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EFFECTS OF THE RATE OF NATURAL GAS PRODUCTION ON THE RECOVERY FACTOR DURING CARBON DIOXIDE INJECTION AT THE INITIAL GAS-WATER CONTACT

The object of research is gas condensate reservoirs, which is being developed under the conditions of the manifestation of the water drive of development and the negative effect of formation water on the process of natural gas production. The results of the performed theoretical and experimental studies show that a promising direction for increasing hydrocarbon recovery from fields at the final stage of development is the displacement of natural gas to producing wells by injection non-hydrocarbon gases into productive reservoirs. The final gas recovery factor according to the results of laboratory studies in the case of injection of non-hydrocarbon gases into productive reservoirs depends on the type of displacing agent and the level heterogeneity of reservoir. With the purpose update the existing technologies for the development of fields in conditions of the showing of water drive, the technology of injection carbon dioxide into productive reservoirs at the boundary of the gas-water contact was studied using a digital three-dimensional model of a gas condensate deposit. The study was carried out for various values of the rate of natural gas production. The production well rate for calculations is taken at the level of 30, 40, 50, 60, 70, 80 thousand m^3/day. Based on the data obtained, it has been established that an increase in the rate of natural gas production has a positive effect on the development of a productive reservoir and leads to an increase in the gas recovery factor. Based on the results of statistical processing of the calculated data, the optimal value of the rate of natural gas production was determined when carbon dioxide is injected into the productive reservoir at the boundary of the gas-water contact is 55.93 thousand m^3/day. The final gas recovery factor for the optimal natural gas production rate is 64.99 %. The results of the studies carried out indicate the technological efficiency of injecting carbon dioxide into productive reservoirs at the boundary of the gas-water contact in order to slow down the movement of formation water into productive reservoirs and increase the final gas recovery factor.

Keywords: 3D model of the field, gas condensate reservoir, water drive, residual gas, injection of carbon dioxide.

1. Introduction

The oil and gas industry is the main branch of the national economy of many countries of the world. The main attention in every society is paid to improving production efficiency as a source of welfare growth.

The development of hydrocarbon deposits is complicated by many geological and technological factors. However, the problem of flooding of productive deposits and producing wells is extremely urgent and important at present for the world practice of natural hydrocarbon production [1].

The complexity of natural gas production is due to uneven drainage of productive deposits, which leads to uncontrolled movement of the gas-water contact along the productive section and the area of gas content in the water pressure regime [2]. The heterogeneity of productive deposits both in thickness and in area leads to the cutting off by the formation water front of the productive reservoir areas with high residual gas saturation [3].

Under the conditions of the manifestation of the water-driven regime of watering of production wells, it is a natural and inevitable process [4]. Usually this can be associated with both an «emergency» breakthrough of water from aquifers due to poor-quality casing of the wells, and breakthrough of formation water through highly permeable interlayers. Breakthrough of formation water leads to a decrease in the current production of hydrocarbons and the production capacity of the field [1].

The natural gas recovery factors from deposits, which are characterized by a water pressure regime, are 70–85 %. The more active the water pressure system, the greater the saturation with residual gas and the lower the hydrocarbon recovery factor [5, 6].

Hydrocarbon fields discovered in recent years are characterized by a complex structure, large depths of occurrence of productive deposits, insignificant reserves and can't significantly affect the maintenance of hydrocarbon production [7]. That is why there is a need to develop optimal ways to maintain hydrocarbon production from existing,

already to a certain extent depleted hydrocarbon fields. Increasing the efficiency of the development of hydrocarbon deposits for the water pressure regime at different stages of their development is possible subject to the introduction of scientific achievements and the latest technologies.

A promising direction for increasing the hydrocarbon yield of gas condensate deposits is the introduction of secondary development technologies using non-hydrocarbon gases [8, 9].

An important task in the design of the secondary hydrocarbon production technology is the choice of the duration of the injection periods of non-hydrocarbon gases, the number and system of location of production and injection wells in the area of the reservoir, as well as the technological parameters of their operation [10].

In this work, the influence of the rate of natural gas production during the injection of carbon dioxide into productive deposits on the verge of the initial gas-water contact on the gas recovery coefficient is investigated.

