hydrocarbon reserves of depleted fields in Ukraine acquires greater urgency in conditions of an acute shortage of hydrocarbon raw materials and requires a careful approach to the design process of oil-gas field development systems.

The research purpose is to increase the efficiency of the development of gas-condensate fields with high initial condensate yield and to increase the ultimate hydrocarbon recovery.

To achieve the purpose set, it is necessary to perform the following tasks:

– analysis of the developed methods for increasing the hydrocarbon recovery from gas-condensate fields with high initial condensate yield in the reservoir gas;

– improvement of existing technologies for the development of gas-condensate field using digital modeling.

2. Research methods

The Eclipse and Petrel software packages of the Schlumberger Company are used to conduct research on increasing the hydrocarbon recovery from gas-condensate fields with high initial condensate yield in the reservoir gas.

Calculations are made on the basis of a digital 3D model of one of the Ukrainian fields. The hydrocarbon reservoirs of this field occur in the depth range of 1150-5000 m, forming productivity levels over 3000 m high. The Moscow, Bashkir, Serpukhov, and Visey oil and gas-bearing complexes are identified within the productivity level.

The productivity of the reservoirs has been determined by the results of well log interpretation and is confirmed by an open-hole test, the results of well testing and development plan.

For calculations, a hydrocarbon reservoir has been selected, which is characterized by the high initial condensate yield in the reservoir gas with the following parameters: depth of the producing reservoir is 4500 m, initial reservoir pressure is 45 MPa, reservoir temperature is 393 K, reservoir thickness is 15 m, average porosity is 0.11, initial gas saturation is 0.8, absolute reservoir permeability is 7.2 mD. Initial gas reserves are 2291 million m^3 and initial condensate reserves are 863 ths. m^3.

A conceptual 3D model of the gas-condensate reservoir is shown in Figure 1.

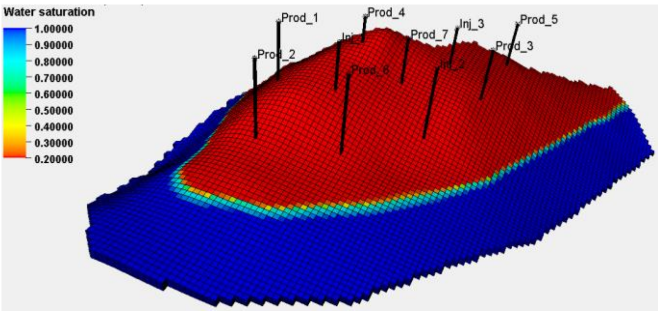

Figure 1. A conceptual 3D model of the gas-condensate reservoir

The gas-condensate reservoir characteristic is studied using both industrial separators of vertical and horizontal types, and a small thermostatic separation unit, which is included in the mobile gas condensate laboratory. The whole research complex is performed in accordance with the requirements of existing methodologies.

To characterize reservoir hydrocarbon systems, standard samples are used, taken in the initial reservoir conditions and corresponding to the reservoir geophysical characteristics.

The composition of reservoir gas-condensate systems is determined from the study of separation, degassing and debutanization gases, as well as the calculation of the potential content of $C_{5+\text{higher}}$, based on the condensate-gas factors (CGR) values obtained during the study of wells from which industrial gas surges have been obtained.

The potential yield of the C_{5+} fraction in the reservoir gas of the gas-condensate reservoir is taken at the level of 340 g/m^3. Change of the potential yield of the C_{5+} fraction in the reservoir gas is shown in Figure 2.

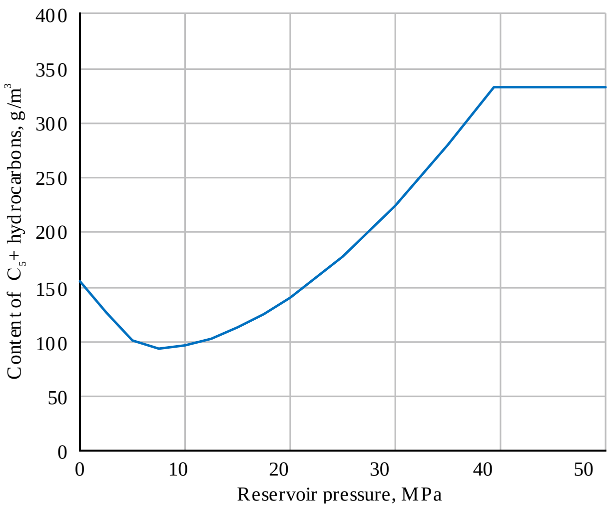

Figure 2. Potential yield of the C_{5+} fraction in the reservoir gas

In order to account for the physical processes that occur during the dry gas injection into a gas-condensate reservoir, a compositional PVT model has been developed and subsequently used [30], [31].