2. The object of research and its technological audit

The object of research is gas condensate fields developed under the conditions of the manifestation of a water pressure regime and the negative effect of formation water on the process of natural gas production.

To improve the existing and develop new technologies for intensifying hydrocarbon production under conditions of a water pressure regime by injecting non-hydrocarbon gases into productive deposits, additional research is required. On the basis of the studies carried out, it is necessary to substantiate the optimal methods and technologies for which it is possible to ensure maximum hydrocarbon recovery factors. Solving the problem of regulating the process of flooding of productive deposits and production wells is one of the directions of energy-saving development of the economy of any state that is engaged in the production of natural hydrocarbons.

3. The aim and objectives of research

The aim of research is to study the efficiency of the technology of injecting carbon dioxide into the reservoir at the initial gas-water contact to regulate the process of formation water inflow into gas-saturated horizons using numerical modeling.

To achieve this aim, it is necessary to complete the following objectives:

1. Investigate the effect of the rate of natural gas production during the injection of carbon dioxide into the reservoir on the activity of the water pumping system.

2. Establish the optimal rate of natural gas production when injecting carbon dioxide into the productive reservoir on the verge of the initial gas-water contact.

4. Research of existing solutions to the problem

The overwhelming majority of oil and gas condensate fields is confined to reservoir water-pressure systems and is developed according to the water-pressure regime, the essence of which is the movement of formation water into gas-saturated horizons and the restriction of residual hydrocarbon reserves in a porous medium.

A significant number of studies have been carried out to develop optimal ways to extract micro- and macro-entrained gas from productive deposits. On the basis of the results of the studies carried out, the mechanism of the behavior of restrained gas by formation water in a porous medium has been revealed [11, 12]. However, until now, the problem of increasing the hydrocarbon production from hydrocarbon deposits developed under the water pressure regime remains important.

According to the analysis of numerous studies, a promising direction for increasing the hydrocarbon production from depleted, watered productive deposits is the displacement of residual gas by injecting non-hydrocarbon gases. Nitrogen, carbon dioxide, flue gases, mixtures of various gases, etc. are used as injection agents into productive deposits in order to increase the hydrocarbon yield [13, 14].

In 1941, it was first proposed to inject carbon dioxide under high pressure into depleted deposits [15]. For the first time, work on injecting carbon dioxide into the reservoir was carried out in the United States in 1949. The studies were carried out on oil reservoirs that were previously flooded and reached the limit of profitable hydrocarbon production under such conditions. An industrial experiment increased the final oil recovery factor by 10 %.

The positive results of the work carried out led to the introduction of the technology under study in ten more different fields. Due to the injection of carbon dioxide, additional production of hydrocarbons was provided, which determined significantly higher production capabilities of the fields. The results achieved made it possible to use carbon dioxide in the fields of the USA and Canada [16, 17]. Also, carbon dioxide is successfully used in Norway to increase the production of carbohydrates from productive deposits under the North Sea [18].

Thus, the technology of injection of carbon dioxide is currently one of the most successful technologies in the field of secondary hydrocarbon production. Numerous studies of the process of injection of carbon dioxide into productive deposits with the aim of increasing their hydrocarbon production confirm its effectiveness [19, 20].

The carbon dioxide injection technique is to create an artificial barrier between water and natural gas, due to which it is ensured that formation water is blocked from entering gas-saturated horizons.

In the case of the introduction of the technology of carbon dioxide injection in the flooding of a part of the deposit, part of the restrained gas is displaced into the production wells. In the zone of injection of carbon dioxide, reservoir pressure increases, causing the creation of an additional hydrodynamic barrier, due to which the process of inflow of reservoir water into gas-saturated horizons is partially complicated. The faster the technology of injecting carbon dioxide in the field is implemented, the higher the efficiency of this technology and the much higher the final coefficients of hydrocarbon recovery [7].

According to the results of modeling the process of developing productive deposits, it was found that the highest coefficient of hydrocarbon production is provided in the case of developing a deposit for depletion to an economically viable boundary with subsequent injection of carbon dioxide into the formation [21, 22].

The results of laboratory studies [23] indicate that the final gas recovery factor in the case of its displacement using non-hydrocarbon gases depends on the type of displacing agent and the degree of reservoir heterogeneity.

The study of the process of developing hydrocarbon fields indicates that in order to ensure a more complete coverage of productive deposits by development, it would be desirable to completely prevent the movement of produced water. To date, no practical solution to this problem has been found [10, 24]. Taking into account the above, in order to improve the existing technologies for the development of natural gas fields, it is advisable to carry out additional research using the tools of hydrodynamic modeling.

5. Methods of research

To assess the effect of the rate of natural gas production on the gas recovery rate when injecting carbon dioxide into the reservoir, the main Eclipse and Petrel hydrodynamic modeling tools from Schlumberger (USA) were used. The study was carried out on the basis of a digital three-dimensional model of a gas condensate field. To reproduce the phase transformations that take place in the pore space with a decrease in reservoir pressure, a composite PVT model was used [25, 26].

The development of the gas condensate bed is carried out using 5 production wells, and the injection of carbon dioxide is carried out using 6 injection wells located at the initial gas-water contact. The acceptance rate of injection wells is taken at the level of 50 thousand m^3/day. Calculations were carried out for production wells flow rates at the level of 30, 40, 50, 60, 70, 80 thousand m^3/day.

The research methodology and processing of the hydrodynamic modeling results are given in [10].

6. Research results

Based on the results of calculations of technological indicators of reservoir development, it was found that due to the injection of carbon dioxide at the boundary of the initial gas-water contact, additional gas production is provided and the volume of formation water production is reduced.

Comparison of the dynamics of accumulated hydrocarbon production during the injection of carbon dioxide and during the development of a reservoir for depletion for a gas production rate of 40 thousand m^3/day is shown in Fig. 1.
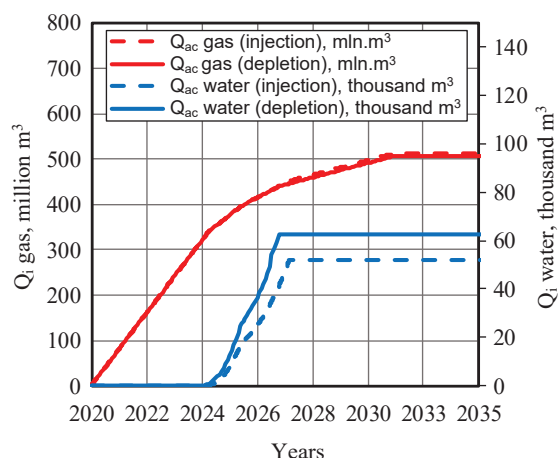

Fig. 1. Dynamics of the accumulated production of hydrocarbons during the injection of carbon dioxide and during the development of deposits for depletion for the gas production rate at the level of 40 thousand m^3/day

Using the results of modeling, the analysis of the dependence of the breakthrough time of carbon dioxide in production wells on the rate of natural gas production was carried out. According to the results of the calculations, it can be concluded that due to the increase in the rate of natural gas production, the period of development of the productive position decreases by the time of the breakthrough of carbon dioxide into the producing wells. The higher the rate of natural gas production, the faster the injection agent breaks into the production wells and the faster it leads to their decommissioning.

During the operation of production wells with a gas flow rate of 30 thousand m^3/day, carbon dioxide reaches the production wells in 70 months. An increase in the production rate of production wells to 80 thousand m^3/day leads to a decrease in the duration of their operation period to 31 months.

Analyzing the dependence of reservoir pressure on the rate of depletion of the productive reservoir, it should be noted that the higher the rate of production, the more intensively the reservoir pressure in the reservoir decreases. It is also necessary to pay attention to the nature of the dependencies obtained for different rates of natural gas production. This nature of the change in reservoir pressure over time is explained by the shutdown of production wells due to the breakthrough of carbon dioxide, or watering. If the well is shut down for one of the above reasons, the production of natural gas from the reservoir decreases, which leads to a decrease in the rate of reservoir pressure drop. The inflow of formation water into the productive horizons after stopping production wells continues, which leads to an intensive increase in reservoir pressure at the final stages of development.