The placement of the wells in the gas-bearing area of the reservoir during the research and their number does not correspond to the actual data. To conduct research, taking into account the peculiarities of the distribution of reservoir rock filtration-capacity properties, a uniform grid of wells is adopted in the 3D model.

Thus, the reservoir is development using 7 wells. The gas flow rate of one well is 80 ths. m^3/day. In the central part of the structure, 3 injection wells are placed. The gas injection rate of injection wells is 186 ths. m^3/day. The ratio of the hydrocarbon production rate to the dry gas injection rate is 1:1.

Calculations are made for different pressure values at the beginning of the dry gas injection into a gas-condensate reservoir (P_{inj} / P_{init} is: 1; 0.8; 0.6; 0.4; 0.2). Dry gas is injected into the reservoir within 24 months. After the specified duration of the dry gas injection period is reached, the injection wells are stopped, and the production wells continue to operate until the technological limitations are reached.

Statistical analysis is used for processing graphical dependences in order to determine the optimal points of the studied parameters [32].

According to the statistical analysis, the function $f(x) = a_0 + a_1 x$ parameter values are chosen in such a way that the deviation of the studied points $(x_i; y_i)$ $i = \overline{1..N}$ from the selected curve is minimal. The parameters a_0, a_1 should be such that the sum of squared deviations of the observed values of y_i from those calculated by the function $f(x) = a_0 + a_1 x$ is minimal. After certain transreservoirs, a system of two linear equations for unknown regression parameters is obtained:

$$\begin{cases} \min\limits_{\nu, a_\nu} \left\{ \sigma_{a\nu}^2 = \dfrac{1}{n_\nu - r_\nu} \sum\limits_{i=1}^{n_\nu} \left[f_\nu(a_\nu, x_i) - y_i \right]^2 \right\} \Rightarrow \left\{ \hat{\nu}, \hat{a}_\nu \right\} \\ \min\limits_{\varepsilon, a_\varepsilon} \left\{ \sigma_{a\varepsilon}^2 = \dfrac{1}{n_\varepsilon - r_\varepsilon} \sum\limits_{i=1}^{n_\varepsilon} \left[f_\varepsilon(a_\varepsilon, x_i) - y_i \right]^2 \right\} \Rightarrow \left\{ \hat{\varepsilon}, \hat{a}_\varepsilon \right\} \end{cases}; \quad (1)$$

$$f_\nu\left(\hat{a}_\nu, x_*\right) - f_\varepsilon\left(\hat{a}_\varepsilon, x_*\right) = 0 \Rightarrow x_* \quad (2)$$

where:

$\sigma^2_{a\nu}$, $\sigma^2_{a\varepsilon}$ – estimation of efficiency variances f_ν and f_ε;

r_ν, r_ε – the number of estimated model parameters $f_\nu(a_\nu, x_i)$ and $f_\varepsilon(a_\varepsilon, x_i)$

Parameters $a_0, a_1, a_2, \ldots, a_n$ are determined by solving this system of equations. The found parameters are substituted into the equation $y = f(x)$ and thus the linear equations are obtained that best describe the calculated data. After that, dependences are constructed for specific calculated data and each of them is approximated by two straight lines, the intersection point of which corresponds to the optimal studied value.

3. Results and discussion

Based on the conducted research results, it has been determined that the dry gas injection into a gas-condensate reservoir ensures that the reservoir pressure is maintained at a higher level compared to depletion development.

Reservoir pressure dynamics during the dry gas injection into a gas-condensate reservoir, depending on the pressure at the beginning of its injection, and during depletion development, is shown in Figure 3. Based on the modeling results, it has been determined that in the case of implementation of reservoir pressure maintenance technology, significantly higher technical-economic indicators of the development of gas-condensate reservoir are provided compared to depletion development. It should be noted that the dry gas injection into a reservoir ensures stable operation of the wells for a longer development period at a constant flow rate mode.