The dynamics of reservoir pressure depending on the rate of natural gas production are shown in Fig. 2.
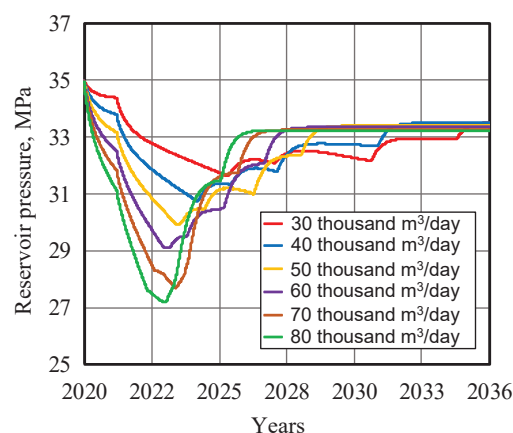
Fig. 2. Dynamics of reservoir pressure depending on the rate of natural gas production

Based on the results of the studies carried out, the calculation of the accumulated production of formation water at the time of the breakthrough of carbon dioxide in the production wells was carried out. Based on the analysis of calculations, it was found that an increase in the rate of natural gas production leads to an increase in the production of formation water at the time of breakthrough of carbon dioxide into production wells.

The dependence of the cumulative water production on the rate of natural gas production at the time of the

breakthrough of carbon dioxide into production wells and during the development of the reservoir for depletion is shown in Fig. 3.

Fig. 3. Dependence of cumulative water production on the rate of natural gas production at the moment of carbon dioxide breakthrough into production wells and during the development of a reservoir for depletion
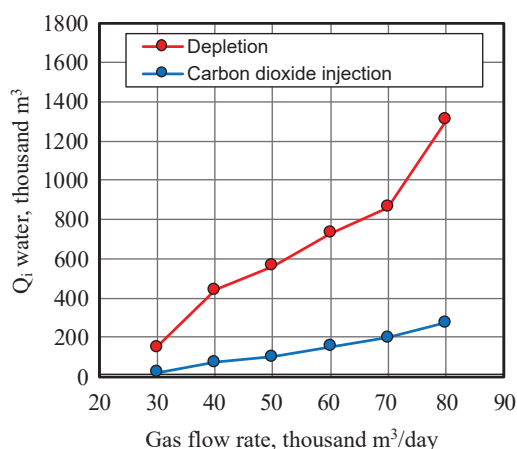
Analyzing the results of modeling the development of deposits for depletion and with injection of carbon dioxide, it should be noted that an increase in the rate of gas production during injection of carbon dioxide leads to a decrease in the production of produced water. Considering the difference in the densities of carbon dioxide and natural gas, as well as its solubility in formation water, it can be argued that the injection of non-hydrocarbon gas provides blocking of selective watering of the reservoirs. If the technology under study is introduced, an artificial barrier is created at the interface between the two phases, which minimizes the negative impact of formation water on natural gas production. This ensures stable and waterless production of production wells for a long period of development of gas condensate deposits. The calculated results indicate the technological efficiency of injection of carbon dioxide into the reservoir in order to regulate the flow of aquifer waters into the gas-saturated horizons.

The accumulated production of water during injection of carbon dioxide, depending on the rate of natural gas production at the end of the development of the productive position, varies within wide limits and is 30 thousand m^3/day – 70.917 thousand m^3; 40 thousand m^3/day – 51.836 thousand m^3; 50 thousand m^3/day – 81.804 thousand m^3; 60 thousand m^3/day – 81.789 thousand m^3; 70 thousand m^3/day – 61.098 thousand m^3; 80 thousand m^3/day – 56.135 thousand m^3.

Using the results of the studies carried out, the calculation of the gas recovery coefficients was carried out during development for depletion and at the moment of breakthrough of carbon dioxide into a number of production wells. The results of the calculations are given in Table 1.

According to the simulation results, it was found that an increase in the rate of natural gas production leads to an increase in the gas production coefficient. Also, it should be noted that if the technology of injecting non-hydrocarbon gas into the reservoir is introduced, significantly higher gas recovery factors are provided at the time of carbon dioxide breakthrough compared to depletion development.

Table 1

Calculation results of the natural gas recovery factor at the moment of carbon dioxide breakthrough in production wells

Natural gas production rate, thousand m^3/day	Gas recovery factor, %	
	Depletion	Injection
30	38.11	39.86
40	40.13	41.95
50	41.33	43.24
60	42.71	44.59
70	44.33	45.82
80	45.72	47.03

The dependences of the gas recovery factor on the rate of gas production at the time of the breakthrough of dioxide and during the development of the reservoir for depletion are shown in Fig. 4.
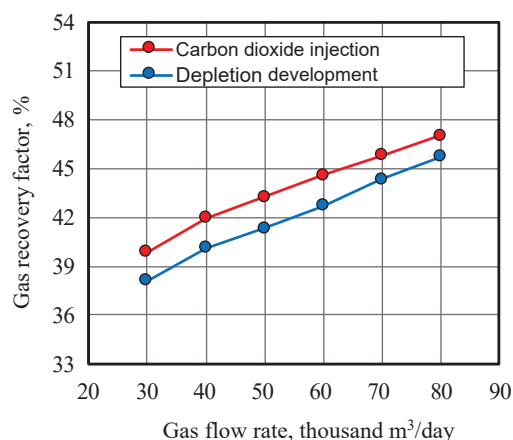

Fig. 4. Dependences of the gas recovery factor on the rate of natural gas production at the time of the breakthrough of dioxide and during the development of a deposit for depletion

Based on the results of the calculated data, the optimal value of the rate of natural gas production was determined when carbon dioxide is injected into a productive reservoir at the initial gas-water contact, outside of which the gas recovery coefficient changes insignificantly. The optimal value of the production well flow rate at the moment of carbon dioxide breakthrough into a number of production wells is 55.93 thousand m^3/day. The predicted coefficient of gas recovery for the given optimal value of the rate of natural gas production when injecting carbon dioxide into the reservoir is 64.99 %, and when developing for depletion – 58.34 %.

The modeling results indicate a high technological efficiency of injection of carbon dioxide into the reservoir at the initial gas-water contact in order to regulate the process of watering gas-saturated horizons and increase the final hydrocarbon recovery factors for the conditions of a particular field.

7. SWOT analysis of research results

Strengths. Based on the results of the conducted studies, a high technological efficiency of the introduction of

secondary technologies for the development of hydrocarbon deposits using non-hydrocarbon gases was established. The simulation results show that the injection of carbon dioxide into the productive reservoir, which is being developed according to the water pressure regime, allows to significantly intensify the process of hydrocarbon production. Thanks to the introduction of carbon dioxide injection technologies, it is possible to regulate the process of watering of gas-saturated horizons and production wells. Based on the results of the studies carried out, it was found that in the case of injection of carbon dioxide, an increase in the natural gas recovery factor by 6.65 % is achieved in comparison with the development for depletion.

Weaknesses. The study of the effect of the rate of natural gas production during injection of carbon dioxide on the efficiency of regulating the process of watering the productive position was carried out on the basis of a hypothetical homogeneous three-dimensional model. The heterogeneity of productive deposits introduces significant uncertainty in the process of justifying optimal technologies. That is why, in order to develop optimal ways to increase the hydrocarbon production from the fields, it is necessary to conduct additional research using permanent geological and technological models of real fields.

Opportunities. The results of the studies carried out make it possible to improve the existing technologies for the development of gas and gas condensate fields according to the water pressure regime. Low coefficients of hydrocarbon recovery under conditions of active inflow of formation water into productive deposits make this kind of research promising. The main task of future research is to establish optimal operating modes for injection wells to ensure reliable hydrodynamic and filtration barriers in water-hazardous areas.

Threats. Carbon dioxide injection technologies are well-known and widely used all over the world to increase the coefficients in the hydrocarbon production of depleted deposits. However, the effectiveness of these technologies depends solely on the availability of a reliable source of supply of carbon dioxide. Failure to provide the necessary volumes of non-hydrocarbon gas for injection into productive reservoirs may lead to a decrease in the predicted effect.

8. Conclusions

1. Based on the results of the studies carried out, it was found that an increase in the rate of natural gas production with the injection of carbon dioxide leads to a decrease in the accumulated production of formation water. If the technology of injecting carbon dioxide into a productive reservoir is introduced, on the verge of the initial gas-water contact, the creation of hydrodynamic and filtration barriers is ensured, due to which the flow of aquifer waters into gas-saturated horizons is partially blocked. Based on the simulation results, it was also established that with an increase in the rate of gas production, the accumulated gas production increases, and, consequently, the final gas production coefficient. The results of the studies carried out indicate the high technological efficiency of the investigated method for increasing the coefficient of gas recovery in the water pressure regime.