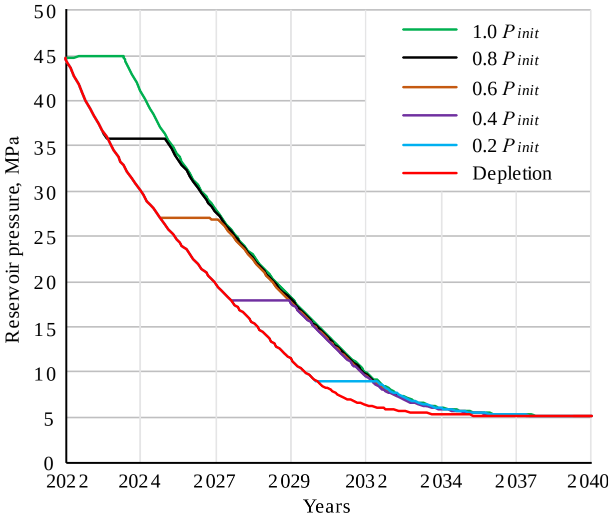

Figure 3. Reservoir pressure dynamics during the dry gas injection into a gas-condensate reservoir, depending on the pressure at the beginning of its injection, and during depletion development

Dynamics of the gas flow rate during depletion development and with the pressure at the beginning of dry gas injection at the level of the initial reservoir pressure (1.0 P_{init}) is shown in Figure 4.

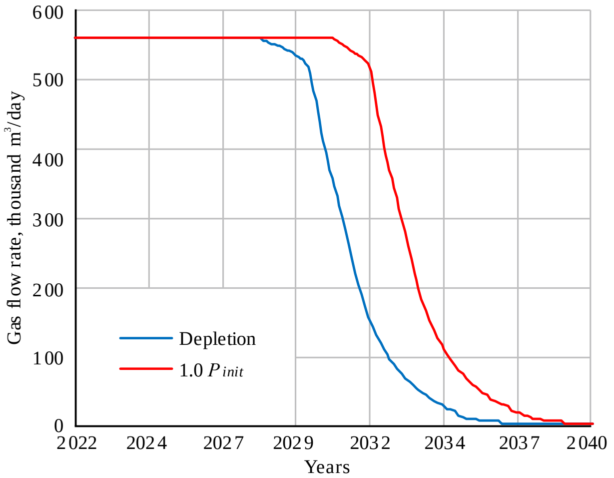

Figure 4. Dynamics of the gas flow rate during depletion development and with the pressure at the beginning of dry gas injection at the level of the initial reservoir pressure (1.0 P_{init})

Analyzing the results of the main technological indicators of the development of gas-condensate reservoir, it has been determined that in the case of dry gas injection, an increased cumulative condensate production is achieved. It should be noted that the faster the reservoir pressure maintenance technology is implemented, the greater the cumulative condensate production.

The cumulative condensate production dynamics during depletion development and during the dry gas injection, depending on the pressure at the beginning of its injection into a gas-condensate reservoir, is shown in Figure 5.

Based on the modeling results, the cumulative condensate production depending on the pressure at the beginning of the dry gas injection into a gas-condensate reservoir is: 1.0 P_{init} – 398.25 ths. m^3; 0.8 P_{init} – 384.73 ths. m^3; 0.6 P_{init} – 371.46 ths. m^3; 0.4 P_{init} – 360.69 ths. m^3; 0.2 P_{init} – 345.22 ths. m^3. In case of depletion, the cumulative condensate production is 324.89 ths. m^3.

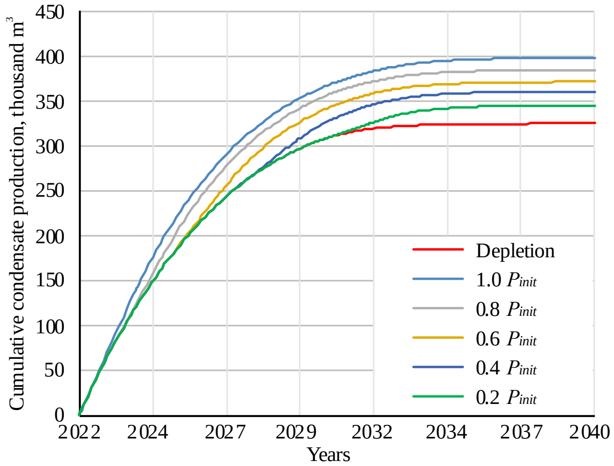

Figure 5. Cumulative condensate production dynamics during depletion development and during the dry gas injection, depending on the pressure at the beginning of its injection into a gas-condensate reservoir