2. Using the results of hydrodynamic modeling, the optimal value of the rate of natural gas production when injecting carbon dioxide into the productive reservoir at

the initial gas-water contact was determined. At the time of the breakthrough of carbon dioxide into a number of production wells, the optimal production rate of a production well is 55.93 thousand m^3/day. The gas recovery factor for the given optimal value of the gas production rate when injecting carbon dioxide is 64.99 %, and when developing for depletion – 58.34 %. The above research results indicate a high technological efficiency of the technology for injecting carbon dioxide into a reservoir at the initial gas-water contact in order to control and regulate the process of formation water inflow into gas-saturated horizons.

References

1. Boiko, V. S., Boiko, R. V., Keba, L. M., Seminskyi, O. V. (2006). Obvodnennia hazovykh i naftovykh sverdlovyn. *Mizhnarodna ekonomichna fundatsiia.* Kyiv, 791.
2. Kondrat, R. M. (1992). *Gazokondensatootdacha plastov.* Moscow: Nedra, 255.
3. Kondrat, R. M. (2005). Active Influence on the Development of Natural Gas Fields with Water Drive Regime with the Aim of Increasing Gas Condensate Extraction. *Nauka Ta Innovacii, 1 (5),* 12–23. doi: http://doi.org/10.15407/scin1.05.012
4. Matkivskyi, S. V., Kovalchuk, S. O., Burachok, O. V., Kondrat, O. R., Khaidarova, L. I. et al. (2020). Doslidzhennia vplyvu neznachnoho proiavu vodonapirnoi systemy na dostovirnist materialnoho balansu kolektoriv. *Rozvidka ta rozrobka naftovykh i hazovykh rodovyshch, 2 (75),* 43–51.
5. Firoozabadi, A., Olsen, G., Golf-Racht, V. T. (1987). Residual Gas Saturation in Water-Drive Gas Reservoir. *SPE California Regional Meeting held.* Ventura, 319–322. doi: http://doi.org/10.2118/16355-MS
6. Charles, S. R., Tracy, S. W., Farrar, R. L. (1999). *Applied Reservoir Engineering.* Vol. 1. OGCI Publications, Oil and Gas Consultants International, Inc. U.S.A., 480.
7. Kondrat, O. R., Kondrat, R. M. (2019). Pidvyshchennia hazovyluchennia z hazovykh rodovyshch pry vodonapirnomu rezhymi shliakhom rehuliuvannia nadkhodzhennia zakonturnoi plastovoi vody i vydobutku zeshchemlenoho hazu. *Naftohazova haluz Ukrainy, 4,* 21–26.
8. Doleschall, S., Szittar, A., Udvardi, G. (1992). Review of the 30 Years' Experience of the CO$_2$ Imported Oil Recovery Projects in Hungary. *International Meeting on Petroleum Engineering.* Beijing. doi: http://doi.org/10.2118/22362-MS
9. Cruz Lopez, J. A. (2000). Gas Injection As A Method For Improved Recovery In Gas-Condensate Reservoirs With Active Support. *SPE International Petroleum Conference and Exhibition.* Villahermosa. doi: http://doi.org/10.2118/58981-MS
10. Kondrat, O., Matkivskyi, S. (2020). Research of the influence of the grid density of injection wells on the gas extraction coefficient when injecting carbon dioxide in reservoir. *Technology Audit and Production Reserves, 5 (1 (55)),* 12–17. doi: http://doi.org/10.15587/2706-5448.2020.215074
11. Geffen, T. M., Parrish, D. R., Haynes, G. W., Morse, R. A. (1952). Efficiency of Gas Displacement From Porous Media by Liquid Flooding. *Journal of Petroleum Technology, 4 (2),* 29–38. doi: http://doi.org/10.2118/952029-g
12. Chierici, G. L., Ciocci, G. M., Long, G. (1963). *Experimental Research on Gas Saturation Behind the Water Front in Gas Reservoirs Subjected to Water Drive.* Proc, Sixth World Pet. Cong. Frankfurt, Sec IV Paper 17-PD6, 483–498.
13. Oldenburg, C. M., Law, D. H., Gallo, Y. L., White, S. P. (2003). Mixing of CO2 and CH4 in Gas Reservoirs: Code Comparison Studies. *Greenhouse Gas Control Technologies.* Kyoto, 1, 443–448. doi: http://doi.org/10.1016/B978-008044276-1/50071-4
14. Mamora, D. D., Seo, J. G. (2002). Enhanced Gas Recovery by Carbon Dioxide Sequestration in Depleted Gas Reservoirs. *SPE Technical Conference and Exhibition.* San Antonio. doi: http://doi.org/10.2118/77347-ms
15. Pirson, S. J. (1950). *Elements of oil reservoir engineering.* New York: McGraw-Hill, 441.