Based on the conducted research, an increase in the cumulative condensate production is observed due to the implemented reservoir pressure maintenance technology for different pressures at the beginning of the dry gas injection into a reservoir compared to depletion development. Thus, according to the calculation results, an increase in cumulative condensate production is: 1.0 P_{init} – 73.35 ths. m^3; 0,8 P_{init} – 59.83 ths. m^3; 0.6 P_{init} – 46.56 ths. m^3; 0.4 P_{init} – 35.79 ths. m^3; 0.2 P_{init} – 20.31 ths. m^3.

Analyzing the calculation results, it should be noted that in the case of the dry gas injection technology implementation with a pressure equal to the initial reservoir pressure (1.0 P_{init}), the highest cumulative condensate production is ensured. The greater the gas-condensate reservoir depletion, the smaller the effect of the implementated reservoir pressure maintenance technology, and, accordingly, the ultimate condensate recovery factor.

Analyzing the modeling results, it should be noted that the lower the reservoir pressure in the gas-condensate reservoir, the higher the pore space saturation with the precipitated condensate. In the case of the implementation of reservoir pressure maintenance technology using dry gas, the process of converting the precipitated condensate into the gas phase occurs and, accordingly, its extraction from the gas-condensate reservoir.

The gas-condensate reservoir saturation with condensed hydrocarbons at the moment of stopping the dry gas injection process for different pressures at the beginning of injection is given in Figure 6.

Based on the conducted research results, the ultimate condensate recovery factors are calculated depending on the pressure at the beginning of the dry gas injection and during depletion. The calculation results are given in Table 1.

Table 1. Results of calculating the condensate recovery factors depending on the pressure at the beginning of the dry gas injection and during depletion development

Pressure at the beginning of injection (P_{inj}/ P_{init})	Condensate recovery factor, %		
	Depletion	Injection	*Δ*
1	37.64	46.14	8.50
0.8	37.64	44.57	6.93
0.6	37.64	43.03	5.39
0.4	37.64	41.79	4.15
0.2	37.64	39.99	2.35

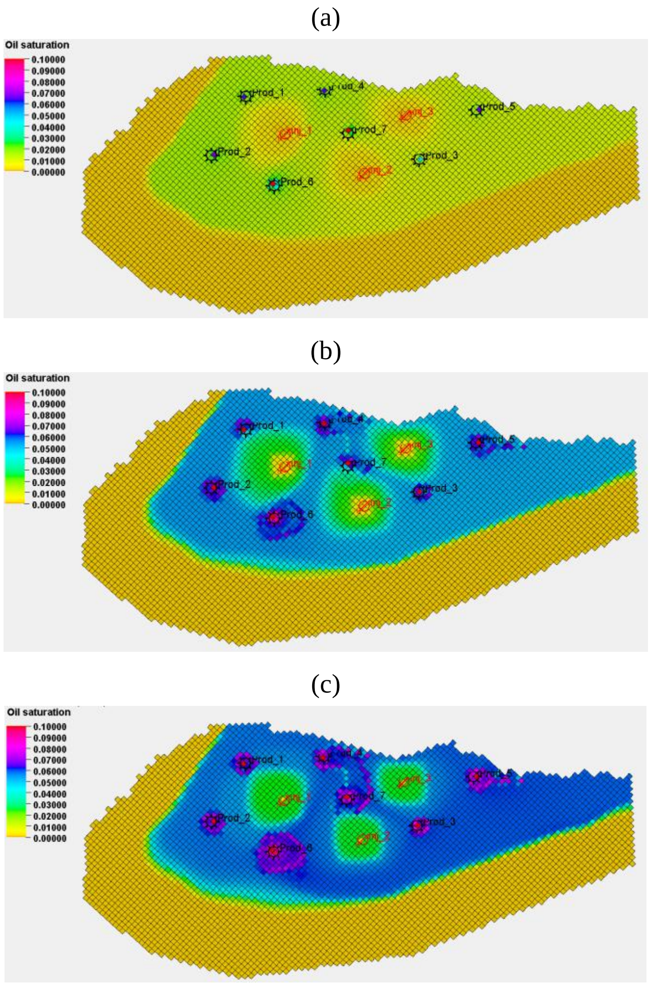

Figure 6. Gas-condensate reservoir saturation with condensed hydrocarbons for pressures at the beginning of injection 1.0 P_{init} (a); 0.6 P_{init} (b); 0.2 P_{init} (c) at the moment of stopping the dry gas injection process

Based on the modeling results, the ultimate condensate recovery factors, while maintaining reservoir pressure, is: 1.0 P_{init} – 46.14%; 0.8 P_{init} – 44.57%; 0.6 P_{init} – 43.03%; 0.4 P_{init} – 41.79%; 0.2 P_{init} – 39.99%. In the case of depletion, the ultimate condensate recovery factor is 37.64%.

Based on the conducted research results, an increase in the ultimate condensate recovery factors, depending on the pressure at the beginning of the dry gas injection, is: 1.0 P_{init} – 8.50%; 0.8 P_{init} – 6.93%; 0.6 P_{init} – 5.39%; 0.4 P_{init} – 4.15%; 0.2 P_{init} – 2.35%.

The dependences of the condensate recovery factors on the pressure at the beginning of the dry gas injection and during depletion are shown in Figure 7. Based on the statistical processing of calculated data, the optimal pressure value at the beginning of the dry gas injection into a gas-condensate reservoir has been determined, beyond which the condensate recovery factor does not change significantly. The optimal pressure value at the beginning of injection is 0.842 P_{init}. The ultimate condensate recovery factor for the given optimal value of the dry gas injection period duration is 44.9%.

The conducted research results correlate well with the already known research published both in domestic and foreign sources. The researchers have revealed that the reservoir pressure maintenance technology, in the development of gas-condensate reservoirs with high initial condensate yield in the reservoir gas, should be implemented at a reservoir pressure higher or close to the pressure at the beginning of condensation.

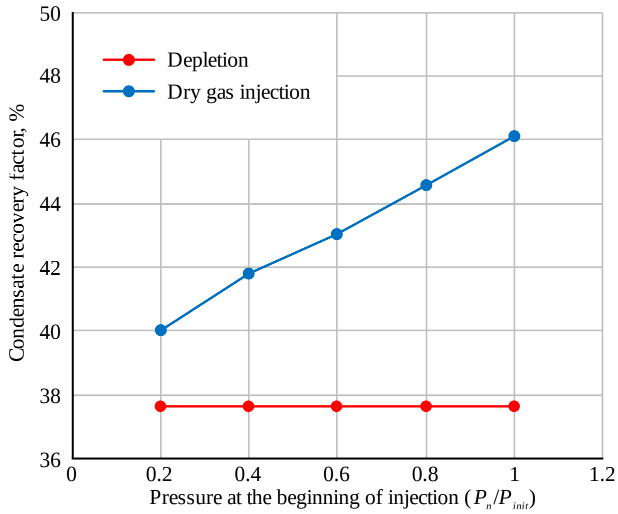

Figure 7. Dependences of the condensate recovery factors on the duration of the dry gas injection period and during depletion

Based on the modeling results using a digital 3D model, it has been determined that the optimal reservoir pressure value is 0.842 P_{init}.

However, it should be noted that the gas-condensate reservoir characteristic significantly affects the efficiency of the reservoir pressure maintenance technologies, namely, the intensity of specific condensate losses with a pressure decrease by 1 MPa. As an example, the gas-condensate reservoir systems of the B-20 level at the Rudivsko-Chervonozavodske field and the B-22 level at the Sakhalinske field are characterized by "precipitous" liquid hydrocarbon condensation in the area of the pressure of the beginning condensation at the level of 100-120 g/m^3·MPa with initial condensate yield in the reservoir gas of 900 g/m^3. Other fields with initial specific condensate yield of 300-500 g/m^3 are characterized by lower specific condensate losses of 8-10 g/m^3 MPa.

For reservoirs with gas-condensate systems characterized by precipitous condensation, the pore space saturation can reach 30-40%, which exceeds the critical saturation and creates conditions for its mobility. For gas-condensate fields with an initial condensate yield less than 500 g/m^3, such conditions occur in the limited bottomhole zone of the reservoir, which is confirmed by modeling.