16. Malik, Q. M., Islam, M. R. (2000). CO_2 Injection in the Weyburn Field of Canada: Optimization of Enhanced Oil Recovery and Greenhouse Gas Storage With Horizontal Wells. *SPE Paper 59327. Presented at the 2000 SPE/DOE Improved Oil Recovery Symposium held.* Tulsa, 25–33. doi: http://doi.org/10.2118/59327-MS

17. Pyo, K., Damian-Diaz, N., Powell, M., Van Nieuwkerk, J. (2003). CO_2 Flooding in Joffre Viking Pool. *Canadian International Petroleum Conference.* Calgary, 1–30. doi: http://doi.org/10.2118/2003-109

18. Agustssen, H., Grinestaff, G. H. (2004). A Study of IOR by CO_2 Injection in the Gullfaks Field, Offshore Norway. *SPE/DOE 14th Symposium on Improved Oil Recovery held.* Tulsa, 1–14. doi: http://doi.org/10.2118/89338-MS

19. Matkivskyi, S., Kondrat, O., Burachok, O. (2020). Investigation of the influence of the carbon dioxide (CO_2) injection rate on the activity of the water pressure system during gas condensate fields development. *Global Trends, Challenges and Horizons.* Dnipro, 1–10. doi: http://doi.org/10.1051/e3sconf/202123001011

20. Turta, A. T., Sim, S. S. K., Singhal, A. K., Hawkins, B. F. (2008). Basic Investigations on Enhanced Gas Recovery by Gas-Gas Displacement. *Journal of Canadian Petroleum Technology, 47 (10).* doi: http://doi.org/10.2118/08-10-39

21. Clemens, T., Secklehner, S., Mantatzis, K., Jacobs, B. (2010). Enhanced Gas Recovery – Challenges shown at the example of three gas fields. *SPE EUROPEC/EAGE Annual Conference and Exhibition.* Barcelona. doi: http://doi.org/10.2118/130151-MS

22. Tiwari, S., Suresh Kumar, M. (2001). Nitrogen Injection for Simultaneous Exploitation of Gas Cap. *SPE Middle East Oil Show.* Manama. doi: https://doi.org/10.2118/68169-MS

23. Sim, S. S. K., Brunelle, P., Turta, A. T., Singhal, A. K. (2008). Enhanced Gas Recovery and CO_2 Sequestration by Injection of Exhaust Gases From Combustion of Bitumen. *SPE Symposium on Improved Oil Recovery.* Tulsa. doi: http://doi.org/10.2118/113468-MS

24. Kondrat, O. R. (1997). Vydobutok zashchemlenoho hazu z obvodnenykh rodovyshch. *Tezy nauk.-tekhn. Konf. Prof.-vykl. Skladu un-tu nafty i hazu.* Ivano-Frankivsk: IFNTUNH, NDI NHT, 6.

25. Burachok, O., Pershyn, D., Spyrou, C., Turkarslan, G., Nistor, M. L., Matkivskyi, S. et. al. (2020). Gas-Condensate PVT Fluid Modeling Methodology Based on Limited Data. *EAGE 2020 Annual Conference & Exhibition Online.* Amsterdam, 1–5. doi: http://doi.org/10.3997/2214-4609.202010155

26. Whitson, C. H., Brule, M. R. (2000). *Phase Behavior.* Richardson, 240.

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