The heterogeneity of productive reservoirs, both in terms of area and thickness, also has a significant impact on the efficiency of reservoir pressure maintenance technologies in the development of gas-condensate fields. An important task in the development of heterogeneous reservoirs is to provide an optimal grid of wells that can ensure uniform drainage of productive reservoirs without creating deep depression funnels and, accordingly, condensate losses during its mass transfer in the case of planar reservoir gas overflows.

In view of the above, it is promising to study the heterogeneity of productive reservoirs, as well as the peculiarities of gas condensate characteristics and their impact on the development of gas-condensate fields with high initial condensate yield in the reservoir gas. The issue of increasing hydrocarbon recovery from depleted oil-gas fields of Ukraine is currently quite acute, especially against the background of an acute shortage of hydrocarbon raw materials in Ukraine and the need to reduce dependence on imported energy carriers.

4. Conclusions

Using the main tools of hydrodynamic modeling, the influence of the pressure at the beginning of dry gas injection on the ultimate condensate recovery factor has been studied. Based on the modeling results, it has been determined that the faster the reservoir pressure maintenance technology is implemented, the higher the ultimate condensate recovery factors compared to depletion development.

Based on the conducted research results, it has been determined that the optimal pressure value at the beginning of dry gas injection into a gas-condensate reservoir is 0.842 P_{init}. The ultimate condensate recovery factor for the given optimal value of the dry gas injection period duration increases by 7.26% compared to depletion development.

The conducted research results indicate the high technological efficiency of the implementation of reservoir pressure maintenance technology using dry gas in the development of gas-condensate deposits with high initial condensate yield in the reservoir gas.

The use of digital modeling in accordance with the world practice of designing the developming of hydrocarbon fields will optimize the existing system the developming of gas-condensate fields with significant condensate reserves and, accordingly, increase their hydrocarbon production.

Acknowledgements

The research results have been obtained without any support in the form of grants or projects. The authors express their gratitude to JSC Ukrgasvydobuvannya for the opportunity to conduct research, the results of which are presented in this paper.

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Оптимізація сайклінг-процесу при розробці газоконденсатних родовищ

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Мета. Підвищення ефективності розробки газоконденсатних родовищ з високим вмістом конденсату в пластовому газі та напрацювання оптимальних шляхів підвищення кінцевого їх вуглеводневилучення.

Методика. Дослідження ефективності впровадження технологій підтримання пластового тиску з використанням сухого газу для розробки газоконденсатних родовищ з високим вмістом конденсату проведено на основі неоднорідної тривимірної моделі з використанням програмних комплексів Eclipse та Petrel компанії Schlumberger. Дослідження технологічних показників розробки газоконденсатного покладу здійснено для різних значень тиску початку нагнітання сухого газу. Розрахунки проведені для тисків початку нагнітання на рівні: 1 $P_{поч}$; 0.8 $P_{поч}$; 0.6 $P_{поч}$; 0.4 $P_{поч}$; 0.2 $P_{поч}$.

Результати. Встановлено, що при нагнітанні сухого газу в газоконденсатний поклад забезпечується підтримання пластового тиску на значно вищому рівні порівняно з розробкою на виснаження. Завдяки цьому забезпечується стабільна експлуатація видобувних свердловин протягом тривалішого періоду розробки покладу. Згідно результатів досліджень слід від-значити, що у випадку реалізації технології підтримання пластового тиску забезпечується переведення чистини випавшого конденсату в газову фазу, що обумовлює його вилучення разом з пластовим газом. На основі результатів моделювання здійснено розрахунок кінцевих коефіцієнтів конденсатовилучення. Результати розрахунків свідчать про те, що у випадку впровадження сайклінг-процесу кінцевий коефіцієнт конденсатовилучення газоконденсатного покладу збільшується на 7.26% порівняно з розробкою покладу на виснаження.

Наукова новизна. На основі аналізу розрахункових даних встановлено оптимальне значення тиску початку нагнітання сухого газу в газоконденсатний поклад, яке становить 0.842 $P_{поч}$.

Практична значимість. Використання результатів проведених досліджень дозволять оптимізувати систему розробки газоконденсатних родовищ з високим початковим вмістом конденсату та підвищити ефективність видобутку розвіданих запасів вуглеводнів в умовах значного дефіциту вуглеводневої сировини в Україні. Результати проведених досліджень свідчать про високу технологічну ефективність технології підтримання пластового тиску з використанням сухого газу.

Ключові слова: *3D моделювання, поклад, ретроградна конденсація, конденсатовилучення, технології, сайклінг-процес*